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Decision Support

A general hierarchical graph model for conflict resolution with application to greenhouse gas emission disputes between USA and China

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ABSTRACT

The general hierarchical graph model, a significant expansion of the graph model for conflict resolution methodology, is designed to analyze interrelated conflicts with hierarchical structures. In a general hierarchical graph model, there are common decision makers, who take part in all related subconflicts, and local decision makers, who participate in only one subconflict. In this paper, preference structures for decision makers in a hierarchical graph model are established, and theorems are developed that elucidate the relationship between stabilities in the overall (hierarchical) model and stabilities in the component submodels. To illustrate, the hierarchical graph model is applied to greenhouse gas emission disputes between USA and China, where local decision makers in the USA are the two parties in Congress, and local decision makers in China are state-owned energy companies. The stability results suggest potential strategic resolutions of bilateral disputes, and how parties can attain them.

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1. Introduction

Conflict is an interaction between parties who have different interests and objectives. Strategic conflicts can be commonly found in the real world, ranging from military confrontation to resource disputes, when decision makers (DMs) make independent choices that generate different outcomes (Li, Hipel, Kilgour, & Noakes, 2005). To formally investigate and effectively handle these conflicts, various conflict analysis methodologies have been developed, such as Game Theory (Von Neumann & Morgenstern, 1944), Metagame Analysis (Howard, 1971), Conflict Analysis (Fraser & Hipel, 1979; 1984), Drama Theory (Howard, 1971), and the Graph Model for Conflict Resolution (Fang, Hipel, & Kilgour, 1993; Fang, Hipel, Kilgour, & Peng, 2003a; 2003b). Game theory is a widely used methodology to mathematically model strategic conflicts in which DMs are assumed to be rational and to have fixed strategies (Nash, 1950; 1951; Von Neumann & Morgenstern, 1944). As counteractions by other DMs are important in determining the course of a conflict (Madani & Hipel, 2011), more solution concepts that reflect behaviors of DMs have been introduced to indicate equilibria of a conflict, such as Sequential Stability (SEQ) (Fraser & Hipel, 1979; 1984), General Metarationality (GMR) (Howard, 1971), and Symmetric Metarationality (SMR) (Howard, 1971). The Graph Model for Conflict Resolution (GMCR) is an improvement of the conflict analysis approach by describing moves for DMs using directed graphs (Kilgour & Hipel, 2010). Having a flexible theoretical structure, it can model irreversible moves and common moves (Kilgour & Hipel, 2005). The foresights of DMs have also been described by introducing new stability definitions: limited moves and non-myopic stabilities. Moreover, the decision support system GMCR II (Fang et al., 2003a; 2003b) and GMCR+ (Kinsara, Petersons, Hipel, & Kilgour, 2015) have been constructed to facilitate model calibration, stability calculations, and interpretation of strategic findings in order to enhance understanding and the decision making process.

In the real world, a conflict is often constituted by smaller disputes that are connected logically or by location. These linked conflicts are called hierarchical conflicts. Failure to perceive the connection among these conflicts may lead to inaccurate predictions regarding the possible outcome for DMs. By considering interrelated conflicts as a system, the investigation of strategic conflicts in

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a hierarchical perspective is important to indicate the behavior for decision makers (Hämäläinen, Luoma, & Saarinen, 2013; Mingers & White, 2010). The hierarchical structure of conflicts has been widely discussed within the Game Theory paradigm. Hierarchical games denote interrelated games with different ranks or multiple levels. Weights and thresholds are assigned to define the seniority of players in a hierarchical game (Beimel, Tassa, & Weinreb, 2008). Possible options are also defined with different levels and labeled with weights (Gvozdeva, Hameed, & Slinko, 2013). Markov chain models have been utilized to analyze hierarchical games constituted by smaller games. The resolution for a DM in each smaller game was investigated in order to form a comprehensive strategy for the entire game. As an application, a game of tennis can be modeled to indicate how players can win the game by optimizing their available energy (Brimberg, Mladenovic, & Salhi, 2004; Gale, 1971; George, 1973; Gillman, 1985; Walker & Wooders, 2001). A Stackelberg game is another type of hierarchical conflict, in which players are divided into a leader and several followers (Simaan & Cruz, 1973; Von Stackelberg, 1934). Specifically, players in a Stackelberg game move sequentially and they have asymmetric information about the game.

The aforementioned models for analyzing hierarchical conflicts require a large amount of input information for model calibration, and are therefore lacking flexibility and simplicity. In particular, in game theory models, it is hard to determine the cardinal utility values to describe the preferences of DMs and threshold values to define the levels in a hierarchical game. The Markov model requires probabilities to carry out rigid computation. As a non-quantitative model, GMCR can be applied to effectively model hierarchical conflicts and provide meaningful results. A basic Hierarchical Graph Model for Conflict Resolution has been proposed to formally analyze hierarchical conflict with an application to water diversion conflicts in China (He, Hipel, & Kilgour, 2014; He, Kilgour, Hipel, & Bashar, 2013). The model contains only one common decision maker (CDM), who supervises the two subconflicts. As an expansion of the basic hierarchical graph model, the general hierarchical graph model that contains any number of CDMs is designed in this paper. This new methodology is applied to the greenhouse gas emission disputes between USA and China.

Global warming has posed a threat for humankind and other species on earth, and has drawn concerns for governments and international communities. The increasing concentration of greenhouse gases is a major contributing factor to global warming (Pachauri et al., 2014). Greenhouse gas contains water vapor, carbon dioxide (CO_2), methane (CH_4), and ozone (O_3) (Kiehl & Trenberth, 1997). As a political effort to reduce greenhouse gas emissions, most countries have joined the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol and the following Doha amendment are extensions of this framework under which countries cooperate to mitigate the global warming. Over the past few decades, the relative amounts of greenhouse gases emitted by major countries of the world have changed dramatically. Emerging industrial countries like China and India have increased their emissions significantly. In light of this, the United States rejected the Kyoto Protocol, claiming that the exemption of responsibilities from the two most populated countries would harm the US economy (Dessai, 2001). Thus, the mitigation goals cannot be achieved without the commitment of the world's two largest economies, USA and China.

Climate change negotiation is an area of study involving interdisciplinary knowledge. To control greenhouse emissions, national governments should first properly identify abatement goals within their own countries (Georgopoulou, Sarafidis, Mirasgedis, Zaimi, & Lalas, 2003). In the international negotiations, these governments should reach agreements that are unbiased, fair, non-myopic, and reflect reasonably allocated responsibilities (Vaillancourt & Waaub, 2004). The negotiation process should take into account political factors such as the influence and the interest of each stakeholder (Heyward, 2007; Penetrante, 2012). Climate change negotiations have been modeled to demonstrate the dynamics of the decision making process (Courtois & Tazdait, 2007). Penetrante (2012) stated that conflict resolution has been a basic dimension of the climate change negotiations. Game theory has been widely used in modeling climate change negotiations, including noncooperative games (Peck & Teisberg, 1999) and classical cooperative games (Chander & Tulkens, 1995). The Kyoto Protocol negotiations have been modeled using extensive games (Ciscar & Soria, 2002; DeCanio & Fremstad, 2013; Forgo, Fulop, & Prill, 2005). These studies provided Nash and correlated equilibria as the solution, which neglects counteractions from other DMs (Madani, 2013). In this paper, by using a general hierarchical graph model, the greenhouse gas emission disputes between the USA and China are investigated in the case study to provide realistic strategic insights by using solution concepts that can reflect the foresights and the perception of risks for DMs.

In the remainder of the paper, a brief introduction about the greenhouse gas emission disputes is given in Section 2. The theoretical structure of the general hierarchical graph model is proposed in Section 3, with explanation of what each definition means in the real world example introduced in Section 2. Solution concepts in the general hierarchical graph model, as well as their connection with those in component graph models, are investigated in Section 4. The steps for calculating stabilities in the general hierarchical graph model are listed in Section 5. The detailed analyses of the real world example are provided in Section 6.

2. Greenhouse gas emission disputes between US and China

The general hierarchical graph model is applied to disputes between the USA and China over adhering to a bilateral climate change agreement. The two countries are also facing opposition from different parties within each nation. On November 11th, 2014, the two super powers reached a deal to curb carbon emissions in the next few decades (Goldenberg, Taylor, & Branigan, 2014). According to the treaty, China committed to limit carbon emissions by 2030 and increase the percentage of clean energy use to 20%. Meanwhile, the USA agreed to emit 26–28% less than the 2005 carbon levels by 2025. Studies clearly indicate that a country like Canada is capable of reducing its greenhouse gas emissions by 60–90% at reasonable cost (Council of Canadian Academies, 2015).

This agreement has shown the determination of the two nations in reducing carbon emissions by cooperation. However, challenges and disputes take place in both nations. In the US Congress, the Republicans threatened to block this deal, because many of the representatives have connections with traditional energy industries. They believed that this agreement would result in fewer jobs and higher energy prices. Although the White House claimed that the abatement target for the US is achievable under the existing environmental laws, experts have pointed out that these goals are hard to meet without new legislation (Levi, 2015). However, as the Republicans have held the majority of seats in Congress, the new climate laws are likely to be blocked by them (Yuhas, 2015). Besides, the emissions targets need a few decades to be achieved. Because the actions for the next administration are unknown, the future of this agreement is in doubt.

In China, large efforts should be made by the government to reach the abatement goal. As China still relies heavily on traditional energy, the energy industry needs to be reformed by implementing stricter environmental laws (Bradsher, 2010; Lewis, 2008). For fear of losing profits, stakeholders such as state-owned energy companies, such as coal and petroleum companies, would actively oppose these laws by lobbying the government using their politi-

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