(IJISE) 2023, Vol. No. 18, Jul-Dec **e-ISSN: 2454-6402, p-ISSN: 2454-812X**

The Application of Game Theory to International Trade: Using Strategic Games to Influence Trade Policy[1]

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Received: 19 July 2023; Accepted: 22 September 2023; Published: 08 October 2023

ABSTRACT

This paper aims to examine the utilisation of game theory in the context of international trade. Due to variations in countries' production capacity, natural resource endowments, levels of technical innovation, and other factors, game theory can be employed as a tool for resource allocation. Theoretical game models posit that players in international trade are rational agents who consistently make sensible choices, which contradicts the actuality of the situation. Usually, participants in international trade consist of individuals that prioritise their own interests and may not always make judgements based on logic. This essay contends that while game theoretic models may not offer comprehensive solutions to all economic problems, their utilisation is crucial in addressing intricate matters related to negotiation, resource allocation, and strategic decision-making in the realm of international trade.

Keywords: *Game theory; international trade; mixed strategy*

INTRODUCTION

Trade on a global scale is a crucial aspect of economics that provides valuable understanding on how individuals, corporations, and governments can maximise their resources through mutually beneficial exchanges. Due to the disparities in factors such as size, natural resources, geography, labour skills, and technological innovation, it is impossible for any single country to fulfil all of its economic requirements. International trade allows a country to obtain goods and services that it is not efficient in producing, by trading with other countries that have a comparative advantage in those areas. The prevailing economic theory advocates that countries can enhance their people's living standards more swiftly by engaging in free trade, as opposed to operating in a closed economy, due to the increased benefits it offers.

According to Alexa & Toma (2012), international trade results in both winners and losers, but as a whole, countries engaged in trade are more prosperous than those that do not participate in trade. As per the principle of comparative advantage, if a country is less efficient in producing two goods compared to its trading partners, it can still gain from trade by focusing on producing other goods where it has the greatest relative advantage. The justification for free trade is rooted in the notion that no single country can achieve complete self-sufficiency in the production of all things. Therefore, in order to promote rapid economic growth, countries must interact with one another through trade.

Historically, game theory has been employed in diverse contexts, including the resolution of international conflicts, talks related to security, and the development of military tactics. However, in a more recent context, the utilisation of game theory was expanded to the domain of economics subsequent to the publication of "Theories of Games and Economic Behaviour" by John von Neumann & Oskar Morgenstern in 1944. The two writers revolutionised game theory by introducing novel concepts that rendered it applicable to the realms of economics and business. The core assumption of game theory is the idea that players make rational decisions designed to maximize their utility functions. This assumption aligns with the economic principle of rationality, which posits that economic behaviour is influenced by rational agents who aim to maximise their utilities (Robert 2022)

[1] *How to cite the article:* Singh R., Singh N.; The Application of Game Theory to International Trade: Using Strategic Games to Influence Trade Policy; *International Journal of Innovations in Scientific Engineering*, Jul-Dec 2023, Vol 18, 23-37

(IJISE) 2023, Vol. No. 18, Jul-Dec **e-ISSN: 2454-6402, p-ISSN: 2454-812X**

As a result of this connection, theoretical games have been utilised to address a diverse array of economic and business issues. According to Alexa & Toma (2012), theoretical games involve multiple participants or decision makers who interact, create coalitions, and sometimes make threats to maximise their own self-interests. In competitive economic systems, participants frequently make decisions in uncertain circumstances with the primary purpose of

Optimise their rewards. Similarly, it becomes troublesome when certain players adopt strategies with the intention of maximising their utility functions while disregarding the well-being of other players. This elucidates the rationale behind countries commonly partaking in trade conflicts, such as the ongoing trade war between the United States and China.

APPLICATION OF EVOLUTIONARY GAME THEORY TO ENHANCE GLOBAL TRADE COOPERATION

Globalisation has yielded benefits for the majority of countries worldwide. Nevertheless, as a result of globalisation, several countries have established a significant economic interdependence, granting them a dominant position in shaping the actions of the reliant country. However, following the financial crisis of 2008, numerous countries transitioned to nationalisation and prioritised domestic jobs and economic growth, while diminishing the significance of globalisation. In addition, developed nations have had sluggish growth compared to developing and rising countries that are involved in the value chain process. This has resulted in trade-related disputes such as the Sino-USA trade wars, in which both countries have responded with retaliatory actions to each other's bilateral measures. Nevertheless, matters pertaining to trade such as trade negotiations and trade wars require strategic planning and a comprehensive comprehension of the perspective held by the opposing nation. This can be effectively collected and strategized through diverse models employed in game theory. Game theory is a scientific field that studies how independent and competitive individuals or groups make optimal decisions in a strategic context. Game theory is a branch of economics that is not only a part of microeconomics but also widely applied in various other economic fields such as international trade, labour economics, macroeconomics, financial economics, and behavioural economics. Many important policy issues involve game theoretic analysis, such as negotiations for mutual reduction of tariffs, international indebtedness and potential default of less developed countries, formation and preservation of customs unions, issues related to international common property, establishment of cartels to manipulate prices of internationally traded goods, international implications of domestic macroeconomic policies, income redistribution in the north-south debate, and the use of trade as a political weapon. There exists a strategic interdependence when the optimal behaviour of one agent is contingent upon the actions of another agent, and vice versa. Trade economists commonly utilise game theory frameworks to analyse trade battles involving multiple countries. Game theory concepts such as the prisoner's dilemma, cooperative games, non-cooperative games, games with incomplete and imperfect information, and others have been employed to derive economic and occasionally political conclusions from the examination of tariff and trade conflicts. This work is broken into three more sections. The first component examines the application of game theory models in international trade. The subsequent section discusses different references in the literature that employ game theory models in the context of trade wars and trade negotiations (Khurana 2022).

The process of globalisation has yielded significant benefits for the majority of countries worldwide. Nevertheless, as a result of globalisation, several countries have developed a significant economic reliance, granting them a dominant position in shaping the decisions of the dependent country. However, following the financial crisis of 2008, several countries adopted nationalisation policies and prioritised domestic jobs and economic growth, while diminishing the significance of globalisation.

In addition, developed nations have been experiencing sluggish growth compared to developing and rising countries that are involved in the value chain process. This has resulted in trade-related disputes such as the Sino-USA trade wars, in which both countries have engaged in retaliatory actions in response to each other's bilateral measures. However, matters concerning commerce such as trade negotiations and trade wars require strategic planning and a comprehensive comprehension of the perspective of the opposing country.

This can be perfectly represented and planned by various models utilised in game theory.
Game theory is a field of study that focuses on the analysis of strategic decision-making by independent and competitive individuals or groups. Game theory is a branch of economics that is not only applicable to microeconomics, but also widely used in other economic fields such as international trade, labour economics, macroeconomics, financial economics, and behavioural economics. Many important policy issues involve game theory, such as negotiations for mutual reduction of tariffs, international indebtedness and potential default by less

developed countries, formation and preservation of customs unions, issues related to international common property, establishment of cartels to manipulate prices of internationally traded commodities, international implications of domestic macroeconomic policies, income redistribution in the north-south debate, and the use of trade as a political weapon (Gunawan et al. 2022).

There is a strategic dependency as what one agent's best action is depends upon what another agent performs and vice versa. A significant number of trade economists have discovered that a game theoretic framework is applicable for analysing trade conflicts involving two or more nations. Game theory concepts such as the prisoner's dilemma, cooperative games, non-cooperative games, games with incomplete and imperfect information, and others have been utilised to derive economic and occasionally political conclusions from the examination of tariff and trade conflicts.

The aim of this study is to examine the utilisation of game theory in the context of international trade. There is a debate among scholars on the extent to which game theory can effectively address problems in international economics. This is primarily because the foundational models of game theory assume that individuals in the games are motivated by rational behaviour. This article operates on the premise that economic analysis is guided by theories and assumptions. It also assumes the presence of two trading actors involved in the exchange of goods and services. This exchange takes place in an environment where there is incomplete information, meaning that one actor is not entirely certain about the payoff function of the other actor in the context of international trade. This essay aims to contribute to the ongoing discussion over the advantages and disadvantages of applying game theory in the context of international trade.

GAME THEORY

Game theory is a conceptual framework used to analyse social situations with competing actors. Game theory can be understood as the study of strategy, specifically the most advantageous decision-making by autonomous and competing individuals in a strategic context.

- Game theory is employed across diverse disciplines to delineate different scenarios and forecast their most probable results. Businesses can utilise it for many purposes, such as establishing pricing, evaluating potential acquisitions, and strategizing legal proceedings.
- Game theory is a conceptual framework used to analyse social situations involving competitive participants.
- The objective of game theory is to achieve optimal decision-making by independent and competing actors in a strategic context.
- Game theory can be employed to analyse and forecast the results of various real-life situations, such as pricing competition and product introductions.
- Examples encompass the prisoner's dilemma and the dictator game, among several others.

AN EXPLANATION OF GAME THEORY

Game theory aims to comprehend the strategic behaviours of multiple "players" in a specific environment with predetermined rules and consequences. Game theory can be applied whenever there is a scenario with multiple players, known payments, and measurable repercussions. It aids in determining the most probable outcomes.

Game theory centres around the game, which functions as a representation of an interactive scenario including rational participants. The fundamental principle of game theory is that the outcome for a player is dependent on the strategy chosen by the other player.

The game discerns the players' identities, inclinations, and viable tactics, as well as the impact of these tactics on the result. Additional prerequisites or assumptions may be required depending on the specific model.

Game theory finds extensive applications in several fields such as psychology, evolutionary biology, warfare, politics, economics, and business. Game theory, despite its numerous advancements, is a nascent and evolving scientific discipline (Pereira et al. 2022).

(IJISE) 2023, Vol. No. 18, Jul-Dec **e-ISSN: 2454-6402, p-ISSN: 2454-812X**

KEY TERMINOLOGY IN GAME THEORY

Below is many frequently employed terminology in the field of game theory:

- **Game:** A situation in which the outcome is determined by the choices made by two or more individuals (players).
- **Players:** Individuals who make strategic decisions inside the game's framework.
- **Strategy**: refers to a comprehensive plan of action that a player will adopt in response to the various situations that may occur during the game.
- **Payoff:** The compensation a player receives upon reaching a specific result. The payment can be in any measurable form, ranging from currency to usefulness.
- **Definition:** The collection of information that is accessible at a specific moment during the game. The phrase "information set" is commonly used when the game involves a sequential aspect.
- **Equilibrium:** refers to the stage in a game where both players have finalised their choices and a result is achieved.

THE NASH EQUILIBRIUM

When a Nash equilibrium is attained, no participant can unilaterally change their decisions to boost payoff. It is also referred to as "no regrets," meaning that once a choice is made, the player won't look back on it, even after taking the repercussions into account.

In most circumstances, the Nash equilibrium is reached over time. The Nash equilibrium won't be altered after it has been attained, though. After learning how to determine the Nash equilibrium, consider the impact of a unilateral action. Does that even make sense? Because it shouldn't, the Nash equilibrium is referred to as having "no regrets."

In general, a game can have more than one equilibrium. But this frequently happens in games when there are more intricate choices than just two made by two players. After some trial and error, one of these numerous equilibria is reached in simultaneous games that are replayed throughout time.

In the business sector, this situation of making different decisions over time until reaching equilibrium is most frequently seen when two enterprises are deciding on prices for highly interchangeable goods, such airline tickets or soft drinks.

TYPES OF GAMES THEORY

Game theory encompasses several classifications such as cooperative and non-cooperative, zero-sum and non-zero-sum, as well as simultaneous and sequential.

Game theory use models to analyse conflicts and situations, aiding in the enhancement of decision-making by devising suitable strategies. Let us provide precise definitions for certain concepts commonly used in game theory.

1. Cooperative VS Non-Cooperative

The most prevalent kinds of game theories are cooperative and non-cooperative, however there are many others, such as symmetric/asymmetric,simultaneous/sequential, and so forth. The interaction of coalitions, or cooperative groups, when only the payoffs are known is the subject of cooperative game theory. Instead of being a game between two players, it is a coalition game that explores the formation of organisations and how they divide rewards among themselves.

The field of non-cooperative game theory examines the strategies that logical economic agents employ to accomplish their own objectives. The most popular type of non-cooperative game is the strategic game, where the

only things listed are the possible strategies and the results of combining certain options. Rock, paper, scissors is a basic illustration of a real-world non-cooperative game.

2. Zero Sum VS Non-Zero Sum

A zero-sum game is one in which several parties directly compete with one another to achieve the same goal. This implies that there are losers for every winner. Alternatively, it indicates that the total net advantage that was gained and lost is the same. A team wins and another team loses in many sporting events, making them zero-sum games.

	A	B
A	–1, 1	3, –3
B	0, 0	–2, 2

A zero-sum game

A game where everyone can win or lose simultaneously is called a non-zero-sum game. Think about business alliances that enhance value for both parties involved and are mutually beneficial. Rather than rivalry and trying to "win," both sides gain.

There are instances when stock trading and investing are viewed as zero-sum games. In the end, a stock will be purchased by one market participant and sold by another for the same price. However, transactions may be advantageous to both parties because various investors have varying risk appetites and investing objectives.

3. Sequential Move VS Simultaneous Move Games

Game theory comes into play in simultaneous move scenarios frequently in real life. This implies that each player must continuously make decisions while their rival is also making decisions. Competing businesses are likewise creating their marketing, product development, and operational plans at the same time.

Sometimes decision-making processes are purposefully delayed so that one side can observe the other's actions before taking their own. This is typically seen in negotiations when one side makes a list of demands and the other has a set amount of time to reply with a list of their own.

4. Symmetric VS Asymmetric

A game is said to be symmetric if it is one in which every participant receives the same payoff when they make the same decision. To put it another way, the identity of the player does not affect the game that is played against the other player.[19] [19] For the most part, the 2×2 games that are commonly studied are symmetric. The symmetric games that are commonly used to symbolise chicken, the prisoner's dilemma, and the stag hunt are all examples of symmetric games. It is possible that certain asymmetric games could be considered examples of these games even by certain scholars (who are they?). On the other hand, the payoffs that are most frequently seen in each of these games are symmetric.

	E	F
E	1, 2	0, 0
F	0, 0	1, 2

An asymmetric game

Asymmetric games are games in which the strategy sets used by both players are not similar. These games are the ones that are researched the most frequently. Both the dictator game and the ultimatum game, for example, contain a variety of distinct strategies that are tailored to each individual participant. On the other hand, it is not impossible for a game to be asymmetric despite the fact that both players employ the same tactical approaches. As an illustration, the game depicted in the graphic for this section is asymmetric, despite the fact that both players have the same strategy sets.

5. One-shot VS multiple games

A single case can start and terminate game theory. The underlying competition begins, moves forward, ends, and cannot be repeated, much like much of life. This is frequently the case with stock traders, who have to make informed decisions about when to enter and depart the market because their choice might not be readily reversed or tried again.

Conversely, certain games that are played repeatedly seem to go on forever. These kinds of games frequently feature the same players every time, and each side is aware of the previous outcome. Think about competitors who are attempting to price their products, for instance. Each time one modifies its pricing, the other might follow suit. This never-ending competition occurs regardless of product cycles or seasonality of sales.

The Prisoner's Dilemma (covered in the next section) is shown in the scenario below. In this illustration, there is no reward following the first repeat. Rather, a new set of possibilities not feasible in one-shot games are brought about by a second iteration of the game.

GAME THEORY EXAMPLES

Game theory examines a variety of "games". We'll go over a few of these in brief below.

- **The dilemma of the prisoner**

In game theory, the most famous example is the Prisoner's Dilemma. Take the case of two offenders who were apprehended for their crimes. In order to convict them, prosecutors lack concrete proof. Officials, however, take the detainees out of their isolation cells and interrogate them individually in different rooms in an attempt to extract a confession. There is no way for one prisoner to speak with the other. Presenting four deals, officials typically arrange them in a 2 × 2 box.

They will each serve five years in prison if they both confess.

Prisoner 1 will receive three years in prison and Prisoner 2 will receive nine years if Prisoner 1 confesses but Prisoner 2 does not.

Prisoner 1 will receive ten years in prison and Prisoner 2 will receive two years if Prisoner 2 confesses but Prisoner 1 does not.

If none of them confesses, they will both spend two years behind bars.

The best course of action is to remain silent. But neither knows the other's game plan, so unless one is convinced the other won't confess, both are likely to confess and get five years in prison. According to the Nash equilibrium, in a prisoner's dilemma, each actor will choose a course of action that is best for them personally but worse for the group as a whole.

In a prisoner's dilemma, "tit for tat" is thought to be the best course of action. Anatol Rapoport established the concept of "tit for tat," a strategy in which each player in an iterated prisoner's dilemma takes a turn that is consistent with the preceding turn of their opponent. For instance, a player might cooperate if they are not provoked, but they might retaliate if they are.

The situation where a participant's choice in the column and a participant's choice in the row may conflict is shown in the image below. For instance, if both sides select row/column 1, they might have the best result possible. However, if the other person does not select the same course of action, each has the danger of gravely negative consequences.

(IJISE) 2023, Vol. No. 18, Jul-Dec **e-ISSN: 2454-6402, p-ISSN: 2454-812X**

- **Game of Dictators**

In this straightforward game, Player A has to choose how to divide a cash prize with Player B; Player B cannot influence Player A's choice. Although this isn't exactly a game theory tactic, it does offer some fascinating perspectives on human behaviour. According to experiments, roughly 50% of participants keep the entire amount to themselves, 5% divide it equally, and the remaining 45% give the other participant a smaller portion.

The ultimatum game, in which Player A is granted a certain amount of money, some of which must be delivered to Player B, who has the option to accept or reject the amount given, is closely linked to the dictator game. The hitch is that neither A nor B will receive anything if the second player declines the sum proposed. There are valuable lessons to be learned about generosity and altruism from the dictator and ultimatum games.

- **The Volunteer's Predicament**

In the volunteer's dilemma, an individual must do a task or duty for the benefit of the group. If no one offers to help, the worst case scenario comes to pass. Take a corporation, for instance, where accounting fraud is pervasive but top management is oblivious to it. Although several junior staff members in the accounting department are aware of the fraud, they are reluctant to alert upper management for fear that doing so will lead to the termination and probable prosecution of the fraudsters.

Later on, there can be certain consequences associated with being called a whistleblower. However, in the case that no one steps up to volunteer, the massive fraud could lead to the company's ultimate collapse and the loss of all jobs.

- **The Centipede Game**

In the extensive-form game theory known as the centipede game, two players take turns taking the bigger portion of a money cache that is steadily growing. The arrangement is such that a player receives less than they would have if they had accepted the pot if they give the stash to their opponent and they take it.

When one person takes the stockpile, the centipede game is over; that player receives the larger portion, while the other player receives the smaller portion. Each player is aware ahead of time of the game's predetermined total number of rounds.

DIFFERENT GAME THEORY STRATEGY TYPES

Participants in game theory have a choice of several main approaches to play their game. Generally speaking, each player must determine the amount of danger they are ready to accept and the lengths they will go to in order to achieve the best result.

- **Maximax Approach**

In a maximax strategy, hedging is absent. Either they will win large or suffer the worst outcome; the player is all in or all out. Think about brand-new startups bringing innovative goods to the market. The market capitalization of the company may grow fifty times as a result of their new product. Conversely, a botched product launch will force the business into bankruptcy. Even when the worst case scenario is conceivable, the participant is willing to take a gamble in hopes of attaining the best result.

- **Maximin Technique**

In game theory, a maximin strategy leads to the player selecting the best possible outcome out of all possible outcomes. The member has made the decision to avoid the worst case scenario by hedging risk and forgoing all benefits. Businesses frequently confront and embrace this tactic when thinking about suing. Companies accept a negative result when they settle out of court and avoid a public trial. If the matter had gone to trial, the result might have been worse.

- **The Dominant Approach**

When using a dominant strategy, a player acts in a way that maximises the play's potential, regardless of what the other players choose to do. In the business world, this could mean that an organisation chooses to grow and enter a new market regardless of whether or not a rival has made the same decision. The most common tactic in Prisoner's Dilemma would be to confess.

- **Just Strategy**

The least degree of strategic decision-making is involved in pure strategy because it is merely a specified choice that is made independent of outside factors or other people's activities. Imagine a game of rock, paper, scissors where one player chooses to toss the same shape every time. The technique is described as pure since the participant's outcome is known ahead of time and can take one of two forms: either a certain shape or none at all.

- **Combination Approach**

Although a mixed strategy may appear to be the result of chance, careful planning must be done when selecting which aspects or actions to combine. Think about the bond between a pitcher and hitter in baseball. It is imperative that the pitcher avoids throwing the same pitch repeatedly to prevent the batter from guessing what will follow next. Rather, the pitcher needs to vary his approach from pitch to pitch in order to generate uncertainty, which it thinks will work to its advantage.

GAME THEORY'S DRAWBACKS

The main problem with game theory is that, similar to most other economic models, it is predicated on the idea that individuals are self-interested, rational actors who maximise their value. We are social creatures after all, and we frequently cooperate at our own expense. Game theory is unable to explain why, depending on the social setting and the individuals involved, we might occasionally enter a Nash equilibrium and other times not.

Furthermore, game theory frequently fails to take into account aspects of humanity like loyalty, integrity, or empathy. Even though the optimal course of action can be determined by statistical and mathematical calculations, humans may choose a different path because of unpredictable and intricate situations including manipulation or self-sacrifice. While game theory can be used to analyse a group of behaviours, it is not a reliable way to predict human behaviour.

REVIEW OF LITERATURE

Pereira, et al. (2022) This paper examines the impact of product differentiation on optimal internationalisation incentive policies, focusing on export subsidy schemes. It develops a two-stage game for three different scenarios: no subsidy, fixed-subsidy scheme, and subsidyper-quantity-exported scheme. The study finds that a subsidy-per-quantity exported scheme is best for export markets with low product differentiation, while a fixed-subsidy scheme is preferable for markets with high product differentiation. This research highlights the importance of considering export market characteristics when designing optimal public incentives for internationalisation.

Khurana (2022) Game theory is a tool used by economists to explain the choice between liberalizing or protecting tariffs in trade policies. It helps determine the level of tariff that maximizes welfare for a country compared to another's. Game theory methods are used to develop the optimal level of tariff for maximum welfare. It also helps analyze the best strategy when two countries are negotiating. Trade wars between countries can lead to trade retaliation, affecting all stakeholders, including multinational firms. US companies are moving out of China and receiving subsidies or grants to shift manufacturing bases. Companies like Huawei face criticism from the US government and pressure allies to ban them from their countries. The Brander Spencer model, using simple prisoner's dilemma, helps analyze strategic behavior in such battles.

Gunawan et al. (2022) Using game theory, economists have attempted to explain the relative merits of protectionist and liberal policies. Any country's trade policy should include tariff setting, and game theory provides a framework for determining the optimal tariff level in relation to the other country's tariff. In order to determine the optimal tariff level in order to achieve maximum welfare, numerous game theory strategies, including those presented in the paper, are employed. We can analyse the optimum strategy for two countries' negotiations using game theoretical tools. Trade retaliation occurs when nations engage in a trade war. This is

because the trade policy affects all parties involved, particularly multinational corporations, and not just the governments themselves. The trade war between the US and China has caused many American companies to relocate their manufacturing operations out of China and into the US, where they are receiving subsidies and incentives. Also, businesses like Huawei are under fire from the US government, which is putting pressure on its partners to prohibit Huawei from participating in 5G experiments or using its products in their own nations. The Brander-Spencer model, which analyses the strategic behaviour of two companies engaged in a fight using the simple prisoner's dilemma as an example.

Mughwai et al. (2021) Analysis of game theory's application to international trade is the aim of this study. Game theory is one of the instruments in resource allocation since nations differ from one another in terms of their capacities for production, their endowments in natural resources, their degrees of technical innovation, and so on. Theoretical game models adopt the unrealistic assumption that participants in global trade are logical actors who make logical choices. The people that participate in international trade are usually self-serving and their choices aren't always logical. This article contends that while game theoretic models are not able to adequately address every economic issue, they are crucial in helping to resolve intricate difficulties pertaining to resource allocation, negotiation, and strategic decision-making in international trade.

Mughwai (2020) The purpose of this study is to examine how game theory is used in international trade. Game theory can be employed as one of the techniques in resource allocation because nations differ from one another in terms of their capacities for production, their endowments in natural resources, their degrees of technical innovation, and so on. The assumption made by theoretical game models, which is at odds with reality, is that participants in international trade are logical actors who make logical judgements. The actors involved in international trade are generally self-serving individuals whose choices are not always based on logic. This essay makes the case that, despite the fact that game theoretic models are unable to adequately address every economic issue, their applications are crucial for resolving challenging problems including resource allocation, negotiation, and strategic decision-making in international trade.

Siddhartha Pradeep (2019) The study explores the use of game theory to understand international relations and real-world events. It argues that the instability in the Kashmir conflict is due to contrasting approaches by India and Pakistan, with India playing the infinite game and Pakistan playing the timing game. Both nations play deterrence games, but their approaches differ. The frequent defection of Pakistan from mutual cooperation in the iterated prisoners dilemma further complicates the dynamics, shifting the games to mutual distrust and chicken, leading to tensions. The author suggests that long-term stability can only be achieved through strict policies against Pakistan-sponsored cross-border terrorism. The paper also discusses the role of clandestine services in strategy determination in modern information warfare. The analysis of incidents and statements by Prime Ministers reveals the complexity of these games.

Nagrajan. P, (2019) This study aims to provide with a comprehensive understanding of game theory, including its history, classification, key elements, mathematical concepts, problem-solving procedures, and examples. It aims to provide students with a clear understanding of game theory, its underlying concepts, and the techniques to apply to solve problems effectively. The course also emphasizes the importance of practical application of mathematical concepts in game theory.

Piraveenan (2019) This study offers an organised survey and analysis of the literature on modelling project management scenarios with game theory. We pick and evaluate thirty-two publications from Scopus, show the chosen papers in a sophisticated three-dimensional categorization, and then examine the citation network that is produced. The studied material can be categorised as belonging to the construction industry, the ICT industry, or the unspecified industry based on the industry-based classification. The literature can be divided into publications that use games involving government contractors, contractor-contractor games, contractor-subcontractor games, subcontractor-subcontractor games, or games involving other types of players based on the categories of players. There are papers that use extensive-form cooperative games, extensive-form cooperative games, extensive-form non-cooperative games, and normal-form cooperative games, depending on the kind of games that are used. Furthermore, we demonstrate that all of the aforementioned classifications contribute to determining which articles are most likely to cite a given work, with the type-of-game classification having the largest impact. The field's citation network is generally sparse, which suggests that writers' knowledge of research conducted by other scholars is not as good as it may be. Our analysis indicates that extensive-form cooperative games should be used when appropriate, and that game theory is a very helpful tool for modelling project management scenarios. Additionally, more work needs to be done on project management in the ICT sector.

Ioana, Dobre. (2018) A general mathematical analysis that investigates the strategic interactions that take place between players is known as game theory(GT). In order to examine the behaviour that rational actors might (or, in some cases, should) exhibit in response to a conflict of interests, game theorists make an effort to provide detailed descriptions of scenarios in which the interests of the parties involved are in conflict with one another. During the process of formulating their plans, players are presumed to take into account the positions and perspectives of other players. In the examples that we will be providing, we will assume that there are two players, that each player has two alternatives, and that the players are both rational and selfish in the sense that they will choose the best options that are accessible to them. In this section, I will begin by providing an overview of some fundamental ideas in game theory. Following that, I will proceed to provide some examples of how game theory may be used to international trade, specifically in the areas of cartel, free trade and protection, and trade policy.

EXPLANATIONS OF FUNDAMENTAL IDEAS IN GAME THEORY

Theoretical games are mathematical scenarios that include a set of players (individuals or firms), a collection of tactics that players can choose from, and reward requirements for any combination of strategies, according to Gibbons (1995). Every actor participates in the game as a player, and the decisions made by interacting players (individuals, businesses, or nations) have an impact on each other's payoff functions. The notion of rationality, or the presumption that each player in the game is rational and, as a result, that their judgements are logical, is one of the fundamental tenets of game theory. Modern game theory was created by Neumann & Morgenstern in 1944, and they connected it to the study of economics. They described game theory as the study of interactions between different agents under the guidance of predetermined rules. Players then follow these rules and methods to establish feasible moves for each player and payoffs for each move combination. As a result, the game might be characterised as a strategic interaction where player actions are restricted.

According to Alexa & Tom (2012), theoretical games in microeconomics can be used to international trade and economic negotiation. However, game theory is used to solve multi-person problems within the firm, such as allocating investment funds among different departments or divisions within the firm, sorting out worker competition for promotions, and so forth. On the individual level, its application has been expanded to include activities like auctioning. The authors also point out that game theory models can be applied at the national level to resolve a variety of economic issues pertaining to international trade and competition, especially when nations cooperate or compete to determine trade policies such as tariffs.

MIXED STRATEGY, NASH EQUILIBRIUM, AND GAME REPRESENTATION

Assuming that two nations engage in commerce, figuring out each nation's decision-making capabilities is a pertinent theoretical game strategy. It is expected that each country has little knowledge of the intentions or activities of its trading partner, for instance, if nation A and nation B engage in commerce. Therefore, each country is expected to employ distinct strategies based on the activities witnessed in the trading process in order to achieve maximum value in their trade relationship.

According to Gibbons (1995), in mixed strategy games, a player assumes the role of another player who is unsure of the first player's decisions and strategy. The first player's decision is based on the realisation of the limited amount of game information that is known. Therefore, the interpretation of the mixed strategy is based on the actions of another player, which is commonly represented by the probability distribution function across the strategies that each player has selected. Also, the basis for this analysis is standard form representation, in which players make decisions concurrently and are aware of their own reward functions, but may not be aware of those of their fellow players.

The idea of Nash equilibrium is useful in figuring out the best game solutions. According to Gibbons (1995), a mixed strategy's Nash equilibrium is a combination of payoffs that ensure each player's mixed strategy is the best reaction to the other players' mixed strategies. According to Gibbons (1995), sealed bid auctions are one instance of this situation wherein each bidder is solely aware of their own valuation and is unaware of the valuations of their rivals. As a result, player actions are seen as occurring simultaneously, and the presence of private information encourages knowledgeable players to communicate with and, occasionally, deceive, their rivals. Those without access to such crucial information also constantly strive to learn and adapt, which may contribute to certain aspects of dynamic games.

PRISONER'S DILEMMA

(IJISE) 2023, Vol. No. 18, Jul-Dec **e-ISSN: 2454-6402, p-ISSN: 2454-812X**

This study use the normal form model of the game, in which each player selects a strategy and the combination of tactics chosen by all players generates the reward functions for each player. In the standard style of game representation, players are typically listed along the top and left sides of the reward matrix. The matrix table has the defined actions in its columns and rows, with payoffs listed in each cell where the actions of the players meet. The prisoner's dilemma idea is expanded to elucidate the techniques employed in international trade within static games using imperfect information. Our main focus is on the trading methods employed by two nations, A and B, and we utilise game theory to establish their respective payoff functions. The commonly employed approach to depict strategic decisions in the normal-form representation of a game is known as the "prisoner's dilemma." This concept refers to a scenario where two suspects are apprehended by the authorities and accused of a crime, but the police do not possess enough evidence to secure a conviction unless at least one suspect confesses. The suspects are presumed to be detained in individual cells, where they are informed of the potential consequences that may arise from their actions or reactions throughout the interrogation process. The prisoners are segregated to prevent any form of interaction and any collusion between them.

It is additionally presumed that the suspects are being accused of a minor offence, however, they have also previously committed a more severe offence. Consequently, the police interrogator is questioning them in order to secure a conviction for the more serious crime. The proposed arrangement by the police to each prisoner is that if both individuals refrain from speaking about the grave offence, they will be sentenced to one year of imprisonment for the minor offence and avoid being found guilty of the serious offence. In the scenario when one prisoner chooses to remain silent regarding the grave offence, but the other prisoner admits guilt, the confessor is granted freedom, while the non-confessing prisoner receives a prison sentence of 9 years. If both convicts admit guilt, they will be charged and sentenced to 6 years in jail for the grave offence. Below is the Payoff matrix for the two suspects. The game's outcome hinges on the choice between "confess" or "not confess".

Table 1. Prisoner's dilemma matrix representation

	Prisoner 2		
Prisoner 1		**Not Confess**	**Confess**
	Not Confess	**(-1, -1)**	**(-9, 0)**
	Confess	**(0, -9)**	**(-6, -6)**

Note: **-9 = 9 years in prison; -6 = 6 years in prison; -1 = 1 year in prison; and 0 = free.**

Based on the matrix provided, if both inmates admit their guilt, they will both receive a conviction and be sentenced to serve a total of 6 years in jail. If neither of them confesses, they will both receive a one-year prison sentence. If Prisoner 1 admits guilt and Prisoner 2 remains silent, the one who confesses is released while Prisoner 2 receives a 9-year prison sentence. Conversely, this matrix is symmetrical, indicating that the opposite is also true. Thus, it may be inferred that remaining silence is always overshadowed by confessing. Therefore, the option of staying silent can be excluded for Prisoner 1, and vice versa, as it is a symmetrical situation. Consequently, the only remaining option is for both players to confess. By iteratively applying the technique of eliminating dominated strategies, we can potentially reach a solution or at the very least make progress towards finding a solution (refining our predictions by eliminating a subset of strategies). The Nash equilibrium refers to this optimal solution. During a game with only two players The Nash equilibrium is achieved when a matrix combination or payout is found where one player's approach is optimal given the strategy of the other player, and vice versa. Put simply, it refers to a situation where no alternative strategy can yield a better outcome, considering the actions of other players. In the aforementioned example of the prisoner's dilemma, the Nash equilibrium is achieved by the combination of both prisoners confessing. This particular combination is the only Nash equilibrium attainable, as dictated by the given payment structure. In other words, the players lack any motivation to select a strategy other than the one where they both own their guilt. For instance, opting for silence results in a 9-year prison sentence, which is a more unfavourable outcome compared to the alternative situation where the suspect receives a 6-year prison term upon confessing. Gibbons (1995) provides a concise definition of the Nash equilibrium, stating that it is the point in a game where no player has an incentive to alter their strategy. Nash equilibrium in mixed strategy games ensures that each player's mixed strategy is the optimal response to the mixed strategies of the other players.

THE STUDY OF SPECIALISED FIELDS, THE IMPLEMENTATION OF PROTECTIVE MEASURES, AND THE FORMULATION OF TRADE POLICIES.

(IJISE) 2023, Vol. No. 18, Jul-Dec **e-ISSN: 2454-6402, p-ISSN: 2454-812X**

This section demonstrates the application of game theory in determining trade specialisation among countries, based on Ricardo's assumption that trade is mutually advantageous for all parties involved. Initially, we examine the application of theoretical games in facilitating a country's specialisation in manufacturing processes. Next, we analyse the strategic approach that each country might adopt when making trade policy decisions. The goal is to determine how strategic games can be employed to optimise each country's utility without compromising the economic well-being of its trading partner. The subsequent sub-section examines the utilisation of protective measures by trade nations to safeguard domestic businesses. While engaging in commerce, it is crucial to consider that it should not have a negative effect on the local production capabilities of each country. Commonly, trade policy instruments frequently employed include import tariffs, import quotas, and protection subsidies granted to domestic sectors, which may be specifically directed towards a particular industry, goods, or services. It is important to note that tariffs and quotas on imports aim to raise the prices of imported goods in order to make locally-produced items more appealing and therefore stimulate the growth of local industries. Game theory can be employed to assist in this endeavour. Hughes (2007) contends that although quotas are implemented to limit the quantity of imported goods or commodities, it is important to exercise caution in order to prevent excessive restrictions. This is because overly restrictive quotas can result in the emergence of exorbitant prices and an illegal black market, which are unintended consequences of free trade.

- **Specialisation and resource allocation**

The prisoner's dilemma concept can be expanded to analyse the methods that trading nations could employ when making judgements about which goods to specialise in for exports and which goods to obtain from other trading partners through imports. As previously said, according to the principle of comparative advantage, countries should focus on manufacturing commodities and services in which they are more efficient compared to other countries. They should then import goods in which they have a relative disadvantage in production. Suppose there are two hypotheticals nations, U.S.A and Russia, engaged in the exchange of two different commodities, good A and good B, respectively. This example demonstrates the utilisation of theoretical strategic games in production specialisation to optimise resource allocation. Due to the presence of only two countries and two items involved in the transaction, the matrix exhibits symmetry. The distribution of payoffs is presented in the subsequent table.

Table 2. Payoff matrix for specialization in cash crop production

Russia	**U.S.A**		
		Product A	**Product B**
	Product A	**($200, $200)**	**($800, $0)**
	Product B	**($0, $800)**	**($500, $500)**

Note: $0= No gain from trade; $200 = $200 million gained; $500 = $500 million gained; and $800 = $800 million gained

According to the given matrix, if both nations decide to manufacture product A, they will each earn $200 million through trade. If both parties opt to manufacture product B, they will collectively accrue a profit of $500 million through trade. By opting for specialisation in the manufacture of product A, Russia reaps a trade benefit of $800, whereas U.S.A, on the other hand, earns no benefit as it decides to create product B. Russia outcomes take precedence over U.S.A outcomes in terms of payoffs. Russia benefits more by producing product A, regardless of U.S.A production choices. On the other hand, if U.S.A focuses on producing product A and Russia specialises in producing product B, the reverse is also true. Both participants achieve optimal value in the trade transaction when they both create Product B, resulting in a payout of $500 million for each nation. In essence, the results of these strategies demonstrate that the individual production of one country does not necessarily optimise the overall utility of both countries.

To mitigate the unintended negative effects of trade intervention, such as trade tariffs and quotas, Branders (1987) suggests that the nation should opt for subsidies. These subsidies should be targeted at domestic producers to incentivize them, compensating for their inefficiencies. However, it is crucial to exercise caution and maintain proportionality in implementing these subsidies. This is important to prevent trading partners from perceiving them as predatory actions, which could trigger retaliation and potentially escalate into a trade war. For instance, under certain unique circumstances, targeted domestic subsidies may be employed to transform a country's status from that of a natural importer to an exporter of a certain item, without adversely affecting the overall trade objective. Likewise, export subsidies can be utilised to incentivize domestic producers to boost their exports to foreign nations, resulting in a broader economic foundation. Branders (1987) argues that excessive export subsidies can result in a transfer of earnings from foreign enterprises to domestic firms, creating a scenario where...

The policy is considered "predatory". It is deemed appropriate only when implemented as a retaliatory measure in response to an existing malicious action by another player, rather than being initiated as a "first strike". The application of game theory's economic tools allows for the optimisation of payoff functions among trading parties, hence minimising trade conflicts.

CONCLUSION

As countries continue to deal with each other more than ever before due to globalization, technological improvement and increasing economic integrations, more obstacles are predicted in resources allocation tasks something that demands the application of game theory. Nations need to establish what sorts of goods and services they should specialize on, how much of each should be produced and how much should be exchanged to take advantage of their relative comparative advantages. This may be a challenging undertaking in lack of creative methods in resource allocation. Game theory can be utilised to handle such specialization and resource-allocation challenges. Even while it cannot properly provide answers to all economic problems related with strategic decision-making and resource allocation, its models are nonetheless helpful in resolving complicated issues in international trade.

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