Group Decis Negot (2017) 26:997–1027
DOI 10.1007/s10726-017-9528-8

Strategy, Complexity and Cooperation: The Sino-American Climate Regime

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Published online: 15 March 2017

Abstract The Graph Model for Conflict Resolution is applied to a potential climate negotiation between the United States of America (USA) and the People's Republic of China (PRC) in order to gain strategic insights into how a successful agreement to reduce greenhouse gas emissions could be reached. In light of the failure of many nations to meet their expected Kyoto Protocol emission reduction targets and the lack of involvement of the world's greatest emitters of airborne pollutants, the USA and PRC, there is a need to determine successful strategies for combating climate change. The issues surrounding the potential implementation of a bilateral agreement between the USA and PRC are systematically analyzed. Information gathered about the decision makers, options and preferences within the potential negotiations is utilized to create a valid conflict model which is used as a basis for carrying out strategic analyses. Moreover, a novel method is implemented within the Graph Model for Conflict Resolution to gain insights into the impact of attitudes on these negotiations. The strategic findings reflect reasonably well what actually occurred in November 2014 when the USA and PRC negotiated a bilateral deal.

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Keywords Graph Model for Conflict Resolution · Sino-American climate regime · Game theory · Cooperative behavior

1 Introduction

Due to the detrimental impact of expanding industrialization upon the global climate, it is important for humanity to begin reducing its climatic impact and to adapt to the changes it has already caused. Homer-Dixon (2008) notes that there has been a "sea change" within the scientific community. A more urgent view of climate change has been adopted by most researchers who study the science of climate change, as data increasingly point towards a greater than expected change in global temperatures, an increase in ice cap melting, significant sea level rises, escalation of superstorms and the need for more immediate political action (Hansen 2009; Hansen et al. 2016; McCauley et al. 2015; Moore and Diaz 2015). Complicating matters, the global environment is a complex system whose behaviour is difficult to predict due to the non-linear and delayed reactions of the climate's response to humans' actions (Homer-Dixon 2007). Connected to this complex environmental system are complicated economic and social systems which are interdependent upon each other and the environment. Moore and Diaz (2015), for instance, demonstrate that temperature impacts on economic growth warrant stringent mitigation policies. Thus, actions to mitigate climate change must account for their effect on these social, economic and environmental systems in order to be effective. To analyze these interconnected systems and the impact of possible actions to combat climate change, the employment of a system of systems (SoS) approach (Hipel et al. 2007, 2008, 2009, 2010; Ge et al. 2014) whereby social, environmental and economic systems are tied together, may provide significant insights. One element of this complex SoS, the socio-political system, is investigated herein. A decision model based on the social and political negotiations is developed in the following sections using the Graph Model for Conflict Resolution (GMCR) (Fang et al. 1993; Hipel et al. 2011; Hipel and Bernath Walker 2011).

The development of a Sino-American climate agreement may be difficult because of the important financial issues associated with reducing carbon emissions and the historic differences between the two nations. Such an agreement may, however, drive a cultural change towards reductions of greenhouse gas emissions within both countries, as Bailey (2008) suggests with respect to agreements between industry and environmental regulators. The United States of America (USA) and the People's Republic of China (PRC) have been diametrically opposed as a result of the stark contrast between the USA's capital-driven society and PRC's Maoist communism, at least within its political system, since the late 1940s. This ideological difference has caused both nations to be pitted against each other in two regional Asian conflicts: the Korean (Edwards 2005) and Vietnam (Zhai 2000) wars. In recent years, however, their relationship has improved, partially due to the PRC's communist ally, the Soviet Union, becoming a capitalist state at the end of the Cold War. This new era in Sino-American relations has led to increased trade between the two nations (Song 2006).

In Sect. 2, the current climate regime (Sect. 2.1) and the political relationships between the PRC and USA (Sect. 2.2) are outlined. In Sect. 3, the Graph Model for

Conflict Resolution (3.1) is described and subsequently, a simple model (3.2) and a more complex model (3.3) are determined for investigating the conflict between the USA and PRC over negotiating a climate regime. In Sect. 4, attitudes, as conceptualized within the Graph Model for Conflict Resolution, are defined (4.1) and then applied to the previously modelled conflict (4.2) with the goal of providing better strategic insights into how a Sino-American climate pact might be agreed upon, given the complex relationship between the nations, as discussed in Sect. 2. In fact, these investigations, which were initially carried out in 2011, mimic what happened in late 2014 when the USA and PRC reached a bilateral agreement. Finally, in Sect. 5, interesting discoveries from the application of the graph model methodology in Sects. 3 and 4 are discussed and final conclusions are drawn in Sect. 6.

2 Conflict over Climate Change

To appreciate the complex negotiations that must take place in order for these two powerful nations to agree to a climate strategy, it is important to consider the structure of the current global climate regime, and the relationship between the USA and PRC. In the following subsection, the current state of climate negotiations including the Kyoto Protocol, and the diplomatic history between the USA and PRC are discussed.

2.1 The Current Climate Regime

2.1.1 Overview

In response to global climate change, governments, corporations and citizens have recognized the need to reduce the emission of greenhouse gases. Internationally, the first step in this process has been the initialization of the international environmental agreement referred to as the Kyoto Protocol. The Kyoto Protocol, a legal instrument under the United Nations Framework Convention on Climate Change, is designed to encourage a reduction in the emission of the gases that cause climate change. Under the protocol there are six main gases that must be reduced: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons, and perfluorocarbons. The protocol was first signed during the period from March 1998 until March 1999 and ratified thereafter, with distinct climate goals set for the 2008–2012 period (United Nations 2007; OECD 1999). During the first commitment period of the protocol, developed nations ratified the protocol and thus agreed to limit or reduce their CO_2 emissions to between -8 and $+10\%$ of 1990 levels. The protocol allows for the trading of emissions certificates by nations that exceed their reduction goals. Thus, it was in the best interest of nations to overstate the impediments to their potential reduction of emissions or to overstate their 1990 emissions levels. Former Soviet Bloc nations held a particular advantage as their emissions had actually dropped significantly since the fall of the Soviet Union and were thus significantly lower than 1990 levels to begin with (Walker et al. 2007).

The protocol also placed heavier responsibility for climate change upon the developed nations that caused it, in a structure referred to as "differential responsi-

bility". Thus, the developed nations became responsible for the significant emissions reductions needed to help reverse, or at least slow down, global climate change. Unfortunately, difficult problems arose in the negotiation of the protocol. Most notably, some developed nations balked at signing an agreement in which developing nations with large carbon emission levels, specifically the PRC and India, were not included. The aftermath of this disagreement was that the largest emitter of greenhouse gases at that time, the USA, refused to ratify the agreement. Therefore, in order for the agreement to come into force it was necessary for Russia to ratify it, thereby satisfying the stipulation that at least 55 nations making up 55% of the world's greenhouse gas emissions were needed before the protocol could be implemented. The most troubling issue of the newly ratified agreement, however, was whether the protocol could actually help reduce emissions of greenhouse gases without the agreement of the world's two greatest emitters of greenhouse gases: the USA and PRC. Certainly, the USA's withdrawal threatened to affect the very legitimacy of the agreement; however, it is the exclusion of the rapidly industrializing developing nations which deterred the USA from taking part and still remains a major stumbling block to American participation.

In recent years, the various parties to the Kyoto Protocol have met to discuss their progress and plans for future negotiations. At the meeting of the Group of 8 (G8) industrialized nations in L'Aquila, Italy from July 8th to 10th, 2009, G8 delegates met to discuss, among other things, the Kyoto Protocol and climate change. Like the industrializing nations of the world, the G8 industrialized nations came to the agreement that action should be taken to assure that global temperature increases by no more than 2 °C (Wintour and Elliot 2009).

In 2009, world leaders came to meet once again to discuss what would be the next steps in the global effort to reduce harmful CO_2 emissions. Held in Copenhagen at the Bella Center between December 7th and 18th, the conference was an opportunity for world leaders to debate potential strategies for the ongoing climate problem. By the end of the conference, however, it appeared that very little headway had been made and indeed, many people saw the outcome as a "weak political statement" and nothing more, mostly due to the antics of developing nations such as China (Taylor 2009).

From November 30th to December 12th, 2015, representatives from 197 countries or "parties" negotiated the Paris Agreement for dealing with climate change. The agreement pledged to hold the "increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C" (United Nations 2015). However, participating countries' emissions reduction targets were voluntary and there was no penalty for failing to keep them. Moreover, the targets would effect a global temperature increase of 2.7–3 °C even if they were met (Harvey 2015). Renowned climatologist James Hansen called the deal a "fraud", arguing that fossil fuels would continue to be used unless a global carbon tax is established (Milman 2015). Nonetheless, on April 22nd, 2016, at the high-level Signature Ceremony for the Paris Agreement held at the United Nations headquarters in New York, nations of the world began signing the Paris Agreement. Subsequently, as of October 5th, 2016, the Paris Agreement came into force because a sufficient number of countries (116 out of 197) had ratified it by that date. The Marrakech Climate Change Conference was held in Morocco from November 7th to 18th, 2016 as a follow-up to the 2015 Paris Agreement for implementing it and tracking progress (United Nations

2016). During this meeting, a dramatic election took place on November 8th in the USA in which Mr. Donald Trump, the Republican candidate for President, became President-Elect. The Trump regime appears to be against the Paris agreement and has appointed a climate-change denier as head of the Environmental Protection Agency (EPA) (Mooney et al. 2016). This could lead to tough climate change and other types of negotiations between the USA and PRC after Mr. Trump is inaugurated as President on January 20, 2017. Hence, the negotiation technologies put forward in this paper could prove to be extremely useful.

One of the key findings of the Report of the Expert Panel on Energy Use and Climate Change is "A transition to a low-emission energy system is achievable with the right combination of stringent and flexible policies" (Council of Canadian Academies 2015). In fact, Canada could cut back in greenhouse gas from 60 to 90% at manageable costs. Hence, rigorous, compulsory economy-wide emission reductions are essential for desired reductions in greenhouse gas emissions to be achieved. Therefore, further negotiations are needed for reaching compulsory legal cutbacks on greenhouse gas emissions by both the USA and PRC and other nations of the world.

Negotiations between the developing and developed nations have suffered from an ideological difference. Fisher and Green (2004) note that for the most part the developing world is disenfranchised from the international environmental agreement (IEA) process, as not only do the agreements not meet the goals of developing nations but implementing the various agreements that have been introduced taxes the infrastructure of the developing world such that it is harder to implement further environmental initiatives. These arguments certainly apply to many of the world's poorer nations, but what of the world's fastest developing and industrializing nation, China?

Within the last 20 years, the economy of the PRC has grown by leaps and bounds. In fact, in early 2009, the PRC overtook Germany to become the third largest world economy behind only the USA and Japan (Seager 2009). It has now surpassed Japan and may overcome the USA soon (Yueh 2014). Unfortunately, coupled with the PRC's quick economic growth has been a tremendous increase in its output of greenhouse gases. Auffhammer and Carson (2007) modelled the PRC's CO_2 emissions to simulate future outcomes and found that while the 37 industrialized nations that make up Annex I—the Annex of developed economies—may be able to reduce greenhouse gases by about 115.9 million tonnes of carbon relative to business-as-usual by 2010, the increase in output by the PRC will be approximately 600 million tonnes of carbon. Weber et al. (2008) suggest that a significant increase in the PRC's emissions of CO_2 comes not only from its rapidly growing energy sector but from the shipping of goods from the PRC to the developed nations. Both reports would suggest a need to include the PRC within the framework of an international climate regime. Indeed, the PRC has already begun to introduce an internal framework for limiting its impact on climate change (China 2007; NDRC 2013).

2.1.2 Previous Analyses of the Current Climate Regime

The governance of climate change is organized internationally through the United Nations' Kyoto Protocol. The structure of the Protocol is typical of the environmental liberalism approach favoured by the world's economic leaders in that the environmen-

tal goals are reached through the use of market tools (Bernstein 2005). Thus, systems analyses of the Kyoto Protocol have focused predominantly on the trading of emissions permits at the tactical or lower-decision level—an aspect of the protocol which lends itself very well to game theoretic analyses. Bernard et al. (2008), for example, analyzed the trading of emissions permits between Russia and Annex I nations using game theoretic methods; numerous others have also analyzed the trading of emissions permits within the protocol (Ellerman et al. 1998; McKibbin et al. 1999). In contrast to these tactical analyses, a strategic analysis of Russia's negotiations with the European Union (EU) and the USA which led to Russia's ratification of the protocol, has been performed (Walker et al. 2007). With the end of the Kyoto Protocol's time period coming in 2012, and with the PRC's inability to come to an agreement in Copenhagen, decision makers are desperately looking for a post-2012 climate regime of which the PRC must definitely be a part. In the next section, a USA–PRC bilateral climate agreement is discussed.

2.2 USA–PRC Bilateral Climate Agreement

One possible post-Kyoto climate regime would be a coalition between the USA and PRC which could encourage both nations to significantly reduce their carbon emissions. Indeed, before Russia finally ratified the Kyoto Protocol, there had been talk of the USA and Russia forming a bilateral climate change coalition (Karas 2006). An agreement between the USA and PRC, as explored by the Pew Centre for Climate Change with the Asia Group, is discussed, in part because of the USA's previous objections to the PRC's exclusion from emissions limits within the Kyoto Protocol (Pew and Asia 2009). The Pew Centre and Asia Group's report suggests that as a basis for the USA and PRC engaging cooperatively to deal with climate change, economic matters such as the global recession and economic competition should not threaten negotiations but be seen as matters that may be manageable by such an agreement. In the following subsections, some of the issues which could possibly impact the implementation of such a bilateral agreement are explored in more detail.

2.2.1 Differential Responsibility

One of the key elements of climate negotiations between developed and developing nations, both within the context of the United Nations Framework on Climate Change Convention (UNFCCC) and the Kyoto Protocol, is the concept of differential responsibility (United Nations 2007). The PRC itself recognizes this concept and states plainly that greater responsibility lies upon the developed nations. Historically, there is certainly a much higher level of total carbon emissions from the USA, due to its longer history of industrialization. The very rapidly growing economy of the PRC has, however, quickly caught up to the USA in terms of annual carbon emissions. It is differential responsibility that resulted in no quantified cap for the PRC's carbon emissions within the Kyoto Protocol and thus the USA's withdrawal (United Nations 2007). As the PRC has included differential responsibility into its own environmental protocol, it is likely that negotiations between the PRC and USA would need to address both nations' historic and current emissions. Indeed, one of the major issues

for the PRC, in order that it be a part to any climate agreement, is that some measure of differential responsibility be included in the agreement (United Nations 2007). In fact, if the "fee and dividend" approach described by Hansen (2009) for reducing greenhouse gases were adopted, differential responsibility could be fairly negotiated between the USA and PRC.

2.2.2 US Domestic Opposition

Within the American political system there is a great divide about what action needs to be taken with respect to climate change. Although an environmentalist candidate, Ralph Nader of the Green Party, has run for the office of the President, the system is essentially a two-party system made up of Republicans (Grand Old Party, or GOP) and Democrats (Democratic National Committee, or DNC). Historically, the GOP has opposed working on resolutions dealing with climate change, while the DNC has supported such resolutions (Kennedy 2004). Within the DNC, however, there are certainly a number of different approaches to the climate change dilemma. Tellingly, although President Bill Clinton, a Democrat, was in favour of ratifying the Protocol, the bipartisan Senate, which included GOP and DNC Senators, voted unanimously against it.

2.2.3 Current Economic Crisis

Starting in 2007, a credit crisis began to affect the American economy. Vast amounts of personal and corporate debt exacerbated the situation, creating an extremely high volume of foreclosures, further causing some financial institutions to fail (Elliott 2008). This gloomy financial climate may reduce each nation's desire to invest in the technology needed to combat climate change. Significantly, the PRC has invested heavily in the American economy and is the largest holder of US Treasury Bonds (Baker and Barrioneuvo 2009; Ferguson 2010). With the lack of growth in the current American economy, the PRC's communist government may decide to diversify its foreign investment.

2.2.4 Political Differences

Complicating matters further is the political tension between the two nations. The victory of communism in China in 1949, coupled with the threat of Soviet aggression, put these two nations at odds. Indeed, the USA fought the Chinese in Korea and supported the opposing side in the Vietnam War (Matray 1991; Zhai 2000). Now, with the Cold War over and the Soviet Union a seemingly democratized nation, the PRC is the most politically important communist nation. Further, the various human rights abuses by the PRC government have made it difficult for a republic, such as the USA, to negotiate in good faith, in spite of their symbiotic relationship (Sorman 2008).

What the two nations desire from a possible climate negotiation is complicated. Xie Zhenhua, the PRC's lead negotiator at the Durban Climate Change Conference, held in Durban, South Africa from November 28th to December 10th, 2011, outlined the key elements of any climate negotiation that the PRC would join, the main one

being differential responsibility. This is, of course, a key factor in the USA's decision not to support the Kyoto Protocol. Nonetheless, the PRC has made a promise to join an environmental treaty to limit greenhouse gases in the year 2020, when the current protocol expires (Broder 2011). Moreover, the parties of the Durban Climate Change Conference agreed to "adopt a universal legal agreement on climate change as soon as possible, and no later than 2015" (United Nations 2012). Regrettably, Canada withdrew from the Kyoto Protocol immediately after its environmental minister, Mr. Peter Kent, returned from the Durban conference (Curry and McCarthy 2011; National Post 2011). Just as the highly effective Montreal Protocol of 1987 evolved from earlier non-binding versions of the agreement for controlling the release of CFCs and other chemicals that reduce ozone in the upper atmosphere, the Kyoto Protocol could eventually emerge as a truly binding international treaty for controlling greenhouse gas emissions (United Nations 2009). It is most unfortunate that the Canadian government acted in a highly myopic fashion at that time. What is clearly needed are meaningful negotiations as discussed herein for the case of the USA and PRC.

3 Conflict Modelling of the USA–PRC Bilateral Negotiations

Von Neumann and Morgenstern (1944) provided solid foundations for the field of game theory through the publication of their landmark book on this topic in 1944. Howard (1971) furnished a unique approach for investigating real world disputes (Hipel and Fraser 1980) through the development of a technique called metagame analysis, which Fraser and Hipel (1979, 1984) cleverly extended and improved within their conflict analysis methodology. Fang et al. (1993) significantly enhanced conflict analysis via the construction of a comprehensive methodology referred to as the Graph Model for Conflict Resolution (GMCR). The key reason for using GMCR is that it provides a flexible methodology for formally modelling conflict that comfortably deals with many aspects of human behaviour under conflict in order to gain strategic insights into what is taking place and thereby furnish a foundation for informed decision making to arrive at a win–win outcome or at least the best possible, realizable resolution to a conflict. Subsequent to defining GMCR in the next section, this useful methodology is employed for modelling and analyzing simple and more complex versions of the greenhouse gas negotiations in Sects. 3.2 and 3.3, respectively.

3.1 Graph Model for Conflict Resolution

GMCR is purposefully designed to show how interactions among individual decision makers (DMs) or groups of DMs lead to a particular final conflict outcome. What differentiates GMCR from other conflict models is the use of a directed graph for a given DM to represent the potential movements in one step among the possible states or scenarios in a conflict and the relative preferences of the DM with respect to the possible states. The ability of GMCR to accommodate qualitative preference information and address the strategic impacts of attitudes make it ideal for handling a strategic conflict such as the possible negotiation of a bilateral agreement between the USA and PRC.

Definition 1 (*Graph Model for Conflict Resolution (GMCR)*) GMCR is a four part set, written formally as (N, S, $(A_i)_{i\in N}$, $(\succ_i, \sim_i)_{i\in N}$). Within the set, N is the set of all DMs, and S is the set of all feasible states in the conflict and is represented by nodes in a graph. A_i is the set of all possible movements in the conflict controlled in one step by DM i from each state and is depicted in the graph by the set of arcs between the states that DM i can move between. Finally, DM i's preferences on S are represented by $\succ_i$ and $\sim_i$, and are defined such that for $s, t \in S$, $s \succ_i t$ means that DM i prefers state s to t, while $s \sim_i t$ indicates that DM i is indifferent between states s and t. In contrast to other game theoretic methods, payoffs and cardinal preferences are not needed and relative preferences are used in their place. Fang et al. (1993) posit the following four elements of the preference structure of GMCR.

(a) $\succ_i$ is asymmetric; hence, for all $s, t \in S$, $s \succ_i t$ and $t \succ_i s$ cannot hold true simultaneously.
(b) $\sim_i$ is reflexive; therefore, for any $s \in S$, $s \sim_i s$.
(c) $\sim_i$ is symmetric; hence, for any $s, t \in S$, if $s \sim_i t$ then $t \sim_i s$.
(d) $(\succ_i, \sim_i)$ is complete; therefore, for all $s, t \in S$ one of $s \succ_i t$, $t \succ_i s$ or $s \sim_i t$ is true.

For defining movements within the conflict model, knowing the states that are reachable by a DM from a given state is useful. To this end, a reachable list (R_i) of states for DM i is defined such that $x \in R_i(s)$ if and only if there exists an arc $a_i \in A_i$ that connects states s and x.

As DMs are assumed to be attempting to make moves which are advantageous, it is useful to define a unilateral improvement (UI) list written as $R_i^+(s)$. A UI list of states for DM i is defined such that $x \in R_i^+(s)$ if and only if there exists an arc $a_i \in A_i$ that connects states s and x and $x \succ_i s$.

A solution concept mathematically defines possible interactions that can occur among DMs when a specific DM is deciding whether or not to unilaterally move from a given state. If it is not advantageous for the DM to unilaterally depart from the state, the particular state is deemed to be stable. Because DMs may behave differently under conflict, a range of solution concepts have been defined. Two informative solution concepts used in this study are Nash stability (Nash 1950, 1951) and sequential stability (Fraser and Hipel 1979, 1984). In order to define solution concepts for analyzing conflicts, various types of movements among states must first be defined (see Fang et al. (1993) for more detailed definitions). Specifically, a reachable list for DM $i \in N$ at state $s \in S$ is given such that i's reachable list from state s is the set $\{t \in S \mid (s, t) \in A_i\}$, denoted by $R_i(s) \subset S$. When a more preferred state is part of a reachable list for some DM $i \in N$ at a state $s \in S$, it is referred to as a UI. DM i's UI list from state s is the set $\{t \in R_i(s) \mid t \succ_i s\}$, denoted by $R_i^+(s) \subset S$.

To define a solution concept, it is useful to define a set of sanctioning states that are less or equally preferred to the starting state. Given DM $i \in N$ and states $s, x \in S$, the set of all states that are less preferred or equally preferred to state s by DM i is $\phi_i^{\succeq}(s) = \{x \in S \mid s \succeq_i x\}$.

Definition 2 (*Nash Stability*) Nash stability occurs when a DM cannot make any unilateral improvements from a given state in the conflict and thus must remain at the

current state. That is, for DM $i \in$ N, a state s $\in$ S is Nash stable for i, denoted by $s \in S_i^{Nash}$, if and only if $R_i^+(s) = \phi$.

Definition 3 (*Sequential Stability (SEQ)*) Sequential stability is a solution concept in which a DM will avoid moving unilaterally to a more improved state because one or more opposing DMs can sanction the DM's UI. In this case, the opposing DMs will only sanction the initial DM by moving to more preferred states, called 'credible moves'. Thus, for a DM $i \in$ N, a state s $\in$ S is sequentially stable, denoted by s $\in S_i^{SEQ}$, if and only if for all x $\in R_i^+(s)$, $R_{N\setminus\{i\}}^+(x) \cap \phi_i^{\simeq}(s) \neq \phi$.

In addition to Nash and Sequential stability, further solution concepts, such as General Metarational and Symmetric Metarational stability (Howard 1971), can be used within the GMCR methodology. Within the examples shown herein, the previously defined movements, preference methodologies and solution concept are employed to model conflicts and determine likely final conflict outcomes.

3.2 Two-DM Model

Pittel and Rubbelke (2008) model a two stakeholder climate regime using 2×2 conflict models developed by Rapoport and Chammah (1965) wherein two DMs each have two strategies, generating four conflict outcomes. One of the simplest of such conflicts is the game of 'chicken' in which two opponents drive their cars towards each other as fast as possible. The person who swerves out of the way is said to be 'chicken' and loses the game. Of course, if both players decide not to swerve out of the way, they both die—a far worse outcome than losing the game. Pittel and Rubbelke (2008) postulate that negotiations surrounding the implementation of a bilateral climate change agreement are similar to this scenario in that neither nation wants to be the one to 'swerve' or begin to act alone on the problem of climate change. Alternatively, neither party wants the situation to reach a point where neither of them 'swerves', thus causing the problem to reach a deadly level for humanity. Each DM has the same possible strategies it controls: be irresponsible (labelled as I) with respect to reducing greenhouse gases and be responsible (R). In Fig. 1, the conflict is shown in graph form with the preferences of the two nations given below the graph. Within each node, the pairing of actions by the two nations is given with the first entry representing the strategy selected by the USA, while the second is the strategy selected by PRC. For example, RR in the top left corner of the figure represents the outcome or state for which both nations act in a responsible manner towards the environment.

As can be seen by the arcs, USA controls movements between RR and IR, as well as RI and II, while PRC is in charge of moves between RR and RI, as well as IR and II. After performing a stability analysis of this conflict, two equilibria occur at states RI and IR. Both of these take place because of the recognition by both parties of the cost of working alone to deal with climate change, the desire for the other party to lead or act alone and the recognition that not acting at all would be catastrophic. This model shows the need for cooperation and negotiation between the two nations to begin to act in unison and shift the negotiations to state RR where both parties are responsible and act to combat climate change. A resolution where both nations act responsibly, RR,

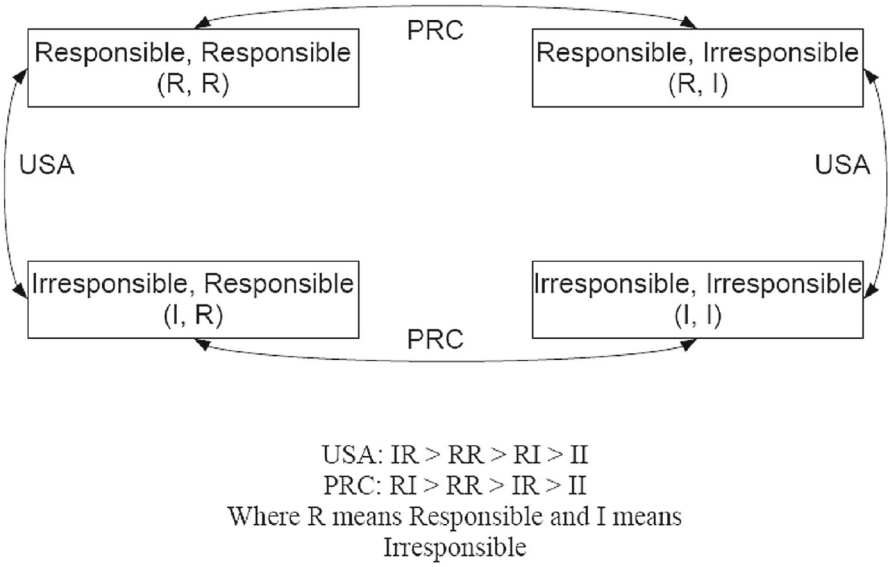

Fig. 1 Bilateral climate negotiation modelled as a game of chicken

does not occur naturally. Both states IR and RI constitute Nash equilibria. To explain why this is so, consider state IR. Notice that if USA causes the conflict to move from state IR to RR in Fig. 1, USA is moving to a less preferred state and therefore does not possess a unilateral improvement. Hence, according to Definition 2, state IR is Nash stable for USA. In a similar fashion, if PRC causes the conflict to shift from state IR to II by changing its strategy from R to I, PRC will move to a less preferred state. Accordingly, state IR is Nash stable for PRC and because it is Nash stable for both DMs in the conflict, it is a Nash equilibrium. One could explain in a likewise manner why state RI is a Nash equilibrium.

Although this model very succinctly describes the possible hazard of not ratifying the Kyoto Protocol as well as the need for cooperation between USA and PRC, it is extremely limited. The model does not address numerous questions that an analyst may have, such as: How can USA and PRC share technology to address climate change? Will PRC want to invest further in USA in spite of its flagging economy? Will USA take on a greater responsibility than PRC, as PRC desires?

The game of chicken is referred to as a 2×2 game since each of the two DMs controls two strategies. In addition to the game of chicken, researchers have analyzed many other types of 2×2 games to assess their appropriateness for investigating climate change negotiations and gaining strategic and policy insights. For instance, Decanio and Fremstad (2013) studied a range of one-shot 2×2 games using Nash and maxi–min stability definitions. Madani (2013) expanded this work by examining 2×2 games for possible employment in multi-shot climate change negotiations in which solution concepts such as general metarationality (Howard 1971), symmetric metarationality (Howard 1971) and sequential stability (Fraser and Hipel 1979, 1984) can be used in an interactive fashion and cooperation can be considered to reach more desirable cooperative resolutions in which progress in the reduction of greenhouse

gas emissions can be made. A range of alternative ways to study climate change negotiations as well as water disputes is put forward by other authors referenced by Madani (2010, 2013) and Madani and Hipel (2011).

More realistic modelling and analyses of climate change negotiations can be carried out by employing informative extensions of the basic GMCR approach. Specifically, using a hierarchical structure within the paradigm of GMCR, He et al. (2017) study greenhouse gas emission reduction negotiations between the PRC and the USA, as well as the connected conflict within each country. In this current paper, investigating more complex games for climate change negotiations and the crucial role that attitudes can play is now formally examined for the first time.

3.3 Three-DM Model

Although there are two nations involved directly in the negotiations, there are numerous peripheral DMs connected to the conflict, both for and against a bilateral climate change agreement. For the purposes of this model, the sides at work with the USA are dissected and a new conflict model is given. Within this model, the US Support represents members of the Democratic National Committee (DNC) who have expressed the desire to reduce carbon emissions 80% from 1990 levels by 2050 and may thus be open to a bilateral agreement with PRC (Reilly 2008). Under the Pew Center's roadmap (Pew and Asia 2009), there are numerous possible actions that President Obama could take. The opposition to a climate change agreement with PRC may come about for numerous causes. The first reason, as alluded to in the Pew report on a possible USA–PRC bilateral agreement, is the history of cold relationships between the two nations (Pew and Asia 2009). Secondly, the anti-environmental leanings of the Republican or Grand Old Party (GOP) have been well-documented both by scholars and news sources (Kennedy 2004). The possibility of joint investment with PRC towards environmental ends in the middle of a global recession may also go against the values of fiscal conservatives.

An example of what a three party conflict could look like is shown in Tables 1 and 2, using a format referred to in GMCR as 'option form', which was originally proposed by Howard (1971). In option form, each DM is listed above each possible option that it could choose. The three DMs are: US Support (USS), US Opposition (USO) and the government of PRC.

If the negotiations between the USS, USO and PRC are as simple as those shown in Table 1, the number of possible states is larger than the four-state conflict modelled in the previous subsection. Each option is either selected, denoted by a 'Y', or not, denoted by an 'N'. Therefore, the total possible number of states in this conflict has grown to $2^5 = 32$ possible conflict outcomes. Using the option form of the conflict, the full set of states is realized and the state identification numbers are chosen using a decimalized numeric format. In decimalized form each option is assigned a numerical value if it is selected. Option 1 has a value of $2^0 = 1$, option 2 has a value of $2^1 = 2$ and so forth. For example, if option 1 and option 3 are selected, but not options 2, 4 and 5, the decimalized form used to identify the state is $2^0 + 2^2 = 5$.

Now this conflict model better reflects what could happen within the negotiations, but it has also become more tedious to analyse in the process. In order to create a

Table 1 Decision makers and options for the climate-change conflict having three decision makers

USS
(1) Propose bilateral emissions trading system (Propose Bilateral Regime)
(2) Joint investment in alternative energy sources (Joint Investment)
USO
(3) Propose alternative domestic system (Oppose Agreement)
PRC
(4) Accept American terms (Accept Proposition)
(5) Demand differential responsibility (Differential Responsibility)

feasible model which can be analysed using simple hand calculations, it is necessary to remove the infeasible states from the total set of states. For instance, one should eliminate states in which option 4 is selected without option 1 or 2 being chosen, as it is impossible for PRC to accept USS's conditions unless the USS has offered something. After removing the infeasible states, the total set of states in the conflict is $S = \{0, 1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23\}$, which are listed in Table 2 in option form. In this table, each column of Y's and N's represents one possible feasible state.

For conveniently carrying out a stability analysis in which there is not a large number of states, the tableau form developed by Fraser and Hipel (1979) can be utilized. Tableau form has been extensively used in the literature for application purposes (see, for example, Shupe et al. 1980; Inohara et al. 2007; Inohara and Hipel 2008a, b), since it provides an intuitive "geometrical" interpretation as to how moves and counter-moves can dynamically occur among DMs. The tableau form of the climate-change conflict is given in Table 3. As can be seen, each of the three DMs are shown: United States Support (USS), United States Opposition (USO) and the People's Republic of China (PRC). To the right of each DM the states are listed in descending order of preference from left to right, where equally preferred states are contained within brackets. Below each state are the unilateral improvements available to the given DM from that particular state. In order to determine stabilities and equilibria, the two aforementioned solution concepts, Nash and sequential stability (Definitions 2 and 3), were applied to this conflict. For example, state 3 for USO is sequentially stable and is thus marked with an 's'. This occurs because from state 3, USO makes a unilateral improvement (UI) to state 7. This can be written as: $R^{+}_{USO}(3) = 7$. Notice that state 7 is a UI from state 3 for USO because from Table 2 only USO changes its option selection from not opposing the agreement (as marked by an N in state 3) to opposing it (as indicated by an Y opposite this option in state 7) while the option selections of the other two DMs remain fixed and from Table 3 state 7 is written to the left of state 3 opposite USO (which means state 7 is more preferred to state 3 by USO). Thus, as $R^{+}_{USO}(3) \neq \emptyset$, the state is not Nash stable. Next, to test for sequential stability, it is important to check for possible sanctions from state 7 by the remaining set of DMs, labelled $N - \{USO\}$, which means the set of N DMs without USO. From state 7 USS has no UIs, while PRC has two UIs to states 15 and 23. To determine the complete set

Table 2 Feasible states in option form for the climate-change conflict having three decision makers

DMs and options	Feasible states																			
USS																				
(1) Propose Bilateral Regime	N	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	N	Y	Y	N	Y
(2) Joint Investment	N	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	N	Y	Y	N	Y	Y
USO																				
(3) Oppose Agreement	N	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	N	Y	Y	Y
PRC																				
(4) Accept Proposition	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N
(5) Differential Responsibility	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
State nos.	0	1	2	3	5	6	7	9	10	11	13	14	15	16	17	18	19	21	22	23

Table 3 Static analysis in tableau form for the climate change dispute with three decision makers

	X	E	E	X	X	X	X	X	X	E	X	E	X	X	X	X	X	X	E	X
	r	s	r	u	r	r	r	r	u	r	r	r	r	r	r	r	u	r	r	r
USS	11	9 11	15	13 15	(0	1	2	3	10) 9 11	(16	17	18	19)	(5	6	7	14) 13 15	(21	22	23)
	r	r	r	s	s	r	r	r	r	r	r	s	u	r	r	r	r	r	u	u
USO	(0	5	13)	(1 5	9) 13	(2	6	7	10	14	15)	(3 7	11) 15	(16	18	21	22	23)	(17 21	19) 23
	r	r	r	r	u	r	u	r	u	r	u	u	u	u	u	u	u	u	u	u
PRC	13	15	(9	18	21 13	22)	(10 18	11	14 22	16	23) 15	(2 10 18	5 13 21	6) 14 22	(0 16	7 15 23	17) 9	19 11	1 9 17	3 11 19

Symbols: *E* Equilibrium state, *X* non-equilibrium state, *r* Nash stable state, *s* sequentially stable state, *u* unstable state

of possible credible sanctions, one could check if USS can make any further moves from 15 or 23. However, as USS has no UIs from these states, the total set of possible sanctions is $R_{N-\{USO\}}(7) = \{15, 23\}$. As state 23 is less preferred by USO to state 3, written as $3 >_{USO} 23$, the move to state 23 is a credible sanction and thus the state is stable by sequential stability given in Definition 3. Notice that because state 15 is more preferred to state 3 by USA, it does not constitute a sanction.

Along the top of the tableau, state equilibrium conditions are given, corresponding to the states as they appear in the first DM's list of states. From this analysis there are five equilibrium states, each marked with an E: states 9, 15, 16, 18 and 22. The state is called an equilibrium when it is stable for all of the DMs in the conflict and thus the state is likely to persist, if it is reached. Notice, for instance, that state 9 is sequentially stable for USS and USO (as marked with an s) and Nash stable for PRC (as indicated by an r above that state). Therefore, overall state 9 is an equilibrium (as marked by an E above it at the top of the tableau). State 13, for example, is not an equilibrium (as indicated by an X written above it at the top of the tableau) because it is Nash stable for USO and PRC (there are no UIs below this state for these two DMs) but unstable for USS (as marked by a u above state 13 for the USS, the other two DMs have no credible sanctions from USS's UI from state 13 to 15 to block the UI). Although equilibrium state 9 is a strong outcome for this negotiation because it allows both nations to work together on a joint climate project, the conflict is just as likely to proceed to state 16, whereby PRC demands differential responsibility and the negotiations go no further.

As is clearly visible in Fig. 2, there are numerous paths from the status quo at state 0. Starting at state 0, it is possible to reach all of the potential equilibrium states. There is, however, only one state that can be reached by a credible move, marked in Fig. 2 in bold, state 16. Credible moves occur when DMs move the conflict from one state to another, according to their preferences. In other words, a DM may move from one state to another if a UI is available.

In Table 4, the movement from the status quo or initial state, state 0, to the final state, state 16, is shown in option form. The black arrow represents the change in option selection by PRC. In particular, PRC moves from doing nothing to demanding differential responsibility. Unfortunately, state 16 is not the resolution for which USS, or the world for that matter, is looking. Thus, it is important to analyze the attitudes and relationships that may be leading to this lose-lose outcome. In Sect. 4, the attitudes framework is defined and applied to the three-DM conflict.

4 Attitudes within the Graph Model for Conflict Resolution

Within GMCR, the consideration of attitudes constitutes an extension which allows a richer range of behaviour to be examined by a decision analyst. The principle behind the attitudes framework is that there is greater complexity to DMs' preferences than their own personal gain. That is to say, sometimes DMs take into account the repercussions of their behaviour upon their foes and allies. Other methods for the investigation of human behavior under conflict (Hipel et al. 2011) include emotions (Obeidi et al. 2005), strength of preference (Hamouda et al. 2004; Xu et al. 2009), cooperation

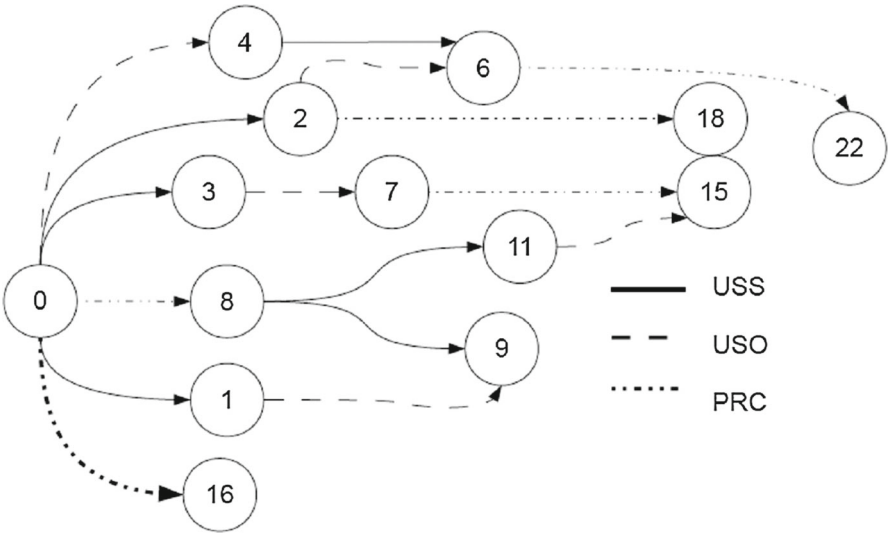

Fig. 2 Possible evolutions of 3-DM climate conflict from the status quo

Table 4 Evolution of the climate change negotiations conflict having three decision makers in option form

DMs and options	Transition from initial state to final state		
USS			
(1) Propose Bilateral Regime	N		N
(2) Joint Investment	N		N
USO			
(3) Oppose Agreement	N		N
PRC			
(4) Accept Proposition	N	$\longrightarrow$	N
(5) Differential Responsibility	N		Y
State nos.	0		16
	Initial state		Final state

(Kilgour et al. 2001; Inohara and Hipel 2008a, b) and misperceptions (Wang et al. 1988; Inohara et al. 2007). The attitudes framework, however, provides a simple way to handle complex preferences while using intuitive solution concepts already developed for GMCR (Inohara et al. 2007; Bernath Walker et al. 2009, 2012a, b, 2013). An attractive feature of these advancements in the GMCR methodology is that they are fully operational and, hence, can be applied to real world conflict situations. In the following sections, attitudes are defined following the definitions originally put forward by Inohara et al. (2007) and subsequently applied to the challenging climate negotiations in Sect. 4.2.

4.1 Attitude Definitions

In order to perform attitude analyses, it is necessary to construct a framework which allows attitudes to be modelled into DM behaviour. Using this framework, a structure which is parallel to the previously defined GMCR structure is formed.

Definition 4 (*Attitudes*) For DMs $i, j \in N$, let $E_i = \{+, 0, -\}^N$ represent the set of attitudes of DM i. An element $e_i \in E_i$ is called the attitudes of DM i for which $e_i = (e_{ij})$ is the list of attitudes of DM i towards DM j for each $j \in N$ where $e_{ij} \in \{+, 0, -\}$. The e_{ij} is referred to as the attitude of DM i to DM j where the values $e_{ij} = +$, $e_{ij} = 0$ and $e_{ij} = -$ indicate that DM i has a positive, neutral and negative attitude towards DM j, respectively.

Definition 5 (*Devoting preference (DP)*) The devoting preference of DM $i \in N$ with respect to DM $j \in N$ is $\succeq_j$, denoted by $\mathbf{DP}_{ij}$, such that for $s, t \in S$, $s\ \mathbf{DP}_{ij}\ t$ if and only if $s \succeq_j t$.

Definition 6 (*Aggressive preference (AP)*) The aggressive preference of DM $i \in N$ with respect to DM $j \in N$ is $NE(\succ_j)$, denoted by $\mathbf{AP}_{ij}$, where $NE(\succ_j)$ is defined as follows: for $s, t \in S$, $s\ NE(\succ_j)\ t$ if and only if $s \succ_j t$ is not true. That is, for $s, t \in S$, $s \mathbf{AP}_{ij}\ t$ if and only if $s\ NE(\succ_j)\ t$ (if and only if $t \succeq_j s$ under completeness of $\succeq_j$).

Definition 7 (*Relational preference*) The relational preference $\mathbf{RP}(e)_{ij}$ of DM $i \in N$ with respect to DM $j \in N$ at e is defined as follows:

$$RP(e)_{ij} = \begin{cases} DP_{ij} & \text{if } e_{ij} = + \\ AP_{ij} & \text{if } e_{ij} = - \\ I_{ij} & \text{if } e_{ij} = 0 \end{cases}$$

where $\mathbf{I}_{ij}$ denotes that DM i is indifferent with respect to j's preference and, hence, $s\ \mathbf{I}_{ij} x$ means that DM i's preference between state s and x is not influenced by DM j's preference.

Using this new preference structure which incorporates DM attitudes, new and adapted solution concepts are formed as defined by Inohara et al. (2007) and Bernath Walker et al. 2009, 2012a, b, 2013). In Definition 8, Total Relational Preferences are defined, which are analogous to regular preferences. In Definitions 9 and 10, analogues to the unilateral and coalitional improvement lists are formed.

Definition 8 (*Total relational preference (TRP)*) The total relational preference of DM $i \in N$ at e is defined as the ordering $\mathbf{TRP}(e)_i$ such that for $s, t \in S$, $s\ \mathbf{TRP}(e)_i\ t$ if and only if $s \mathbf{RP}(e)_{ij}\ t$ for all $j \in N$.

Definition 9 (*Total relational reply (TRR)*) The total relational reply list of DM $i \in N$ at e for state $s \in S$ is defined as the set $\{t \in R_i(s) \cup \{s\} \mid t\ \mathbf{TRP}(e)_i s\} \subset R_i(s) \cup \{s\}$, denoted by $\mathbf{TRR}(e)_i(s)$.

Table 5 Attitudes analysis in the climate change negotiations conflict having three decision makers

Regular				Devoting USS/aggressive PRC			
DM	PRC	USS	USO	DM	PRC	USS	USO
PRC	+	0	0	PRC	+	−	0
USS	0	+	0	USS	+	0	0
USO	0	0	+	USO	0	0	+

Definition 10 (*Total relational reply list of a coalition*) The total relational reply list of coalition $H \subset N$ at e for state $s \in S$ is defined inductively as the set $\mathbf{TRR}(e)_H(s)$ that satisfies the next two conditions: (i) if $i \in H$ and $t \in \mathbf{TRR}(e)_i(s)$, then $t \in \mathbf{TRR}(e)_H(s)$, and (ii) if $i \in H$ and $t \in \mathbf{TRR}(e)_H(s)$ and $u \in \mathbf{TRR}(e)_i(t)$, then $u \in \mathbf{TRR}(e)_H(s)$.

Definition 11 (*Relational less preferred or equally preferred states*) The symbol $R\phi^{\simeq}(e)_i(s)$ is an analogue of $\phi_i^{\simeq}(s)$ given in Sect. 2. Hence, $R\phi^{\simeq}(e)_i(s)$ is the set $\{t \in S \mid \mathrm{NE}(t\ \mathbf{TRP}(e)_i\ s)\}$ of all states which are not relationally preferred to s by DM i under attitude e. Note that $\mathrm{NE}(t\ \mathbf{TRP}(e)_i\ s)$ means that "$t\ \mathbf{TRP}(e)_i\ s$" is not true.
Note: $s \notin R\phi^{\simeq}(e)_i(s)$ always holds.

By using these new movement definitions, Nash and sequential stabilities are altered to Relational Nash and Relational sequential stabilities in order to incorporate attitudes into solution concepts, which parallel those given in Definitions 1 and 2.

Definition 12 (*Relational Nash stability (RNash)*) For $i \in N$, state $s \in S$ is relational Nash stable at e for DM i, denoted by $s \in S_i^{RNash(e)}$, if and only if $\mathbf{TRR}(e)_i(s) = \{s\}$.

Definition 13 (*Relational sequential stability (RSEQ)*) For $i \in N$, state $s \in S$ is relational sequential stable at e for DM i, denoted by $s \in S_i^{RSEQ(e)}$, if and only if for all x $\in \mathbf{TRR}(e)_i(s)\backslash\{s\}$, $\mathbf{TRR}(e)^{N\backslash\{i\}}(x) \cap R\phi^{\simeq}(e)_i(s) \neq \phi$.

4.2 Attitudes Analysis of Climate Change Negotiations

In order to gain insight into how a climate change agreement between USA and PRC could occur given their 70-year history of political and financial opposition, attitudes analysis will be applied to the previously completed analysis. In Table 5, the attitudes associated with a regular analysis are shown on the left. Notice that in a regular analysis, a given DM has a positive attitude towards itself, as indicated by the + sign and a neutral attitude towards others as marked by a zero. The attitudes associated with a devoting US support, due to the Obama American administration, are given on the right.

By implementing the second set of attitudes, new possible conflict outcomes can be contrasted with the results determined in Sect. 3.3. Here, PRC holds negative attitudes against USS specifically and opposes a possible agreement, while USS wishes to

make a deal that is equitable not only for the USA but for PRC and the rest of the international community. Applying these new attitudes to the tableau analysis given in Table 3, some UIs that brought about more preferred states for PRC and USS are now no longer palatable to PRC. These new attitudes give rise to the tableau analysis shown in Table 6.

Similar to the static analysis performed previously, state stabilities are checked using RNash, RSEQ, Nash and SEQ solution concepts. For example, state 11 is unstable, which is denoted by a 'u'. As $\text{TRR}_{\text{USS}}(11) \neq \{11\}$, the state is not RNash stable for USS by definition. As USS's attitudes are such that USS has a positive attitude towards PRC ($e_{\text{USS}-\text{PRC}} = +$) and is indifferent towards itself and USO ($e_{\text{USS}-\text{USS}} = e_{\text{USS}-\text{USO}} = 0$), any sanction against USS's move to state 9 from state 11 must be such that $\exists\, x \in \text{TRR}_{\text{N/USS}}(11) \,|\, 11 >_{\text{PRC}} x$. In this case, from state 9 USO can move to state 13 ($\text{R}^{+}_{\text{USO}}(9) = 13$), which is more preferred to state 11 by PRC ($13 >_{\text{PRC}} 11$). Thus, the total relational reply is not sanctioned and hence the state is unstable by both RNash and RSEQ stabilities.

Employing the relational solution concepts, four conflict equilibria were determined: 13, 18, 21 and 22. This time, the troublesome equilibrium state 16 has been removed as an equilibrium because USS now has credible movements from state 16 to state 18. However, this state is no more of a resolution than is state 16. State 13 is a welcome equilibrium which would occur under conditions of agreement between USS and PRC.

In Fig. 3, it can be seen how the conflict could evolve from the status quo. The credible moves, for which DMs act according to their attitudes, are shown in bold. Thus, the move from state 0 to state 18 is the only one that can occur. This movement is shown in option form in Table 7. Paths do exist to other equilibrium states; however, they all require one or more moves that are not credible. For example, from the status quo to state 6 there are two paths: (i) USS moves to state 2 and USO moves from 2 to 6 or, (ii) USO moves to state 4 and USS moves from state 4 to 6. By path (i) USS can make a credible move to state 2 as $2 >_{\text{PRC}} 0$ and thus, $2\ \text{TRP}_{\text{USS}}\ 0$ as $e_{\text{USS}-\text{PRC}} = +$, $e_{\text{USS}-\text{USS}} = e_{\text{USS}-\text{USO}} = 0$. However, $2 >_{\text{USO}} 6$, which is behaving according to rational attitudes and thus, it is not a credible move for USO to move from state 2 to state 6. Therefore, path (i) cannot work using credible moves. Examining path (ii), the initial move by USO from state 0 to state 4 is not credible as $0 >_{\text{USO}} 4$ and thus path (ii) also cannot be followed using credible moves.

As can be seen in both Fig. 3 and Table 7, the combination of American devotion and Chinese aggression leads to a stalemate situation where PRC demands differential responsibility, USS agrees to a joint investment in a technology transfer and no further move is taken. Although numerous equilibrium states occur under the new attitudes applied to the conflict in Tables 5 and 6, only state 18 is reachable by any set of credible moves from the status quo. This outcome may suggest that it is in the interest of USS to not concede too heavily to the PRC negotiators and that, further, a different strategy, set of attitudes, or type of movement is needed in order for a more beneficial outcome to be reached.

To that end, a new set of attitudes is presented in Table 8. Here, the movements of PRC are not constrained by a negative attitude towards USS, while USS still has a positive attitude towards PRC and an indifferent attitude towards itself. This set of

Table 6 Attitudes stability analysis in tableau form in the climate change negotiations conflict

	X	X	X	E	X	X	X	X	X	X	X	E	X	X	X	X	X	E	E	X
	u	rr	u	rr	u	u	rr	u	u	u	u	rr	u	rr	rr	u	u	rr	rr	u
USS	11	9	15	13	(0	1	2	3	10)	(16	17	18	19)	(5	6	7	14)	(21	22	23)
	9		13		2	0		0	9	18	16		16			5	13			21
						2		1			18		17			6	15			22
								2					18							
	r	r	r	s	u	r	r	r	r	r	r	s	u	r	r	r	r	r	u	u
USO	(0	5	13)	(1	9)	(2	6	7	10	14	15)	(3	11)	(16	18	21	22	23)	(17	19)
				5	13							7	15						21	23
	rr	rr	rr	rr	rr	rr	u	rr	u	rr	rr	u	u	u	u	u	rr	rr	u	u
PRC	13	15	(9	18	21	22)	(10	11	14	16	23)	(2	5	6)	(0	7	17)	19	1	3
							18		22			18	21	22	16	23			17	19

Symbols: *E* Equilibrium state, *X* non-equilibrium state, *r* Nash stable state, *s* sequentially stable state, *u* unstable state, *rr* Relational Nash stable state, *rs* Relational sequentially stable state

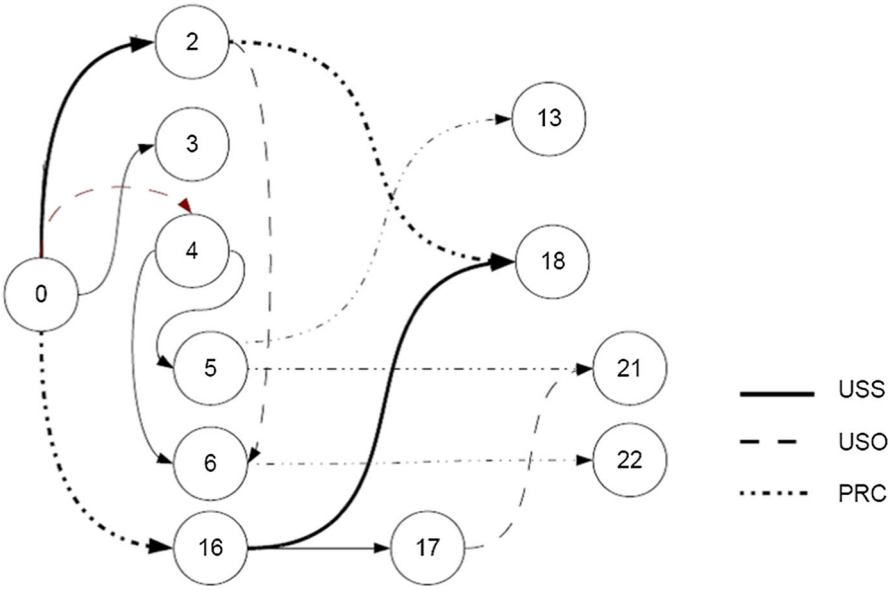

Fig. 3 Evolution of 3-DM Sino-American climate conflict from the status quo under attitudes

Table 7 Evolution of the 3-DM conflict in option form under the influence of attitudes

USS											
1) Propose Bilateral Regime	N	→	N		N		N		N	→	N
2) Joint Investment	N		Y		Y		N		N		Y
USO											
3) Oppose Agreement	N		N		N		N		N		N
PRC											
4) Accept Proposition	N		N	→	N		N	→	N		N
5) Differential Responsibility	N		N		Y		N		Y		Y
STATE #s	0		2		18		0		16		18
	Initial State		Trans. State		Final State		Initial State		Trans. State		Final State

attitudes suggests that perhaps PRC is more open to the negotiation of an agreement and USS is willing to put itself out to make an agreement occur.

If the negotiations can be brought about in a manner that encourages a level of cooperative negotiation, it may be wiser and indeed more accurate to model the conflict with devoting attitudes on the part of USS and rational attitudes on the part of PRC. This change of attitudes means that PRC's unilateral credible movements will be unilateral improvements, as in the first static analysis. USS and USO will maintain the same unilateral movements from the previous attitudes analysis. The tableau form of this new analysis, shown below in Table 9, illustrates that there are now three possible equilibria, one of which involves PRC agreeing to join a climate regime with the USS.

Table 8 Second attitudes analysis

Regular				Devoting USS			
DM	PRC	USS	USO	DM	PRC	USS	USO
PRC	+	0	0	PRC	+	0	0
USS	0	+	0	USS	+	0	0
USO	0	0	+	USO	0	0	+

Of these outcomes, state 18 sees PRC asking for differential responsibility and thus the negotiation of a climate agreement does not occur, and state 22 is identical except for the inclusion of USO providing domestic political pressure against the agreement. It is state 13 that is the best resolution, potentially, to the problem. At state 13, the USS offers a reasonable climate agreement, to which PRC agrees and the USO objects. Figure 4 below illustrates the possible moves from the status quo state to each of the three equilibria.

As portrayed in Fig. 4, there are various paths by which DMs' actions can lead to the final outcome of state 13 which is preferred by all involved. The hitch, however, is that again none of the paths are composed entirely of credible moves and they are based on the assumption that these DMs are acting in a totally independent manner. If one were to look at credible moves alone, the conflict would move to state 18, as it had in the previous attitudes analysis. In such a case, as shown in Table 10, credible moves by USS and PRC would cause the USS to offer joint investment in a technology transfer and PRC to demand differential responsibility.

Thus, in order for a resolution which would ensure the two DMs come to an agreement, it is necessary that they move cooperatively from the status quo. Although Inohara and Hipel (2008a, b) explore the implications of full coalition formation under a range of coalition solution concepts, what is useful here is the existence of a coalition jump, as described by Kilgour et al. (2001). Although USO makes a move from state 9 by objecting and thus moving the conflict to state 13, the coalition jump by USS and PRC is essential for reaching the final outcome whereby the two nations agree to a climate agreement. This coalition jump is similar to the "equilibrium jump" made by multiple DMs from one equilibrium to another. In this case, careful negotiations between the DMs allow for a cooperative move which avoids the posturing of state 18 and ultimately leads to the final outcome of state 13. The option form of this jump is seen in Table 11.

5 Attitudes and Preferences

As was explained previously, attitudes are a structure which allows a decision analyst to consider a DM's desires to hurt or help itself or other DMs, or be neutral. As the structure of movements and solution concepts are parallel to those defined in Definitions 1 through 3, it is possible to rewrite a new set of preferences which incorporate attitudes into it (Bernath Walker et al. 2009, 2012a, b). For example, in the second relational analysis, USO's set of attitudes, $e_{USO-USO} = 0, e_{USO-PRC} = +, e_{USO-USS} = 0,$

Table 9 Second attitudes stability analysis for the climate change negotiations conflict

	X	X	X	E	X	X	X	X	X	X	X	E	X	X	X	X	X	X	E	X
	u	rr	u	rr	u	u	rr	u	u	u	u	rr	u	rr	rr	u	u	rr	rr	u
USS	11	9	15	13	(0	1	2	3	10)	(16	17	18	19)	(5	6	7	14)	(21	22	23)
	9		13		2	0		0	9	18	16		16			5	13			21
						2		1			18		17			6	15			22
								2					18							
	r	r	r	s	u	r	r	r	r	r	r	s	u	r	r	r	r	r	u	u
USO	(0	5	13)	(1	9)	(2	6	7	10	14	15)	(3	11)	(16	18	21	22	23)	(17	19)
				5	13							7	15						21	23
	r	r	r	r	u	r	u	r	u	r	u	u	u	u	u	u	u	u	u	u
PRC	13	15	(9	18	21	22)	(10	11	14	16	23)	(2	5	6)	(0	7	17)	19	1	3
					13		18		22		15	10	13	14	16	15	9	11	9	11
												18	21	22		23			17	19

Symbols: *E* Equilibrium state, *X* non-equilibrium state, *r* Nash stable state, *s* sequentially stable state, *u* unstable state, *rr* Relational Nash stable state, *rs* Relational sequentially stable state

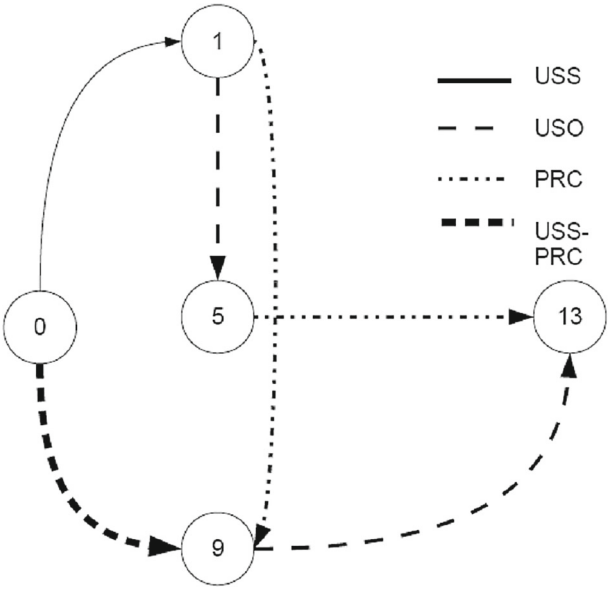

Fig. 4 Evolution of 3-DM climate regime towards an amicable agreement at State 13

means that it only wishes to take actions that are more preferred for PRC. Thus, its preferences could be rewritten to be the same as PRC's. Similarly, in the first relational analysis, PRC's attitudes are $e_{PRC-PRC} = +, e_{PRC-USS} = -, e_{PRC-USO} = 0$. Here, PRC's preferences must reflect a desire to improve its own position while hurting USS. In Table 12, a new parallel set of preferences is developed for PRC using these attitudes. Instead of a linear preference ranking, the new preferences, which were previously represented by the attitudes, are intransitive. For example, in the preference rankings determined in Sect. 3, 10 $>_{\text{PRC}}$ 2, 2 $>_{\text{PRC}}$ 17 and thus, 10 $>_{\text{PRC}}$ 17, due to the transitive nature of the preferences. Under the new preferences, transitivity does not always work: 14 $>_{\text{PRC}}$ 2, 2 $>_{\text{PRC}}$ 19; however, 2 NE($>_{\text{PRC}}$) 14 (where NE denotes Not Equal).

Using these new preferences, it is possible to execute a standard static stability analysis within the GMCR framework. This parallelism between standard analyses and relational attitudes means that attitudes analysis can be used as a "short hand" which allows for easier modelling of complex preferences due to attitudes held by DMs.

6 Conclusions and Insights

The application of GMCR and the attitudes framework to the conflicts surrounding the negotiation of a bilateral climate regime between PRC and USA illustrates the need for cooperation, the importance of DM attitudes and the role of strategic thinking. Indeed, only recently has PRC agreed that it will enter into a binding legal agreement with other nations to reduce its greenhouse gas emissions (European Council 2011).

Table 10 Evolution of 3-DM conflict in option form under the influence of attitudes

USS											
1) Propose Bilateral Regime	N	→	N		N		N		N	→	N
2) Joint Investment	N		Y		Y		N		N		Y
USO											
3) Oppose Agreement	N		N		N		N		N		N
PRC											
4) Accept Proposition	N		N	→	N		N	→	N		N
5) Differential Responsibility	N		N		Y		N		Y		Y
STATE #s	0		2		18		0		16		18
	Initial State		Trans. State		Final State		Initial State		Trans. State		Final Stat

Table 11 Coalition Jump for Conflict under second set of attitudes

DMs and Options	Transition from Initial State to Final State via Trans. State				
USS					
(1) Propose Bilateral Regime	N	⟶	Y		Y
(2) Joint Investment	N		N	⟶	Y
USO					
(3) Oppose Agreement	N		N		N
PRC					
(4) Accept Proposition	N	⟶	Y		Y
(5) Differential Responsibility	N		N		N
State nos.	0		9		13
	Initial state		Trans. state		Final state

Clearly, without cooperative movements there is essentially no chance that the DMs will come to any sort of agreement. Indeed, as all three analyses show, the DMs tend to work towards a stalemate when they are acting independently. Thus, it would be the responsibility of any moderator or third party to ensure that the DMs do not act independently. This applies to all three DMs, although it specifically is relevant for PRC and USS whose coalition jump in the third analysis is responsible for bringing about a final win–win outcome. Additionally, the implementation of the attitudes analysis helps illustrate the complexity of DMs' preferences and their dependencies upon each other's decisions. Attitudes within GMCR provide a methodology for representing the intricate relationships between DMs in complex international conflicts, such as the negotiation of a Sino-American climate regime. Such a methodology has useful applications in the development of climate management strategies by allowing a clear understanding of complex decisions.

The climate change negotiations studied in this research are for the situation in which the attitudes reflect the positive attitudes of an Obama administration in the

Table 12 Parallel preferences for relational analysis

PRC	13	15	(9	18	21	22)	(10	11	14	16	23)	(2	5	6)	(0	7	17)	19	1	3
USS	11	9	15	13	(0	1	2	3	10)	(16	17	18	19)	(5	6	7	14)	(21	22	23)
a	0	1	2	3	5	6	7	9	10	11	13	14	15	16	17	18	19	21	22	23
$x >_{PRC} a$	2, 5, 6, 10, 14, 16, 18, 21, 22, 23	2, 5, 6, 7, 10, 14, 16, 17, 18, 19, 21, 22, 23	10, 14, 16, 18, 19, 21, 22, 23	5, 6, 7, 10, 14, 16, 17, 18, 19, 21, 22, 23	21, 22, 23	21, 22, 23	21, 22, 23	13, 15	18, 21, 22	9, 13, 15, 18, 21, 22	–	21, 22	13	21, 22	5, 6, 7, 14, 21, 22, 23	–	5, 6, 7, 14, 21, 22, 23	–	–	–

USA. Because the new Trump administration appears to have a negative attitude towards China, the possibility of reaching a win–win resolution with respect to keeping climate change in check is extremely daunting. A flexible tool like attitude analysis, used within the overall GMCR methodological structure, can be used to forecast the negative strategic impacts of having a negative attitude and why this is the case. Fortunately, it can be cleverly utilized to understand and explain the kinds of attitudes and cooperation required to reach a resolution that will be highly beneficial for society.

As pointed out earlier, the conflict studies presented in this paper were initially executed in 2011 to determine how a possible agreement between USA and PRC could be negotiated. Fortunately, in November 2014, those two nations reached an initial agreement on reducing emissions. Even though this agreement is criticized by many for not being sufficiently strong and binding, the fact is some type of agreement was reached. Hopefully, this will inspire other nations around the world to cooperate in finding an effective international treaty on reducing greenhouse gas emissions, as was done in Paris in December 2015. An informative tool like GMCR could prove to be useful for checking which potential resolutions are strategically feasible and how attitudes and value systems should be influenced in order to attain meaningful resolutions. One could, for instance, employ what is called inverse GMCR (Kinsara et al. 2015) to ascertain the preferences required by one or more DMs in order to reach a desirable resolution. As is now widely recognized, without such an agreement, the negative impacts of not keeping temperature increases below 2 °C could be devastating upon societal systems (Moore and Diaz 2015) and both terrestrial and marine ecosystems (McCauley et al. 2015).

Acknowledgements The authors would like to express their appreciation to the anonymous referees who provided useful suggestions for improving their paper. Sean Bernath Walker would like to thank the Centre for International Governance Innovation (CIGI) for its support of this research and his doctoral studies. CIGI is a renowned nonpartisan think tank, located in Waterloo, Ontario, Canada, that investigates international governance challenges, including important environmental policy problems, through collaboration with governments, businesses and academia. K.W. Hipel is a Senior Fellow at CIGI and Fellow at the Balsillie School of International Affairs. They would also like to thank Mr. Conrad Hipel for his expert editing of the paper as well as Mr. Yi Xiao and Ms. Amanda Garcia for their assistance with the final revisions to the paper.

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