Ecological Economics 90 (2013) 68–76

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Commentary

# Modeling international climate change negotiations more responsibly: Can highly simplified game theory models provide reliable policy insights?

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ARTICLE INFO

*Article history:*
Received 4 June 2012
Received in revised form 21 February 2013
Accepted 22 February 2013
Available online 2 April 2013

*Keywords:*
Game theory
Climate change
Non-cooperative
Conflict resolution
Policy

ABSTRACT

In a recent article in this journal entitled "Game Theory and Climate Diplomacy", DeCanio and Fremstad (2013) provide an interesting treatment of a range of simple game theoretic characterizations of international climate negotiations. The authors use the Nash and Maxi-min stability definitions to analyze 25 two-by-two ordinal games, which they recognize as "possible game-theoretic characterizations of climate negotiations between two players (e.g., Great Powers or coalitions of states)". The authors' main conclusion that the Prisoner's Dilemma might not be the best description of climate negotiations game is consistent with the findings of others who have studied two-by-two conflicts over natural commons (Bardhan, 1993; Madani, 2010; Sandler, 1992; Taylor, 1987). Nevertheless, given the importance of the climate change issue, as well as the potential effects of our actions on the state of the environment and the well-being of future generations, I would like to address some gaps in their analysis, which result in it having limited usefulness for policy purposes. Of course, all models are simplified representations of reality, full of limitations. "Essentially, all models are wrong, but some are useful" (Box and Draper, 1987). So, "the practical question is how wrong do they have to be to not be useful" (Box and Draper, 1987). Models' limitations need to be carefully considered when interpreting them or applying their results to policy but some models are too simple to provide useful policy advice.



## 1. Introduction: Reliability of Simple Game Theory

As an analytical tool, game theory can enhance our understanding of real-world conflicts and provide valuable suggestions for policy development processes (Dietz and Zhao, 2011; Dinar et al., 2008; Finus, 2008; Heitzig et al., 2011; Howard, 2006; Madani, 2011; Wood, 2011). However, considerable simplifying assumptions can limit the applicability of game theory models to real world applications, which must be considered when modeling results are used to develop policies (Madani and Hipel, 2011; Wood, 2011). In my opinion, prescribing policy actions that can affect the state of nature and the well-being of billions of people around the globe must not rely on simple game models that ignore some essential characteristics of the problem. While simplifications are integral to modeling complex conflicts, the effects of simplifying assumptions on the modeling outputs should not be overlooked when interpreting the results.

DeCanio and Fremstad (2013) (DF hereafter) use highly simplistic models to analyze climate change negotiations. While their analysis provides some useful insights, in my opinion the models they consider are too simple to be used in policy advice. This is despite the fact that the literature on "climate change and game theory" (Aldy et al., 2010; Asheim et al., 2006; Camerer and Thaler, 2003; Dutta and Radner, 2004, 2009; Finus, 2008; Froyn and Hovi, 2008; Heitzig et al., 2011; Levy et al., 2009; Pittel and Rübbelke, 2008; Rübbelke, 2011; Rubio and Ulph, 2006; Walker et al., 2007; Weikard et al., 2010; Wood, 2011) is fairly rich and has improved significantly over the last decade due to the importance of the climate change topic. Researchers have adopted game theory approaches that better reflect the reality of climate change negotiations and can suggest practical resolutions.

In this commentary, I raise some fundamental questions about the key assumptions of DF's analysis, and briefly discuss alternative assumptions and solution methods that could lead to more reliable and realistic policy insights. While my comments are specifically addressed to DF's article, they can be generalized to other game theory models of climate change and natural resources conflicts. Given the limited length of commentaries, the supporting analysis has been provided as an appendix. Readers interested in the background game theory science and methods may consult the provided references.

## 2. Question 1. Are Nash and Maxi-min Solution Concepts Appropriate for Climate Games?

DF mainly rely on the Nash and Maxi-min solution concepts (stability definitions) for determining the equilibria (possible outcomes) of

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0921-8009/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ecolecon.2013.02.011

climate games, and for determining the dominant strategies of the players. However, these stability definitions may not be appropriate for modeling real-world conflicts, due to their highly restricted assumptions (Selbirak, 1994). Essentially, based on these stability definitions, players' decisions are independent from each other. Players, who make decisions based on these simplistic solution concepts, completely ignore the chance of counteractions by other players when judging the potential benefits of changing strategies (Madani and Hipel, 2011). That is why, for example, Nash stability fails to predict the obvious equilibrium in generic games like Prisoner's Dilemma and Chicken when the players are not myopic and countermovements are credible, i.e. "the breakdown of rationality" (Howard, 1971). Restrictive individual-rationality-based solution concepts have been found inappropriate for predicting the outcomes of real-world common resource games, in which players' decisions are not solely based on individual rationality (Finus, 2008; Madani and Dinar, 2012; Ostrom, 1990, 1998; Ostrom et al., 1994; Wood, 2011). Therefore, it can be argued that the Nash and Maxi-min stability definitions fail to reliably predict the outcomes of international climate games, involving smart negotiators, who are not myopic, do not make decisions independently, and do not ignore the possible counteractions by other negotiators.

Less-restrictive stability definitions such as General Metarationality (Howard, 1971), Symmetric etarationality (Howard, 1971), Sequential Stability (Fraser and Hipel, 1979, 1984), Limited-Move Stability (Fang et al., 1993; Kilgour et al., 1987; Zagare, 1984), and Non-Myopic Stability (Brams and Wittman, 1981) could be applied to improve the ordinal finite-strategy strategic climate game models, and facilitate obtaining reliable policy insights. These stability definitions have been proposed to better reflect the behavior of players in strategic decision making environments, and have been found reliable in finding the equilibria of many interactive real-world games (Fraser and Hipel, 1983; Fraser and Kilgour, 1986; Hamouda et al., 2006; Hipel et al., 1997; Li et al., 2004; Ma et al., 2005; Madani and Lund, 2011; Noakes et al., 2003; Shupe et al., 1980; Wright et al., 1980; Zagare, 1981, 1983). Table 1 summarizes the main characteristics of these solution concepts and compare them with the ones used by DF, namely Nash and Maxi-min.

While I am not suggesting that $2 \times 2$ games provide the best framework for analyzing international climate negotiations, the suggested equilibrium concepts can be applied to the games suggested by DF to show how the choice of stability definition can affect the results of game models. Appendix A presents the results of the stability analysis of the 25 climate relevant $2 \times 2$ games considered by DF, based on the aforementioned stability definitions. Each table in Appendix A shows the stability analysis details for one of the 25 studied games. In essence, these tables show whether the possible outcomes of each game are stable to the players based on the different stability definitions. Fig. 1 compares the results of the analysis by DF with the findings of this commentary. This figure shows that Nash and Maxi-min stability concepts fail to identify some of the possible equilibria of strategic games in which players are not myopic, do not act independently, and may consider the possible counteractions of the other players when making decisions. Consideration of the stability definitions which better reflect the players' behavioral characteristics in interactive strategic games, results in identifying 17 more possible equilibria in the analyzed games. Given that an equilibrium of the game is essentially a possible resolution of a conflict (or negotiation), the figure shows that some possible outcomes of the "possible" climate negotiation games remain hidden in 16 of the analyzed games, when only Nash and Maxi-min solution concepts are considered. Therefore, one can argue that the provided policy insights are not reliable. For example, while the authors do not recognize (Abate, Abate) as an equilibrium in the Prisoner's Dilemma game (game 111), the stability analysis results (Table A.1) show that this outcome can be a likely resolution of interactive strategic Prisoner's Dilemma games with real decision makers. This finding is consistent with the "breakdown of rationality" discussion by Howard (1971), and extensive lab and field experiments with real agents, suggesting that many commons have been protected and "tragedy of the commons" has been prevented in practice through cooperation among the parties within the Prisoner's Dilemma game structure (Dietz et al., 2003; Ostrom, 1990, 1998; Ostrom et al., 1994).

It should be noted that while the suggested stability definitions do a better job in simulating the behavior of decision makers in interactive games, it is never possible to capture all behavioral characteristics of different decision makers. Therefore, stability definitions are associated with simplifications and limitations. In the absence of information about the actual behavior of human agents in interactive environments, the literature suggests analyzing the game with a range of solution concepts. The states that are identified as equilibria under a larger number of solution concepts have a higher chance of being the final outcome of the game (Kilgour and Eden, 2010; Kilgour et al., 2001; Madani and Hipel, 2011). In this analysis only a few non-cooperative stability definitions which better reflect human behavior in interactive games (Fang et al., 2003; Madani and Hipel, 2011) were applied to highlight the importance of consideration of different stability definitions and to indicate the sensitivity of the results to the stability definitions considered. Future studies of climate change negotiations can consider additional stability definitions to strengthen their models after making sure the selected stability definitions are applicable to the type of the game being analyzed.

**Table 1**
Summary of the players' behavioral characteristics under different non-cooperative solution concepts.

| Stability definition | Stability description | Characteristics | | |
|---|---|---|---|---|
| | | Foresight | Disimprovemen | Knowledge of preferences |
| Nash | Player cannot unilaterally move to a more preferred state. | Low (1 move) | Never | Own |
| Maxi-min | Player selects a strategy for which the worst possible outcome is at least as good as the worst outcome from any other strategy. | Low (1 move) | Yes (conservatively) | Own |
| General meta-rationality (GMR) | All unilateral *improvements* are blocked by subsequent unilateral *moves* by other players. | Medium (2 moves) | By opponent | Own |
| Symmetric meta-rationality (SMR) | All unilateral *improvements* are still blocked by other players even after possible responses by the original player. | Medium (3 moves) | By opponents | Own |
| Sequential stability (SEQ) | All unilateral *improvements* are blocked by subsequent unilateral *improvements* by other players. | Medium (2 moves) | Never | All |
| Limited (h)-move | All players are assumed to act optimally and maximum number of state transitions is specified. | Variable (h moves) | Strategically | All |
| Non-myopic | Limiting case of limited move stability as the maximum number of state transitions increase to infinity. | Unlimited | Strategically | All |