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Negotiating on water: insights from non-cooperative bargaining theory

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ABSTRACT. The purpose of this paper is to review the applications of non-cooperative bargaining theory to water management problems. The interest in this subject stems from two considerations: (i) water resources continue to be mismanaged, despite their recognized importance for sustainable development, in particular in developing countries; (ii) negotiated decision making has the potential to improve water management, yet there is still little formal understanding of the forces driving bargaining processes, and applications of formal negotiation theory to water issues are also lacking. This paper surveys the existing non-cooperative bargaining models applied to water management problems, with the purpose of preliminarily assessing whether such a formal approach in the phase of problem exploration and policy formulation can support decision makers in the real world. It is the contention of this paper that the proposed approach may offer *direct* and *indirect* support by: shortening the time needed to reach an agreement through the (theoretical) identification of an 'acceptability space', and helping select policies which are self-enforcing and, therefore, acceptable.

1. Introduction

There is no doubt that water is an essential resource for the socio-economic development of every nation, as well as for the maintained functioning of key ecosystems, environmental goods, and services. The role of water is recognized at all levels of governance: at the global level, for instance, water plays a key role in the achievement of the development goals contained

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in the Millennium Declaration (UN, 2000). At the 2002 World Summit on Sustainable Development (Johannesburg, South Africa, in August–September 2002), water was recognized as a fundamental component of the three pillars of sustainability. In addition, the UN Secretary Kofi Annan proposed the WEHAB initiatives, which target actions in five key areas, including water and sanitation; furthermore, regional programmes such as the NEPAD initiative attribute high importance to sustainable water management (NEPAD, 2003, Programme Area 4 on Conservation and Sustainable Use of Coastal, Marine and Freshwater Resources).

The attention that national and international policies devote to water targets in many fields of development reflects the widespread concern about the increasing scarcity of water resources at the global level, both in terms of quantity and quality. According to Gardner-Outlow and Engelman (1997), if the situation is not altered significantly, by 2050 at least one in four people will live in countries affected by chronic or recurrent shortage of freshwater. More recently, the Board of Directors governing the Millennium Ecosystem Assessment process highlights how 'Water withdrawals from rivers and lakes for irrigation, household, and industrial use doubled in the last 40 years. Humans now use between 40 per cent and 50 per cent of the fresh water running off land to which the majority of the population has access. In some regions, such as the Middle East and North Africa, humans use 120 per cent of renewable supplies (due to the reliance on groundwater that is not recharged)' (MEA, 2005: 11). As pointed out in the report, water supply (for both consumption and ecosystem functioning) is one of the major concerns for future development (see also the findings of the UN World Water Development Report, UNESCO, 2003, the Global Environment Outlook 3, UNEP, 2003, and the numerous reports by the World Water Council (www.worldwatercouncil.org, and references therein).

The problems of water (un)availability are becoming increasingly acute in the face of climate change, which increases the unpredictability of water quantity and, as a consequence, quality. The joint effect of climate change and natural stochastic variations in water flow is the increased incidence of extreme events – floods as well as droughts – which hit disproportionately hard developing countries. These adverse impacts are further exacerbated in developing economies, where responsive capacity is lower, governance weaker, and, at the same time, the pressure to expand water supply much stronger. Furthermore, the intensification of pressures on water resources leads to increasing tensions over water use – and, in some cases, to open conflict – placing strains not only on the resource itself, but also on socio-economic structures of nations and regions. There is a general belief that access to and use of internationally shared water resources are likely to trigger international conflicts – with localized conflicts being fought over control of local productive assets such as water and land (see, for instance, Diehl and Gleditsch, 2001).[1]

However, as concluded by Lonergan (2001) it is quite unlikely that water scarcity will lead to violent conflict at the international level, whereas, at the

[1] A comprehensive and up-to-date list of water related conflict can be found at http://www.worldwater.org/conflictIntro.htm.

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sub-national level, conflicts over water sharing seem more likely to emerge. Internationally shared water resources can encourage cooperation: as highlighted by the largest empirical study of water conflict and cooperation at the international level, carried out by the Oregon State University, of the 1,735 cases of water-related disputes observed in the last 50 years, only 507 resulted in conflicts (in UNESCO, 2003).

Despite the well-recognized importance of water, its management remains at best inefficient, resulting in shortages and conflicts over allocation regimes, degradation of available water by pollution, or inappropriate sharing rules. The past approaches to water management, rooted either in an interventionist approach – e.g. command and control instruments – or a traditional market-based approach – e.g. the assignment of property rights for improving the workings of the market economy – have proved by and large ineffective. These approaches fail to fully take into account the intrinsic characteristic of the resource – first of all the multiplicity of its uses, which are often in conflict with one another. To complicate matters further, non-consumptive uses of water are often difficult to identify, and not readily marketable. From a physical point of view, water is unevenly distributed both in time and space, is hard to transport and allocate, and is often of the transboundary nature.[2]

It is clearly urgent to find new ways and means for improving water use and allocation, if substantial progress is to be made towards the management of water from the long-term, sustainable development perspective.

In recent years, one of the responses has been to promote collective *negotiated decision-making procedures*, both nationally and internationally; negotiated decisions can lead to management choices that are better adapted to local conditions, easier to implement, less conflictual, and more stable. Furthermore, negotiated policy making opens up the possibility of participatory planning, which is becoming increasingly important particularly for natural resources, as already highlighted in 1992 in Chapter 8 of Agenda 21 (UN, 1992).

In real life, there are many examples of international negotiations over other global and regional natural resources, such as atmosphere, the seas, biodiversity, fish stocks, and so forth (for some examples, see Breslin *et al*., 1990, 1992). Similarly, there are many examples of international cooperative efforts to manage shared water resources. One of the oldest attempts is the Baltic Sea agreement, linking environmental quality issues with nations' development policies. Similar attempts can be found in the Aral Sea, and in the Caspian Sea, as summarized in Conca and Dabelko (2002).[3]

[2] About 40 per cent of the 261 river basins in the world are shared among two or more nations, as indicated in Wolf *et al*. (2003).

[3] Many more examples could be cited, some very well known – for instance, water sharing in the Middle East (analysed by, among many others, Dinar and Wolf, 1994a and 1994b; Kilot, 1994 or, more recently, Shmueli, 1999 and Haddadin, 2002); negotiations over sharing of the Nile waters (see, for instance, Dinar and Alemu, 2000); and South Asia (Crow and Singh, 2000); other cases perhaps less widely discussed – such as the agreements between the US and Mexico, and among Southern Africa states (in Conca and Dabelko, 2002).

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Most of the analyses of real negotiation processes adopt an empirical, *ad hoc*, approach, without paying due attention to underpinning theories, or attempting to develop a unified, formal, theory of negotiation.[4] Furthermore, there are no analyses in the literature of failed negotiation attempts, thus offering an incomplete exploration of negotiations strategies and outcomes (Dinar and Alemu, 2000: 333). As a result, we are still far from understanding, in a broad enough range of situations, which factors may affect agreements, and where and how bargaining processes can be shaped to obtain a more desirable state of affairs with respect to a shared resource.

The purpose of this paper is thus to review the applications of negotiation approaches and analyses to the management of water resources. The ultimate aim is that of showing the usefulness of the approach in supporting decision making by identifying the conditions under which agreements are likely to emerge, and their characteristics; and to advance our understanding of how the 'rules of the game' may be designed to achieve the desired results.

Given the wide variety of approaches to negotiation, the focus will be restricted to formal models based on non-cooperative game theory. This choice stems from the realization that, especially for water resources where different and conflicting uses are possible, management rules need to be self-enforcing. Furthermore, relatively little is understood about the interactions between the structure and the outcomes of the negotiating process in general, and with respect to water management in particular.

In order to determine which outcome will result from negotiations over the partition of a resource, models of non-cooperative 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. While this approach allows an explicit treatment of issues such as equity and political power, which play a very strong role in real-life negotiations, it does not make *a priori* assumptions over the final individual shares. In fact, for multiple issues and multilateral bargaining, there are indeed many partitions that could emerge (see Carraro *et al*., 2005b).

In the remaining part of this paper, the existing non-cooperative bargaining models applied to water allocation problems will be discussed. In particular, the focus will be on those which explicitly formalize the process of negotiation, although some other non-cooperative bargaining models will also be briefly discussed (for a more extended review, see Carraro *et al*., 2005a). Section 2 will present in more detail applications to domestic water management issues: starting from groundwater in section 2.1, surface water allocation among competing sectors will be described in section 2.2, whereas section 2.3 will deal with water quality issues. International-level negotiations will be discussed in section 3. First of all, games with side payments will be presented (section 3.1). More innovative

[4] See Yoffe *et al*. (2004).

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approaches will then be described – auction games in section 3.2 and issue linkage in section 3.3. A model that attempts to link national and international negotiation levels will be discussed in section 4. The paper concludes by highlighting the potential usefulness of non-cooperative bargaining theory for decision making.

2. Allocation at the domestic level

Competition among sectors for water use is the *status quo* in many countries, where often there is a conflict among different consumptive uses and environmental sustainability constraints. Thus, 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.

This section will first review some of the applications of game theory to groundwater management. These are numerous, but the majority adopts a dynamic setting without explicitly considering the intrinsic strategic interactions among players. Section 2.2 will discuss surface water allocation problems, with a wider array of models and bargaining approaches – including some attempts at addressing the bargaining procedure explicitly. Finally, section 2.3 will discuss modelling games of water quality.

2.1. Ground water management

Groundwater resources present all the characteristics of open access resources, where the use by one agent has negative impacts on other users, which are not accounted for. A substantial literature has thus developed, exploring the welfare implications of different management regimes. This is despite the paradoxical empirical results first obtained by Gisser and Sanchez (1980): observations comparing central control and open access groundwater management regimes in the Pecos Basin in New Mexico seemed to indicate that the magnitude of the benefits from optimally managing groundwater resources is negligible.[5]

In the literature of game theoretic applications to natural resources, various authors propose the use of *differential games*[6] to explore resource use strategies, and their efficiency and sustainability properties. In the water realm, most applications are found in the groundwater literature – even though players' strategic interactions and the process of negotiation are often not treated with the due importance. An attempt in this direction has been made by Dixon (1999) who models a simplified version of

[5] The Gisser-Sanchez effect rests mainly on the theoretical assumption of very steep groundwater use benefit curves (implying relative price insensitiveness of users). For a recent criticism of the Gisser-Sanchez effect see, for instance, Koundouri (2004).

[6] Differential games belong to a subclass of dynamic games called 'state space games', where a set of state variables describes the state of the dynamic system at any point in time during the game, reflecting the influence of past decisions on the payoffs at subsequent times. 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.

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groundwater exploitation in a dynamic setting, in which there are two agents with access to one of two interdependent and identical groundwater cells. Agents maximize net benefits from water abstraction, subject to the water quantity in each cell. This is a typical situation in which appropriation externalities exist, and in which uncoordinated exploitation leads to inefficient outcomes. Dixon estimates the 'myopic' (individualistic), the socially optimal (cooperative), and the strategic (individualistic) solutions, and then compares the resulting welfare levels. Under the socially optimal solution, the impact of pumping on ground-water levels is accounted for, total profits are maximized, and the payoffs are equally split between the two identical users. Under the myopic solution, each agent maximizes his own net benefits, without taking into account the externalities of their water extraction on the *future* water level. The strategic solution relaxes the assumption that agents act without foresight, although they still act non-cooperatively. Strategic solutions can be derived using two different concepts: under open-loop solutions, agents maximize net present value, 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,[7] in which players pre-empt the opponents by extracting more (strategic externality). When players behave strategically, the closed-loop solution should be used; this predicts that users adjust their extraction paths according to observed actions by other players. The sub-game perfect equilibrium extraction paths (and payoffs) of the closed-loop solution incorporate both the stock and strategic externality.

Applying the model to groundwater use in the San Joaquin Valley, Dixon's simulation results confirm the theoretical expectations: the myopic payoff is much smaller than the socially optimal individual payoff; however, when individual strategic behaviour is considered (including both stock and strategic externalities), the difference between the socially optimal and the strategic individual payoff is much reduced. Dixon proceeds then to consider the trigger strategy[8] 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, then collusion can be sustained as an equilibrium outcome of the game. Simulating the solutions for a given set of parameters, the author shows that, for reasonable parameters and

[7] By assumption, in the open loop solution each agent takes the opponent's extraction path as given. This approach 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.

[8] For trigger strategies 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. 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.

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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 ground-water exploitation.

Other applications of dynamic games to groundwater management include Provencher and Burt (1993), who estimate the rate of groundwater extraction under a common property management regime, identifying the externalities present under this management strategy and investigating the effects of different risk-aversion parameters for water users. Similarly, the same authors (Provencher and Burt, 1994) apply a dynamic model to compare the welfare effects of different property rights regimes 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. These approaches 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.

The literature on groundwater has also attempted to address the problem of uncertainty in water supply, mostly within an economic optimization approach. For instance, Zeitouni (2004) explores the optimal management of aquifers when the stock is stochastic. Tsur and Zemel (1995) explore how the possibility of irreversible changes in groundwater resources affects the optimal management and allocation rules. Using groundwater and reservoirs as buffers against uncertainty can smooth out stochastic variations in water supply. Tsur (1990) and Tsur and Graham-Tomasi (1991) investigate the role of groundwater as a buffer for stochastic variations in surface water levels – and find 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 analyse the precautionary behaviour emerging from a robust-control approach to modelling water resources.

2.2. Surface waters

The management of surface waters is rather complex as many and often conflicting uses – ranging from recreational to water abstraction – need to be reconciled. This can be achieved through participatory planning, which can be supported by analysing the problem within a formal negotiation frame.

The model proposed by Rausser and Simon (1992) is a framework for non-cooperative, multilateral negotiation that explicitly addresses strategic behaviour through an offer and counteroffer procedure.

The Rausser-Simon framework has been used to explore 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 *ex-post* to the so-called 'three way negotiations',

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whereby the three major stakeholder groups (agricultural and urban users, and environmentalists) informally negotiated over 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 non-cooperative bargaining model. The authors simulate results under different scenarios, in order to analyse the impact of changes in the institutional setting of the game on the negotiated agreement. The parameters analysed are: bargaining power, heterogeneity (between and within group) and changes to the issue space.

The results are consistent with intuition. In both applications increasing the political weight of a group leads to an outcome relatively more favourable to that group – and of groups with similar preferences. 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 agreements; more specifically, the higher is a group's utility in disagreement, the more bargaining power the group has – and, therefore, the more favourable to that group the negotiated agreement is. Thus, the relative utility derived in case of no agreement (players' default strength) is also an important source of bargaining power.

In Thoyer *et al*. (2001), the effect of removing one player from the negotiating table is analysed. As expected, the resulting allocation scheme will be further away from the excluded group's preferred position. More interestingly, and as a consequence of unanimity being the decision rule, players' preferences influence the negotiated agreement even when their political weight is zero, but they take part in the negotiation process without intervening.

In their application to the California case study, Adams *et al*. (1996) explore the effects of removing one policy dimension from the negotiated package, and of restricting its interval of admissible values. Through their simulations, the authors conclude that significant gains from bargaining are lost when the issue space is reduced, and that restricting the admissible values a dimension can take has a non-linear impact on players' utilities. The authors explain these results as a shrinking of the bargaining set – the mutual gains to be had through negotiations are lower.

Finally, Adams *et al*. (1996) examine the impact of within-group heterogeneity on the final negotiated outcome, and the effect of imposing a spokesperson, which maximizes the averaged utilities of the coalition members – with the effect of reducing group's heterogeneity.

Intuitively, increasing the distance between the preferred outcomes of two sub-sets of players belonging to the same group should weaken the

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groups' bargaining power, as the two sub-sets compete to represent the interest of the whole group. In reality, the effect of different preferences over one policy dimension is affected by groups' relative preferences over another policy variable. In these cases, the introduction of a spokesperson will usually benefit the coalition as a whole. Yet, this is so because the negotiator can discriminate against a sub-set of members; 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.

From these applications, it emerges that 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. The analytical framework proposed could thus help to improve water governance, explicitly modelling the negotiation process and recognizing the importance of relative political power.

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. With respect to uncertain water supply, Simon *et al*. (2003) attempt to model it through scenarios with different abundances of water, but within this settings the scenarios are all deterministic, and do not affect players' preferences, rankings, or strategies.

2.3. Water quality

The applications discussed so far focus on water *quantity* issues; however, determining the most desirable water *quality* level – and how it should be attained – may also be subject to negotiation, between government and polluters, for instance. This is the approach taken by Šauer *et al*. (2003), who develop a model for negotiation over water pollution levels between a regulating authority and polluters. 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, are the key features of this framework.

The game is an extensive form game with two types of players – an authority and many polluters – who alternate their proposals until an agreement is found, subject to environmental and financial constraints. The negotiation is bilateral – that is, between the authority and each polluter in turn. The authority sets per unit pollution charge, which is not negotiable; polluters respond by proposing development projects, which would help reduce emissions and the required financial support from the authority for their implementation. Finally, proposals are ranked by the Authority, and the most cost-effective projects are funded. The negotiation continues until funds for environmental improving projects are exhausted, and the required water quality is achieved. Šauer *et al*. (2003) apply the model to an ideal case on the basis of river pollution levels and emission charges in the

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Czech Republic, with the goal of achieving the best distribution of Fund's money to polluters. 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, without considering possible synergies with other operators. The model adopts the latter, and it thus does not allow exploring more strategic behaviour of the actors. Furthermore, the quality level is non-negotiable – despite the importance of the issue space for bargaining, as demonstrated both at the theoretical level (see, e.g., Carraro *et al*., 2005b) and in applications (e.g. in Adams *et al*., 1996).

When economic sectors use water in a non-consumptive way, competition may arise about differing preferences over water levels and quality. This is the case analysed by Krawczyk and Tidball (2003), who develop a model of 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 levels, and the latter lower levels of water. Simulation results show that sustaining the natural water level is not possible in a decentralized way, through individualistic (un-coordinated) behaviours, 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 analysing 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. This model of water quality-quantity does not however explicitly represent the bargaining process among competing, uncoordinated agents exploiting or otherwise affecting groundwater resources.

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). The two main characteristics of the problem are: countries' 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.

In the context of international water resources, particular attention has been devoted to the problem of sharing an *international river*. A peculiar feature of this problem is the *unidirectionality* of river flow. Within this context, static games may generate outcomes in which the dominant strategy for the upstream country is not to cooperate, whereas

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the downstream country's dominant strategy is to cooperate. The resulting equilibrium is not (globally) efficient.

The next sections will present and discuss various mechanisms that have been proposed in the literature as means to induce the upstream country to internalize the externality: from repeated bargaining games with side payments, to auction games and models applying linkage strategies to negotiations over the allocation of international water flows.

3.1. International water allocation with side payments

Repeated games with side payments[9] have been proposed in the literature to solve coordination problems and sustain cooperative actions in the allocation of water resources from international rivers. This approach is embedded in the papers by Ambec and Sprumont (2000) and Kilgour and Dinar (1995 and 2001) where compensation schemes are bargained over, which ensure the attainment of the 'optimal' water allocation scheme in the international context.

In Ambec and Sprumont (2000), the focus of the model is on the asymmetric access to water that countries have. The paper differentiates itself from the majority of literature by concentrating on welfare allocation rather than on the problem of designing suitable institutions and mechanisms for sharing the resource. A sustainable water allocation mechanism is defined as *stable* in the sense of the core (i.e. give coalition members at least as much utility as their secure level of welfare), and with a *fair welfare distribution*. An allocation is deemed fair in this context if no coalition or individual enjoys a welfare higher than the welfare level it would enjoy in the absence of all other players. Using a cooperative approach, the authors characterize the Pareto efficient and equitable welfare sharing arrangement. Then, different forms of behaviour which could sustain the Pareto optimum are explored – namely non-cooperative bargaining and decentralized behaviour.

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 that satisfies both constraints is the downstream incremental distribution, which lexicographically maximizes the welfare of an agent and its successors, subject to the core constraint. That is, a player's welfare is 'his marginal contribution to the coalition composed of his predecessors along the river' (p. 5). The authors consider two forms of decentralized behaviour: myopic competitive behaviour and sophisticated strategic behaviour. In the former, a decentralized market structure is imposed through the allocation of tradable water rights. Of interest in this context is however strategic behaviour, which is to be expected when the number of players is small. Modelling the problem in a game theoretic context, the authors argue that it is possible to implement the downstream incremental welfare distribution

[9] 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 lose. The latter group is made at least as well off as under the non-cooperative arrangement.

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in an extensive form non-cooperative bargaining game. The bargaining rules are such that players are successively allowed to make offers, which the others can either accept or reject. If a player's allocation offer is rejected, she gets allocated a quantity of water equivalent to the natural recharge at her location, and the next agent along the river gets to propose an allocation for the remaining players. If the proposal is unanimously accepted, it is enforced in the successive stage. If the last stage of the game is reached, the second to last player proposes an allocation for two players, which is enforced if player 1 agrees. 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. The authors are, therefore, able to identify a set of rules of a non-cooperative bargaining game that, if satisfied, would allow the emergence of the optimal sharing rule, which satisfy both the core stability and the fairness constraints.

3.2. *Auction games*

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';[10] second, and perhaps more important, countries are reluctant to implement 'victim pays' (e.g., Missfeldt, 1999), as this strategy is likely to earn victims a reputation of weak negotiators.

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 (Colorado, Wyoming and Nebraska) sharing it. The purpose of their research exercise is to investigate 'the use of game models for developing scientifically sound *and politically feasible* resource management plans for the Middle Platte ecosystem' (p. 961, emphasis added). The authors thus propose an auction approach as a *potential tool* for deciding who should supply an *ex ante* determined quantity of instream water for endangered species, and at what price. The auction is designed as a second price, sequential auction game, with repeated bidding and pre-determined 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. The cost of supplying a block of water is determined by water acquisition cost and third party cost; that is, costs incurred by parties not directly involved in the procurement decision. In addition, states incur a political cost, which represents an 'equity' payment above the real opportunity cost of supplying a block of water that states

[10] 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, and so on.

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may require as compensation for the political difficulties associated with reallocating water away from domestic consumption.

The strategy profile emerging as an equilibrium 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, and the lowest cost player 'wins' the auction with a bid equal to (or slightly below) the second lowest cost.

The inclusion of political costs is a mechanism for reaching an agreement where one would otherwise not exist, and to model the role of political and strategic forces at play.

The budgetary cost of providing water relative to the theoretical minimum cost is higher, but at the same time higher is the probability that the supply arrangement will be implemented. Furthermore, the second price auction minimizes welfare costs, because the bidder with the lowest cost actually supplies the water. The second price auction and the inclusion of political compensation change the sharing of welfare among the parties, but do not affect total welfare.

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.

3.3. Issue linkage

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 issues of interest to at least two of the parties. Issue linkages may play an important role in solving international externalities,[11] especially in cases in which side payments would be needed, resulting in the 'victim pays principle'.

Bennet *et al*. (1998) propose a model where two players, engaged in negotiations over two separate issues (one of which concerning the allocation of water resources), are given the possibility to link them in a nested game (Tsebelis, 1990) as there may be gains from trading concessions. That is, if one negotiator would gain from cooperating in one issue, but would lose from cooperating in another – and the other negotiator(s)

[11] The profitability and effectiveness of linkage strategies have been largely studied, especially in the literature on coalition formation. Pioneering contributions are those by Tollison and Willett (1979) and Sebenius (1983), who proposed linkage mechanisms to promote cooperation on a number of matters, such as security and international finance. Issue linkage was formally introduced into the economic literature on international environmental cooperation by Folmer *et al*. (1993) and by Cesar and De Zeeuw (1996) to solve the problem of asymmetries among countries. Other significant contributions are those by Barrett (1997), Carraro and Siniscalco (1997), Katsoulacos (1997), and, more recently, Alesina *et al*. (2001).

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have differing preferences – then there are potential gains for all parties to negotiate simultaneously over all issues. The introduction of linkage strategies enlarges the bargaining set and consequently generates outcomes that could not be obtained when issues are tackled independently, as players are able to condition the outcome in one negotiation to outcomes in the other one(s).

Bennet *et al*. (1998) apply this framework for analysing at the theoretical level two different case studies. The results are similar for the two applications: the equilibrium emerging from the negotiation game is, in both cases, the non-cooperative outcome when the water allocation game is played in isolation, while a water sharing agreement can be achieved if countries link water allocation to other issues. The first application concerns water conflicts in the Aral Sea. There are several factors that make it very difficult for countries to reach an agreement over water sharing in this region, primarily the highly strategic role of water, 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: in one 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, which can either subsidize abatement activities in Tajikistan, or not. If the games were 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 in figure 1. 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 conclusions are obtained in the second application, where a negotiation game between Turkey and Syria for the allocation of water quantity from the Euphrates River is linked to another bargaining situation involving the same two countries, but concerning water pollution in the Orontes River basin.

Although the results obtained are interesting and encouraging, care must be taken in advocating for issue linkage. First of all, the payoffs used in the games are theoretical, and may not reflect the true preference ranking of the players. Moreover, issue linkage is profitable only if it can lead to an enlarged bargaining set for all players, that is if new strategies are made possible which were not available under the two independent games. Just and Netanyahu (2000) examined this point and found that, contrary to general assertions, there are many cases where linking games does not enlarge the bargaining space. In general, issue linkage is more successful when the games are strongly asymmetric, and when there are equity concerns. In some cases, for example, full cooperation may be *efficient*, but not *equitable*: players are therefore reluctant to pursue full cooperation, but partial cooperation strategies may be feasible, which give

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(A) The Amu Darya River Game

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

(B) The Air Pollution Game

		Tajikistan: Abate	Tajikistan: Don't abate
Uzbekistan	Subsidise	3 1	-3 2
	Don't subsidise	4 -1	0 0

(C) The Nested Game

		Tajikistan: Not divert Abate	Tajikistan: Not divert Don't abate	Tajikistan: Divert Abate	Tajikistan: 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

Figure 1. *Payoff structures for the different games*
Source: Bennet *et al.* (1998).

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.

4. Two level games: linking domestic and international negotiations

Broadly speaking, water allocation can be at two levels – nationally, between different user groups, consumptive and non-consumptive uses, etc – and internationally – among different countries sharing the same resource. These two levels are interrelated – how much water can be allocated among sectors within a country ultimately depends on how much water is available – which may depend on how an international water body is

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divided. At the same time, how much a country is willing to concede at the international level may depend on its domestic situation. A decision at one level may thus have significant implications for the other level of negotiation: models which fail to take this interdependence into account may therefore be misleading.

According to Putnam (1988), 'the politics of many international negotiations can be conceived as two-level games. At the national level, domestic groups pursue their interests by pressuring the government to adopt favourable 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, assuming that the cooperative solution approximates the (more suitable) non-cooperative game when the discount rate is sufficiently low (Binmore *et al*., 1986 and Rubinstein, 1982).

In Richards and Singh's formulation, the bargaining game varies according to the assumptions made with respect to the two levels of the game; that is, the level of utility parties gain from non-agreement (the disagreement point) varies. The Nash bargaining solution changes accordingly: intuitively, the higher is the disagreement payoff relative to that of the others, the stronger is the bargaining position of the group or country.

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 in isolation. The result is important in understanding why some agreements are not achieved, or do not appear efficient, when the bargaining model only accounts for either of the two levels and treats agents as monolithic. However, the use of the cooperative Nash bargaining solution may provide misleading results; although it approximates the non-cooperative solution under certain conditions, it may not in this context – especially when modelling four parties' negotiations.

5. 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 not only 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,

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or binding agreements cannot be signed. This situation is pervasive, not only in the context of global or regional resources; even domestic level implementation may be extremely problematic where weak institutions, power and income inequalities, and conflicting objectives exist – as in the vast majority of developing countries and economies in transition.

The existence of a negotiated settlement Pareto superior to individualistic (uncoordinated) behaviour is no guarantee that agents 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.

Furthermore, 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 that are least cost and waste no resource – may not be feasible and/or socially acceptable, leading to a failure of implementation, or outright rejection of the policy. The value added of exploring management problems within a non-cooperative bargaining framework lies in the ability of the approach to help find politically and socially acceptable compromises, as political and social constraints are often disregarded in economic analyses. Furthermore, game theory has the added advantage of offering 'the potential of inverting the problem from a case where stakeholders' representatives propose solutions to each other to a case where stakeholders respond to solutions suggested by game models, thus increasing the possibility that an equilibrium solution be found' (Supalla, 2000: 263).

Reviewing past national and international negotiations over water sharing within this framework could offer interesting *a posteriori* insights into which institutional, structural, socio-economic factors have a significant impact on the negotiated outcome, allowing a simplification of the framework within which we understand negotiations. The deriving benefits would be primarily in a new ability to predict negotiation strategies and outcomes, and to alter the rules, incentives and structures in such a way as to obtain a more desirable agreement – be it a 'fairer' or a more efficient one. The bargaining rules matter, but the question of how to determine them has hardly been addressed in the economics and game theory literature (Muthoo, 1999: 188).

Finally, what is still missing in the literature is a negotiation model that considers incomplete information over the resource itself. Water resources are intrinsically unpredictable, and the wide fluctuations in water availability are likely to become more severe over the years. Formally addressing 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.

In conclusion, the non-cooperative bargaining approach proposed to explore the problem may support policy making directly and indirectly, by (i) shortening the time span needed to reach an agreement through the (theoretical) identification of an 'acceptability space'. That is, the values for

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which a proposed policy is more likely to be accepted can be identified using models of non-cooperative bargaining, and policies which would be (almost) certainly rejected can be ruled out at the outset. And (ii) exploring the management problem within a non-cooperative bargaining framework can help select among a set of policies the one which is self-enforcing and, therefore, acceptable. As shown in various papers, this self-enforcing policy 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.

As a final word of caution, the assessment of game theoretic models in analysing past behaviour, or predicting future agreements, will not be complete as long as utility functions and constraints are assumed by researchers, rather than derived from actual behaviour. In order to truly harness the potential benefits of a formal analysis of negotiation processes, more research effort is needed to characterize players' utility functions, as well as environmental parameters, in a way that is a true reflection of reality. To achieve this, substantial input needs to come from players themselves, through the application of supporting field-research methodologies, such as social network analysis, questionnaires, and interviews.

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