WPS3641

APPLICATIONS OF NEGOTIATION THEORY TO WATER ISSUES

Carlo Carraro, Carmen Marchiori and Alessandra Sgobbi *

Abstract

The purpose of the paper is to review the applications of noncooperative bargaining theory to water related issues – which fall in the category of formal models of negotiation. The paper aims to identify the conditions under which agreements are likely to emerge and their characteristics, and to support policy makers in devising the "rules of the game" that could help obtain a desired result. Despite the fact that allocation of natural resources, especially trans-boundary allocation, has all the characteristics of a negotiation problem, there are not many applications of formal negotiation theory to the issue. Therefore, this paper discusses the non-cooperative bargaining models applied to water allocation problems found in the literature. Key findings include the important role noncooperative negotiations can play in cases where binding agreements cannot be signed; the value added of politically and socially acceptable compromises; and the need for a negotiated model that considers incomplete information over the negotiated resource.

World Bank Policy Research Working Paper 3641, June 2005

This paper is a product of the study "Stable arrangements for allocation of water among competing uses under stochastic supply conditions". The study is funded by DECRG. The study team includes: Carlo Carraro, Carmen Marchiori, Irene Parachino, Fioravante Patrone, Alessandra Sgobbi, Stefano Zara, and Ariel Dinar (TTL).

*Carlo Carraro is Professor of Environmental Economics at the University of Venice, Department of Economics, San Giobbe 873, 30121, Venice, Italy, and Research Director of the Fondazione Eni E. Mattei. Carmen Marchiori is a Ph.D. Student at the London School of Economics. Alessandra Sgobbi is junior researcher at the Fondazione Eni E. Mattei. The authors are grateful to Ariel Dinar, Zmarak Shalizi and to Anastasios Xepapadeas for helpful comments on a previous version of this paper.

Table of Contents

1 Introduction

Bargaining situations are pervasive in life, from marriage to parenthood, to wage negotiations; even government policies are the outcome of negotiations among different parties or interested stakeholders. The interest in the investigation of negotiation theories and techniques has significantly increased in the research literature, and has expanded from its traditional domain of labor-management relations, to other strategic areas – such as trade and natural resources.

In the theory of negotiation, a 'conflict' is interpreted as a situation in which the agents, decision makers, or 'players'[1] could mutually benefit from reaching an agreement, but have opposite interests over which agreement to conclude, i.e. how to cooperate. Where aims partially diverge, conflict and cooperation become two faces of the same coin, and should therefore be dealt with holistically. Negotiation theory seeks to identify the variables that determine the outcome of negotiations, bargaining power, and power relations, using a game theoretic (GT), formal approach.

Many natural resource and environmental problems are best handled within a GT framework, and by means of formal GT models. In many issues related to natural resource *management* the characteristics of a Prisoner's Dilemma game are present: the dominant strategy for players is not cooperative, and the resulting equilibrium is not Pareto efficient – the payoff for at least one individual could be improved, without some other individual being made worse off. Despite the fact that the cooperative outcome Pareto-dominates the equilibrium, cooperation is unlikely to result without outside intervention, or without altering the incentive structure, because all parties have incentives to free-ride, or defect, and binding agreements are often not possible. The *allocation* of a shared resource size is, on the other hand, often modeled as a game of pure conflict – in which the payoffs to one individual imply a reduction in the payoffs of his opponents. In these situations, players need to find a strategy to divide the resource in a way that is agreeable to all parties, and which possesses some desirable characteristics. Often the allocation rule needs to be self-enforcing, especially in the context of

---

[1] These could be individuals or groups of individuals, sectors, nations, etc.

transboundary natural resources, where a super-national body to enforce the agreement is not present. In order to determine which outcome will result from negotiations over the partition of a resource, models of noncooperative bargaining theory focus on the process by which agreement is reached, approximating it through an offer and counteroffer procedure, following the seminal work by Rubinstein (1982). In this framework, players bargain over the allocation of a surplus of strictly positive size, by making offers over the partitions of the cake, or rejecting/accepting opponents' proposals. This approach does not make a priori assumptions over the partition of the cake that will be reached in equilibrium, and, for multiple-issues and multilateral bargaining, there are indeed many partitions that can be sustained as an equilibrium to the game (see Negotiation Theory – Part 1). The approach allows an explicit treatment of issues such as equity and political power, which play a very strong role in real-life negotiations. However, it does not allow for the possibility of sub-coalitions of players to form: rather, it is implicitly assumed that all relevant players take part in the negotiation, and that the final allocation rule is agreed by all of them.

It has been shown in the theoretical literature that cooperation can be sustained as an equilibrium outcome in the case of repeated games, even though the incentives to defect remain, especially in the case when players' preference sets are very different (Just and Netanyahu 2000). Cooperative behavior may be induced by the use of threat strategies, whereby deviations from cooperation are punished by reverting to the non-cooperative behavior. Threat strategies are only effective if the gains from deviating in current periods are outweighed by the benefit losses from future non-cooperative payoffs. However, as in many cases the punishers incur costs from implementing the punishment strategies, threat strategies may not be credible, and the theoretical models predict that the non-cooperative outcome will result.

Increasingly, negotiated policy making is advocated as an approach to natural resource management, which could improve management, both domestically and internationally. It is in fact widely agreed that negotiated policies are more in line with actual needs, are more readily accepted by the people concerned, and are therefore easier to implement and enforce.

The purpose of the paper is therefore to review the literature on non-cooperative bargaining approaches to water related issues – which fall in the category of formal models of negotiation. The ultimate aim is, on the one hand, to identify the conditions under which agreements are likely to emerge, and their characteristics; and, on the other hand, to support policy makers in devising the "rules of the game", in order obtain a desired result. Despite the fact that allocation of natural resources, especially of trans-boundary nature, has all the characteristics of a negotiation problem, there are not many applications of formal negotiation theory to the issue. In Section 2, the non-cooperative bargaining models applied to water allocation problems found in the literature will be discussed. Particular attention will be given to those directly modeling the process of negotiation, although some attempts at finding strategies to maintain the efficient allocation solution will also be illustrated. Negotiations are complex processes, especially when more than two parties are involved, and more than one issue is to be decided. For this reason, Section 3 of this paper is concerned with presenting the main elements of Negotiation Support Systems (NSS) developed to support the process of negotiation. This field of research is still relatively new, however, and NSS have not yet found much use in real-life negotiation. The paper will conclude by highlighting the key remaining gaps in the literature.

2 Application of negotiation models to water issues

Most of the literature on water allocation uses optimization models to characterize the most efficient water allocation scheme. Mechanisms proposed typically include: marginal cost pricing; public sector allocation (government intervention); water markets; and user based allocation (Dinar et al. 1997). Guiding principles for allocation may focus on economic efficiency or equity; the alternative allocation mechanisms respond to the two principles in different ways, and to different degrees.

The economic literature focuses to a large extent on market allocation mechanisms (such as tradable water rights). It is argued that these allow the achievement of the efficient allocation at the least cost. For instance, Booker and Young (1994) build an optimization model of transferable water rights, which includes a comprehensive hydrological component (including water quality as well as quantity), and models both *offstream* (consumptive) and *instream* (non-consumptive) water demand. Their non-linear optimization model analyses the impact of alternative scenarios for the Colorado River basin, with respect to institutions and water demand, over the choice of water abstraction and salt discharges. The results indicate that an institutional allocation mechanism which allows intrastate water transfers based on both consumptive and non-consumptive use values significantly improves welfare.

Although the decentralized market solution is in theory efficient and least cost, and maximizes welfare (in terms of economic surplus), there are various reasons why it may not work within the context of shared waters: for instance, non user values are not readily marketable; water is a highly strategic resource, and it is often politicized. Booker and Young themselves, in the above mentioned paper, recognize that the inclusion of non-consumptive use values is problematic both on technical and equity grounds: these benefits are non rival in consumption, and they may have asymmetric consequences for the bargaining parties – making the proposed allocation unlikely to be viewed as fair.

In addition, the fact that water supply may vary stochastically through time introduces further complexities in the problem of managing the resource, adding one more reason why traditional approaches may not yield the expected welfare improving results. Some attempts at addressing uncertain water supply in theoretical models can be found in the literature, especially for groundwater resources. For instance, Zeitouni (2004) explores the optimal management of aquifers when the stock is uncertain, and proves that there is a threshold level determining whether there should be any abstraction at all. When pumping costs are sufficiently high, the optimal abstraction coincides with water recharge level. Tsur and Zemel (1995) explore how the possibility of irreversible changes in groundwater resources affects the optimal management and allocation rules. In the presence of such exogenous uncertainty the optimal process does not converge to a unique equilibrium steady state, and exploitation policies should be more conservative.

Using groundwater and reservoirs as buffers against uncertainty can smooth stochastic variations in water supply out. Tsur (1990) and Tsur and Graham-Tomasi (1991), for instance, explore the role of groundwater as a buffer for stochastic variations in surface water levels – and finds that the stabilization role of groundwater may well be larger than the benefits derived from increasing water supply. Similarly, Roseta-Palma and Xepapadeas (2004) explore the role of water reservoirs in protecting users against uncertain water supply, and analyze the precautionary behavior emerging from a robust-control approach to modeling water resources. In this paper, the authors introduce uncertainty over the occurrence of precipitation, in the sense the stochastic process followed by precipitation is not perfectly known to the decision maker, and its implications for quantitative water used in both a static and a dynamic setting. A precautionary behavior emerges in the dynamic setting, where the decision maker lowers surface water abstraction because of the integration of worse-case precipitations.

All the above mentioned approaches, however, do not address explicitly the issue of how to allocate (uncertain) water resources among competing uses, leaving out the process of negotiation.

The strategic and political nature of water, as well as its human right aspect, calls for a different approach to the allocation problem, one which considers the strategic behavior of actors, as well as their motivations. Negotiation models can therefore provide very helpful insights into the actual allocation of water resources – by identifying strategies which may sustain cooperation as an outcome, and by taking into account strategic behavior and social/political feasibility of the allocation proposed, as well as power asymmetries, incomplete information, and other relevant aspects of the process.

2.1 Ground water management

Groundwater exploitation is a typical case of open access resource, where externalities in consumption, therefore, exist. Although the paradoxical empirical results first obtained by Gisser and Sanchez (1980)[2] have persisted in the groundwater literature, this has not prevented a substantial literature to develop, exploring the welfare implication of different management regimes.

---

[2] What has become Gisser-Sanchez effect basically states that the magnitude of the benefits from optimally managing groundwater resources is negligible. The result rests mainly on the theoretical assumption of very steep groundwater use benefit curves (implying relative price insensitiveness of users), and on empirical observations comparing central control and open access management regimes for groundwater exploitation of the Pecos Basin in New Mexico. For a recent criticism to the Gisser-Sanchez effect see, for instance, Kounduri (2004).

For instance, Dixon (1999) models a simplified version of groundwater exploitation, in which there are two agents with access to one of two interdependent and identical groundwater cells. Each agent lowers the water table in his own cell by pumping. The water table rises due to exogenous recharge, and water flows between the two cells according to specified environmental parameters. Agents maximize net benefits from water abstraction, subject to the equation of motion for the depth of water in each cell. This is a typical situation in which appropriation externalities exist – that is, in which actions by one agent have negative impacts on the benefits to other agents – and in which uncoordinated exploitation leads to inefficient outcomes. Dixon proceeds by estimating the non-cooperative, the optimal, and the collusive solutions (open and closed loop), and then compares the resulting welfare levels[3].

Under the myopic (non-cooperative) solution, each agent maximizes his own net benefits, Π_i^{my} discounted using the private discount factor, without taking into account the externalities of their water extraction on future water level. Under the socially optimal solution, the impact of pumping on ground-water levels is accounted for. Total profits, Π_i^*, are maximized using the social discount factor, and the payoffs are equally split between the two identical users. Cooperative behavior can be determined using two different solution concepts. Under open-loop solutions, agents maximize net present discounted[4] value, Π_i^{OL}, given the withdrawal of the others. The solution is a Nash equilibrium. Payoffs are larger than in the myopic case but, since agents still fail to account for the negative externalities imposed on others (stock externality), they are lower than the optimal payoff. The open loop solution overlooks strategic responses[5], in which players pre-empt the opponents by extracting more (strategic externality). Yet, it can be realistic when players do not observe the state of the resource, for instance, and therefore cannot respond to opponents' moves, or when some sort of binding agreement can be signed. When players behave strategically, the closed-loop solution should be used, which does not overlook strategic response, and predicts that users adjust their

---

[3] When the social and private discount factors are equal, the social optimal is equivalent to the cooperative solution.

[4] Using real *private* discount rate.

[5] By assumption, in the open loop solution each agent take the opponent's extraction path as given.

extraction paths according to observed actions by other players. The sub-game perfect equilibrium extraction paths (and payoffs) of the closed loop solution, Π_i^{CL}, incorporate both the stock and strategic externality. Therefore, it is expected that $\Pi_i^{CL} < \Pi_i^{OL} < \Pi_i^{*}$.

Dixon applies this simplified model to groundwater use in the Joaquin Valley, taking baseline parameters from the existing literature when available, and making reasonable assumptions about the discount rate and length of the game. The results confirm the theoretical expectations: the difference between Π_i^{*} and Π_i^{OL} is given by the stock externality, and accounts for 18% of the overall difference between the collusive (optimal) and myopic payoffs. The strategic externality is measured by the difference between Π_i^{CL} and Π_i^{OL}, and amounts for another 7%. As expected, the myopic equilibrium is the farthest from the optimal equilibrium, with a 75% difference in payoffs.

For trigger strategies[6] to be feasible, agents must first agree on what to play in the periods prior to deviation – that is, they must agree on the cooperative exploitation paths. In addition, it is assumed that players can observe others' actions. Dixon considers the trigger strategy in which a player extracts the collusive amount as long as all the others do the same in the preceding period. If one agent defects, all agents will return to the closed-loop equilibrium strategies for all successive periods. If the set of trigger strategies is a sub-game perfect Nash equilibrium (that is, if for each player j the best response is to play it, given that all other players also play it in each period), then collusion can be sustained as an equilibrium outcome of the game.

Simulating the solutions for a given set of parameters, and varying the discount rate to assess its impact on the stability of trigger strategies of the kind described above, the author shows that, for reasonable parameters and low enough discount rates, it is possible for agents to set up a self-enforcing agreement to play the collusive solution – the "tragedy of the commons" is not necessarily the outcome of non-cooperative groundwater exploitation. The critical value of the discount factor below which the set of trigger strategies does not form an equilibrium is 0.53 (for a discount rate of 0.89).

---

[6] A trigger strategy is defined as a strategy in which a player starts by cooperating, and continues to cooperate provided that the opponent also cooperates. If the opponents cheat, then the player reverts to the non-cooperative strategy for a pre-defined period of time.

In the literature of game theoretic applications to natural resources, various authors propose the use of *differential games*[7] to explore resource use strategies, and their efficiency and sustainability properties. In fact, resources are intrinsically dynamic – especially renewable resources, which vary through time according to the rate of growth of the resource stock, and other parameters. In the water realm, most applications are found in the groundwater literature. For instance, Provencher and Burt (1993) estimate the rate of groundwater extraction under common property management regime, identifying the externalities present under this management strategy, and investigating the effects of different risk-aversion parameters for water users.

In this paper, the outcome emerges from dynamic strategies and the resulting resource evolution. The solution concept used is that of Feedback (or closed-loop) Nash equilibrium, where solutions assume that the state of the system at any one time depends on the past choices and outcomes, not only on the initial state[8]. Similarly, the same authors (Provencher and Burt 1994) apply a dynamic model to compare the welfare effects of different property rights regime for groundwater pumping, when players have different risk-aversion factors: central (optimal) control dominates private property with tradable permits when water users are risk neutral, but with risk-averse firms both regimes are sub-optimal, and tradable property rights can be a feasible and desirable alternative to central control. This is because the market for permits provides opportunities for risk management in the face of changing conditions, flexibility which central control does not allow. Furthermore, in cases in which the value of a resource is lower under the private property rights regime than under command and control, in practice this difference is small, and the private property regime may be preferable on the grounds of easier implementation.

---

[7] Differential games belong to a subclass of dynamic games called “state space games”, where a set of state variables describe the state of the dynamic system at any point in time during the game. The hypothesis is that the influence of past decisions on the payoffs at subsequent times is captured adequately by the evolution over time of the state variables. When the laws of motion of the state variable can be modelled in continuous time, the state space game becomes a differential games, whereas in the case of discrete time variables, the game is a difference game. Differential games, therefore, combine the principles of game theory, calculus of variation and control theory, to determine the strategic interactions between players in a dynamic context.

[8] Open Loop Nash Equilibria strategies, by contrast, assume that the controls depend on the *initial* state of the system under investigation, and time.

These approaches, however, concentrate on the efficiency and optimal control of groundwater exploitation, rather than on the "real-life" issue of allocating water among competing users – which is the main object of negotiating water policies.[9]

2.2 Allocation among sectors

Competition among sectors for water use is the *status quo* in many countries, where often there is a conflict between agricultural and urban use, and environmental sustainability constraints. Negotiation over water allocation typically involves bargaining over multiple issues (for instance, water abstraction, as well as water quality), and multiple players – different user groups of the resource, e.g. farmers, urban dwellers, recreational users.

A multi-person, multiple issues, negotiation model for water allocation is that developed by Rausser and Simon (1992). Their model is a framework for non-cooperative, multilateral negotiation that explicitly incorporates the structure of the process, such as the input of each player in the bargaining, the partition of groups into sub-groups, and the issue space. In the bargaining game, a finite number of players select a policy from some collection of possible alternatives. Among the set of possible allocations, there is a *disagreement policy*, which will be imposed if the players fail to reach an agreement by the terminal time T. The authors examine the limit points of the equilibrium outcomes of the finite bargaining horizon game, as the time horizon is extended without bounds. The limit points are interpreted as a proxy for the equilibria of the bargaining game with finite but arbitrarily large bargaining rounds.

Let $I = \{1,\ldots,I\}$ denote the finite set of players in the negotiation game, indexed by i. Players choose a policy package $x \in X$, where X is assumed to be a compact subset on the n-dimensional Euclidean space, and n denotes the number of issues to be negotiated.

---

[9] In fact, approaching the issue of groundwater management using non-cooperative bargaining models could be quite useful even for development projects, such as the Groundwater and Soil Conservation project implemented in Nepal, and sponsored by the World Bank: in that context, exploring how the various stakeholders – farmers, local councils of different villages, government institutions, etc – view the water abstraction *and* the pattern of land use to identify proposals acceptable to all parties could have facilitated implementation, especially in the observed context of weak institutional presence.

For an agreed upon policy vector $\vec{x}$, player *i* gets a utility of $u_i(\vec{x})$, whereas player *i*'s disagreement payoff is $\vec{u}^0$. By assumption, the set of admissible coalition is *I* = {1,…,*I*} that is, unanimity is needed to reach an agreement. The game has a finite number of rounds *T*.

The negotiation game is played in the following way: at each round $t < T$, provided no agreement has yet been reached, a proposer is chosen according to exogenously specified vector of access probabilities, $\vec{w} = (w_i)_{i \in I}$. The probability of player *i* being chosen, w_i, is such that $0 < w_i < 1$, and $\sum_i w_i = 1$. The access probability of a player can be interpreted as her "political effectiveness". The selected player makes a proposal for the policy vector in *X*, and the other players vote on whether to accept or reject it. If the proposal is accepted by all players, the game ends. Otherwise, another player is selected randomly to be a proposer in the next round. If the final round *T* is reached, and no policy vector in *X* has been unanimously agreed upon, the disagreement policy vector is imposed on players, who receive a payoff of $\vec{u}^0$. In the model, it is assumed that there is a policy vector $x \in X$ that strictly Pareto dominates $\vec{u}^0$.

The sub-game perfect equilibrium of the game can be characterised as follows:

- ⇒ At the terminal time *T*, player *j* accepts a proposal by player *i* ($I \neq j$) iff $u_j(\vec{x}_i^T) \geq u^0{}_j$, that is, a player will only accept an offer in the final round, if it gives her at least as much utility as her disagreement payoff.
- ⇒ Similarly, at time $t < T$, player *j* accepts a proposal by *i* iff $u_j(\vec{x}_i^t) \geq \sum_{i=1}^{I} w_i u_i(\vec{x}_i^{t+1})$, that is, if it yields at least as much utility as the expected continuation payoff, i.e. the w_i-weighted sum of the utilities obtained from all parties' (including herself) proposals in the following round.

The authors show that, if *X* is compact and each player utility is strictly quasi-concave in *X*, the game can be solved recursively to yield a unique solution vector, consisting of an equilibrium proposal in *X* for each player. Players propose their equilibrium policy vector whenever they are chosen to be the proposer in the first round (like in the Rubinstein's model). Moreover, with probability 1, the other players will accept the proposal in round one. Convergence is ensured by the characteristics of the disagreement outcome: if no compromise is reached in the last round, then a pre-specified disagreement policy is imposed, which yields to all players a lower utility than any negotiated outcome.

The Rausser-Simon model of multilateral, multi-issues negotiation has been applied to water allocation problems in two different contexts: Adams et al. (1996) apply it to water allocation in California, where disputes over water resources are very common because of the conflicting demands of the large agricultural industry, expanding urban population, and strong environmental groups. The model is applied to the so-called “three way negotiations”, whereby the three major stakeholder groups (agricultural and urban users, and environmentalists) informally negotiate water allocation regimes – the degree to which water rights are transferable, the type and level of environmental standards, and the level of infrastructure development.

Thoyer et al. (2001) and Simon et al. (2003) apply the Rausser-Simon model to negotiations over water use, water storage capacity, and user prices in France, where seven players (one farmer group for each of the three sub-basins of the river; two environmental groups; a water manager; and a representative of elected local councils, called “taxpayer”) bargain over seven policy dimensions (levels of irrigation quotas per hectare of cultivated land, in each of the sub-basins; residual flows allocated to environmental services; the price of water; and the size of three reservoir dams).

These two situations, with their differences and similarities, offer good test cases for the Rausser-Simon model. Group preference ranking over the set of policies is specified, and utility functions constructed and estimated. Environmental and budgetary constraints are also modeled. The authors simulate the model under different scenarios, in order to analyze the impact of changes in the institutional setting of the game on the negotiated agreement. The parameters analyzed are: bargaining power, measured by players’ access probability; heterogeneity (between and within group); and issue space.

The results are consistent with intuition: in both applications, (i) increasing the political weight of a group leads to an allocated outcome relatively more favorable to that group – and of groups who have similar preferences. The political weight of a group, however, is not its sole source of bargaining power: the default strength, that is, the relative utility derived in case the no agreement policy is imposed, is also a source of bargaining power. In Adams et al. (1996), the results of the simulations indicate that asymmetries in the disagreement payoff of the bargaining groups result in different negotiated agreement: more specifically, (ii) the higher is a group's utility in disagreement, the more bargaining power the group has – and, therefore, the more favorable to that group the negotiated agreement is.

In Thoyer et al. (2001), the simulations confirm the intuition with respect to the effect of removing one player from the negotiating table: that is, the resulting allocation scheme will be further away from the excluded group's preferred position than when the group takes active part in the bargaining. More interestingly, a player's preferences influence the negotiated agreement even when her political weight is zero, but she takes part in the negotiation process without intervening. This is a consequence of unanimity being the decision making rule.

In their California application, Adams *et al* explore the effects of removing one policy dimension from the negotiated policy package, and of restricting its interval admissible values. Through their simulations, the authors conclude that significant gains from bargaining are lost when one policy dimension is excluded, and that restricting the admissible values a dimension can take has a non-linear impact on players' utilities. So, for instance, when the range of admissible levels for infrastructure development is restricted, the utility of the group preferring less infrastructure to more increases for less stringent restriction, whilst the others' utilities decrease. Eventually, however, even the utility of this group will start declining. The authors explain these results as a shrinking of the bargaining set – the mutual gains to be had through negotiations are lower.

Adams et al. (1996) examine the impact of within-group heterogeneity on the final negotiated outcome, and the effect of imposing a spokesperson, who maximizes the averaged utilities of the coalition members – with the effect of reducing group's heterogeneity. In the first case, the group of farmers is divided into two sub-groups, A and B, with different preferences over only one policy dimension. In this case, agreement requires only quasi-unanimous approval, that is, agreement among the environmental and urban user groups, with *either* of A or B joining the sub-coalition. Intuitively, increasing the distance between A's and B's preferred negotiated outcome should weaken the groups' bargaining power, as the two sub-groups compete to represent the interest of farmers. In reality, the effect of different preferences over one policy issue (water transfer in the simulation) is affected by groups' relative preferences over another policy variable (infrastructure investment in the simulation). In addition, the simulation analyses indicate that when there is a significant divergence of interests between coalition members, the introduction of a spokesperson will usually benefit the coalition as a whole. Yet, this is so because the negotiator can discriminate against one member: the negotiated allocation may therefore require side payments to be feasible, and induce the non favoured group to join. Further, changing the decision rule away from unanimity strengthens the negative effect of within group heterogeneity, as sub-groups compete to form larger coalitions.

The analytical framework proposed can be applied to water resources to achieve sustainable governance, and it explicitly models the negotiation process recognising the importance of relative political influence and power in determining the disagreement outcome. The outcome of multilateral multi-issue negotiations depends crucially on the constitutional structure of the negotiation process, as well as groups' preferences and internal structures. Moreover, by carefully selecting the issues to be negotiated over, and the stakeholders to take part in the bargaining, the decision maker can manipulate the outcome of the bargaining process.

Although the Rausser-Simon model provides a useful tool to support negotiations, it has some simplifications that limit its applicability. First of all, convergence of the results relies on all players preferring any negotiated agreement to the default policy – yet this may not necessarily be the case, especially when some user groups are closer to the government than others.

In addition, the model structure implies perfect information, whereas not only groups may not be fully aware of the preferences of other groups, but also they may not have themselves a clear ranking and tradeoffs amongst issues negotiated upon. Strategic misrepresentation of group preferences may also alter the result of the negotiation in practice, although this aspect fails to be captured by the model.

Water resources are assumed to be deterministic and known at all points in time. Although in Simon et al. (2003) different scenarios are modelled – depending on the assumed abundance of water – they are all deterministic, and do not affect players' preferences, ranking, or strategies. The traditional features of the model can be extended to include issues such as asymmetric information, moral hazard, uncertainty, and network formation, (Rausser (2000)), but, to our knowledge, no attempts have yet been made.

2.3 Allocation among countries

Water resources are typically transboundary: allocation procedures and mechanisms are more problematic in this context, as widely discussed in the literature of international agreements (see for instance, Hanley and Folmer (1998)), as they require agreement among sovereign states as opposed to intra-country jurisdiction. The two main characteristics of the problem are: countries' levels of welfare are interdependent, through water quantity/quality; and all solutions to the allocation problem must be consistent with the principle of national sovereignty – that is, a country's compliance with the agreement must be strictly voluntary and self-enforcing.

A feature peculiar only to international river (as opposed to boundary rivers, seas or enclosed sea basins) is the *unidirectionality* of river flow, which makes the allocation process even more difficult. Within this context, static games may generate outcomes in which the dominant strategy for the upstream country is not to cooperate, whereas the downstream country's dominant strategy is to cooperate. In this context, the resulting equilibrium is not efficient.

Side payments[10] have been suggested in the literature as means to induce the upstream country to internalize the externality. In repeated games, coordination problems can be resolved, and the cooperative action can be the resulting equilibrium of the game – interaction over time introduces the possibility of rewarding cooperative actions.

This approach is embedded in the papers by Ambec and Sprumont (2000) and Kilgour and Dinar (2001), Kilgour and Dinar (1995) where compensation schemes are bargained over, which ensure the attainment of the "optimal" water allocation scheme in the international context. Similarly, Supalla et al. (2002) investigate a scheme in which a second price auction is implemented in order to establish the contribution of each user

---

[10] When there are gains to be made from cooperation, but these are not equally distributed, cooperation can be achieved through the transfer of (part of) these gains from the parties who stand to gain to those who loose. The latter group is made at least as well off as under the non-cooperative arrangement.

group to a fixed amount of water for instream services, and how payments can be apportioned, to ensure the agreement is enforceable.

Although the repeated game approach with side payment resolves the problem of coordination when a unidirectional externality is present, the resulting equilibrium may be seen as an application of the "victim pays" principle, as the downstream country has to effectively bribe the upstream country not to over-consume or over-pollute water. This regime may be undesirable: first, there is large consensus over the "polluter pays principle"[11]; second, and perhaps more importantly, countries are reluctant to implement "victim pays", as this strategy is likely to earn victims a reputation of weak negotiators. Bennet et al. (1998) propose a different approach to solving unidirectional externalities in water sharing between countries, one which relies on issue linkage, rather than side payments. Similarly, Bhaduri and Barbier (2003) investigate the effects of linking the implementation of the Ganges River Agreement to a separate negotiation over water augmentation from Nepal. Despite the encouraging results shown in the literature on issue linkage, Just and Netanyahu (2000) question the welfare improving qualities of issue linkage in negotiation, which is useful only in cases where there are strong asymmetries in payoffs, and equity is a concern.

2.3.1 International water allocation with side payments

In Ambec and Sprumont (2000), the focus of the model is on the asymmetric access to water that countries have. In contrast with the majority of literature, which focuses on the problem of designing suitable institutions and mechanisms for sharing the resource, this paper is concerned with welfare allocation. A water allocation mechanism, to be sustainable, should be stable in the sense of the core (i.e. give coalition members at least as much utility as their secure level of welfare), and distribute welfare fairly. As fairness is not a universal concept, the definition given by the authors is that a welfare distribution is fair if no coalition or individual enjoys a welfare higher than its aspiration level, that is, higher than the welfare level it would enjoy in the absence of all other players – that is, if

---

[11] Of course, whether the upstream or the downstream country *should* bear the burden of the agreement depends on the initial property rights allocation, on the perceived fairness of the allocation rule, on the countries' relative political and economic power, development stage,…

it could use all the water available. The authors proceed as follows: first, they adopt a theoretical, cooperative approach to characterize an efficient and equitable welfare sharing arrangement. Then, they focus on non cooperative arrangements and decentralized behavior, which could sustain the “optimal” solution.

Let $I = \{1,\dots,I\}$ be the set of agents sharing a river, which flows through their location, and order them according to their position, with $i < j$ meaning that i is upstream of j. Agents have a utility function (differentiable, strictly concave and strictly increasing) defined over water and money, of the form $u_i(x_i, t_i) = b_i(x_i) + t_i$ - where x_i represents water allocated to player i, and t_i is player i's net money transfer. The river picks up volume along its course, increasing by a specified amount $e_i > 0$ between any two locations. A consumption plan is any vector $x \in R_+^I$. An allocation is a vector $(x,t) \in R_+^I \times R^I$ satisfying the feasibility constraints:

$\sum_{i \in I} t_i \leq 0$ and $\sum_{i \in P_j} (x_i - e_i) \leq 0$, for every $j \in I$, with P_j denoting the set of predecessors to player i.

Let $z \in R^I$ be a vector of welfare distribution of some allocations x and t.

The optimal allocation, which defines an allocation ($x^*(I)$,$t^*(I)$), is Pareto efficient if it maximizes the sum of all agents’ benefits, and wastes no money. The core stability constraint and the fairness constraints (determining lower and upper bounds on welfare) single out the optimal consumption plan. Ambec and Sprumont prove that the only welfare distribution which satisfies both core stability and fairness constraints is the *downstream incremental distribution*, which lexicographically maximizes the welfare of agent i, and its predecessors, subject to the core constraint.

The authors consider two forms of decentralized behavior: myopic competitive behavior, and sophisticated strategic behavior. In the former, a decentralized market structure is imposed through the allocation of tradable water rights: however, in order to achieve downstream incremental distribution, it is necessary to know players’ preferences. Allocating an equal share of property rights to agents, in particular, does not always lead to the stable and equitable welfare allocation defined above.

Strategic behavior is, on the other hand, to be expected when the number of players is small. Modeling the problem in a game theoretic context, the authors argue that it is possible to implement in a sub-game perfect equilibrium the downstream incremental welfare distribution. The game is an extensive form non-cooperative bargaining game in which i, i-1,…,2,1 are successively allowed to make offers, which the others can either accept or reject. If player i's allocation offer is rejected, she gets the bundle $(x_n,t_n)=(e_i,0)$, and agent i-1 gets to propose an allocation for i-1 players. If the proposal is unanimously accepted, it is enforced in the successive stage. Otherwise, player i-1 gets a bundle $(e_{n-1},0)$. If the last stage of the game is reached, then player 2 proposes an allocation for 2 players, which is enforced if player 1 agrees. Otherwise, player 2 and 1 get allocation $(e_2,0)$ and $(e_1,0)$ respectively. Backward induction shows that the downstream incremental welfare distribution is generated for every sub-game perfect equilibrium of the game and for every preference profile.

As the Rausser and Simon models presented before, the model proposed by Ambec and Sprumont assumes perfect information and deterministic water supply. In addition, water allocation is determined according to optimality and efficiency principles, which do not take into account the strategic and political nature of the resource. Only monetary transfers are bargained over, and it is assumed that they can compensate for water transfers fully. Lastly, the model so formulated focuses on the rival aspect of water consumption, ignoring the non rival nature of water. Moreover, the marginal cost of consumption never exceeds the benefits.

A similar problem is analyzed by Kilgour and Dinar (1995) and Kilgour and Dinar (2001), where the possible welfare improving consequences of a more flexible water allocation scheme that takes into account not only the underlying hydrology, geography and economic conditions in a river basin, but also annual fluctuations in river flow, is investigated. What is proposed by the authors is an annual adjustment of allocation on the basis of new data and information gathered, which increases the accuracy of water quantity assessment. This adjustable scheme improves total welfare, relative to best fixed scheme. Whereas water allocation is uniquely determined, the monetary transfers are determined by the structure of the bargaining game: standard cooperative game theory models can be applied to produce a specification of the efficient compensation scheme. It turns out that, for a two person bargaining problem, virtually all the standard solution concepts yield the same result: the surplus benefit from compensation is divided equally between the two agents. It would be interesting to explore the result given by a negotiation framework over both water sharing and money transfer – rather than cooperative agreements over monetary transfers alone – including some notion of fairness in the procedure.

2.3.2 Auction games

A different approach is adopted by Supalla et al. (2002), who apply auction theory to determine the shares of water for environmental services in the Platte river to be provided by the three states sharing the river.

The Platte River flows through Colorado, Wyoming and Nebraska. Conflicts over water use – both within and among states – are rampant. In addition, the river system provides critical habitat for fish and wildlife. The central resource management problem is that there is insufficient water to satisfy competing consumptive needs, and instream flow for species conservation.

Supalla *et al* use an auction mechanism to model part of the decision making process in the Platte river system. The issue of who is to supply a previously agreed (exogenously given, and determined by environmental services requirements) quantity of water to instream services is addressed within this framework.

The auction is designed as a second price, sequential auction game, with repeated bidding and predetermined cost shares. The only players are the three states. Each of them bids in a pre-determined order to supply a given quantity of water (a block). The bidding is repeated until all parties except one (the low bidder) have passed. The block is then supplied by the low bidder, at a price equal to the second lowest bid. Note that cost shares are predetermined, and determine how much each state has to contribute to the common pool funds to purchase water for instream services.

Consider a set of agents $N = \{1,2,3\}$, consisting of the three states (Colorado, Nebraska and Wyoming respectively). Cost shares[12] are predetermined, and denoted by s_n. The cost of supplying a quantity q is determined by water acquisition cost (AC_n), and third party cost (TP_n), that is, costs incurred by parties not directly involved in the procurement decision. In addition, states incur a political cost, PC_n, where PC_n represent an "equity" payment above the real opportunity cost of supplying a block of water, which states may require as compensation for the political difficulties associated with reallocating water away from domestic consumption. All costs, with the exception of the political cost[13], are common knowledge, and differ among states. States are induced to reveal their (true) supply preferences when each block of water is auctioned, by choosing either to supply it, or to pay someone else for its provision. The auction works in the following way: the winning bidder, j, supplies the block of water at a cost $C_j(q)$, and receives a payment equal to the second lowest bid, B. However, the winner has to pay its predetermined share of supply cost, s_j. The payoff from winning is therefore $(1-s_j)B-C_j(q)$. The other players have to pay their pre-determined share of cost. In this case, players losing the auction incur a positive cost. It is well documented that, for a sealed bid second price auction, it is a dominant strategy for players to announce costs truthfully, but the model adopted by Supalla *et al* uses a descending order English auction design that does not necessarily lead to truthful cost revelation: however, because of the repeated nature of the game, it results in the same strategic actions. This strategy profile is a Nash equilibrium, and it is such that all players bid until only the two lowest cost players are left; then the agent with the second lowest cost stops at his costs, and the lowest cost player wins the auction with a bid equal to (or slightly below) the second lowest cost.

Supalla *et al* estimate the *AC* and *TP* costs for the three states on the basis of existing data: acquisition costs were imputed from the existing literature, whereas *TP* costs were estimated assuming that only water from irrigation could be diverted: hence, *TP* costs were assumed to be the indirect economic losses associated with lower agricultural activity (e.g. lower employment levels, or lower yields).

The inclusion of political costs is a mechanism for reaching an agreement where one would otherwise not exist, and to model the fact that political and strategic considerations are also at play, when deciding who should contribute the water for environmental services. *PC* costs are assumed to escalate exponentially with the quantity

---

[12] In addition the three states' contribution, the Federal Government contributes a fixed share, s_4.

[13] If all costs were known, for any given quantity of water Q, one could analytically solve for the cost minimising shares for each state.

of water supplied by one state, i.e., with the needed reallocation from national consumptive use to in-stream uses.

Simulations of the second price auction to determine the share of instream water to be supplied by each state show that, if no political compensation is allowed, Nebraska would need to supply 79% of the water for environmental uses. This result is due to the fact that most of the low-cost water is to be found in Nebraska – yet this cost minimizing scheme is unlikely to be politically acceptable. Nebraska is unlikely to be willing to supply so much of the water, and compensations are therefore necessary to find an agreement. Under moderate compensation, the aggregate cost of supplying the required amount of instream water increases by 16% per year, but the burden sharing is more likely to be accepted by all states. Even more so under a scheme of high compensation – although supply costs increase by 30%.

The inclusion of political compensation in a second price auction increases the budgetary cost of providing the required amount of water, relative to the theoretical minimum cost, but at the same time it increases the probability that the supply arrangement will be implemented. In a real world setting, however, the real minimum is not known, and the second price auction at least minimizes welfare costs, because the bidder with the lowest cost actually supplies the water. The actual cash transfer may be higher by an amount equal to the difference between the winning bid and the next highest price. The second price auction, and the inclusion of political compensation, change the sharing of welfare among the parties, but do not affect total welfare (the loss to the paying parties equal the gain to the receiving party). The political compensation makes the water supply plan politically acceptable.

The simulations suggest that second price sequential auction is an effective tool to induce participants to reveal their true minimum price for supplying different quantities of water and guarantee that a feasible solution is found, although actual costs would depend on how much political compensation is required.

The interesting feature of the model proposed by Supalla *et al* is the explicit inclusion of the political and strategic aspects linked to water sharing. Political feasibility of the allocation scheme (equivalent to some form of equity concern) has the effect of driving a wedge between the (economic) efficient agreement, and the actual outcome of a negotiation process. It is therefore clear that efficiency cannot be the only consideration, when determining water allocation or cost sharing schemes. The inclusion of political considerations creates a bargaining space, which would not otherwise exist in practice – although the game theoretic models would indicate its existence in theory.

It would be interesting to extend the model proposed by Supalla et al. (2002) to include negotiation over the quantity of water to be released for instream services, rather than only to determine which states should supply it, and at what cost. A two-level game, similar in concept to the one described in Section 3.4, could provide the required tools.

A similar effect to the introduction of political compensation payment in the second price auction described by Supalla et al. (2002) can be obtained by linking water sharing to other issue of interest to at least two of the parties. Issue linkages play an important role in solving international externalities, especially in cases in which side-payments would be needed, resulting in "victim pays principle".

2.3.3 Issue linkage

Bennet et al. (1998) propose a modeling framework in which two players, engaged in negotiations over separate issues, may gain by linking the issue in a nested game (Tsebelis, (1990)). It is argued that countries with weak negotiation position often try to improve their leverage by linking issues: modeling water allocation non-cooperative bargaining situations as interconnected games can generate outcomes that cannot be obtained when issues are modeled independently. Issue linkages enlarges the bargaining set, by allowing countries to condition the outcome in the water allocation negotiations to past outcomes in non-water games. Two case studies are presented, in which the equilibrium of the negotiation game is non-cooperative, if the water allocation game is played in isolation, but a water sharing agreement can be found, if countries link water allocation to other issues. One of these is presented in more detail.

Since the break-up of the Soviet Union, water conflicts in the Aral Sea have increased dramatically, and water quality has deteriorated. There are several factors that make it very difficult for countries to reach an agreement over water sharing, primarily the highly strategic role of water as a major input for food production, which make it the dominant strategy for each country to pursue uncoordinated, individual strategies. Bennet et al. (1998) model water sharing between Uzbekistan and Tajikistan as a nested game: Tajikistan has the choice of developing the Amu Darya river to gain additional water, whereas Uzbekistan has to decide whether or not to support rebel groups in Tajikistan; in the other game, Tajikistan has to decide whether to abate air pollution affecting Uzbekistan – who can either subsidize abatement activities in Tajikistan, or not. If the games where played separately, the dominant strategies would be *Divert* and *Support*, with a payoff of [0,0], in the first game; and *No abatement* and *No subsidies* in the second game. These outcomes are clearly sub-optimal. If the games are played in a nested fashion, Uzbekistan's dominant strategies are *Not support* and *No subsidies*, whereas Tajikistan's are *Divert* and *Abate*. The payoff matrixes are reproduced below.

A) The Amu Darya River Game

		Tajikistan	
		Not divert	Divert
Uzbekistan	Don't support	2 1	-2 1.5
	Support	1 -1	**0** **0**

B) The Air Pollution Game

		Tajikistan	
		Abate	Don't abate
Uzbekistan	Subsidize	3 1	-3 2
	Don't subsidize	4 -1	**0** **0**

C) The Nested Game

		Tajikistan			
		Not divert Abate	Not divert Don't abate	Divert Abate	Don't divert Don't abate
Uzbekistan	No support Subsidies	5 2	-1 3	1 2.5	-5 3.5
	No support No subsidies	6 0	2 1	**2** **0.5**	-2 1.5
	Support Subsidies	4 0	-2 1	3 1	-3 2
	Support No subsidies	5 -2	1 -1	4 -1	0 0

By allowing countries to link outcomes of the negotiations for the Amu Darya river basin and air quality, the bargaining space has been enlarged, and all countries are better off.

Similar results are obtained in another application: allocating water of the Euphrates between Turkey and Syria, linked to a game in which water pollution levels by Syria in the Orontes River basin is also negotiated.

Although the results obtained are interesting and encouraging, care must be taken in advocating for issue linkages: the payoffs used in the games are theoretical, and may well not reflect the true preference ranking of the players. It has been shown in the theoretical literature that, as long as the payoffs are of the same order of magnitude and represent the true ranking of players' preferences, and the games have asymmetric prisoner's dilemma payoffs structure, then the theoretical payoffs will suffice to illustrate the benefits of issue linkage (p. 74, Bennet et al. (1998)). However, careful consideration of the actual payoff is needed, to ensure that the theoretical ranking is indeed a true reflection of countries' preferences.

In the paper by Bhaduri and Barbier (2003), there is an attempt to link water transfers, and international water allocation negotiations. The authors examine the scope of extending the recent Ganges water sharing agreement[14] between India and Bangladesh, linking it to an additional provision of water augmentation from Nepal. It is argued that this issue linkage would improve the negotiating leverage of the weaker (downstream) country, Bangladesh, and deter India from diverting water in excess of the share agreed under the treaty.

The existing treaty contains no provision of water transfers from third parties, yet there are serious concerns that in the near future there will be an acute shortage of water to satisfy increasing water demands in both India and Bangladesh. By creating water storage facilities in Nepal, surplus water could be released to the Ganges during drought periods. As water release from Nepal is non-separable between India and Bangladesh, any such augmentation scheme would need to be negotiated by the three countries, and it

---

[14] The Ganges River Treaty was signed between India and Bangladesh in 1996. For a detailed overview of the dispute between India and Bangladesh over sharing the Ganges see, for instance, Crow and Singh (2000).

would necessarily require India and Bangladesh to both pay for any additional water transfers from Nepal requested by any one country.

Bhaduri and Barbier develop a Stackelberg leader-follower game to determine the optimal water diverted by India, with and without augmentation provision. Given the unilateral externality involved in water diversion by upstream countries, and given the stronger position of India, India is the leader, and Bangladesh the follower. In the case of water augmentation, it is argued that the bargaining position of Bangladesh is improved, as the country can unilaterally buy additional water from Nepal, increasing water costs to India as well. However, examining past attempts at achieving a sharing agreement, when Bangladesh insisted on linking water sharing with proposals to augment dry season flows in the Ganges through transfers from Nepal, suggest that India would not gain from a water augmentation scheme.

In the model, it is assumed that water is allocated initially between the two countries on the basis of proportional rights, and that both countries have the option of purchasing water from Nepal. Consumptive use of water is therefore maximized individually, given transfers from Nepal – that is, an augmentation treaty would establish (fixed) shares of water from Nepal for both India and Bangladesh. India has the option of deviating unilaterally from the Ganges's treaty, rather than buying water from Nepal. By contrast, Bangladesh can only increase its water supply, by purchasing additional water from Nepal – who will release additional water only if both countries pay. Thus, buying more water from Nepal, Bangladesh forces India to buy additional water as well.

Countries use water input from either the Ganges or Nepal's water release, to produce economic goods, and maximize net profits. The game can be solved by backward induction, first solving for Bangladesh's reaction function to any arbitrary share of water diverted by India, then solving India's problem given Bangladesh's reaction.

The results of the model imply that, if India's share of water from Nepal increases relative to Bangladesh's, the optimal amount of water diversion for India will *decrease*. However, when water scarcity is not binding for India, and there is no provision for water augmentation, India's profits are higher, and there is a larger diversion of water from the Ganges. India is better off without a water augmentation scheme, and has therefore no incentives to agree to it. The Ganges Water Treaty is therefore likely to become unstable, unless ways of inducing India to negotiate a water augmentation treaty are found: if water scarcity becomes more stringent for India, the country will have strong incentives to defect from the treaty.

The results of the analysis do provide policy directions, in that they show that a water augmentation treaty is unlikely to be signed – despite it being necessary. However, the results depend crucially on the assumptions that the cost of water released from Nepal is decreasing in quantity: although this may be realistic for relatively low levels because of the initial infrastructural investment, it is likely that political considerations would make water release politically costly at higher quantities, as shown by Supalla et al. (2002). If water supply costs to Nepal are not declining with quantity, Bangladesh's threat is not credible, and the proposed augmentation scheme would not lead to a more stable agreement on the sharing of Ganges' waters. In addition, the authors stop short of providing ways in which India could be encouraged to sign a binding and enforceable trilateral water augmentation agreement, as it is not individually rational for the country to do so.

Despite the encouraging results of issue linkage care must be taken in identifying linking opportunities. Just and Netanyahu (2000) examine the circumstances under which issue linkage can lead to an enlarged bargaining set. In general, issue linkages are more successful when the games are strongly asymmetric, and there are equity concerns. Linking games can bring benefits when the resulting feasible choice set for both players is expanded, and when it makes new strategies possible, that are not possible under the two independent games. Under these circumstances, countries are more likely to exchange in-kind side payments than monetary payments, and to sustain self enforceable agreements. In their paper, Just and Netanyahu analyze various game structures (prisoner's dilemma; assurance; iterated dominance; and chicken), and compare the outcome in the isolated 2-person, 2 strategy games to the outcome if the games are linked. It is shown that, for the case of two PD games, the linked outcome dominates the aggregated outcomes only when the payoff combinations are substantially different from the full cooperation case. In these cases, outcomes other than full cooperation are chosen out of equity concerns. In many cases, however, and contrary to general assertions, linking games does not generate an enlarged bargaining set (in Just and Netanyahu (2000), p. 97). Moreover, even in cases when linking does expand the bargaining set, the equilibrium outcome may not be affected. When linking games other than PD, the benefits of issue linkage are significantly lower: in these cases, a significant proportion of the frontiers of the aggregated and the linked games overlap, suggesting that the chances of coming to a full cooperative equilibrium are not increased to a significant extent by issue linkage.

The dominance of linking over aggregated payoff is obtained only when full cooperation is *not* preferred: this may be because, although full cooperation may be *efficient*, it may not be *equitable*: players are therefore reluctant to pursue full cooperation, but partial cooperation strategies may be feasible, which give them a payoff preferred to non-cooperation and to full cooperation, given equity considerations. This may explain why, especially in the international arena, players pursue seemingly irrational strategies, and do not prefer full cooperation.

2.4 Two level games

As illustrated by the applications discussed so far, water allocation can be at two levels – nationally, between different user groups, consumptive and non-consumptive uses, etc – and at the international level – among different countries sharing the same resource. Although discussed separately, these two levels are interrelated – how much water can be allocated among sectors ultimately depends on how much water is available – which may depend on how an international water body is divided. On the other hand, how much a country is willing to compromise on international water allocation may depend on its national settings, power groups, priorities, etc. Typically, a decision at one level has significant implications for the other level of negotiation: models which fail to take this interdependence into account may therefore be misleading.

Two-level games (Putnam (1988)) provide some insights as to which agreement is to be expected, when two negotiation games are interdependent. According to Putnam, “the politics of many international negotiations can be conceived as a two-level game. At the national level, domestic groups pursue their interests by pressuring the government to adopt favorable policies and politicians seek power by constructing coalitions among those groups. At the international level, national governments seek to maximize their own ability to satisfy domestic pressures, while minimizing the adverse consequences of foreign developments" (p. 436).

In their 1996 working paper, Richards and Singh (1996) provide a simplified 2-level game of two countries bargaining over water allocation, when within country negotiations between two user groups also take place. State agents are assumed to be benevolent, and the initial allocation of water (both within and between countries) inefficient. Richards and Singh develop a cooperative model of bargaining for both levels of negotiation, on the assumption that the cooperative solution approximates the (more suitable) non cooperative game, when the discount rate is sufficiently low (as shown in Binmore et al. (1986)).

In the paper by Richards and Singh (1996), there are 2 countries, A and B, and two groups within each country, 1 and 2 in country A, 3 and 4 in country B. Utility depends on two good, water, w, and a *numeraire* good, y. Utility functions are assumed to be quasi-linear, implying transferable utility, and the Pareto frontiers are straight lines or hyper-planes. The initial allocation of water and *numeraire* good is $\overline{w}_i, \overline{y}_i$ respectively, for i =1,…,4. Initial utility for group i is therefore $u_i(\overline{w}_i, \overline{y}_i) = v_i(\overline{w}_i) + \overline{y}_i$. The initial utility is assumed to be the disagreement payoff, d_i, (or threat point) of the water bargaining game.

Let w_i^* denote the optimal water allocation. The condition for water optimality is that the marginal utility of water be equated across groups. The reallocation of water requires compensatory payments, t_i^*. The optimal amount of water is uniquely determined, but the transfers of the *numeraire* good needed to sustain the optimal water allocation are determined by the outcome of the bargaining game(s).

The bargaining game varies, according to the assumptions made with respect to the two levels of the game. For instance, when only national or international negotiations take place, the Nash bargaining solution (or its generalization to n-players), with d_i as the disagreement payoffs, is the relevant model. On the other hand, when the negotiations at the two levels are linked, the disagreement payoffs change, and so does the Nash bargaining solution:

- when national negotiations are only a fallback strategies, if international negotiations between the four user groups fail, the disagreement payoff in the international game is determined by the utilities to players in the national only negotiation game;

- when domestic negotiations take place only after successful negotiation between the countries, the international bargaining game takes the initial allocation of water as the disagreement point;
- if national bargaining always follows international bargaining, the disagreement points in the first game are given by the Nash bargaining solution to the game when only domestic negotiations take place[15].

Comparing the equilibrium allocations of the bargaining games under the different scenarios, the following results emerge:

- a group may prefer domestic negotiations only to all-party international negotiations only, when its relative bargaining power is reduced in an all-parties negotiations.
- All-parties and two-nations bargaining at the international levels give the same result. This generalization, however, does not hold for other models: equivalence holds if the relative bargaining strength of domestic groups vs. each other is the same at both negotiation levels.
- International bargaining, followed by national bargaining independently of the outcome, is preferred by all parties to domestic negotiations alone.
- The country that gains more from a domestic agreement has a higher disagreement payoff at the international level, and therefore prefers to have negotiations which assume that domestic bargaining will always occur, independently of the results of the international bargaining.

It appears clear that what matters in the determination of the outcome of the bargaining game is the disagreement point. Intuitively, the higher is the disagreement payoff relative to that of the others, the stronger is the bargaining position of the group or country.

In the case of asymmetric countries, where one country can hold national negotiation in the event of failed international negotiations, whereas the other cannot, the country which is less flexible is penalized. It follows that it is a dominant strategy for

---

[15] Other symmetric cases reduce to one of these three.

each national government to commit to domestic negotiations irrespective of what the other government does, as this improves the threat point in the international bargaining game.

This paper shows, through the use of a simplified cooperative bargaining model with transferable utility and perfect information, that linked two-level (domestic and international) bargaining over water allocation leads to different results than national or international bargaining taken in isolation. The result is important in understanding why some agreement fail to be achieved, or do not seem to be efficient, when the bargaining model only accounts for either of the two levels and treats agents as monolithic. However, the use of the Nash bargaining solution as the solution concept may provide misleading results: although it does approximate the non-cooperative solution under certain conditions, it may not be the case in this context – especially when modeling 4 parties negotiations.

2.5 Water quality

Determining the most desirable water quality levels – and how it should be attained – may also be subject to negotiation, between government and polluters, for instance. This is the approach taken by Sauer et al. (2003), who develop a model for negotiation over water pollution level between polluters and a regulating authority. Key to the bargaining model is the asymmetry in information (true pollution abatement costs are only known to polluters), and the use of market based instruments to reach the desired goal.

The game is an extensive form game with two types of players – an authority and polluters – who alternate their proposal until an agreement is found, subject to environmental and financial constraints. The negotiation proceeds as follows: in the first step, the authority sets per unit pollution charge – which is not negotiable. Polluters respond by proposing a development project which would help reducing emissions and the required financial support from the authority. This is to be financed through pollution charges. The authority ranks the proposal according to their cost effectiveness (cost per unit of pollution abated), and agrees to fund the most effective projects within the fund's limits. The discussion continues until a solution is agreed upon, which also meets the required environmental quality.

Šauer *et al* apply the model to an ideal case on the basis of river pollution levels and emission charges in the Czech Republic, with the goal of achieving the best distribution of Fund's money to polluters. In the first negotiation round, the authority sets the vector of unit payments for each pollutant j, denoted by p_j. These unit charges are taken from Czech regulations. The authority also computes the amount of payments to the fund in period 1, equal to $\sum_i \sum_j p_j z_{ij}$, where z_{ij} is the emission of pollutant j by polluter i. In the second stage, polluters compute the minimum subsidy requirement for the abatement investment, D_i, and provide information about the abated level of emission, e_i. Authorities are now in a position to rank proposed projects, and establish which ones will be funded given their budget constraint. If some funds remain unused, they are brought forward to the next time period. Polluters evaluate the subsidy support and, in the last round of negotiation, the outcome of the proposed solution is evaluated in terms of its environmental impact. If the minimum environmental quality is met, binding agreements are signed, and the negotiated plan is implemented. In the simulated results, the environmental constraints were met in round one of the negotiation.

This model presents an offer-counteroffer bargaining procedure, where agreement is sought over the distribution of subsidies for "environmental technologies", which improve the quality of river water. The central authority bargains individually with polluters, but the strategic behavior of polluters is not analyzed in depth. In addition, there is no bargaining over the desired level of environmental quality – which is instead set by legislation. Yet, it is shown in the theoretical models (see Negotiation Theory – Part 1) that the issue space matters in determining the negotiated outcome. It is possible to envisage two different solutions to the game: either polluters cooperate on some or all environmental improving projects, and agree on how to share the costs and benefits of cooperation; or each polluter acts individually, in a non-cooperative fashion, without considering possible synergies with other operators.

Similarly, Kerschbamer and Maderner explore the implications of information asymmetries on the equilibrium compensation payments required by an upstream country to reduce river pollution. As illustrated in the models by Ambec and Sprumont (2000), Kilgour and Dinar (1995), and Kilgour and Dinar (2001), in the case of shared river the unidirectional effect of the externality implies that upstream countries have no incentives to cooperate, whereas downstream countries would stand to gain from cooperation: side payments are required to induce the upstream country to participate in the cooperative agreement.

Whereas water allocation was the issue in these models, the model by Kerschbamer *et al* investigates the implications for river pollution. In their simplified model, a downstream country, *d*, proposes a package to an upstream country, *u*, which pollutes the river[16]. This package consists in the desired level of pollution abatement on behalf of *u*, and in the compensation offered by *d* to *u* to achieve this abatement level. However, because of asymmetries in information, the victim is unable to determine with certainty polluter's preferences towards environmental protection: the observed river quality level may be the result of ambient pollution, or of uncontrolled emissions of the upstream country.

In contrast with the existing literature, this model compares the agreement solution with the equilibrium *status quo* situation, in which the two players maximize their own utility, taking other's actions as given – with respect to the Nash-Cournot solution, therefore. In the negotiation case, the offer of compensation by *d* implies two opposing incentives for *u*: (1) to understate own concern for the environment, and overestimate the benefits of the *status quo*. This would require *d* to offer higher compensation to induce *u* to participate in the agreement. And (2), to overstate own concern for the environment, so as to induce *d* to believe that high environmental standards are already applied, and any additional emission reduction is therefore very costly.

The authors show that, in equilibrium, the second effect dominates the first, and the optimal bribe is such that the more caring polluters may be induced to refuse it – that is, the equilibrium abatement level of all players, but the least caring one, is distorted downwards. This result is in contrast with existing literature, which suggests that under asymmetric information the binding incentive problem is to prevent polluters from claiming not to care about the environment. The difference in result is generated by the

---

[16] As in the case of bargaining games with side-payments, one could argue that this approach is not desirable because it seems to confute the polluter pays principle (vs. the victim pays principle). See also Footnote 10.

different starting point of the negotiation – that is, whereas in this paper the starting point is the equilibrium Nash-Cournot solution, previous literature derived solutions from non-equilibrium *status quo*. In a Nash-Cournot solution, the more caring polluters have already implemented higher environmental standards.

When economic sectors use water in a non-consumptive way, competition may arise when different water levels and quality are preferred by each sector. This is the case analysed by Krawczyk and Tidball (2003), who develop a model for intertemporal competition for water levels in the Camargue region in southern France. In this two-person, finite horizon dynamic game, fishermen and watercress producers have conflicting interests over water levels – with the former preferring high level of water, and the latter lower water levels. Simulation results show that sustaining the natural water level is not possible in a decentralized way, through non cooperative behavior, and government intervention is therefore necessary to lessen the negative impacts of agents' economic activities: it is in fact possible for a Government to compel agents to a feedback Nash equilibrium where environmental standards are obeyed.

Roseta-Palma (2002), on the other hand, combines dynamic models of groundwater exploitation to aquifer pollution models, where the externality comes from productive activities, with the aim of analyzing the interaction between quality-quantity trade-offs. Despite its simplifying assumptions, the model provides some interesting results: when taking joint decisions over quality and quantity, for instance, the efficient-steady state polluting activities may be *higher* than the one chosen under private, uncoordinated resource management, as long as steady-state water quality is higher. Despite the interesting and stimulating results, however, this model of water quality-quantity does not explicitly represent the bargaining process among competing, uncoordinated agents exploiting or otherwise affecting groundwater resources.

3 Negotiation Support System Tools

In general, game theoretic models provide descriptions of the negotiation process, and prescriptions of how players should behave. However, as experimental evidence has shown, the predictions of the standard theoretical models are often not realised in real negotiation processes, and the models are therefore not very useful as decision support tools. The complexity of many negotiation problems calls for the use of computer models to support the process: negotiation is viewed as a kind of multiparty decision making activity: through strategies and movements, players try to achieve points within the bargaining space, or an acceptance region. The process of negotiating does not only entail the presentation of proposals and compromises, but also the attempts of players to elicit opponents' preferences and strategies. Parties to the negotiation must attempt to identify and explore the impacts of various alternatives, the ensuing cost and benefit sharing scheme, etc.

Negotiation Support System (NSS) are a special case of Decision Support System, where the tool is designed to support the process of negotiation (p.260, Holsapple et al. (1997)) when there is disagreement among various parties as to what decision to adopt. In order for an NSS to be developed, stakeholders and stakeholders' preferences need to be well defined. The program itself must be flexible enough to accommodate changing issues and preferences, not to constrain or limit the options and their identification (Thiesse et al. (1998)).

NSS can provide support for a variety of issues, and at different stages of the negotiation process: NSS can therefore be classified according to their function as either Negotiation Preparation Systems – supporting pre-negotiation strategic planning – or as Negotiation Information Management Systems – facilitating negotiation in real time. The latter group can be further classified into Negotiation Context Support System models – which focus on the behavior of the system, and how it evolves, given some strategic choices; and Negotiation Process Support System models, which are instead concerned with the process of negotiations and the dynamics involved, identifying possible areas of agreement among conflicting parties. These NSS are designed to assist the negotiation process by increasing the likelihood that a mutually beneficial agreement is found, or by improving on an inefficient agreement.

The literature on negotiation support tools is varied, and mostly focuses on the conceptual developments of software and models. However, a few applications to water negotiations can be found. We will present in what follows some examples of NSS developed for resolving water conflicts. In the first part, Negotiation Context Support

Systems will be discussed through the Multi-Agent and Agent-Based Systems discussed by Becu et al. (2003) and Barreteau et al. (2003), and the status quo analysis illustrated by Li et al. (2004). The development and use of Negotiation Process Support System models is on the other hand represented by two applications, by Thiesse et al. (1998) and Hämäläinen et al. (2001).

3.1 Negotiation Context Support System Models

In order to enter effectively into negotiations and to facilitate the achievement of an agreement, stakeholders need descriptive and integrative models of the issues to be negotiated. This is the idea behind the use of Multi-Agent Systems (MAS) to simulate different water management scenarios, and hence help parties to identify the preferred management solution.

Becu et al. (2003) developed a MAS to simulate small catchment water, in order to facilitate water management in Thailand. CATCHSCAPE enables the simulation of a catchment's features, as well as farmers' individual decisions. CATCHSCAPE is an integrative, spatially distributed and individually-based model – able to cope with the complexity and dynamics of catchment management issues. The NSS is composed of: a biophysical module, simulating the hydro geological cycle, irrigation scheme management, and crop and vegetation dynamics; a social module, describing the social dynamics in terms of resources (land, water, cash and labor force). Water management is described according to the different level of water control (collective, individual, catchment).

To increase models' flexibility, Barreteau et al. (2003) propose an Agent-Based Simulation (ABS) tool to support negotiations over water allocation among farmers in the Drome river valley in the South of France. Their work is based on an experiment conducted on water allocation rules.

The major water use in the Drome river valley is for agriculture: for this reason, the focus of the research is on NSS to support the allocation of water to irrigation. The first model, SimSage, was developed to assess the collective consequences of various scenarios of water allocation rules, and resource availability. Scenarios were generated in terms of downstream water flow levels, occurrence of crisis, water pumping restriction levels, etc. The simulated scenarios were then presented to farmers for discussion, and for choosing the best policy alternative. A second model was developed, the GibiDrome, in order to tackle new requirements – such as the definition of practically enforceable allocation rules. This second model used the same input data and assumptions as SimSage, but a different architecture. GibiDrome is an ABM in which each class of agents has a set of variables to choose, satisfying given constraints, and interactions with other agents.

GibiDrome has proven to be much more flexible than SimSage, as it was designed to accept new scenarios of complementary resources. The flexibility of programming characteristics of ABM makes these tools more suitable for this type of negotiation, which takes place in highly evolving contexts.

In assessing their usefulness as negotiation support tools, the authors conclude that ABM, in addition to being flexible, enlarge the field of information to stakeholders, and reveal connections between components of the model, which would not otherwise be apparent. ABMs are thus efficient at supporting negotiations, facilitating the organization and management of the collective decision making process. ABM models may act as catalysts to generate discussion among stakeholders, playing a role akin to Single Text Negotiation procedures, and help in identifying factors of strategic relevance. Precisely for this reason, according to the authors the exercise of building the ABM model in a participatory way – that is, choosing the values and variables to be included together with stakeholders – may be more valuable than the realism of the model itself. Li et al. (2004) model conflict over water sharing between the US and Canada as a strategic conflict amongst different interest groups, adopting a graph approach. The graph model of conflict resolution is a simple but efficient decision support tool, which takes as the unit of analysis the outcome of the conflict, rather than individuals' choices. It is implemented using decision support systems, which speed up the stability analysis, and hence make the tool more useful as a decision support tool. Players' preferences are considered when conducting a stability analysis, that is, when individual and aggregate stabilities of a state are analyzed[17]. Stability analysis is essentially a static exercise, treating each possible

---

[17] The stability of a state can be assessed using a variety of concepts, from individual/collective rationality to sequential stability.

outcome individually, and assessing whether players have individual or collective incentives to deviate from it. It does not address the issue of how the state is achieved.

Starting from the *status quo*, the graph method can be used to analyze the evolution of the conflict, and assesses the likelihood that a given solution to the conflict is reached (*status quo* analysis). This exercise can provide useful insights on whether a status is attainable, and how a player should act or interact with other players, to direct the conflict to the desired solution.

A status quo analysis diagram is a directed graph, rooted in the *status quo*. The basic components are states, and moves and countermoves of players are then represented as direct arcs joining the states. At each iterative step, an algorithm determines which states can be reached at each stage, by examining the list of unidirectional improving states that are attainable at the immediate previous step for all players[18]. Two consecutive moves by one player are ruled out. The process stops when no more states or arcs can be added to the diagram.

From the *status quo* analysis, it is possible to assess the reachability of outcomes – only those which appear in the graph are attainable. Outcomes which only have incoming arcs are strong equilibria, and satisfy stability conditions. The graph analysis allows the identification of paths leading to a desired equilibrium, and can therefore prescribe strategies to guide the conflict towards the desired direction.

The *status quo* analysis is applied *a posteriori* in this paper to the water disputes in the Flathead river, which flows from British Columbia (Canada) into Flathead Lake in Montana (US). The methodology assesses the reachability of the equilibria, and examines the dynamics of the conflict, as it evolved from 1988 onwards. The set of possible outcomes, given players' strategies, is identified, and listed. Preference ranking over feasible set for each of the four players is then inferred from players' behavior, and imposed on the feasible states[19]. Stability analysis is carried out on all the outcomes: the application of the method identifies three strong equilibrium solutions to this conflict, which are the therefore most likely outcomes. Status quo analysis is then carried out,

---

[18] Other algorithms have been developed, which allow the any unilateral move. These may lead to different conclusions about the feasibility of equilibria.

[19] The graph model can handle both transitive and intransitive preferences. However, in this case, preferences are assumed to be transitive.

using a NSS to implement the graph-generating algorithm. Feasible equilibria, and paths to reach them, are identified: of the 55 possible outcomes identified in stability analysis, only 23 may be reached from the status quo, provided that players can only make unilateral improving moves. The model singles out three strong equilibria, and the paths to reach them. And in fact it is one of these equilibria that materialized in the actual negotiation process, consistent with one of the three shortest paths in the status quo analysis.

3.2 Negotiation Process Support System Model

Whilst the previous NSS were concerned with predicting the possible outcomes and simulating various scenarios, the Interactive Computer-Assisted Negotiation Process Support System (ICANS) guides parties in real time negotiation towards the selection of a mutually beneficial agreement in a dynamic, multiple issues, multilateral negotiation (Thiesse et al. (1998)).

ICANS supports the identification of relevant issues, as well as their feasible/acceptable ranges. Information on parties' preference over single issues, as well as ranking of those issues, must be provided (confidentially), to construct partial relative satisfaction functions. ICANS creates internal measures of total relative satisfactions for each party, from any set of issue values. These are based on party's relative satisfaction functions – one for each issue – aggregated to a total satisfaction function. In this way, comparison among multiple alternative proposals for each party are possible. From this information, the NSS is able to generate an acceptable set of issue values, starting from parties' individual proposals. The alternative generated by ICANS will be such that, for every party, it is (at least) equivalent in terms of relative satisfaction to their initial proposal. If such an alternative does not exist, then the alternative generated by ICANS will be such that each party's total relative satisfaction will be reduced by a minimum equal amount. Once a tentative agreement is identified, ICANS will explore possible Pareto improving alternatives. In order to move the agreement towards the Pareto frontier, ICANS find those values that maximize the minimum gain in total relative satisfaction, while assuring that the total net gain to all parties cannot be further improved.

Thiesse *et al* tested the effectiveness of ICANS in a series of limited controlled experiments with simulated two party water resources conflicts. Issues to be negotiated over varied from 2 to 7. The results suggest that programs like ICANS can help negotiators find an agreement, and then improve on the agreement. However, equity issues are not incorporated in the NSS, nor can they be, unless players are prepared to make subjective judgments about the relative worth of benefits to different parties. The usefulness of NSS programs depends on the willingness of parties to supply (truthful) information about their preferences and ranking: concerns over the possibility that parties may try to influence the outcome of the negotiation by providing false information remain, but it is not clear whether players can indeed determine the effectiveness of cheating.

The use of multi-criteria decision making software as a basis for supporting water negotiation is also explored by Hämäläinen et al. (2001). The framework proposed starts from the multi-criteria structuring and modeling phase, and ends in the final negotiation support. The NSS is tested with two role-playing groups to assess the method of improving directions – an iterative method for identifying Pareto-optimal alternatives. The proposed NSS differs from ICANS discussed by Thiesse *et al* in the algorithm and method adopted to generate improving alternatives from the initial tentative agreement: however, as pointed out by various authors, there exist a variety of methodologies that can be used to generate compromises, and improve on them. Direct comparison among different NSS is however not useful, as they rest of different assumptions and rely on different procedures. The choice of which methodology should be used depends crucially on the constitutional structure of the negotiation process.

The process is organized in three phases. Initially, the stakeholders are identified, together with their most important decision criteria. In this structuring phase, the decision variables are chosen – in this case, the decision variable is target water levels at different times of the year. Value tree analysis can be used to evaluate the range of admissible values for the control variables, as well as their likely impacts on other variables of relevance (e.g. risk of flooding, ecological factors…). In the second stage, a set of Pareto-optimal alternative is generated, using the method of improving directions and the related *Joint Gains* NSS – based on the Single Negotiation Text negotiation strategy. In the final phase, the identified Pareto-optimal alternatives are ranked by stakeholders, and through joint problem representation, agreement over one alternative is sought.

The three-steps procedure is applied to water level regulation in a lake-river system in Finland (Lake Paijanne, Lakes Konnivesi and Routsalainen, and River Kymijoki). Major interest groups and interests are identified, together with the values that need to be maximized through management of water levels (the control variables), such as water quality, economic benefit, electricity generation, etc.

Starting from the *status quo*, parties' preferences are identified locally, by asking to compare alternatives. In this way, the direction of improvement for each player can be identified. Only local preferences are required, so that players' utility functions need not be completely described, and only a part of this local information needs to be revealed to the mediator.

The basic principle of the method of improving direction[20] is to produce a sequence of moves such that subsequent alternatives are preferred by all parties to the previous ones, so that the set of efficient alternatives is gradually approached. Starting at an initial alternative, parties' preferences about alternative in the neighborhood are identified. Directions along which alternatives are preferred to the initial point are therefore singled out – these are the directions along which players gain most compared to other directions (utility function gradient direction), and can be identified by selecting the player's most preferred alternative on an appropriately chosen circle around the initial point. A jointly improving direction can then be calculated solving a non-linear optimization problem. The next step is to find a jointly preferred alternative on the jointly improving direction. The procedure is repeated until jointly improving alternatives cannot be found.

The resulting NSS was tested in two role-playing experiments. These showed that players can understand the method, and answer the required questions consistently. The experiments support the use of gradient methods of optimization – significant improvements can already be seen after two iterations. In addition, the method of improving direction allows learning, and changes in preferences during the process.

---

[20] For a detail exposition of the method, see Hämäläinen et al. (2001).

It should be noted that this method can only be useful when the objectives and preferences of players are not completely opposite to those of another because, in this case, almost all feasible alternatives become Pareto optimal. In these situations, NSS could be based on generating specific bargaining solutions based on different fairness rules. For instance, the adjusted winner procedure proposed by Brams and Taylor (1996, 2000) for allocating different goods among different parties has received a lot of attention in the literature.

The aim of NSS should be to offer negotiators the possibility of defining and evaluating possible settlements: however, despite the (theoretical) potential of NSS tools to help decision makers to manage conflicts over water use (and other types of conflict), most NSS reported in the literature are still in the conceptual stage, and play a relatively passive role in the negotiation process. Often, they support a professional mediator, rather than the negotiating parties themselves. Yet decision makers could benefit from improved tools to identify the zone of agreement when there are conflicting interests, and to improve on the agreement, when this is not efficient. Not only is the development of NSS in its initial stage, but also, and perhaps more importantly, there remains a gap between scientists working in the field, and decision makers who would benefit from the tool.

Recent developments are encouraging, but more efforts are needed at integrating formal theories into NSS development, and in disseminating the use of such a tool in real-life negotiation settlements.

4 Concluding comments

Many natural resource and environmental problems involve negotiations over how to share resources, or how to determine their quality. Most of the economic literature addresses these problems from an optimization point of view, specifying a priori the characteristics that the agreements should have – most notably, (economic) efficiency. Yet, non-cooperative game theory can provide a useful framework for deciding how to better share or manage a common resource, but also and perhaps more importantly it can help identify which mechanisms and management regimes can be implemented and sustained in situations where enforcement is problematic or binding agreements cannot be signed.

In fact, the existence of a negotiated settlement Pareto-superior to non-cooperative behavior is no guarantee that the players will agree to cooperate: a shift in emphasis is needed, towards the development of negotiation models which make no assumptions about which agreement will be reached, but rather provide a structure for the negotiation process itself. Given the complexity of the processes and issues often involved, NSS have a high potential to help in the process of finding an agreement acceptable to all parties, and on improving on that agreement. The proposed approach may support the negotiation process either directly or indirectly, by shortening the time-span needed to reach an agreement through the (theoretical) identification of an "acceptability space". That is, the values for which a proposal is more likely to be accepted are identified, and proposals which would be (almost) certainly rejected can be ruled out at the outset. The negotiation process can then start directly with acceptable agreements, improving on them.

Alternatively, when the tool is used to support policy making, it can help select a set of policies that are self-enforcing and, therefore, acceptable. As shown in various papers, the self-enforcing allocation is not necessarily the one which is most efficient from the economic point of view, but rather the one which is socially and/or politically acceptable as well.

It must indeed be realized that efficiency cannot be the only criterion against which to judge the agreed allocation scheme: other issues, such as perceived equity, political power, and strategic considerations, play a key role in negotiations – especially for resources such as water, which are politically charged. "Optimal" management schemes – that is, regimes which are least cost and waste no resource – may not be feasible and/or socially acceptable, hence leading to a failure of implementation, or even to outright rejection of the policy. The value added of exploring management problems within a non-cooperative bargaining framework is indeed related to the extent to which the approach helps finding politically and socially acceptable compromises, as political and social constraints are often disregarded in economic analyses.

Finally, what is still missing in the literature is a *negotiation* model that considers also incomplete information over the resource itself. A multiple issues, multiple parties negotiation model, which explicitly addresses the bargaining process without making assumptions over which allocation should be achieved, and which accounts for the stochasticity of the resource, as well as the political, social and strategic feasibility of any allocation scheme, would significantly contribute to decreasing conflicts over water.

References

1. Adams, G., Rausser, G., and Simon, L. (1996) Modeling multilateral negotiations: an application to California Water Policy. *Journal of Economic Behavior and Organization* **30** (1), 97-111.

2. Ambec, S. and Sprumont, Y. (2000) Sharing a river. *GREEN* **00** (06).

3. Barreteau, O., Garin, P., Dumontier, A., and Arami, G. (2003) Agent based facilitation of water allocation: case study in the Drome River Valley. *Group Decision and Negotiations* **12** 441-461.

4. Becu, N., Perez, P., Walker, A., Barreteau, O., and Le Page, C. (2003) Agent based simulation of a small catchment water river management in northern Thailand: description of the CATCHSCAPE model. *Ecological Modeling* **170** 319-331.

5. Bennet, Lynne L., Ragland, Shannon E., and Yolles, Peter. Facilitating international agreements through an interconnected game approach: the case of river basin. Just, Richard and Netanyahu, Sinaia. Conflict and cooperation in transboundary water resources . 1998. Norwell, MA, Kluwer Academic Publishing.

6. Bhaduri, Anik and Barbier, Edward B. Water transfer and international river basic cooperative management: the case of the Ganges. Dept. of Economics, University of Wyoming . 2003 .

7. Binmore, K., Rubinstein, A., and Wolinsky, A. (1986) The Nash Bargaining Solution in Economic Modeling. *The Rand Journal of Economics* **17** (2), 176-188.

8. Booker, J.F. and Young, R.A. (1994) Modeling intrastate and interstate markets for Colorado River water resources. *JEEM* **26** 66-87.

9. Brams, S. J. and A. D. Taylor (1996), ‘Fair division: from cake cutting to dispute resolution’, Cambridge University Press, Cambridge, UK.

10. Brams, S. J. and A. D. Taylor (2000), ‘The Win-Win solution: guaranteeing fair shares to everybody’, W.W. Norton & Company, New York.

11. Crow, B. and Singh, N. (2000) Impediments and innovations in international rivers: the waters of South Asia. *World Development* **28** (11), 1907-1925.

12. Dinar Ariel, Rosegrant, M., and Meinzen-Dick, R. (1997) Water allocation mechanisms: principles and examples. *World Bank Working Paper* **1779**.

13. Dixon, L.S. (1999) Common property aspects of ground-water use and drainage generation.

14. Gisser, M. and Sanchez, D.A. (1980) Competition vs. optimal control in groundwater pumping. *Water Resources Research* **16** 638-642.

15. Hanley, N. and Folmer, H. (1998) *Game theory and the environment*. Edward Elgar, Cheltenham.

16. Holsapple, C.W., Lai, H., and Whinston, A.B. (1997) Implications of negotiation theory for research and development of Negotiation Support Systems. *Group Decision and Negotiations* **6** (3), 255-274.

17. Hämäläinen, R.P., Kettunen, E., and Ethamo, H. (2001) Evaluating a framework for multi-stakeholder decision support in water resource management. *Group Decision and Negotiation* **10** 331-353.

18. Just, R.E. and Netanyahu, S. (2000) The importance of structure in linking games. *Agricultural Economics* **24** 87-100.

19. Kerschbamer, Rudolf and Maderner, Nina Pollution under asymmetric information.

20. Kilgour, M.D. and Dinar, A. (1995) Are stable agreements for sharing international river now possible? *Policy Research Working Paper, The World Bank* **1474**.

21. Kilgour, M.D. and Dinar Ariel (2001) Flexible water sharing within an international river basin. *Environmental and Resource Economics* **18** (1), 43-60.

22. Kounduri, P. (2004) Potential for groundwater management: Gisser-Sanchez effect reconsidered. *Water Resources Research* **40**.

23. Krawczyk, Jacek B. and Tidball, Mabel. A model of intertemporal competition for water levels. Conference on Computation in Economics and Finance. 2003.

24. Li, K.W., Kilgour, M.D., and Hipel, K.W. (2004) Status quo analysis of the Flathead River conflict. *Water Resources Research*.

25. Provencher, B. and Burt, O. (1993) The externalities associated with the common property exploitation of groundwater. *Journal of Environmental Economics and Management* **24** (2), 139-158.

26. Provencher, B. and Burt, O. (1994) A private property rights regime for the commons: the case for groundwater. *Land Economics* **69** 325-340.

27. Putnam, R.D. (1988) Diplomacy and domestic politics: the logic of two-level games. *International Organizations* **42** 427-460.

28. Rausser, G. (2000) Collective choice in water resource systems. In: Dinar, A. (ed), pp. 49-78, Oxford University Press, New York.

29. Rausser, G. and Simon, L. (1992) A non cooperative model of collective decision making: a multilateral bargaining approach. *Department of Agricultural and Resource Economics (University of California, Berkeley)* **Working Paper** (618).

30. Richards Alan and Singh, N. (1996) Two level negotiations in bargaining over water. *Dept. of Economics WP, University of California, Santa Cruz*.

31. Roseta-Palma, C. (2002) Groundwater management and endogenous water quality. *Journal of Environmental Economics and Management* **44** 44-93.

32. Roseta-Palma, C. and Xepapadeas, A. (2004) Robust control in water management: special

issue: risk and uncertainty in Environment and Resource Economics, International Conference, Wageningen, The Nethelands. *Journal of Risk and Uncertainty* **29** (1), 21-34.

33. Rubinstein, A. (1982) Perfect Equilibrium in a Bargaining Model. *Econometrica* **50** (1), 97-110.

34. Sauer, P., Dvorak, A., Lisa, A., and Fiala, P. (2003) A procedure for negotiating pollution reduction under information asymmetry. Surface water quality case. *Environmental and Resource Economics* **24** (2), 103-119.

35. Simon, Leo, Goodhue, Rachel, Rausser, Gordon, Thoyer, Sophie, Morardet, Sylvie, and Rio, Patrick Structure and power in multilateral negotiations: an application to French Water Policy. August 14, 2003, *mimeo*.

36. Supalla, R., Klaus, B., Yeboah, O., and Bruins, R. (2002) A game theory approach to deciding who will supply instream flow water. *Journal of the American Water Resources Association* **38** (4), 959-966.

37. Thiesse, E.M., Loucks, D.P., and Stedinger, J.R. (1998) Computer assisted negotiation of water resource conflicts. *Group Decision and Negotiations* **7** 109-129.

38. Thoyer, S., Morardet, S., Rio, P., Simon, L., Goodhue, R., and Rausser, G. (2001) A bargaining model to simulate negotiations between water users. *Journal of Artificial Societies and Social Simulation* **4** (2).

39. Tsebelis, G. (1990) *Nested Games: rational choice in comparative politics*. University of California Press, USA.

40. Tsur, Y. (1990) The stabilization role of groundwater when surface water supplies are uncertain: the implications for groundwater development. *Water Resources Research* **26** 811-818.

41. Tsur, Y. and Graham-Tomasi, T. (1991) The buffer value of groundwater with stochastic surface water supplies. *Journal of Environmental Economics and Management* **21** 201-224.

42. Tsur, Y. and Zemel, A. (1995) Uncertainty and irreversibility in groundwater resource management . *Journal of Environmental Economics and Management* **29** 149-161.

43. Zeitouni, N. (2004) Optimal extraction from a renewable groundwater aquifer with stochastic recharge. *Water Resources Research* **40**.