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Game Theory and its Application in International Trade: Use of Strategic Games in Trade Policy

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Abstract

The objective of this paper is to analyze the application of game theory in international trade. Given the fact that countries differ with each other in terms of their production capabilities, natural resource endowments, levels of technological innovation and so forth, game theory can be used as one of the tools in resource allocation. Theoretic games models assume that players in international trade are rational actors who make rational decisions something that is contrary to the reality. Typically, actors in the international trade are comprised of self-interested individuals whose decisions are not necessarily based on rationality. This article argues that even though game theoretic models cannot sufficiently provide answers to all economic problems, its applications are essential in resolving complex issues in bargaining, resource allocation and strategic decision-making in international trade.

Keywords

Game theory, international trade, mixed strategy, prisoner's dilemma, nash equilibrium

JEL Codes: C70; C71, F11

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1. Introduction

International trade is one of the key areas in economics that offers insights on how individuals, firms and countries can optimize their resources by trading with each other. Given the fact that countries differ from each other in various aspects ranging from their sizes, levels of natural resource endowments, geographical characteristics, educational skills of their labor forces, technological innovation and so forth, it is not possible for one country to meet all its economic needs. While one country can be more efficient in the production of certain goods and services based on its relative comparative advantage, it is through international trade that the country in question can acquire from its trading counterpart(s) the goods and services which it has a relative comparative disadvantage. The economic theory generally promotes the idea that through free trade; countries can gain more benefits and therefore, be able to raise their people's standards of living more rapidly than if they operate in a closed economy.

Alexa & Toma (2012), contend that although international trade produces winners and losers, overall, trading countries are better-off compared to non-trading countries. According to the law of comparative advantage, assuming there are two traded goods and that one country is less efficient in the production of both goods relative to its trading counterparts, it can still benefit from trade by specializing in the production of other goods for which it has the highest relative advantage. Thus, the rationale for free trade is based on the idea that one country cannot be self-sufficient in production of all goods and that for faster economic development; countries need to engage with each other through trade.

Game theory was traditionally used in various applications such as handling of international disputes, security negotiations and designing of military strategies. But, more recently, the application of game theory was extended to the field of economics following the release of "*Theories of Games and Economic Behavior*" by John von Neumann & Oskar Morgenstern in 1944. The two authors redefined game theory in ways that made its application relevant to the fields of economics and business. The basic assumption of game theory is the idea that players make rational decisions aimed to maximize their utility functions. This assumption corresponds with economic principle of rationality, which states that economic behavior is driven by rational agents whose objectives are to optimize their utilities.

Due to this linkage, theoretic games have been applied to solve a wide range of economic and business problems. Alexa & Toma (2012), contend that theoretic games are characterized by a number of players or decision makers who interact with each other, form coalitions and in some cases threaten each other in order to maximize their self-interests. In the competitive economic systems, players oftentimes make decisions under uncertain environments with a sole objective to

maximize their payoffs. In the same token, it becomes problematic when some players pursue strategies aimed to maximize their utility functions at the expense of other players. This explains why countries typically engage in trade disputes like the current trade war between the US and China.

The objective of this article is to analyze the application of game theory in international trade. Ostensibly, there exists some controversy among researchers on whether game theory can adequately provide answers to issues in international economics especially due to the fact that its fundamental models are based on the idea that players in the games are influenced by rational behavior. Since economic analysis is typically steered by theories and assumptions, this article also assumes that there are two trading actors engaged in an exchange of goods and services under an environment of incomplete information whereby one actor is not completely certain about the payoff function of another actor in international trade. The expectation is such that this article will contribute to the discussion about the merits and demerits of game theory application in international trade.

2. Theoretical review of issues in international trade

According to Alexa & Toma (2012), the fundamental principles of economic trade theory date back to the mercantilist doctrine in the 1600s and 1700s where the economic strength of a nation was determined precisely by the amount of precious metals (gold and silver) that the nation in question owned. Hence, during that period, the country's goal was to maintain a trade balance surplus by maximizing on exports (paid for by precious metals) while at the same time minimizing the levels of imports. This doctrine was implemented through strict government intervention measures pursued to increase the export to import ratio and hence more gold reserves. Nonetheless, this system was later on challenged by two classical British economists, Adam Smith and David Ricardo, who developed the principles of absolute advantage and comparative advantage respectively.

In "*The Wealth of Nations*", Smith (1776), who is regarded as the father of modern economics, challenged the mercantilist view of trade arguing that this doctrine not only led to an unsustainable economic system, but it was also self-interested and benefitted one side of the trade equation at the expense of others leading to a zero-sum-game. Apart from the fact that the world did not have enough gold reserves to support the mercantilist trade system (most countries do not have gold), Smith feared that the overall benefits of trade could not be realized under this doctrine. Instead, he introduced the principle of absolute advantage, stating that the nation has an absolute advantage over another nation if it requires fewer inputs (labor and capital) in production of certain goods or services than another nation. According to this school of thought, if nations specialize in production of goods in which they possess an absolute advantage and trade their excesses with other nations; ultimately both nations stand to gain from trade. Unlike, in mercantilist system which advocated for government intervention, Smith argued that there exists an economic efficiency and better allocation of resources if each nation would specialize in production of goods of its absolute advantage and trade parts of its output with other nations that produce goods of its absolute disadvantage. Moreover, all nations tend to gain more from trade if they operate under free trade arrangements and practice non-interventionist *laissez faire* approach.

The key assumption under the principle of absolute advantage is a belief that ultimately, specialization and international trade increase the productivity of the nations and their overall total output something that cannot otherwise be attained in the same scale under a different trading system. One major pitfall with this principle, however, is when a nation has an absolute advantage in production of both goods and services and finds no reason to trade with other nations due to a perceived sense of self-sufficiency.

According to Hughes (2007), David Ricardo offered a solution for this pitfall, by challenging the concept of absolute advantage when he introduced the principle of comparative advantage. According to this principle, a nation can consume more goods and services if it specializes in some particular industries or produces goods for which it is especially efficient in their production relative to other nations and trade its excess output with other nations to consume the goods produced by others. The theory of comparative advantage as a basis for international trade has become one of the most important ideas in economics. This principle is presently used by individuals, firms, nations and regional economic groupings to conduct inter-trade activities.

Despite the fact that there have been many economic theories since the classical period dealing with issues of trade, many trade conflicts continue to exist in the international economic system. Certainly, the problems of self-interests and zero-sum-game in international trade practices are still present today more than 200 years since Adam Smith & David Ricardo developed their theories. The World Trade Organization (WTO) was established, to among other things, deal with trade disputes and ensure that the global standards and regulations on trade are respected. Ostensibly, the objectives of the WTO are far from being accomplished as more and more countries engage in trade wars that violate its principles of fair trade.

Another problem is an existence of uneven playing field between trading countries, especially when weaker countries trade with more powerful ones. While the conventional wisdom has always assumed that market forces will efficiently resolve trade problems, more recently critics question whether under the current WTO regulations, both countries in the trade equation reap the benefits of fair trade on equal terms. Nonetheless, economists believe that most markets are perfectly competitive and even though there may be losers from trade, the gains from winners outweigh the losses incurred by losers in that eventually winners do compensate the losers in one way or another.

But, Alexa & Toma (2012) still challenge this viewpoint arguing that while it may sound palatable, in reality, the winners have never compensated the losers. Also, the idea that markets are perfectly competitive is misguided because in actual fact, markets are not perfectly competitive. There are various factors that differentiate one country from others leading to unequal economic strengths, varying degrees of educational skills, levels of investment, technologies etc.

McMilan (1994) undertook an extensive research on the application of game theory in international business and trade and argued that the main rationale for free trade is a notion that trade is always a win-win proposition for all countries involved. This viewpoint is supported by classical literature, as it has been noted in the earlier sections. That is to say, even though trade may lead to winners and losers, at the end of the day nations are better-off trading with each other compared to their economic welfare under closed economic systems. For example, Deng Xiaoping introduced China's opening-up policies in 1979 ultimately it joined the WTO in 2001. Currently, China is now one of the most powerful economies in the world having jumped from the 11th position in 1979 to becoming the 2nd largest economy in the world by 2010 after the United States. In fact, it is predicted that if China continues to grow in the current pace, it could become the most powerful economy in the world within a short period.

The standard wisdom in economic theory is based on the assumption that markets are perfectly competitive with no single producer having a monopoly of market power. But, the interaction in the global economy where many countries are involved in trade and where various goods and services are being traded pose a big challenge. As countries decide what products they should produce, how much of such products should be consumed domestically and how much should be exported and so forth, game theoretic models can be helpful to solve these kinds of challenges.

3. Definitions of basic concepts of game theory

Gibbons (1995) defines theoretic games as mathematical scenarios that encompass a set of players (individuals or firms), a set of strategies available to players, and payoff specifications for each combination of strategies. Each actor is a player in the game and the outcomes of the decisions made by interacting players (individuals, firms or nations) are affected by the payoffs functions of other participating player. One key assumption of game theory is the idea of rationality, the assumption that all players in the game are rational and, hence, the decisions they make are also rational. Neumann & Morgenstern (1944) developed the modern game theory and linked its application to the field of economics. They defined game theory as an interaction between various agents, governed by a set of specific rules. These rules and strategies pursued by players then determine possible moves for each participant and payoffs for each combination of moves. Thus, the game can be described as a strategic interaction that includes the constraints on the actions that players take.

Alexa & Tom (2012), assert that in microeconomics, theoretic games can be used in economic bargaining and international trade. But on the individual level, its application has been extended to include activities such as auctioning whereas in the firm level, game theory is used to solve multi-persons problems within the firm such as sorting out workers' competition for promotions, competition in investment funds allocation among various departments or divisions within the a firm and so forth. The authors further note that in the national level, game theory models can be used to solve a wide range of economic problems in international trade and competition particularly in situations where countries compete or collude in choosing tariffs and other trade policies.

3.1. Game representation, mixed strategy and Nash equilibrium

Assuming two countries are involved in trade, the relevant approach in theoretic games is to determine how each country can make decisions. If, for example, nation A trades with nation B, it is expected that each nation has limited information about the actions or motives of its partner. Thus, in order to attain maximum value in their trade interaction, each nation is expected to apply different strategies based on the actions observed in the trading process.

Gibbons (1995) contend that in mixed strategy games, one player represents another player's uncertainty about the first player's choices and strategy and the first player's choice in turn depends on the realization of small amount of information available about the game. The mixed strategy is therefore, interpreted in terms of what another player will do which is typically illustrated by the probability distribution function over the players chosen strategies. This analysis is also based on

normal form representation whereby players choose their actions simultaneously and each one knows his or her own payoffs function but may be uncertain about the other player's payoff function.

The concept of Nash equilibrium is helpful in determination of optimal solutions in the game. Gibbons (1995) defines the Nash equilibrium in a mixed strategy as a combination of payoffs which guarantee each player's mixed strategy is the best response of the other player's mixed strategies. Gibbons (1995) assert that one example of this scenario are sealed bids auctions where each bidder only knows about their own valuation but not that of other competing bidders. Thus, players' actions are considered to happen simultaneously and the existence of private information leads to informed players communicating and (in some cases misleading) their competitors and a constant attempt by those without such vital information to try to learn and respond which could lead in some aspects of dynamic games.

3.2. Prisoner's dilemma

This analysis applies the normal form representation of the game whereby each player chooses a strategy and a combination of strategies chosen by players determines the payoffs functions of each player. In normal form game representation players are usually listed on the top and left side of the payoff matrix. The available actions are defined in the columns and rows of the matrix table and payoffs are listed in each matrix cell where the actions of player's intersect. The concept of the prisoner's dilemma is extended to explain the strategies used in international trade under static games with incomplete information. Essentially, we are concerned with the trading strategies adopted by two nations A and B and use game theory to determine their payoff functions. The strategy often used to illustrate strategic choices in normal-form representation of the game is "prisoner's dilemma" – a concept described as a situation which occurs when two suspects are arrested by the police and charged for a crime but the police lack sufficient evidence to convict unless at least one suspect confesses. It is assumed that the suspects are held in separate cells and each is explained the consequence that could happen based on the action or responses that he or she gives in this interrogation exercise. The prisoners are separated so that there is no interaction and possible collusion between the two.

It is further assumed that the crime that the suspects are charged for is a minor offence but the suspects also committed a more serious offence in the past and therefore the police interrogator is questioning them to obtain a conviction on a serious crime as well. The deal that the police propose to each prisoner is that if both remain silent for the serious crime, they serve 1 year in prison for the light crime and escape a conviction on a serious crime. If one prisoner remains silent for the serious crime but the other one confesses, the confessor is set free while the other prisoner gets 9 years in prison. If both prisoners confess, both are prosecuted for the serious crime and get 6 years in prison. The Payoff matrix for the two suspects is shown below. The decision of the game is "confess" or "not confess".

Table 1. Prisoner's dilemma matrix representation

Prisoner 1	Prisoner 2	
	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.

From matrix above, if both prisoners confess they both get a conviction to serve 6 years in prison. If both do not confess they both get one year in prison. If Prisoner 1 confesses but Prisoner 2 does not confess, the confessor is set free while Prisoner 2 gets a conviction of 9 years in prison. The opposite is also true since this matrix is symmetrical. It can therefore be concluded that, remaining silent is always dominated by confessing. Thus, remaining silent can be eliminated from Prisoner 1's and vice versa since the same is symmetric. Therefore, the only combination that remains possible is confessing for both players. If the procedure of elimination of dominated strategies is repeated we could get a solution or at least get closer to getting the solution (tightening of our predictions by eliminating a few strategies). This ultimate solution is what is known as the Nash equilibrium. In a 2-player game The Nash equilibrium occurs if we find a matrix combination or payoff in which one player's strategy is optimal for a given strategy by another player and vice versa. In other words, it is a payoff combination in which one cannot do any better by choosing a different strategy given the action taken by another player. From the prisoner's dilemma example above, the Nash equilibrium is obtained by (confess, confess) combination which, in essence, according to this payoff arrangement, it is the only available Nash equilibrium. That is to say, the players have no any incentive to choose a different strategy than the one where they both confess. For example, if one chooses to remain silent, he or she gets 9 years in prison which is a worse-off scenario compared to the scenario where the suspect will get a conviction of 6 years in prison (the worse-case scenario if he or she confesses. Gibbons (1995) sums up the description of the Nash equilibrium arguing that it is the payoff point at which no one player would want to change his or her

strategy. Nash equilibrium in mixed strategy games guarantees that each player's mixed strategy is the best response to other player's mixed strategies.

4. Specialization, protectionism and trade policy

Based on the Ricardo's assumption that trade is mutually beneficial for both players, this section illustrates how game theory is used to determine trade specialization among countries. First, we look at how theoretic games can be used to help a country to specialize in production processes. Second, we consider how each country can strategize in setting trade policy decisions, the objective here being to see how strategic games can be used to maximize each country's utility in a way that its actions do not undermine the economic welfare of its trading partner. The second sub-section looks at how protective measures can be used by trading countries to protect local industries. As each country pursues trade, it is important to be mindful that trade does not adversely impact local production capacities. Typically, the trade policy tools often used are tariffs and quotas on imports and protective subsidies provided to local industries or may be targeted to a particular product, goods or services. It is worthwhile pointing out that while tariffs and quotas on imports are meant to increase the prices of imported goods so that locally-produced goods can become attractive and in turn boosting the local industries, game theory can be used to aid this process. Hughes (2007) argues that while quotas are applied to restrict the number of units of imported goods or commodities, one has to be cautious that quotas do not become too restrictive because by so doing it will lead into an emergence of exorbitant prices and illegal black market as unintended consequences of free trade.

4.1. Specialization and resource allocation

The concept of prisoner's dilemma may be extended further to analyze what kinds of strategies trading nations could adopt, first, in making specialization decisions on what goods to produce for exports and, second, what goods to acquire from other trading partners through imports. As it has been noted in previous sections, per the principle of comparative advantage, nations should produce those goods and services that they are more efficient in producing relative to other nations and then import those goods that they have relative comparative disadvantage on their production. Let us assume that there are two imaginary African countries (Tanzania and Ghana) involved in trade of good A and good B respectively. This example aims to show how theoretic strategic games can be used in production specialization in a way that maximizes resources. Since there are only two countries and two goods are used in the trade, the matrix is symmetric. The payoff allocation is summarized in the following table.

Table 2. Payoff matrix for specialization in cash crop production

Ghana	Tanzania	
	Product A	Product B
	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

Based on the above matrix, if both nations choose to produce product A, they both gain \$200 million from trade. If both choose to produce the product B, they both gain \$500 million from trade. If Ghana chooses to specialize in production of the product A but Tanzania chooses to produce the product B, Ghana gains \$800 from trade and Tanzania gains nothing. The payoffs are such that Ghana's outcomes come first and Tanzania's outcomes come second. Whatever Tanzania chooses to produce, Ghana gains more by producing the product A. Conversely, if Tanzania specializes in the production of product A and Ghana produces product B the opposite is true. Collectively, both players get maximum value in the trade interaction if they both produce the Product B whereby the payoff is \$500 million for each nation. Essentially, the outcomes of these strategies show that whatever each country gets if it produces individually does not necessarily maximize the utility of both countries.

In order to avoid the unintended consequences of trade intervention through trade tariffs and quotas, Branders (1987), argues that the best approach is for the nation in question to use subsidies aimed to encourage domestic producers by compensating on some of their inefficiencies but then this should be done carefully and proportionately without necessarily being interpreted by the trading partners as taking predatory actions which could potentially be retaliated against leading to a trade war. For example, in some special situations, the domestic subsidies could be applied selectively in ways that actually change the nation's status from being a natural importer to an exporter of a given commodity but without having the negative impact of the overall trade objective function. Similarly, export subsidies may be applied to induce local producers to increase their levels of exports to other countries leading to an expanded economic base. According to Branders (1987), since excessive export subsidies can shift the profits from foreign firms to domestic firms, leading to a situation where such

policy is viewed as “predatory”, this policy can only be acceptable if it is carried out as a retaliatory measure against an action of ill-intent already made by another player than if it is a “first strike”. It is through economic tools offered by game theory that these kind strategies, actions and payoff combinations can be applied to optimize the payoff functions of the parties involved in trade to avoid unnecessary trade conflicts.

5. Pitfalls of game theory

Despite the advantages of game theory in setting business decisions, there are also its shortcomings. Firstly, game theory is based on a notion that players are rational and that they make rational decisions. But, in reality, this is not always the case. For instance, marketing decisions are made based on the idea that consumers could sometimes be irrational in that buying choices are not usually based on rationality. Instead, consumers oftentimes buy based on “emotions” contributed by various factors including advertising techniques. This explains why marketers use of advertising techniques in social media, print media, radio or television etc. focusing on how emotions can be triggered among buyers. In other cases, buying decisions could be made due to other factors such as peer pressure among young people, for example, where one buys something just because his or her friend has one. Secondly, game theory assumes that players act strategically and consider the competitive responses of their actions while the reality of the matter is that not all business persons across the globe act or made decisions strategically. There are many scenarios where companies fail for failure among its managers to be strategic in their decision-making processes relative to their competitors leading to inefficiency and huge losses.

Third, game theory is assumed to work better when players understand the expected positive and negative payoffs of each other's actions something that is not always possible. It is widely known that each firm seeks to promote its self-interests in typical business activities and in some cases by undertaking unfair practices against their competitors in order to gain an advantage. That being the case, it is certainly expected that each firm would try to conceal its most essential business information (profit margins, marketing strategies, and so forth) in order to win in the competition. In fact, due to the complexity involved in business, it is not possible for firms to fully understand their own payoffs function let alone those of their competitors. McMillan (1994) argues that the distinctive feature of game theory is presence of interdependence among the players where one's utility depends not only on his own actions, but also on the actions of each of the other players. The author goes on to observe that although, it did not meet all the expectations, the application of game theory has been helpful in solving complex problems in social sciences particularly in the field of economics where its application is used in the study of oligopolies, cartels, externalities involved in provision of public goods, in managing auction activities and in the sub-field of international trade and negotiations.

6. Conclusions

As countries continue to trade with each other more than ever before due to globalization, technological advancement and increased economic integrations, more challenges are expected in resources allocation tasks something that requires the application of game theory. Nations need to determine what kinds of goods and services they should specialize on, how much of each should be produced and how much should be traded to take advantage of their relative comparative advantages. This may be a daunting task in absence of innovative tools in resource allocation. Game theory can be used to resolve such specialization and resource-allocation problems. Even though it cannot sufficiently provide answers to all economic problems concerned with strategic decision-making and resource allocation, its models are still helpful in resolving complex issues in international trade.

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