Giuseppe Attanasi (France), Aurora García-Gallego (Spain), Nikolaos Georgantzís (Spain), Aldo Montesano (Italy)

Environmental agreements as a Hawk-Dove game with confirmed proposals

Abstract

This paper aims at two different contributions to the literature on international environmental agreements. First, the authors model environmental agreement making as a generic situation, characterized as a Hawk-Dove game with multiple asymmetric equilibria. Second, the article applies the theory on non-cooperative games with confirmed proposals, based on an alternating proposals bargaining protocol, as a way of overcoming the usual problems of coordination and bargaining failures in environmental agreement games, due to payoff asymmetry and equilibrium multiplicity.

Keywords: environmental agreement, environmental standard setting, Hawk-Dove game, bargaining, confirmed proposals.
JEL Classification: C72, C78, F53, Q50.

Introduction

There is hardly any doubt that the management and protection of the natural environment occupies a central position in the agenda of most political parties and governments. It is particularly interesting, that unlike other issues, as for example trade, the environment cannot be treated as a unified domain under a common ‘umbrella agreement’, because of the large diversity of issues involved, like climate change, resource exploitation, environmental product and process safety, pollution and emission standards, to mention a few. Partly due to this, the number of international environmental agreements in force today is several times larger than the number of international agreements on other important issues like migration or trade[1]. It is beyond the scope of this article to review all possible issues regulated by international environmental agreements or to exhaustively classify the types of problems and solutions observed during the bargaining process[2]. However, it is a common place that the issue-by-issue approach adopted worldwide allows each country to differentiate its role and bargaining attitude across different international organizations according to its interest in the issue under negotiation. Many have observed, for example, that ‘strong’ countries like the US often choose to play a secondary role in a specific negotiation process, because they do not intend to incur any of the costs entailed in the implementation of the agreed rules and, thus, do not participate as actively as they could with aggressive lobbying, a strong representative in the negotiation, etc. Another paradoxical observation is that although some agreements are not successful in inducing participation and compliance, they are not abandoned in favor of a better agreement.

As Barrett and Stavins (2003) observe focusing on the Kyoto Protocol, problems are likely to arise regarding both the participation in and the compliance with international environmental agreements. However, that paper investigates alternative goals and policy instruments as a means of achieving compliance and participation. Barrett (2002, 2003) has also focused on the content of environmental agreements proposing a cooperative R&D approach to environmental innovation and standard-setting as a means of overcoming participation and compliance failures. However, the asymmetries entailed in most agreements seem to be the largest obstacle against an environmental agreement’s ability to promote participation and compliance. In fact, as Carraro and Siniscalco (1993) note, the obvious solution of side-payments can be of limited help in promoting cooperation. For example, as noted by Barrett (2001) on the case of the Montreal Protocol, the treaty ended up as a mechanism for monetary transfers from industrialized to developing countries, rather than as a means of reducing emissions.

We have seen that most of the existing literature on participation in and compliance with environmental agreements has focused on the content of the agreements, whereas the negotiation process and the parties’ negotiating strategies have remained unexplored. We claim that some of the participation or compliance failures of multilateral environmental agreements may

Financial support by the Foundation for an Industrial Safety Culture (Fondation pour une Culture de Sécurité Industrielle) and by the French National Research Agency (ANR) through the project on ‘Fair Environmental Policies’ is gratefully acknowledged. Financial support by the Spanish Ministry of Education (ECO 2011-23634) and Junta de Andalucía (P07-SEJ-03155) is gratefully acknowledged.

[1] In fact, according to the WTO, the number of Multilateral Environmental Agreements (over 250) exceeds the number of Trade and Migration Agreements taken together (approximately 200, although migration is mostly regulated by bilateral, rather than multilateral agreements). Available at http://www.wto.org/english/tratop_e/envir_e/envir_neg_mea_e.htm.

[2] For an exhaustive review of types of agreements, see Churchill and Ulfstein (2000).

be precisely due to the parties' positions and strategies during the negotiation process. Thus, in this paper, we deal with the bargaining process itself. We show how an alternating proposals protocol can modify the outcome with respect to the one-shot structure resulting from pre-established individual bargaining attitudes brought into a convention as binding commitments by the negotiating parties. Our framework can be used to explain why some agreements are achieved even if they yield no gains to all the parties involved and why some countries may choose to assume a soft bargaining attitude when the negotiation of new environmental standards is at stake. Furthermore, we explain why unsuccessful environmental agreements are not abandoned and the status quo prevails even in the presence of potential unilateral gains from a new agreement.

For the sake of generality, we envisage the bargaining process leading to an international environmental agreement as a game whose outcome may be more or less favorable to one of the parties involved. In the extreme case, one of the parties may decide to adopt the softest attitude possible, minimizing its lobbying activities and other costs entailed in the bargaining process and let the others decide, incurring minimal compliance costs and benefits from the agreement. Of course, if all parties adopted the same passive attitude the status quo would prevail, but this would not be an equilibrium, because one of the passive negotiators would find it profitable to become active, promoting and eventually imposing its favorite type of agreement. But if all parties adopted a hard attitude, maximizing their lobbying activities they could end up in a situation which could be worse than both the status quo and than any asymmetric agreement. It must be clear by now that the situation resulting from this scenario resembles a Hawk-Dove game, with passive participants playing Dove and with aggressive ones playing Hawk. The one-shot version of the game would correspond to a situation in which the parties decide and commit on their positions before they reach the negotiation table. This feature represents the fact that the agreement may become victim of unilateralism, or may simply become a 'tote-board' for international cooperation, as noted by Levy (1993). But the high supervision costs of each country's observance make unilateral compliance and participation desirable in the sense proposed by Schelling (1998). Equilibrium predictions are asymmetric, yielding a higher benefit to the tough negotiator than to the soft one. One variation to this situation can be represented by the sequential version of the game in which the first-mover party has an advantage and can implement its favored asymmetric equilibrium.

We propose a novel approach, the Hawk-Dove game with confirmed proposals, which apart from the aforementioned asymmetric equilibrium outcomes includes the symmetric situation of universal participation and compliance to the status quo. Some of the game-theoretic literature has dealt with bargaining as a non-cooperative game[1]. Another strand has focused on 'rationally justifiable play' in bargaining[2]. In some of these articles, the interactions between cooperative and non-cooperative games emerge. However, traditional game theorists usually start their analysis by exogenously specifying that the strategic interaction among players belongs to the family of non-cooperative games or to the one of cooperative games. But in real life strategic interactions, as those leading to international environmental agreements, the nature of the game itself is an endogenous feature and it often happens that players start to act competitively, realizing only ex-post that they were playing a 'cooperative game', because the outcome they reach is always more collusive than what they imagined at the beginning. The 'confirmed proposal' mechanism introduced by Attanasi et al. (2011a, 2011b) is a non-cooperative process leading to cooperative results. They call their bargaining protocol – that may be seen as an extension of Rubinstein's (1982) model of bargaining over the split of a pie – 'Game with Confirmed Proposals' (henceforth GCP). Attanasi et al. (2011a) introduce this alternating proposals protocol with a confirmation stage as a way of solving a Prisoner's Dilemma game. They let the two players bargain over their strategies in a Prisoner's Dilemma: the bargaining supergame ends when one of the two players confirms his/her proposal and the proposal of his/her opponent. At that point, the original Prisoner's Dilemma is finally played according to the proposed and confirmed strategy profile. Focusing on the Prisoner's Dilemma, they show that when players alternate in exerting the power to end the game, the unique equilibrium confirmed agreement is the cooperative (Pareto-efficient) outcome. They test their theory in the lab: the experimental results provide strong support for the prediction of cooperation in social dilemma games with confirmed proposals. Attanasi et al. (2011b) apply a modified version of the confirmed proposals protocol with alternating power of confirmation to a variety of one-shot and two-stage original games, including the battle of sexes, a trust game, a game of entry and ultimatum bargaining. In their modified confirmed proposals protocol, bargaining periods are overlapping: in each bargaining period, the counterproposal of the second mover represents at the same time the proposal of the first mover in the subsequent bar-

[1] See, among others, Nash (1950, 1953) and Sutton (1986).
[2] See Harsanyi (1962), Friedman (1971), Smale (1980), and Cubitt and Sugden (1994).

gaining period. Moreover, each time a player re-proposes the same strategy after the opponent's counterproposal, the game ends with a confirmed agreement, given that a 're-proposal' leads to 'confirmation'. This additional rule works as a 'chain' between subsequent proposals of one player. That is why they call such mechanisms 'Games with chained Confirmed Proposals' (henceforth GcCP). Their results confirm the intuition that the confirmed proposals protocol is especially efficient as coordination-facilitating, inequality-reducing and cooperation-enhancing device.

In this paper, we apply both bargaining mechanisms (GCP and GcCP) to an international environmental standards game where two countries have to decide whether to stick to a previously agreed status quo environmental agreement or to unilaterally adopt a new standard in their own environmental practices. If both countries decide to break the status quo, then they engage into a new negotiation leading to a new agreement over environmental standards. First, we frame this 'original' game as a Hawk-Dove game. If the original game is played simultaneously or as a two-stage game with observable actions, in equilibrium one of the two countries breaks the status quo agreement by imposing its new preferred environmental standard. Conversely, we show that if the two countries bargain over the strategy profile to play in the original Hawk-Dove game, cooperation in maintaining the status quo agreement may emerge in equilibrium. Indeed, if the adopted bargaining mechanism is a GCP with alternating power of confirmation, the two asymmetric equilibria of the Hawk-Dove game are still possible equilibria of the GCP. However, also cooperation in maintaining the status quo can be reached as equilibrium of the bargaining supergame. Furthermore, if specific restrictions over the set of possible proposals are added inside the bargaining protocol (GcCP), cooperation in preserving the previously agreed environmental standard emerges as the unique equilibrium outcome.

The paper may be seen as a follow-up of both Attanasi et al. (2011a) and Attanasi et al. (2011b) in two directions. First of all, we apply the two confirmed proposals mechanisms, respectively GCP and GcCP, to an original game, the Hawk-Dove, which was not previously analyzed under these bargaining protocols. Further, we show the importance of the application of these new negotiation mechanisms to the field of environmental agreements formation and maintenance. In this regard, the aim of this paper is to highlight how the complexity of the strategic interactions behind an agreement over international environmental standards requires the adoption of more sophisticated bargaining protocols that merges strategic non-cooperative features with those cooperative incentives evolving from repeated negotiation.

The remaining part of the paper is structured as follows. In section 1, we represent the strategic interaction over setting the international environmental standards as a Hawk-Dove game. Section 2 describes the theoretical framework for the study of bargaining as a solution of a Hawk-Dove game. The final section concludes.

1. The environmental agreement game

1.1. A Hawk-Dove game. As discussed above, the negotiations for international environmental standards and objectives among a number of countries can be modeled as a Hawk-Dove game. Following the original intuition behind this game[1], let us define as $V_i > 0$ the value of a given environmental agreement for country *i* when countries negotiate over adopting or not a new environmental standard. Assume that only two countries (1 and 2) are involved in the negotiation. In the status quo agreement – reached through previous negotiations – countries 1 and 2 get, respectively, V_1^s and V_2^s (with V_i^s possibly different for each *i*), where the superscript *s* indicates the *s*tatus quo.

Suppose that a more efficient environmental standard is now available to both countries. The adoption of the new environmental standard by country *i* involves a technological cost for *i* that cannot be shared with the other country *-i*. However, if only country *i* sets the new standard, this cost is more than counterbalanced by the comparative advantage over the old standard. If an agreement is reached over country *i* unilaterally adopting the new standard, the new distribution of total value is $V_i^h > V_i^s$ and $V_{-i}^l < V_{-i}^s$, $i = 1, 2$, where superscript *h* (*l*) indicates the higher (lower) value obtained under the new agreement by the country adopting (not adopting) the new technological standard. If instead both countries decide to break the status quo agreement by adopting the new standard in environmental practices, the comparative advantage vanishes. In particular, if a new agreement is reached over both countries adopting the new standard, each country will be worse-off with respect to any unilateral standard-setting agreement, i.e. $V_i^m < V_i^l$ for $i = 1, 2$ (with V_i^m possibly different for each *i*), where superscript *m* indicates the minimum payoff a country can get in the environmental standard setting game.

This is a key assumption characterizing a Hawk-Dove strategic situation: if both countries choose to engage in environmental innovation, the individual

[1] The earliest presentation of a form of the Hawk-Dove game is due to Smith and Price (1973).

cost of 'fighting' will be greater than the increase in the individual value the (new) agreement may eventually lead with respect to the status quo.

1.2. Simultaneous game. Suppose that each of the two countries sets its own environmental standard without knowing the choice of the opponent. The one-shot structure of the Hawk-Dove game may also exemplify the participation in an international environmental convention by the two countries' representatives, having pre-established and binding commitments with their own countries.

This situation is represented in Figure 1 as a simultaneous 2x2 game. The action '*Hawk*' indicates the country's decision to adopt the new environmental standard and the action '*Dove*' indicates its choice to avoid competition by leaving the other country free to set the new standard (if the opponent chooses '*Hawk*') or leave things as they are in the status quo, without any new environmental agreement (if the opponent chooses '*Dove*' too).

1 \ 2	*H*	*D*
H	(V_i^m, V_{-i}^m)	(V_i^h, V_{-i}^l)
D	(V_i^l, V_{-i}^h)	(V_i^s, V_{-i}^s)

Fig. 1. Payoff matrix of the Hawk-Dove game

From Figure 1 it can be easily seen that each country does not have any incentive to fight if it expects the other to be aggressive in the negotiation (notice that the payoff outcome linked to the strategy profile (*Hawk*, *Hawk*) is Pareto-dominated by any of the other three outcomes of the game). Further, if one country expects the other not to implement the new standard, the former has a clear incentive to do it, due to the comparative advantage in this case.

Thus, the Hawk-Dove game in Figure 1 has two Nash equilibria in pure strategies (and one in mixed strategies). In both pure strategy equilibria (*Hawk*, *Dove*) and (*Dove*, *Hawk*), each country picks one of the two possible strategies, and the other country simultaneously chooses the opposite strategy.

Therefore, the equilibrium analysis of this strategic situation clearly leads to an anti-coordination result: there exists no pure strategy equilibrium where the two countries maintain the environmental standard on which they previously agreed.

1.3. Two-stage game. Now suppose that the interactive strategic situation is dynamic either because one of the parties has an advantage in the timing of commitments, or simply because it has a history as a credible leader in the negotiation. Thus, one country sets its environmental standard first. The other can observe the opponent's choice before deciding its own environmental standard setting strategy. In the dynamic Hawk-Dove game represented in Figure 2, one of the two countries (i, with i = 1,2) decides first and the other (-i) observes the first-mover's 'proposal' before choosing its own.

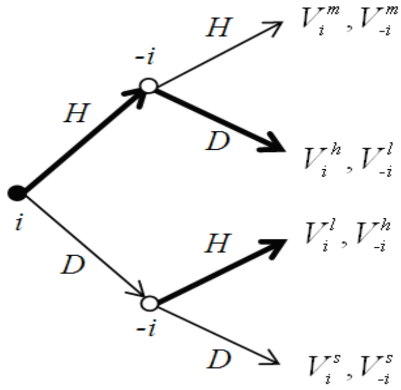

Fig. 2. Two-stage Hawk-Dove game

In the two-stage dynamic version of the game, the player moving first has an advantage. Indeed, the choice of the first mover is actually equivalent to a commitment: the second mover best-replies by choosing the opposite action, i.e. *Hawk* if *Dove*, and *Dove* if *Hawk* (bold arrows). Therefore, in the unique subgame-perfect equilibrium of the two-stage game, the first mover decides to set the new environmental standard and the second mover keeps the old one. Thus, the country deciding first increases the payoff with respect to the status quo, while the opponent accepts a lower payoff. Therefore, the first mover imposes its preferred agreement (*first-mover advantage*).

2. Choice of the environmental strategy through confirmed proposals

2.1. Bargaining over strategies in the Hawk-Dove game. Notice that in both situations analyzed in the previous section, in equilibrium there is no collaboration in setting the international environmental standard. Independent of the fact that the negotiation is simultaneous (Figure 1) or dynamic (Figure 2), the *de facto* standard after the negotiation will be 'imposed' by only one of the two parties. But imagine now that the two countries have no pre-established simultaneous or sequential commitments and can interactively alternate proposals on their standard-setting strategies. This is equivalent to a situation in which the parties arrive at the negotiation table with flexible attitudes and are prepared to announce their strategies before confirming them in an irreversible manner. We assume that such announcements are like cheap talk with the only difference that they can be turned into actual strategies in a confirmation stage, after all players' announcements have become public knowledge. If a standard-setting strategy profile is confirmed in the bargaining supergame, then the countries have a binding agreement over how to play the Hawk-Dove environmental game.

2.2. Infinite game with confirmed proposals. Suppose now that the two countries bargain over the strategies to play in the international environmental standards Hawk-Dove game shown in Figure 1 according to a confirmed proposals mechanism. Figure 1 above – besides presenting the one-shot original game – at the same time shows all the possible outcomes of the bargaining (super-) game with confirmed proposals built on it.

A GCP is in interactive strategic situation in which at least one player, in order to give official acceptance of a contract, must confirm its proposal in combination with the proposal of its opponent. Given the set of possible strategies $S_i = \{H, D\}$ for country i = 1,2 in the Hawk-Dove game in Figure 1, the GCP represents the way according to which the two countries bargain about strategies in S_i.

In each bargaining period t, players are randomly assigned one over two roles: *proposer* or *responder*. Each bargaining *period t* is constituted by three *stages*, namely (t.I), (t.II), and (t.III). At stage (t.I) the proposer picks a strategy in S_i (proposal); at stage (t.II), the responder, after having seen the strategy picked by the proposer, picks a strategy in S_i (counterproposal)[1]; finally, at stage (t.III) the proposer decides whether to confirm or not the strategy profile picked by the two players. The proposer is actually the only player having the power to confirm the proposed strategy profile in a period. The game ends if and only if the proposer at the end of a bargaining period confirms the proposal-counterproposal sequence in that period. In this case, the confirmed sequence leads to a confirmed strategy profile that is successively played in the Hawk-Dove game. If the proposer in a period does not confirm the strategy profile proposed in that period, another bargaining period with the same rules starts. Therefore, the GCP through which the two players bargain over the strategy profile to be played in the Hawk-Dove game has a potentially infinite sequence of bargaining periods, i.e. $t = 1,2, \ldots,+\infty$. The proposer in the next bargaining period can be the same of the previous period or not. In this paper we focus on a GCP with *alternating* power of confirmation: once a player is randomly selected to be the proposer in period 1, it will play as proposer in period 1 and in each odd period; the opponent will play as proposer in each even period. Hence, players alternate in exerting the power to end the game (by confirming the agreement reached in a period). Without loss of generality, suppose that the player randomly selected to be the proposer in period 1 is player i in the Hawk-Dove game, with i = 1, 2.

[1] Recall that in the original Hawk-Dove game the two players have the same set of strategies.

The GCP version of the Hawk-Dove game is represented in Figure 3. The payoff set of this super-game is the same as the original game in Figure 1, with the first of the two payoffs referring to the proposer in bargaining period 1 and the second referring to the responder in bargaining period 1.

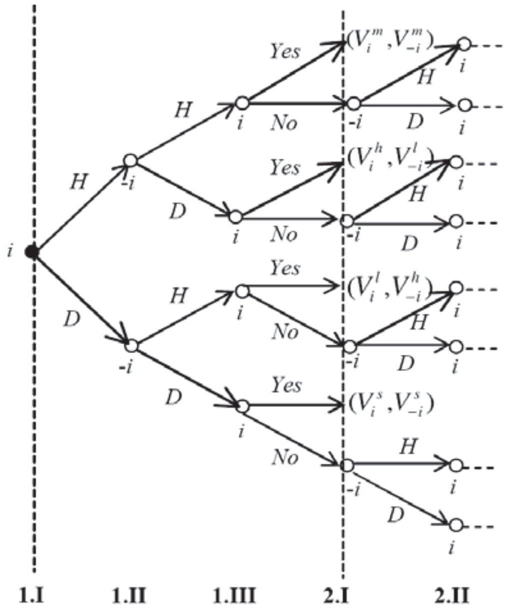

Fig. 3. Hawk-Dove game with confirmed proposals

As in Attanasi et al. (2011a), we assume that each player's preference relation among the possible agreements of the GCP satisfies the three conditions: patience (the bargaining period where the contract is signed is irrelevant); stationarity (the preference between two outcomes does not depend on the bargaining period); the payoff each player receives if no contract is signed is not better than the minimum payoff of the game (in the Hawk-Dove situation in Figure 1, this payoff is V_i^m for each player i = 1,2).

Proposition 1 shows that in the GCP version of the Hawk-Dove game, if the power of confirmation is alternated, all strategy profiles of the original game apart from the one in which both countries break the status quo environmental agreement can be confirmed in equilibrium.

Proposition 1. The set of subgame perfect equilibrium outcomes in the Hawk-Dove game with confirmed proposals and alternating power of confirmation is $\{(H,D)(D,H)(D,D)\}$. Each of these *three outcomes* can be confirmed in *any* bargaining period $t = 1, 2, \ldots, +\infty$.

Proof of Proposition 1. Consider the game in Figure 3. First of all, notice that players cannot agree in equilibrium on the strategy profile (*H*, *H*), giving the proposer a payoff of V_i^m. In each bargaining period *t*, the proposer in that period will never confirm this contract, given that it can always commit to play the strategy (*D*, *Yes*), allowing a payoff of at least $V_i^l > V_i^m$ in period *t*. Therefore, contract (*H*, *H*) is not an equilibrium outcome. Conversely, all other strategy profiles of the original Hawk-Dove game can be equilibrium outcomes. This can be verified by using a stationarity argument. Given that the game horizon is infinite, all subgames starting in odd nodes are identical and the same holds for all subgames starting in even nodes. Since players are rational, strategy profiles confirmed in period *t* will be the same as the ones that would have been confirmed at *t* + 2, with *t* = 1, 2, …, +∞. Hence, we can characterize a subgame perfect equilibrium based solely on stationary strategies. Suppose that (*D*, *H*, *Yes*) is an equilibrium outcome. In a stationary equilibrium, the payoff profile at the end of period *t* = 1 has to coincide with the payoff profile at the end of each other period *t* > 1. Therefore, given that the game starting in stage (*t*.I) and the one starting in stage (*t* + 1.I) are isomorphic (the sets of strategies in the two games are the same and the original game is symmetric) for each *t*, we can assign to each non-terminal node at the end of every bargaining period *t* the payoff profile $\left(V_i^l, V_{-i}^h\right)$. Therefore, also the payoff profile in the continuation game at the end of period *t* is $\left(V_i^l, V_{-i}^h\right)$ for all non-terminal histories. That would lead the first proposer, player *i*, to choose *Yes* at stage (*t*.III) in every nodes apart from (*H*, *H*), since the payoff profiles $\left(V_i^h, V_{-i}^l\right)$, $\left(V_i^s, V_{-i}^s\right)$ and $\left(V_i^l, V_{-i}^h\right)$ are no-worse for *i* than $\left(V_i^l, V_{-i}^h\right)$. In particular, since the payoff it obtains in the terminal node (*D*, *H*, *Yes*) is the same as in the non-terminal node (*D*, *H*, *No*), it is indifferent between confirming the agreement on the strategy profile (*D*, *H*) and not confirming it. Going backwards, in any case the responder -*i* would best-reply with *H* whatever *i*'s first proposal, thereby always getting $\left(V_{-i}^h\right)$, the highest possible payoff for *i*. Hence, at the beginning of period 1, player *i* would be indifferent between *H* and *D*. Therefore, (*D*, *H*) can be an equilibrium agreement. Through the same stationary argument, we can show that also (*D*, *D*) and (*H*, *D*) can be equilibrium agreements. Let us first verify that the game may end in some period *t* with the plan of actions (*D*, *D*, *Yes*). Given that we assign to each non-terminal node at the end of bargaining period *t* the payoff profile $\left(V_i^s, V_{-i}^s\right)$, the proposer does not confirm (*H*, *H*) and (*D*, *H*), confirms (*H*, *D*) and does not decline (*D*, *D*), given that it gets the same payoff in the terminal node (*D*, *D*, *Yes*) and in the non-terminal node (*D*, *D*, *No*). Going backwards, the responder would best-reply to *H* with *H* and to *D* with *H* or *D*, hence leading the proposer to be indifferent between proposing *H* or *D* at the beginning of the period. Finally, let us verify that the game may end in some period *t* with the plan of actions (*H*, *D*, *Yes*). Given that we assign to each non-terminal node at the end of bargaining period *t* the payoff profile $\left(V_i^h, V_{-i}^l\right)$, the proposer does not confirm at stage (*t*.III) any strategy profile in the original game apart from (*H*, *D*). In particular, (*H*, *D*) is not declined by the proposer because it gets the same payoff in the terminal node (*H*, *D*, *Yes*) and in the non-terminal node (*H*, *D*, *No*). Going backwards, the responder would be indifferent between *H* and *D* whatever the first proposal (in every terminal and non-terminal node at stage (*t*.III) it gets the same payoff, V_{-i}^l), hence leading the proposer to be indifferent between proposing *H* or *D* at the beginning of the period.

2.3. Infinite game with chained confirmed proposals. Let us now suppose that the two countries bargain over the strategy profile to play in the original Hawk-Dove game through an alternative bargaining mechanism, where exogenous constraints are laid down over the set of possible paths of proposals.

This alternative confirmed proposal mechanism entails a *chain*: if a strategy profile is not confirmed in a bargaining period, it becomes the starting point for the next negotiation period. This means that in each bargaining period the counterproposal of the second mover represents at the same time the proposal of the first mover in the subsequent bargaining period. Therefore, the bargaining periods are *overlapping*. Moreover, each time a player proposes the same strategy in periods *t* and *t* + 2, the game ends with a confirmed agreement in period *t* + 2, given that a 're-proposal' leads to 'confirmation'.

To be more explicit, suppose that in period 1 player *i* proposes strategy *H* and that player –*i* counter-proposes strategy *H* (which is conditional on strategy *H* for player *i*). If player *i* says *Yes* (that is, 'I play *H* if you play *H*, taking into account that you play *H* if I play *H*'), then the game ends in the first bargaining period with the two players agreeing on playing (*H*, *H*) in the original Hawk-Dove game. If instead player *i* proposes *D* after the sequence *H-H* (that is, 'I play *D* if you play *H*'), this is equivalent to *No* confirmation of the strategy profile (*H*, *H*), and so the negotiation continues. If player -*i* says *Yes* (that is, 'I play *H* if you play *D*, taking into account that you play *D* if I play *H*'), then the game ends in the second bargaining period with the two players agreeing on playing (*D*, *H*) in the original Hawk-Dove game. If instead player -*i* proposes *D* after the sequence *H-H-D* (that is, 'I play *D* if you play *D*'), this is equivalent to *No* confirmation of the strategy profile (*D*, *H*), and so the negotiation continues. And so on and so forth.

The GcCP version of the Hawk-Dove game is represented in Figure 4. Again, the payoff set of this supergame is the same as the original game in Figure 1, with the first of the two payoffs referring to the proposer in bargaining period 1 and the second referring to the responder in bargaining period 1.

Notice that, due to overlapping bargaining periods, the bargaining period 1 goes from period t = 1 till period t = 3, the bargaining period 2 goes from period 2 till period 4, and so on and so forth. Hence, period t = 2 indicates at the same time stage (1.II) and stage (2.I); period t = 3 indicates at the same time stage (1.III), stage (2.II) and stage (3.I); period t = 4 indicates at the same time stage (2.III), stage (3.III) and stage (4.I); and so on and so forth.

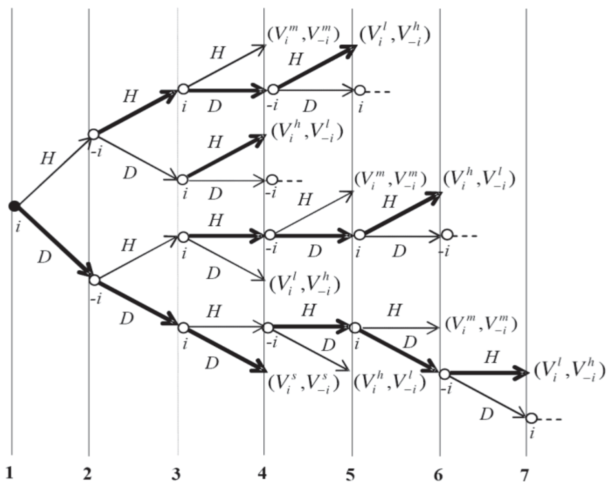

Fig. 4. Hawk-Dove game with chained confirmed proposals

Hence, with respect to the GCP analyzed in the previous section, such a mechanism entails an additional rule limiting the set of possible strategies a player may follow in the bargaining game. The reasons for the adoption of such 'constrained' mechanism may be many. For example, in an ex-ante stage of the bargaining game, players themselves may have agreed on this limitation in order to reduce the possibility of toughness challenges by some player. In the real world, the negotiating parties are usually not strangers and the value of eliciting the other's 'true' toughness may be limited. Besides that, such a mechanism is able to improve the meaning of the tacit communication behind a specific sequence of proposal-counterproposal-(no) confirmation. In fact, the strategy announced by a country in the pre-confirmation stages may have a signaling role on the country's intentions in this specific negotiation. Furthermore, limitations of the possible sequences of proposals-counterproposals-(no) confirmation may be due to the wish of speeding up the time needed to find a consensus over the strategy profile to play. Indeed, in a 'standard' GCP, Attanasi et al. (2011a) show that players may be 'tempted' to lengthen the negotiation by sending confusing signals to their counterpart.

In the GcCP version of the Hawk-Dove game, only the cooperative outcome can be confirmed in equilibrium, as formally stated in Proposition 2.

Proposition 2. The Hawk-Dove game with chained confirmed proposals has a *unique* subgame perfect equilibrium *outcome* (*D*, *D*), confirmed in bargaining period 1.

Proof of Proposition 2. Let us consider the infinite game in Figure 4. Each tree branch belonging to the equilibrium path (bold arrows) is part of a weakly dominant strategy. More precisely, each player's strategy leads to the following result: the payoff obtained by the player through confirming a strategy profile in period t, with t = 3, 4,…, +∞, equals the highest payoff it can get by continuing the game. Observe that in Figure 4 (first 7 periods of the game) there are four decision nodes where one of the two players can confirm the strategy profile yielding its highest payoff possible. At period 4, after the non-terminal history (*H*, *H*, *D*), player *-i* can get V_{-i}^h by choosing *H*, hence confirming its most preferred strategy profile in the original game, (*D*, *H*). If, instead of confirming, player *-i* chooses to continue the game, in any subgame in the continuation game, it can get at most a payoff of V_{-i}^h, by confirming the same strategy profile it could already confirm at period 4. Therefore, for player *-i* confirming the strategy profile (*D*, *H*) at period 4 weakly dominates continuing the game. The same holds for player *i* at period 3, after history (*H*, *D*), and at period 5 after history (*D*, *H*, *H*, *D*); and for player *-i* at period 6 after history (*D*, *D*, *H*, *H*, *D*). Therefore, each player's equilibrium strategy in the GcCP prescribes confirming the favorable asymmetric outcome whenever possible. At the same time, in order to prevent the opponent from doing the same, each player's equilibrium strategy in the GcCP prescribes confirming also the agreement (*D*, *D*) whenever possible. Therefore, at each period $t \geq 3$, each player proposes *D* in a stage every time where in the two previous stages the two players' proposals were equal, and proposes *H* otherwise. This leads to the terminal history (*D*, *D*, *D*).

Thus, in the unique subgame perfect equilibrium of the bargaining game, player *i* starts by proposing strategy *Dove* to player *-i*, who counter-proposes strategy *Dove*. Then, player *i* confirms its strategy *Dove*, such that the original game strategy profile (*D*, *D*) is the (unique) confirmed agreement. This is reached already at the end of bargaining period 1 (i.e., at period 3), after the first interaction between the two players takes place.

The comparison of Proposition 2 and Proposition 1 indicates that the possibility of a new agreement to emerge instead of the status quo critically depends on the parties' ability to freely re-consider their preceding proposals in favor of a new proposal-counterproposal sequence. Lack of such flexibility reduces the ability of the confirmed proposals bargaining protocol to lead the process away from the status quo. As Barrett (2003) has already observed, the asymmetry of an agreement in favor of one or the other country may work against its adoption by the less favored countries. However, here, we offer an alternative explanation and solution to compliance and participation problems, based on the argument that more flexible mechanisms in the absence of pre-negotiation and pre-agreement commitments are more likely to lead to the acceptance of asymmetric agreements.

Conclusion

Environmental agreements are negotiated and eventually signed by asymmetric players. The countries involved may differ in size, technology and most importantly in development levels. Most of the literature on the difficulties faced within a multilateral environmental agreement focuses on the content of the agreement, which is expected to deal with the issue of asymmetries in order to solve compliance and participation problems. Thus, the bargaining process has remained an under-investigated domain. Part of this lack of connection between the bargaining and the environmental agreements literature is due to the fact that the former belongs mostly to the domain of cooperative games, while real-world environmental agreements are negotiated through non-cooperative processes. Thus, it has been a rather challenging task for bargaining theorists to deal with environmental agreements.

In this paper, we have suggested the confirmed proposal version of a Hawk-Dove game to illustrate how coordination problems and asymmetries may be overcome to explain the emergence of new asymmetric agreements or the survival of the status quo. We have also illustrated how the existence of inflexibilities in the negotiation and re-negotiation process may hinder potentially beneficial departures from the status quo. Rather than mitigating the intrinsic and often inevitable asymmetries entailed in international environmental agreements, our framework implies that asymmetric outcomes are perfectly sustainable, as long as the (re)negotiation process allows players to use strategies which are not dictated by any type of negotiation commitments or pre-established negotiation positions, entailing the risk of coordination failures, and thus the emergence of the worst of all outcomes: costly unprofitable agreements.

References

1. Attanasi, G., García-Gallego, A., Georgantzís, N. and A. Montesano (2011a). An Experiment on Prisoner's Dilemma with Confirmed Proposals, TSE Working Papers 11-274, Toulouse School of Economics (TSE).
2. Attanasi, G., García-Gallego, A., Georgantzís, N. and A. Montesano (2011b). Non Cooperative Games with Chained Confirmed Proposals. In L.A. Petrosjan and N.A. Zenkevitch (Eds.), *Contributions to Game Theory and Management*, 4, pp. 19-32.
3. Barrett, S. (2001). International Cooperation for Sale, *European Economic Review*, 45, pp. 1835-1850.
4. Barrett, S. (2002). Towards a Better Climate Treaty, *World Economics*, 3, pp. 35-45.
5. Barrett, S. (2003). *Environment and Statecraft: The Strategy of Environmental Treaty-Making*, Oxford: Oxford University Press.
6. Barrett, S. and R. Stavins (2003). Increasing Participation and Compliance in International Climate Change Agreements, *International Environmental Agreements: Politics, Law and Economics*, 3, pp. 349-376.
7. Carraro, C. and D. Siniscalco (1993). Strategies for the International Protection of the Environment, *Journal of Public Economics*, 52, pp. 309-328.
8. Churchill, R. and G. Ulfstein (2000). Autonomous Institutional Arrangements in Multilateral Environmental Agreements, *American Journal of International Law*, 94, pp. 623-659.
9. Cubitt, R. and R. Sugden (1994). Rationally Justifiable Play and the Theory of Non-cooperative Games, *Economic Journal*, 104, pp. 798-803.
10. Friedman, J.W. (1971). A Non-cooperative Equilibrium for Supergames, *Review of Economic Studies*, 38, pp. 1-12.
11. Harsanyi, J. (1962). Bargaining in Ignorance of the Opponent's Utility Function, *Journal of Conflict Resolution*, 6, pp. 29-38.
12. Levy, M.A. (1993). European Acid Rain: The Power of Tote-Board Diplomacy. In R.O. Keohane, P.M. Haas and M.A. Levy (Eds.), *Institutions for the Earth: Sources of Effective Environmental Protection*, Cambridge, MA: MIT Press, pp. 75-132.
13. Nash, J. (1950). The Bargaining Problem, *Econometrica*, 18, pp. 155-162.
14. Nash, J. (1953). Two-person Cooperative Games, *Econometrica*, 21, pp. 128-140.
15. Schelling, T.C. (1998). *Costs and Benefits of Greenhouse Gas Reduction*, Washington, DC: AEI Press.
16. Smale, S. (1980). The Prisoner's Dilemma and Dynamical Systems Associated to Non-cooperative Games, *Econometrica*, 48, pp. 1617-1634.
17. Smith, J.M. and G.R. Price (1973). The logic of animal conflict, *Nature*, 246, pp. 15-18.
18. Sutton, J. (1986). Non-cooperative Bargaining Theory: An Introduction, *Review of Economic Studies*, 53, pp. 709-724.