Game Theory as a tool for dispute management in shared resource utilization

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1. INTRODUCTION

Cooperation possibilities are ubiquitous in every system where two or more participants or players are involved. Yet often times it is observed that the players don’t collaborate. They rather opt for individual strategies (Ishii et al., 2013; Rogers, 1969). Such strategies may result in distress and misunderstanding among them. Conflicts among the players prevent them from making the best use of their shared resources. Cooperation may reduce these conflicts by adopting schemes and strategies of mutual benefit (Bhagabati et al., 2014; Mylopoulos et al., 2007). The benefit outcome of such individual strategies is often found to be less than what can be achieved had they adopted cooperative strategies.

This paper draws attention to the concepts of Game Theory and how such concepts can be applied to different situations. The main objective of this paper is to review the different cooperative approaches adopted in a variety of fields, such as transportation systems, transboundary watershed management, regional cooperation, air-pollution, and so on. Authors believe that review of such problems will provide alternative possible directions for future research.

2. GAME THEORY

Game theory is a science of decision making, either simultaneous or sequential, on how individual or groups of people interact. In other words a game is a model of strategic interaction, which arises when the outcome of one individual’s actions depends on actions taken by others (Myerson, 1997).

In 1928, John von Neumann introduced Game Theory into mathematical economics. Since 1944, it has been a central tool for understanding how cooperative entities can overcome the obvious fitness and payoff disadvantages and persists in the face of cheating and exploitation (Doebeli & Hauert, 2005). The requirement of any mechanism to promote collaboration is that cooperative acts must occur more often between the players than expected (Queller, 1985). Cooperation is not the desired end of a system, it is rather perceived as the basis for proceeding with development of shared resources. Cooperative game theory has proved to be very effective for finding “fair” methods for allocating common benefits and costs (Hennet & Arda, 2008; Rogers, 1993).

2.1 Types of Game Theory

Game Theory can be categorized into four different types: a) cooperative and non-cooperative; b) symmetric and asymmetric; c) zero-sum and non-zero-sum; and d) simultaneous and sequential games. Any particular game can be categorized into one or more than one types. In this paper we would like to focus mainly into the first category, i.e., cooperative and non-cooperative games, although we would discuss other categories as well.

In non-cooperative game, individual players try to interact with one another in an effort to attain their own goals. But, in a cooperative game players try to attain a state which is beneficial for all the players involved. The games such as Nash equilibrium, Stackelberg game, transferrable utility (TU) game and zero-sum game are the most common in practice (Akiyama & Kaneko, 2000; Bhaduri & Liebe, 2013; Del Pozo et al, 2011; Larbani, 2009; Pruzhansky, 2013; Wang et al., 2010).

The simplest game is a two player sequential game (Curiel et al., 1989) where the second player takes a decision after the decision of the first player. This game is not so common as such ideal condition is very rare. The more common form of this game is the two player simultaneous game (Godinho & Dias, 2010) where, as the name suggests, both the players take decision simultaneously. A much more complex form of this game is the game involving three or more players (Wu et al., 2013). Such games are very difficult to model and analyze as the complexity of the game increases exponentially as the number of players is increased.

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3. GAME THEORY AS A TOOL FOR DISPUTE MANAGEMENT

The scope of game theory is broad and it has the potential to be used as a tool for dispute management among players when utilizing shared resources. Game Theory can be applied in different fields/areas such as transportation systems (McCain, 2008), geo-politics (Biba, 2013), medical science (Mamani et al., 2013), watershed management (Hensel et al., 2006), hydropower development (Sneddon & Fox, 2007) and so on. The sections below will show how effective the use of Game Theoretic approach can be.

3.1 Transportation systems

As discussed earlier, game theory can be applied to transportation systems/problems, Laporte et al., (2010), used a stochastic game theoretic framework to develop a robust railway transit system which can perform when the edges may fail, Hennet & Arda (2008), showed how game theory can be applied in a supply chain coordination system. They showed efficiency achieved when different contracts between the partners are involved.

Ishii et al., (2013), used a non-cooperative game theoretical approach to examine the effect of inter-port competition. They compared the results of a two-player port competition model with the historical data available. Their results showed that while the theoretical model explains that ports should set lower rates when demand elasticity is high and port expansion activities are both high and almost simultaneously undertaken by competing ports, the actual decision by the Japanese government was contrary to the theory. Using the concepts of game theory, they showed possible alternative scenarios where the two ports could have attained a better traffic balance, and higher benefits and efficiency.

3.2 Decision support systems

Decision support system is an essential part of logistics, supply chains, market share, etc. Lozano et al., (2013), showed how game theory can be used as a decision support system by allocating benefits of horizontal cooperation among shippers. Kabiraj (2007), applied the concepts of game theory in product market competition. The author portrayed situations to show that non-cooperative R&D can occur even if the probability of success in R&D is large. Their results showed that when the innovation size is large, cooperative research is likely to occur. Similar research has been done by Nagarajan & Sošić (2008) on supply chain agents and Okamoto (2008) on fair cost allocation.

3.3 Transboundary watershed management

Transboundary waters face a multiplicity of governance challenges. The effectiveness of transboundary governance plays a vital role in regional cooperation (Paisley & Henshaw, 2013). In this regard, Anghileri et al., (2013) have used the Alpine watershed in Italy as a study area to analyze the long lasting conflicts about the upstream hydropower development and the downstream irrigational water usage. The authors have designed a coordination mechanism at the watershed scale to foster negotiation between the riparian. Comair et al., (2013) have demonstrated a similar problem in the Orontes River Basin shared between Syria, Lebanon and Turkey. The authors have developed an optimization model based on nine factors of the UN Convention (1997) to allocate water equitably between the co-riparian. The use of Geographic Information Systems (GIS) datasets also plays an important role in modeling such real world problems (Gleditsch et al., 2006; Yoffe et al., 2004).

In the transboundary scenario, Hensel et al., (2006) examined the peaceful and militarized techniques used by the states to manage river claims. They also compared the success of the different techniques used for resolving the issues under contention. In the context of transboundary river floods management, Bakker (2009a) provided new insights in the relationships between flood losses and vulnerability factors. Bakker (2009b) also argue that institutional capacity plays a role in the reduction of flood-related casualties and affected individuals.

3.4 Regional cooperation

China’s unilateral exploitation of the upper watershed for hydroelectricity and navigation has raised concerns about negative socio-ecological impacts on the downstream states (Alam et al., 2009; Hudson-Rodd & Shaw, 2003). Recent empirical evidence shows that China is gradually getting involved in negotiations and processes with the downstream states (Biba, 2012; Onishi, 2007). Improved regional governance, in the decades to come, depends upon efforts by many actors to raise the incentives for intergovernmental cooperation, expand civil society engagement, and strengthen mechanisms for cross-border accountability (Ratner, 2003).

Transboundary protected areas are often characterized as a viable strategy in facilitating the participation of cross-border communities in cross-border nature-based tourism business partnerships (Tumbare, 2005). But often times due to some cognitive barriers the expected cooperation is not achieved which result in conflicts among the riparian nations (Chaderopa, 2013). Rogers (1993) argue that the sharing of river basins between and among countries is the rule rather
than the exception for the major river systems of the world. Cooperation may reduce these conflicts by adopting schemes and strategies of mutual understanding (Sadoff & Grey, 2005).

Game theory can play a vital role in such situations as it can provide the players or rather the countries with alternative strategies to resolve such disputes. By following such coalition strategies, the total as well as individual benefits can be maximized and the losses minimized. Bhagabati et al., (2014) has shown the same by using a transferable utility cooperative game in transboundary hydropower development context. They did optimization of transboundary hydropower development in the Sesan, Sekong and Srepol (commonly known as 3S) sub-basin of the Mekong River. They also performed feasibility analysis to provide better sets of results for numerous different coalition scenarios. With the upcoming ASEAN Economic Community (AEC), such research may provide policy decision makers a basis for equitable development and regional cooperation in the hydropower development context.

Most papers cited in this paper developed methodologies to estimate the benefits of cooperation. Contrary to that, Tilmant & Kinzelbach (2012) developed methodology to assess the economic costs of noncooperation when managing large-scale water resources systems involving multiple reservoirs.

3.5 Air pollution

In the early 1990s, increasing emission of pollutants raised concerns among the European countries. This transboundary air pollution issue resulted in negotiations among the countries to sign the 1194 Oslo Protocol. The paper by Apsimon & Warren (1999) described the scientific and technical work undertaken in the development of the protocol. A similar case study was done with East Asia as the study area by Min (2001). In this context, the author has suggested that a multilateral cooperation approach for environment safety is more beneficial than a bilateral approach. The author also argued the requirement of regional environmental protocols/treaties.

Using the concepts of cooperative game theory, such conditions resulting distress among the countries can be eliminated. New strategic coalitions can be proposed which can minimize such deputes, thereby increasing the benefits of the players.

3.6 Other transboundary issues

Apart from the main transboundary issues such as watershed management, hydropower development, ground water issues and fisheries management, there are few more issues like environmental policies, air pollution and hazardous wastes management.

As the amount of hazardous wastes produced annually is increasing exponentially, the poor and under-developed countries are being targeted as the new dump yards. This movement of hazardous wastes is a very important issue. The steady increase in the importation of such wastes threatens the environment. Using Taiwan as a study area, Hsing et al., (2004) proposed few strategies to tackle this alarmingly increasing transboundary movement of hazardous wastes.

Another interesting research involving game theory was done by Lindelauf, et al. (2013) where they used the Shapley value in a cooperative game to identify the key players in a terrorist organization and hence suggest what efficient allocation of surveillance measures should be taken.

Andritsos & Tang (2013) showed how a Game Theoretic model can be applied in the field of medical sciences in the transboundary context. Their health care model studied the "free choice" of patients to receive care abroad. The results showed cross-border patient movement can increase patient welfare and access to care for all countries involved.

Dshalalow & Huang (2008) modeled and analyzed a non-cooperative hybrid stochastic game involving two players. The main phase of the game is preceded by "unprovoked" hostile actions by one of the players that at some time transforms into a large scale conflict between two players. The game lasts until one of the players gets ruined.

4. CONCLUSION

From the literature review it can be asserted that Game Theory is indeed an efficient tool to model problems seeking cooperation. It was observed that most papers developed simple models for solving problems such as transportation problem, supply chain, cost allocation problem, watershed sharing, air pollution, health care systems, etc. Most of the papers on watershed sharing demonstrated a two-player benefit sharing model (Anghileri et al., 2013; Rogers, 1993). Comair et al. (2013a) demonstrated a three-player benefit sharing problem in a shared watershed. Bhagabati et al., (2014) did a cooperative transboundary cooperation analysis on three-player and three-sub-basins in the Lower Mekong Basin. It should be noted that the level of complexity in such analysis increases exponentially as the number of players increases in the game. The type and extent of cooperation among the players also plays a major role in deciding strategies as it may change the total outcome of the coalition scenarios.

In all the different researches involving cooperation, it was observed that total cooperation could not be effected in a purely deregulated system. Also it should be noted that optimization always aims at maximizing the total benefit. But
the best scenario always favors a particular player, unless there is sharing of benefits.

In the context of regional cooperation, the concepts of game theory has showed some promising results. Such results can be applied for framing new policies to facilitate negotiations among the countries. This in turn will provide policy decision makers a basis for equitable regional development. It was also observed that in most of the papers, analysis was done with only few parameters (four to five). However few papers did took into account more than ten parameters.

Another important finding is that in models lacking real data, i.e., having a number of assumptions and arbitrary data, most of the times due to lack of data; sensitivity analysis should be performed to minimize any possibilities of error and thereby making the results more practical and appealing. Bridging the gap between theoretical and empirical research is one of the main challenges for future studies of cooperation, and we have a number of promising fields where these concepts can be tested experimentally.

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References


