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Structure and Power in Multilateral Negotiations: An Application to French Water Policy -

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1. INTRODUCTION

Many areas of public policy are characterized by an increasing emphasis on *devolution*, i.e., direct stakeholder participation in the policy formation process. In some cases, this participation extends to the actual design of the policies that will ultimately be implemented. The trend toward devolution has been particularly significant in the area of water policy design where the goal is to design policies that are not only environmentally and economically sustainable but also politically viable. Examples abound, ranging from Armenia to Palestine to the United States. One such collective negotiation among stakeholders, the so-called Three-Way Negotiations that took place in the early 1990s in California, was analyzed in Adams, Rausser, and Simon. Other, more recent examples of devolution include large-scale, rural-urban water transfers in the U.S.-Mexico border region (examined in Frisvold and Emerick), the San Francisco Estuary Project, and the Sacramento Water Forum. In France the idea of devolution has been institutionalized in the water law promulgated in 1992. This law specifies that specific development plans be set up at the level of each hydrological basin and that water regulations be negotiated at the smaller, catchment scale. It is required that regulations be negotiated locally between all stakeholders under the supervision of local authorities.[1]

Although stakeholder negotiation is an increasingly important policymaking tool, relatively little is understood about the interactions between the structure of the negotiating process and the interests of the participating stakeholders. How do these considerations influence the negotiated outcome? In this monograph we analyze the nature of stakeholder power within a negotiation, focusing on how this power is affected by the structure of the negotiation process and the relationship between the interests of the participants. Understanding these interactions is important for negotiation participants and for policy makers designing such processes.

For our purposes, we define bargaining power as the capacity of a stakeholder to influence the negotiated outcome in order to increase the utility he receives in the equilibrium of the negotiation game. We are interested in the bargaining power wielded by a subset of stakeholders whose interests are sufficiently aligned so that they may be thought of as a loose *coalition*. In our case the coalition consists of farmers who are located at different points along a river. While these farmers compete with each other for water, their interests are more closely aligned with each other than with the other stakeholders at the table, particularly those representing environmental and other nonagricultural uses of water. We analyze three questions related to the bargaining power of our coalition. First, what are the sources of bargaining power and how do they interact? Second, is it ever advantageous for some or all of the coalition members to cede their seats at the bargaining table to a "spokesman" charged with the task of representing their joint interests? Third, how does the definition of the bargaining space (i.e., the vector of variables over which negotiations take place and the restrictions imposed on these variables) affect bargaining power and the resulting utilities of participants? In particular, in some of the bargaining spaces we consider, individual farmers are permitted to pursue their own interests at the expense of the interests of the coalition as a whole by allocating more water to their own subbasins at lower prices than other farmers pay. Do coalition members benefit when restrictions are imposed on the degree to which they can distinguish their own interests from those of other farmers?

Understanding the factors determining the answers to such questions will facilitate the design of negotiation processes that represent the interests of all stakeholders in an implementable and sustainable fashion. At an intuitive level, stakeholders' power in the negotiation process is measured by their "access" to the decisionmaking process. Access is a catchall term for many considerations, including the number of representatives included in the process, the capacity to set agendas, placement on key committees, etc. We demonstrate that the *prima facie* benefits of access

[1] Loi N92-3 du 3 janvier 1992, *Journal Officiel de la République Française* du 4 janvier 1992. See also Jiang.

can be dominated by other, more subtle kinds of negotiating power arising from the nature of the interactions between stakeholders and from the structure of the bargaining environment. If a negotiation process is to fairly represent all interests, these interactions must be taken into consideration when policy makers design the negotiation process.

In order to address these questions, we model a specific instance of negotiations over the use and storage of water in the upper Adour Basin in southwestern France. The upper Adour Basin is a water catchment area that extends from the Adour's source in the Pyrenees mountains to its junction with the Midouze River. It consists of three subbasins separated by points where minimum water flows are measured by the French government. For our purposes, this negotiation process has a number of advantages as a research topic. First, the negotiation process is well-defined and relatively transparent. The national government clearly specified the rules determining participants as well as the outcome in the event that the parties were unable to negotiate a solution. Under the specified structure, the participants reached an initial agreement regarding the guiding principles of the negotiation process within a year: They agreed to initiate and fund studies regarding future water needs and supplies, farmers agreed to fund a significant share of management and maintenance costs, and stakeholders agreed on a total water volume for consumptive purposes, which is one of the three critical variables we model. However, the second stage of negotiations deadlocked over the other two critical issues we examine here: allocating water among farmers and managing limited supplies during droughts (Thoyer et al. (2004)). Second, our modeling task is facilitated by the availability of extensive information regarding the scientific and economic relationships that affect stakeholder preferences (Gleyses and Morardet; Faysse). The underlying hydrology of the river basin is well documented (Faysse and Morardet). A great deal of information is available regarding the agricultural use of water, in terms of both quantities used and the value of the resulting production. This information provides us with hydrologic and economic parameters for our simulation analysis. Third, two types of environmental goals are recognized explicitly by participants: the value of "residual flows,"[2] which promote aquatic life, and the scenic costs of dams, which destroy attractive valley landscapes. These two goals compete with each other and with farmers' use of water for production purposes. Finally, the natural division of farmers by subbasin provides us with a subset of "natural allies:" a coalition consisting of stakeholders whose interests are similar but not perfectly aligned. The quality of the data and institutional information provides us with a rich and realistic simulation environment for examining the effect of process structure on participant power.

The monograph is organized as follows. In section 2 we review the Rausser-Simon multilateral bargaining model (referred to as the MB model), which provides the theoretical basis for this application. Section 3 relates the MB model to the literature on multilateral negotiations. Section 4 introduces the Adour Basin, explains the nature of the negotiations and describes our simulation model of the bargaining problem. Section 5 contains our comparative statics analysis. Section 6 concludes.

[2] Residual flows are total flows net of agricultural usage. See section 4.2 for a more complete definition.

2. THE UNDERLYING BARGAINING FRAMEWORK

The analytical framework for this study is the noncooperative MB model developed in Rausser and Simon and applied in Adams, Rausser, and Simon. In this section we review the main features of the model, drawing extensively from the presentation in section 2 of Adams, Rausser, and Simon. Complementing the vast theoretical literature on bilateral bargaining spawned by the seminal work of Rubinstein, the MB framework is designed specifically as an application tool to analyze complex multi-issue, multiplayer bargaining problems. It has no closed-form solution and so must be solved using computational techniques.

The specification of a *multilateral bargaining problem* includes a finite set of players denoted by $I = \{1, \cdots, I\}$ and indexed by i. The players meet together to select a *policy vector* from some set x of possible alternatives. The set x is assumed to be a compact, convex subset of n-dimensional Euclidean space where n is the cardinality of the vector of issues being negotiated. The policy vector, $\mathbf{x}$, yields player i a utility of $u_i(\mathbf{x})$ where $u_i(\cdot)$ is assumed to be strictly concave on x. We denote by $\mathbf{u}^0$ the vector of *disagreement* payoffs, i.e., the payoffs players receive if they fail to negotiate an agreement. Throughout this monograph we assume that decisions are reached by *unanimity*, i.e., an element of x can be selected as the solution to the bargaining problem only if it is accepted by all parties at the bargaining table.

A *bargaining game* is derived from a bargaining problem by superimposing upon it a "negotiation process." We begin by formulating a bargaining game with a finite number, T, of *bargaining rounds*. Under the conditions we assume, each such game has a unique *limit dominance solvable* (LDS) equilibrium.[3] We then define the *solution* to the *limit bargaining game* to be the limit of these finite-round equilibria. At the beginning of the $t \leq T$th round of the finite game, provided that the game has not already concluded by this round, nature chooses at random some player to be *the proposer* for this round. Nature's choice is governed by an exogenous probability distribution, $\mathbf{w} = (w_i)_{i \in I}$ where $w_i \in [0, 1]$—player i is chosen with probability w_i—and $\sum_i w_i = 1$. Vector $\mathbf{w}$ is interpreted as a distribution of *access* to the political system and w_i is referred to as player *i's access probability*.[4] The player selected by nature makes a *proposal*, which is a policy vector in x, and all players vote on whether or not to accept it. The game concludes in this round if and only if all players vote to accept the proposal; if some player votes against it, play proceeds to the next round. If the Tth round of the game is reached and if the proposal put forward in this round is rejected, then players receive the vector of disagreement payoffs, $\mathbf{u}^0$. To avoid dealing with degenerate special cases, we assume throughout that x contains a proposal that strictly Pareto dominates $\mathbf{u}^0$.[5]

There is a simple characterization of the unique LDS equilibrium strategies for a game with T rounds of bargaining. This characterization is given by the following backward-inductive construction: A proposal made by player i in period T is accepted if and only if it yields each player $j \neq i$ a utility level at least as great as j's disagreement utility, u_j^0. Similarly, in round $t < T$, a proposal by i is accepted if and only if it yields each j a utility level at least as great as *j's expected* utility from playing the subgame starting from round $t + 1$.[6] Thus, the game can be solved recursively, starting from the last round: In each round t, player i computes the

[3] Limit dominance solvability is a solution concept that extends in an intuitive way the finite-game notion of trembling-hand perfection (Selten 1975) to extensive form games with a continuum of actions. We prove in Rausser and Simon that every bargaining game satisfying the conditions assumed in this monograph has a unique LDS equilibrium.

[4] Access probabilities are referred to as "recognition probabilities" in the literature spawned by Baron and Ferejohn (1987). While some branches of the political economy literature treat the distribution of political power as endogenous, this monograph, along with the other bargaining analyses reviewed in section 3, treats this distribution as externally determined.

[5] It should be emphasized that this last assumption is not a necessary one; given our other assumptions, however, it is necessary and sufficient to ensure the existence of a unique negotiated agreement.

[6] In round $t + 1$, player i is chosen with probability w_i to be the proposer. Under the conditions we assume, every proposal that is part of an LDS equilibrium profile is accepted. Therefore, j's expected utility from playing the subgame starting at $t+1$ is the $\mathbf{w}$-weighted sum of the utilities he obtains from all parties' proposals in this round.

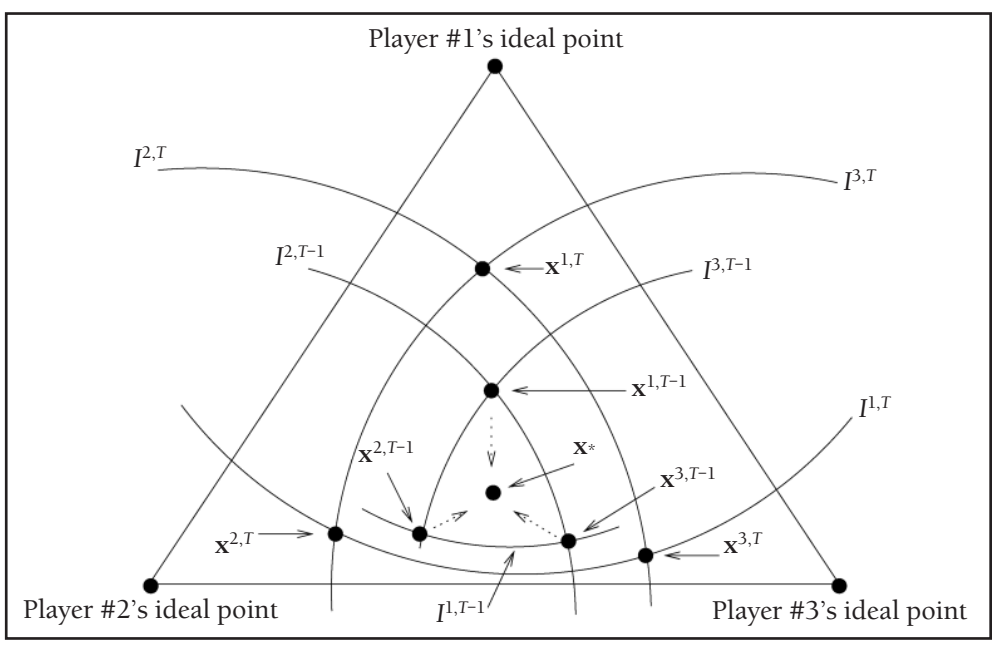
policy vector that maximizes i's utility, subject to the constraint that, for each $j \neq i$, the vector yields player j no less than j's default utility (if $t = T$) or j's expected utility conditional on reaching the next round (if $t < T$). Thus, the task for i in each round is to solve a classical nonlinear programming problem: maximize a strictly concave function on a convex set.[7] Our conditions ensure that in each round the unique solution to this problem will yield i greater utility than i's expected utility, conditional on reaching the next round. It follows from this construction that, for every finite game, there is a unique, stochastic *outcome vector* consisting of a point in x for each player that will be proposed by that player if he is chosen in the first round to be the proposer. With probability one, players in round one accept whichever proposal is made. Given a sequence of finite-round bargaining games, all identical except that the number of bargaining periods increases without bound, any sequence of outcome vectors for these games has a unique, *deterministic* limit in x, i.e., all players' first-round proposals converge to the same point in x. Formal details of this construction are provided in Rausser and Simon.

We now provide an elementary example, designed to provide some intuition for the basic mechanics of the model. The example, reproduced from Adams, Rausser, and Simon, belongs to the class of problems known as *spatial problems*, in which the policy space consists of alternative *locations*. Each player has a most-preferred location called an *ideal point*. We assume that the utility derived by a player from a particular location is a decreasing function of the Euclidean distance between this location and the player's ideal point. The example illustrates why a deterministic limit solution must exist.

There are three players. The space of possible locations is represented by a triangle in Figure 1. Players' ideal points are at the vertices of the triangle. Player i's access probability will be denoted by w_i. Consider a game with T rounds of bargaining. For each j, the line $I^{j,T}$ in Figure 1 is the level set corresponding to player j's *reservation utility* in the last round of bargaining: Any proposal on this line yields player j a utility level equal to j's *disagreement utility*. This line is the boundary of player j's *participation constraint* on negotiations in round T. Player i's task in this round is to choose the point closest to i's ideal point that satisfies both of the other agents' participation constraints.

The outcome conditional on reaching round T is that proposal $\mathbf{x}^{j,T}$ will be agreed upon with probability w_j. Clearly, player i's expected utility conditional on reaching this round is strictly higher than u_i^0 since each $\mathbf{x}^{j,T}$ yields i *at least* u_i^0 while i's own proposal yields a utility strictly higher than u_i^0. Thus, i's participation constraint in round $T - 1$ will be strictly "tighter" than in round T. This is illustrated in Figure 1. The set of

Figure 1. An Illustration of the Rausser-Simon Model (Figure 1 in Adams, Rausser, and Simon)



[7] The feasible set is convex because it is the intersection of upper contour sets for the other players; these sets are convex because all players' utilities are concave and, hence, quasiconcave.

proposals for which unanimous agreement can be obtained—i.e., the set bounded by the $I^{j,T-1}$s—is strictly contained in the set bounded by the $I^{j,T}$s. Accordingly, the distance between players' proposals in round $T-1$ is also smaller than in round T. Clearly, however, it is strictly better for agent i to propose an alternative that will be accepted in the current round than to propose an alternative that is rejected and proceed to the next round. Proceeding by backward induction from round $T-1$ to the first round, this distance between proposals continues to shrink. Thus, if T is sufficiently large, the maximum distance between any two players' proposals in the *first* round of bargaining will be arbitrarily small. This is the intuition for why in the limit, as T goes to infinity, the solution to the game is deterministic, i.e., all negotiators propose the same alternative in the first round.

3. RELATED LITERATURE

Compared with the voluminous literature on bargaining between two players over a single dimension, the literature on multiplayer, multi-issue bargaining problems is relatively sparse. We begin with a discussion of the two seminal papers in the former literature—Nash and Rubinstein—that have strongly influenced the directions in which the latter has evolved. Nash's approach is axiomatic: Given a set, S, of possible utility pairs and a disagreement outcome (or default payoff), d, Nash identified a unique outcome in S that satisfies four axioms about bargaining outcomes. Extensions of Nash's original paper—the *Asymmetric Nash Bargaining Model* (ANBM)—introduce the possibility of asymmetric "bargaining weights," reflecting the two agents' relative bargaining power (see Roth).

While the first three of Nash's axioms are innocuous, the fourth, *independence of irrelevant alternatives* (IIA), is highly restrictive. IIA requires that, if a given bargaining problem is modified in a way that leaves unchanged the "shape" of the bargaining frontier in any open neighborhood of the solution to the original problem, then the solution to the modified problem must coincide with the solution to the original one. We argue here that this implication of IIA is highly problematic for many real-world applications.

In contrast to Nash's axiomatic approach, Rubinstein's is strategic. In an infinite-horizon, discrete-time model, two players make alternating offers to each other concerning the division between them of a "pie." The game has a unique solution that depends only upon which player makes the first offer and the relative "impatience" (i.e., discount rates) of the two players. While their frameworks are entirely different, the solutions reached by Nash and Rubinstein are closely linked (see Binmore, Rubinstein, and Wolinsky and, for further elaboration, Osborne and Rubinstein): As the time between offers in Rubinstein's discrete time model goes to zero, the solutions to his model converge to the solution to the ANBM with bargaining weights that reflect the Rubinstein agents' relative impatience. In this sense, Nash's axiomatic and Rubinstein's strategic approaches yield "the same" solution to the bargaining problem. It follows that Rubinstein's model also exhibits IIA. Indeed, IIA plays a central role in the vast literature on the strategic approach to bargaining theory that has evolved based on Rubinstein's work. To illustrate, when Rubinstein's model is augmented by providing one of the players with an "outside option,"[8] this additional strategic advantage affects the equilibrium outcome of the game *only* if the outside option provides the player with a utility level that strictly exceeds her equilibrium utility in the game without the option.

Both the Nash and the Rubinstein approaches have been extended to a multiplayer context. Thomson and Lensberg include an extensive treatment of n-person axiomatic bargaining theory, including Nash Bargaining. Krishna and Serrano (KS) construct an n-player generalization of Rubinstein's game in which the unique solution to the problem of sharing a pie corresponds to the solution of the n-person ANBM. In KS's model, each player can accept or reject the current pie-division proposal. Players who accept the proposal exit the game and immediately consume their shares of the pie; the remaining players continue to bargain over what remains. Thus, unanimity is not required for agreement. The "pie-eating" structure of this setup is clearly restrictive: i's utility from consuming his share is independent of whether or not other players are consuming so that the possibility of interpersonal externalities is excluded. Kultti and Vartiainen have generalized KS's equivalence result to a general context that admits interpersonal externalities.

The MB model applied in the present monograph represents a departure from the Nash-Rubinstein tradition in that its solution does not exhibit independence of irrelevant alternatives. In particular, equilibrium outcomes in the MB model depend a great deal on the nature of the offers that are made in the final rounds of negotiations. By contrast, the absolute levels of offers made in the tail of a sequence of Rubinstein offers have no influence on the nature of offers made at the head of the sequence (i.e., the equilibrium

[8] This extension was first introduced in Shaked and Sutton, Binmore, and Binmore, Shaked, and Sutton.

offers).[9] This distinction has important implications for the applicability of Rubinstein-type models to the study of certain real-world multilateral bargaining situations. In the context of collective decisionmaking, an impending deadline can provide a dramatic impetus to compromise: witness the frequency of last-minute resolutions of congressional deadlocks and of post-midnight compromises in wage negotiations when strikes are scheduled for the following morning. To the extent that the threats and counterthreats made in these final moments of negotiations involve proposals that are outside of some neighborhood of the ultimate compromise, the solutions of models consistent with Nash's IIA axiom *must* be invariant with respect to the way events unfold at the "eleventh hour." In the MB model, by contrast, these events can have a dramatic impact on equilibrium outcomes.[10]

Of the other multiplayer, noncooperative bargaining theoretic papers, most involve some kind of modification of Rubinstein's alternating-offer framework. Binmore considers several alternative extensions of Rubinstein's analysis to the problem of "three players and three pies." Each pair of players exercises control over the division of a different pie, only one of which can be divided. A result attributed to Shaked[11] shows that, in any infinite-horizon, alternating-offer, three-player pure-division problem, if unanimity is required for agreement and if players are not extremely impatient, then any division of the pie can be implemented by subgame-perfect equilibrium strategies.[12]

An interesting *n*-player variant of the alternating-offer model, called the "Proposal-Making Model," has been advanced by Selten (1981). A player is selected by nature to make the first proposal. He proposes a utility vector, a coalition, and a "responder." The responder either accepts or rejects. If he rejects, the responder then proposes a new utility vector, a new coalition, and a new responder. If he accepts, the responder designates another member of the coalition as the next responder and so on until all members of a coalition have agreed to some proposal. This model has been studied extensively in Chatterjee et al. and by Bennett, writing alone and with various coauthors.[13]

Manzini and Mariotti have studied multilateral bargaining problems in which an *n*-member alliance negotiates with another party. In their framework, bargaining proceeds in two stages. The "outer stage" is a standard Rubinstein two-person alternating-offer bargaining game. During the "inner stage," alliance members negotiate among themselves over the choice of a proposal; once they have agreed, the proposal is offered to the other party as part of the outer stage. In Manzini and Mariotti (2005), the authors discuss in abstract terms the method by which alliance members decide on a proposal, considering a variety of different "internal procedures." The main finding in this paper is that procedures requiring unanimous agreement by alliance members result in more aggressive bargaining stances than procedures based on majority rule. In Manzini and Mariotti (2003), the model is applied to the problem of negotiations between an alliance of polluting firms and a regulator. Using a unanimity procedure, they find that the outcome of negotiations is entirely determined by the preferences of the "toughest" alliance member.

One advantage of the Manzini-Mariotti framework relative to many others in the multilateral bargaining literature is that it delivers a unique solution to the bargaining problem even when decisionmaking within the alliance is governed by majority rule. This

[9] More precisely, the relationship between equilibrium offers and those made in the final rounds of the finite-horizon games that approximate Rubinstein's model becomes vanishingly small as the time horizon increases (Fudenberg and Levine).

[10] It should be emphasized at this point that in the *equilibria* of the MB model—and all other complete information bargaining models—agreement is always reached in the first round of bargaining so that last-minute *equilibrium* agreements never arise. The distinction between Rubinstein's and the MB models arises from *out-of-equilibrium* interactions at the eleventh hour, which, in the latter but not the former, are transmitted via backward induction to the beginning of the game. Applied economists are generally highly skeptical of arguments that involve long and intricate backward-inductive chains. To some extent, this justifiable skepticism may be mitigated when applied to the MB model because, typically, the basic shape of the solution is more or less determined after only a few rounds of backward induction (see section 5). This fact may also reassure experimentalists since there is overwhelming evidence that experimental subjects seem unable to induct backward much beyond three periods (see, for example, Neelin, Sonnenschein, and Speigel; Speigel et al.; Binmore et al.; and Johnson et al.).

[11] Proposition 3.7 in Osborne and Rubinstein. The result is also discussed in Sutton.

[12] Sutton and Osborne and Rubinstein note that Shaked's result can easily be extended to *n* players.

[13] Bennett (1991), Bennett (1997), Bennett and Houba, and Bennett and Damme.

advantage, however, has a significant cost. Technically, the result is obtained by separating into distinct rounds the multilateral bargaining within the alliance and the (bilateral) bargaining between the alliance, acting as a unit, and the other party. This structure, however, limits the applicability of the framework. In many bargaining situations, such as the one we study in this monograph, the distinction between an alliance and "the other side" is far from clear-cut and "alliance" members interact with each other within plenary negotiating sessions without ever constituting themselves as a distinct group with a unitary "voice."

Cai (2003) also studies bargaining between a single "active" player and an (implicit) alliance of many "passive" players who exhibit different degrees of toughness (see also Cai (2000)). In Cai's model, the active player negotiates with each of the passive players in turn in an exogenously specified order. If an agreement is reached with a passive player, that player leaves the game with a contingent commitment that will be honored by the active player. Provided that the players' common discount factor exceeds a prespecified value $\bar{\delta} < 1$, Cai's game has one efficient Markov equilibrium and multiple inefficient Markov equilibria. The source of inefficiency (necessarily) is that agreement is not reached in the first round. In the inefficient equilibria, the passive players have different strategies. In the three-player version of this game, the active player proposes to the tougher of the two passive players and agreement is not reached. The second passive player is now obliged to accept a bad deal rather than wait for another round of bargaining. As the discount factor goes to unity, the tougher passive and the active players receive essentially equal shares and the weaker passive player receives a smaller share.

The models discussed so far were all developed by economists. Models of multilateral bargaining and negotiations have also been developed within other disciplines, especially political science, psychology, and management science. Of these, perhaps the most influential has been the framework that Baron and Ferejohn (BF) (1987, 1989a, 1989b) introduced. Their framework considers a problem in which n identical players must divide up a pie using majority rule. One variant of BF is strikingly similar to the MB model yet draws quite different conclusions: Players propose divisions of the pie in odd-numbered rounds, nature chooses one of the proposals at random, and voting follows in even-numbered rounds. In the two-round version of this model, each proposer keeps slightly more than half of the pie and distributes a small portion to enough others to obtain a majority vote. In the infinite-horizon version of the game, as usual, virtually any division can be supported as an equilibrium. The two-period outcome, however, is identified as the unique outcome that can be supported by "stationary" or Markov-perfect strategies. These are strategies that can only depend on "current and immediate-future" conditions, such as the set of available strategies in the current round, the parties that are bidding in the next round, etc. Strategies involving punishments for past deviations from the equilibrium path are thus excluded. Also excluded, however, are strategies that exploit impending deadlines since a player's strategy cannot depend on the number of remaining bargaining rounds. Because of this choice of solution concept, the BF and MB models have strikingly different properties in spite of their very similar extensive forms.

The BF model has spawned a very large literature. We mention here only a small selection. Eraslan and Eraslan and McLennan have shown that a unique stationary equilibrium exists for the BF model under quite general conditions. Jackson and Moselle extend the bargaining space of the BF model to two dimensions, an ideological and a distributive dimension, and study the stationary equilibria of this model. Players' preferences are separable across the two dimensions. Along the distributive dimension, each bargainer prefers the largest possible share and is indifferent with respect to the distribution of the share that he does not receive. Along the ideological dimension, each player has single-peaked preference as in the standard unidimensional voting model. While proposals may be linked or decoupled, equilibrium proposals are always linked.

Norman focuses on the finite-horizon version of the BF game. When all players have identical discount rates, he establishes that, when there are at least five bargainers ($n \geq 5$) who are sufficiently patient, any division of the pie in which each player receives a positive share can be supported as an equilibrium

when the time horizon is sufficiently long. The proof of this multiplicity result involves an argument quite different from the one used to establish multiplicity in an infinite horizon game: It depends critically on the fact that proposers are indifferent with respect to the compositions of the coalitions that support their proposals and so can be modeled as selecting coalitions in ways that support the punishment of deviations from the equilibrium path. On the other hand, when players' discount rates differ, he shows that, except for a measure zero set of discount rate vectors, there is a unique vector of subgame-perfect equilibrium payoffs for each finite-horizon game when $n \geq 5$. While Norman's generic eradication of the multiplicity problem is potentially encouraging, it exhibits the unsatisfactory property that equilibrium outcomes fluctuate dramatically with respect to the time horizon of the game: Players who have the lowest equilibrium payoffs in the T-period game will be the cheapest ones to bribe in the first round of the T+1-period game and, hence, will be selected by all proposers in that round and will have the highest equilibrium payoffs in that game. In this sense, this model, while interesting, has essentially no predictive power because the outcome is so sensitive to perturbations in T. This oscillatory property appears to be an unavoidable consequence of assuming decisionmaking by majority rule. It is precisely to avoid such oscillations that we assume in the current application of the MB model that proposals must be accepted unanimously.

We complete this review of the bargaining theory literature with a brief discussion of some other papers developed by noneconomists. In Doron and Sened (1995, 2001), the political bargaining process is characterized as distinct from economic bargaining in several dimensions: It is usually more complex; it often involves numerous actors who are endowed with unequal skills, leverage, and information; it is typically dynamic and tends to yield nonunique outcomes; the participants are rarely of equal status; they often act on behalf of an undefined "public interest" or in the name of the uninformed population of voters and supporters. The resources allocated are a mix of tangible and intangible goods, which often cannot be ascribed fixed prices or comparable values. Political commodities, such as sovereignty, independence, equality, or legitimacy, are all unlikely to have a market-determined value. They must be provided to the public through institutionalized and nonvoluntary mechanisms.

Stokman and van Oosten develop an exchange model of policy networks that assumes that players reach collective decisions after using threats and conflict. de Mesquita (1985, 1990) models political decision makers as expected utility maximizers. Each actor will calculate the utility that he will attain from making different offers and from possible offers made by the other actors and then will select the route that will result in the highest expected utility. The bargaining process, then, can be viewed as a search by the actors among different alternatives according to their perceptions of what the outcome will be in each situation. Druckman conducts a meta-analysis of the literature on bargaining experiments to identify which variables have the strongest effect on compromising behavior and time to resolution in bargaining; his findings suggest that the initial distance between positions, time pressure, and the negotiator's orientation are among the strongest determinants of the outcome.

The economic literature applying bargaining theory and game theory to negotiations over water scarcity has grown as such negotiations have become more common. One strand of this literature has focused on the application of cooperative game theory to water negotiations. Dinar, Ratner, and Yaron provide an extensive survey of work in this area and Parrachino, Dinar, and Patrone summarize more recent developments. Dinar et al. compare the cooperative approach to a negotiated approach utilizing interactions between analysts and stakeholders for allocating water in the Kat Basin in South Africa. They find that results are similar and that cooperative game theoretic modeling may complement an interactive stakeholder negotiation approach.

Carraro, Marchiori, and Sgobbi extensively examine applications of negotiation theory to problems involving water management. After surveying the literature on standard theoretical models and noting that the predictions of these models are often not realized in real negotiation processes, attention is turned to the relatively new field of research on negotiation

support system (NSS) tools. These tools, developed by computer scientists, political scientists, and engineers to assist negotiators, are essentially computer models that support the negotiation process by performing constrained optimization with multiple objectives and multiple issues. The survey reports on a number of studies that address topics closely related to the one analyzed in this monograph. Becu et al. developed a multi-agent system to facilitate water management in Thailand. The model includes a biophysical module and a social module and is designed to simulate different water management scenarios. Barreteau et al. developed an agent-based simulation tool to support negotiations over water allocation among farmers in the Drome Valley in France. Computer models assess the collective consequences of alternative water allocation scenarios under different assumptions about water availability. The results are presented to stakeholders in the negotiations and the issue space is modified according to their reactions. Other support system tools are designed to be used interactively. For example, Thiesse, Loucks, and Stedinger created the Interactive Computer Assisted Negotiation Support System to provide real-time assistance to parties on all sides of the negotiating process, facilitating the selection of a mutually beneficial agreement. Negotiators are presented with different alternatives that emerge from their preferences on the issue space and the physical constraints. The effectiveness of this tool was tested in controlled experiments with two parties and up to seven issues. A limitation of the approach is that equity issues cannot be incorporated; also, the system relies heavily on truthful revelation by participants about their rankings over alternatives.

4. Adour River Negotiations

We will apply the model introduced in section 2 to a specific negotiation in southern France over water use, water storage capacity, and user prices. Our analysis is based on extensive background research regarding the hydrology, agriculture, and political economy of the upstream part of the Adour River Basin in southwestern France, from its origin in the Pyrenees to its junction with the Midouze River.

See Gleyses and Morardet, Faysse, Faysse and Morardet, Cemagref, Thoyer et al. (2004), Thoyer et al. (2001), and Goodhue et al. (forthcoming) for additional information regarding institutions and extensive discussions of technical, agricultural, and hydrological parameters; stakeholder groups; and preferences.

4.1. Background

Under the national French water law passed in 1992, water is a national resource and stakeholders are assigned responsibility for designing the regulations governing its use, subject to the overall guideline that these regulations will balance the needs of water users against environmental considerations. The national law requires that specific water development plans be formulated for each hydrological basin and that the regulations to implement these plans be designed and enforced at the catchment level. The Adour Basin is one such catchment area. At this more localized level, regulations must be negotiated among all stakeholders under conditions defined by the relevant government authorities.

Use of river water from the Adour Basin for irrigation has increased substantially over the past twenty years and is now its most important use by volume, accounting for roughly two-thirds of total water use. Agriculture uses water primarily in the dry summer months of July and August when the river flow is low. Corn is the most important irrigated agricultural crop, followed by soybeans. Increased irrigation has led to a water shortage in the basin equal to roughly a fifth of annual agricultural use. Several environmental groups have been concerned over the effect of irrigation-induced reductions in river flows on the welfare of aquatic life. One proposed solution to these concerns has been to construct one or more dams that would capture water during the wet months and then release it in July and August. Other environmental groups have opposed this proposal because of the expected impact of dam construction on the natural landscape. To resolve the issue, a negotiation has been initiated, to be conducted according to a process mandated by the national government.

The water development plan for the Adour Basin required stakeholders to consider whether or not to build one or more dams and how the operating costs of these dams would be allocated among users. The variables to be negotiated included river flow requirements (and, hence, irrigation quotas) and quota prices. Specifically, Adour Basin stakeholders were charged with determining the amount of water that should be allocated to irrigation, how this water should be allocated among agricultural users, and the price that users should pay for this water. The parties at the negotiating table included elected representatives of agricultural producers; environmental interests; a group representing the interests of all nonagricultural water users in the basin, including urban and recreational users downstream from our study area; representatives of agricultural and environmental agencies from local and central governments; representatives of elected local governments; and the manager of the semipublic Adour Basin water authority that maintains infrastructure, delivers water, and monitors river flow.

4.2. Model

Applying the MB framework reviewed in section 2, we developed a stylized computer simulation model of the negotiation problem described in section 4.1, the results of which are presented in section 5. In this section we describe the components of the simulation model. Many of the details, suppressed here to save space, are available elsewhere (see Goodhue et al. (1999) and Thoyer et al. (2001)).

Structure of the Problem

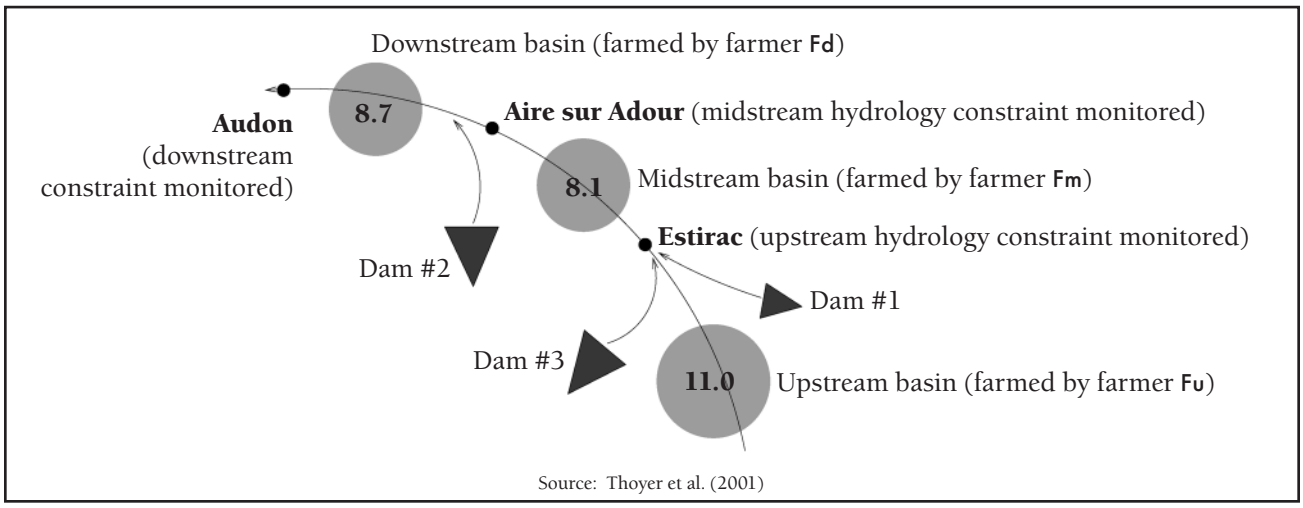
The Adour Basin consists of three subbasins (see Figure 2) separated by flow measurement points. The label inside each circle indicates the number of hectares (in thousands) under irrigation in each subbasin. We label these by U, M, and D for "upstream," "midstream," and "downstream," respectively. The upstream subbasin is above Estirac. The midstream subbasin is below Estirac and above Aire sur Adour. The downstream subbasin is below Aire sur Adour and above Audon where the Midouze joins the Adour. As Figure 2 indicates, the sizes of the three subbasins differ substantially. In particular, the upper subbasin is larger than the other two. We assume that, corresponding to each subbasin, there is a single *representative farmer*, labeled Fu, Fm, and Fd, respectively. The pattern of agricultural activity differs across subbasins.

Farmers in each subbasin negotiate over the quota allocation they will receive. The negotiated quota allocation determines the maximum amount of water that a farmer is entitled to use per eligible hectare farmed.[14] The quota does not depend on technical parameters such as the crops a farmer intends to grow or the on-farm technical efficiency of water use. Quotas may, however, vary by subbasin because farmers' needs and the externalities resulting from water use are significantly different across subbasins.

Farmers are required to pay a fixed unit price for each quota unit at the time it is allocated. After-tax operating revenue from quota sales—the inner product of prices and the quota allocation—accrues to the *water manager* to offset his operating costs.[15] The level of quota sales is related to the minimum level of quota prices by the *administrative budget constraint* (ABC). The ABC requires that after-tax operating revenues from water management cover operating costs, which are an affine function of aggregate dam capacity.

Quota sales are limited by *hydrology constraints* that specify minimum *residual flows* of water downstream of each subbasin. The residual flow at a measurement point is calculated as the total volume of water that flows into the subbasin immediately above the point, including releases from existing and proposed new upstream dams, minus the total volume of water used by farmers within that subbasin. In the absence of dams, these flows would be determined by the *natural flows* of water after deducting quotas allocated to farmers. The Adour-Garonne Water Development Plan proposed that the natural flows should be supplemented by building as many as three dams, provided stakeholders could negotiate an agreement regarding the size of each dam, subject to capacity limits

Figure 2. A Schematic of the Adour Basin



Source: Thoyer et al. (2001)

[14] In practice, the actual water used during the two-month period modeled is between 64 percent and 70 percent of the quota allocation. Generally, water is scarce enough that farmers use their entire purchased allocation over the entire growing season.

[15] Note that the manager's revenue depends on the quota *allocation*, not on the amount of water actually applied by farmers. Even if a farmer uses less than his quota allocation, he must pay for his entire allocation.

determined by technical considerations (See Figure 2 for proposed dam locations and the measurement points at which flows are monitored.[16]). The dams, if constructed, would have different implications for water flows: As Figure 2 indicates, dam #2 would increase flows at the measurement point downstream of subbasin D only, while dams #1 and #3 would each increase flows at all three measurement points. Farmers would be required to finance the operating costs of the dams but not the capital costs. Local government entities would share responsibility for the capital costs with the national agricultural and environmental ministries (Faysse and Morardet).

Dam construction is controversial. The advantages are that new dams would increase the residual flows of water. Such residual flow increases would benefit users who are downstream of the subbasins, promote aquatic life, and relax the hydrological constraints on farmers. The disadvantages are that dams are costly and degrade the quality of the rural landscape.[17]

We now explain the hydrology constraints in more detail. For each subbasin, the residual flow of water cannot fall short of a minimum level called the *flow objective*, which was set in the Adour-Garonne Water Development Plan (SDAGE) in order to protect aquatic life in the river (Faysse and Morardet). Two of the three classes of variables being negotiated will directly affect the hydrology constraints: dam capacities, which affect water inflows, and quotas, which determine water outflows. The other class of variables—quota prices—interact with hydrology constraints through the administrative budget constraint. When dam capacities increase, administrative operating costs increase also. Holding quota levels constant, quota prices must rise in order to keep the administrator's budget constraint in balance.

The Bargaining Space

There are three classes of negotiated variables: prices, quotas, and dam capacities. There are three proposed dams and three price-quota pairs, one for each subbasin. In the bargaining games we simulate, we distinguish between three bargaining *regimes* identified as "Common Prices, Common Quotas" (CPCQ), "Common Prices, Individual Quotas" (CPIQ), and "Individual Prices, Common Quotas" (IPCQ). The regimes differ in the flexibility they provide a representative from one subbasin to differentiate that subbasin's treatment under the bargaining outcome from the treatment that the other subbasins receive. In regime CPCQ the bargaining space is restricted so that a common price and a common quota apply to all subbasins. In regime CPIQ the price remains common but bargainers are allowed to specify distinct quota levels for each subbasin. In regime IPCQ prices are common and quotas are distinct. In both CPIQ and IPCQ we impose (and, in section 5.3, vary) a *heterogeneity bound* on the degree to which subbasin-specific negotiated variables can be differentiated from each other.[18] In the absence of such a bound, each subbasin representative would attempt to acquire for his own subbasin the highest possible quota at the lowest possible price, offloading the entire scarcity (in CPIQ) or cost (in IPCQ) burden onto the other subbasins to the maximum extent allowed by their participation constraints. By varying these bounds continuously, we can conduct comparative statics experiments on the impact of restricting players' flexibility within the bargaining space.

Analyzing these three distinct regimes enables us to explore the effect on bargaining performance of different institutional specifications of the bargaining space. In particular, we test the natural conjecture that, if farmers are limited by institutional constraints on the extent to which they can pursue their own interests at the expense of their "coalition partners," then their performance as a group will be enhanced.

Each regime is examined under both *normal* and *drought* conditions. Historically, in eight out of ten years, rainfall in the Adour Basin has been sufficient to provide farmers with adequate water without violating

[16] Dam #1's maximum capacity is one-quarter the maximum capacity of either of the other two dams.

[17] In general, it is by no means obvious that dams would benefit downstream aquatic life. In this monograph we model the benefits reported by stakeholders (Faysse). We are indebted to an anonymous referee for emphasizing this point.

[18] Specifically, in regime CPIQ (IPCQ), we impose a bound on the variance of the three quotas (prices) announced in a given proposal.

the hydrology constraints. We refer to conditions in these years as "normal" and calibrate our model so that the hydrology constraints are not binding in equilibrium under normal conditions (although they may bind off the equilibrium path). By contrast, our calibration of "drought conditions" ensures that at least one of the hydrology constraints binds in equilibrium. These two scenarios represent alternative operating assumptions on which negotiations might be based: Rational stakeholders would adopt quota proposals consistent with binding flow constraints if and only if they collectively acknowledged the possibility of drought conditions.[19] As will hereafter become apparent, the negotiating environment—and, hence, the comparative statics properties of our model—will be quite sensitive to this critical assumption.

Bargaining Participants and Their Payoff Functions

There are seven "players," each one representing either a single stakeholder or a composite of stakeholders. Because the distribution of political power among these stakeholders is not a primary consideration in this study, we specify exogenously that each player in our benchmark model has the same access probability. (This assumption is standard in the literature, cf. Baron and Ferejohn (1987) and the large literature that this paper spawned.)

Each player has a strictly concave utility (or payoff) function defined on the space of bargaining proposals. In multilateral, multi-issue bargaining contexts such as ours, *weak* concavity would be a more natural assumption since many dimensions of the bargaining space, though of critical importance to some negotiators, will have no impact at all on others. However, strict concavity is required in the MB model if we are to obtain unique solutions and, hence, meaningful comparative statics. The problem with weak concavity is that decisions that have a significant impact on one party may be determined by an arbitrary resolution of indifference by another.[20] Indeed, in a computational model such as ours, the numerical solution algorithm may resolve indifference in a significantly different way in response to an insignificant change in parameter specifications, generating a comparative statics effect that appears to be dramatic but is in fact completely artificial.

When we impose strict concavity on a problem involving the allocation of a burden (or benefit) among multiple parties, we encounter two distinct kinds of problems. The first is a general one, common to all multi-issue problems: Typically, not every negotiator necessarily cares about each one of the variables being negotiated. The second is special to allocation problems: When the burden is being shared among some or all of the negotiating parties, the most parsimonious assumptions are (1) an individual who bears a portion of the burden cares about the size of his share but is indifferent between alternative distributions of the remaining share, and (2) for an individual who bears none of the burden, the *aggregate* size of the burden may matter but how the burden is allocated is of no consequence.

It is relatively easy to resolve the first, general problem: We model each agent as having nondegenerate preferences over all "aggregate" variables in the bargaining space. But, to sharpen our analysis, we weight variables that are less important for that agent by negligibly small coefficients. For example, each farmer in our model is primarily concerned about the price and quota he negotiates for himself but also has a negligible preference for larger over smaller dams. To resolve the second, special problem, we assume, without particularly strong foundations, that negotiators have an extremely mild "second-order" preference for

[19] In the actual negotiation procedure on which this study was based, no provision was made for assigning quotas conditional on rainfall levels. As a result, the agreed-upon total consumptive use would result, under drought conditions, in unsustainable levels of water usage, reducing residual flows to below government-defined crisis flow levels. In such an event, the water manager would be authorized to halt all irrigation. This rigidity in the negotiating procedure has an obvious and unfortunate consequence: If the assumptions on which farmers base their negotiating positions are too conservative, they will deprive themselves of available water under normal conditions; if the assumptions are not conservative enough, farmers risk the possibility of catastrophic shutdowns under drought conditions. In turn, this rigidity contributed to the deadlocking of the negotiations.

[20] A precisely analogous problem is endemic in extensive-form game theory though it arises in a quite different context: Decisions made by one agent at "off-the-equilibrium-path" decision nodes are of no consequence to that agent but will, in general, have a significant impact on the set of opportunities available to other agents.

"equity;" that is, we assume that each agent obtains a vanishingly small increment in utility from a symmetric allocation of a given residual burden (i.e., excluding his own share) relative to an asymmetric allocation of the same residual. To implement this second idea, we add to each player's "real" or *first-order* utility function a second, almost flat function that is strictly concave in the variables being allocated—prices and quotas. The net result of our adaptations is that each agent's utility function will have indifference surfaces with significant curvature along the dimensions that really matter to that agent and barely perceptible curvature along the dimensions that do not.[21] As the discussions of our results that follow will demonstrate, these second-order preferences for equity affect none of our results in a significant way.

We now introduce our seven agents and their preferences.[22]

(1) Three representative *farmers*, one from each subbasin, labeled Fu, Fm, and Fd. The term Fi denotes the generic farmer. Fi's objective is to maximize profits from farming in the *i*th subbasin. Profits increase with quota levels and decrease with quota prices. Because of differences in agricultural patterns at the subbasin level, farmers differ in their willingness to pay for quotas. For a given quota, Fm's willingness is greatest, then Fu's, and then Fd's. To ensure that farmers' preferences depend to some degree on all the variables being negotiated, we assume that farmers have a slight preference for larger rather than smaller dams but that this preference is very weak. (Note that, while dam capacities are not significant *direct* contributors to farmers' utilities, they do have an important, indirect effect through the model's constraint structure.)

Formally, Fi's first-order utility is translog in his quota price, p_i, and quota level, q_i:

$$\ln\left(u_i(p_i, q_i, \mathbf{d})\right) = a_i^0 + \sum_{k=1}^{5} a_i^k x_i^k(p_i, q_i) + \sum_{j=1}^{3} b_i^j \ln(1+d_j),$$

where

$$\mathbf{x}_i(p_i, q_i) = \left(\ln(1+p_i)\ln(1+p_i^2)\ln(1+q_i)\ln(1+q_i^2)\ \ln((1+p_i)(1+q_i))\right).$$

The vector $\mathbf{a}_i \in \mathbb{R}^6$ is estimated from linear programming simulations based on microeconomic farm models (Gleyses and Morardet); the vector $\mathbf{d} = (d_j)_{j=1}^3$ where d_j is the capacity of the *j*th dam expressed as a fraction of its maximum feasible capacity. The b_i^js are only negligibly larger than zero. It should be noted that the arguments of Fi's utility are not the regular inputs and output of an agricultural production function. Rather, once quotas have been negotiated, the maximum quota level available to Fi, q_i, will be a constraint on production. Moreover, since Fi must pay for the quota level he has agreed to regardless of his actual production level, he will view $p_i q_i$ as a sunk cost.

(2) An *environmentalist* (Ev). This stakeholder, a composite of diverse environmental interests,

[21] This idea is very similar in spirit to the notion of "trembling-hand perfection" introduced in Selten (1975). The difference is that, while Selten represented second-order preferences by sequences of arbitrarily small trembles, we cannot work with infinitesimals; our second-order preferences make a small but finite contribution to agents' overall preferences.

[22] To each agent's *u* term defined below, we add his corresponding *v* term, representing the agent's second-order preferences for equitable distributions of burdens and benefits. The γs are very small in absolute value, with signs that match agents' preferences for the corresponding first-order variables, e.g., farmers prefer higher quotas and lower prices, both for themselves and for other farmers, while negotiators on the "other side" have the reverse preferences.

(1) *farmer groups*: $v_i = \gamma_i^p \sqrt{\Sigma_{\iota \in \{U\,M\,D\}} p_\iota^2} + \gamma_i^q \Pi_{\iota \in \{U\,M\,D\}} q_\iota^{1/3}$ where $\gamma_i^p < 0$ and $\gamma_i^q > 0$.

(2) *the manager*: $v_{Mg} = \gamma_{Mg}^p \Pi_{\iota \in \{U\,M\,D\}} p_\iota^2 + \gamma_{Mg}^q \Pi_{\iota \in \{U\,M\,D\}} q_\iota^2$ where $\gamma_{Mg}^p, \gamma_{Mg}^q > 0$.

(3) *other players*: $v_m = \gamma_m^p \Pi_{\iota \in \{U\,M\,D\}} p_\iota^2 + \gamma_m^q \sqrt{\Sigma_{\iota \in \{U\,M\,D\}} q_\iota^2}$ where $\gamma_m^p > 0$ and $\gamma_m^q < 0$.

The effect of adding the *v*s to the *u*s is that, whenever a decision "really matters" to an agent, the choice that the agent makes will be determined, effectively, by that agent's *u* and not by his *v*. For example, if the participation constraints (see section 2) of farmers Fm and Fd are binding when farmer Fu makes a decision, then how Fu allocates benefits and costs between Fm and Fd will be determined (except for a very small error term) by the lagrangians on those constraints. When neither participation constraint is binding, however, the effects of farmer Fu's choice on Fm and Fd will be determined by Fu's *v* function.

is primarily concerned about the quality of the rural landscape and secondarily about maintaining adequate river flow rates. Since the rural landscape is negatively impacted by dam construction, Ev's constant elasticity of substitution (CES) utility function is decreasing in the vector **d** and increasing in the vector **r**: d_j is the capacity of the jth dam expressed as a fraction of its maximum feasible capacity; r_i is the residual flow of water in the ith subbasin, again expressed as a fraction of the maximum feasible residual flow.[23] (Note that players do not explicitly *propose* values for the residual flow vector, **r**; rather, each proposal implies a unique value for **r** that increases with proposed dam capacities and decreases with proposed quotas.) Clearly, Ev's two goals can be reconciled only by reducing the water used by farmers.

In our specification of nonfarmers' utilities, the capacities of dams #1 and #2 are viewed as virtually perfect substitutes for one another and imperfect substitutes for the capacity of dam #3. (The qualifier "virtually" is required to ensure strict rather than weak preference concavity.) Dam #3 is treated specially because its construction would have a particularly significant negative impact on the landscape. It is located in the mountains in a very scenic valley. Also residual flows in subbasins U and M are virtually perfect substitutes for one another and imperfect substitutes for residual flows below subbasin D. Flows below subbasin D are treated specially because they are considered particularly important for maintaining aquatic life and recreational activities.

We assume that Ev has a very weak preference for higher rather than lower levels of total revenue from quota sales, $\sum_{i=1}^{3} p_i q_i$; local authorities tax these sales at a proportional rate and utilize the tax receipts for maintaining the river, and Ev obtains some utility from these tax-financed government services. In symbols, let $\phi(\mathbf{x})$ and $\varphi(\mathbf{x})$ denote, respectively, strictly concave and strictly convex functions that are both arbitrarily close to the function $\sum_{j=1}^{n} x_j$. Now define

$$u_{\mathsf{Ev}}(\mathbf{d}, \mathbf{r}) = \left(a_i^0 \sum_{k=1}^{5} a_{\mathsf{Ev}}^k \left(x_{\mathsf{Ev}}^k(\mathbf{d}, \mathbf{r})\right)^{\rho_{\mathsf{Ev}}}\right)^{1/\rho_{\mathsf{Ev}}}$$

where

$$\mathbf{x}_{\mathsf{Ev}}(\mathbf{d}, \mathbf{r}) = \left(\phi(r_{\mathrm{U}}, r_{\mathrm{M}}), r_{\mathrm{D}}, (2 - \varphi(d_1, d_2)), (1-d_3), \sum_{i=1}^{3} p_i q_i\right), \text{ and}$$

$$\mathbf{a}_{\mathsf{Ev}} \in \mathbb{R}_{++}^5$$

with $a_{\mathsf{Ev}}^5 \ll a_{\mathsf{Ev}}^1, a_{\mathsf{Ev}}^2 \ll a_{\mathsf{Ev}}^3, a_{\mathsf{Ev}}^4$ and $a_{\mathsf{Ev}}^5 \approx 0$. Note that increases in proposed dam capacities affect utility positively through the first two arguments of u_{Ev} and negatively through the third and fourth. When a dam is small, its *net* effect on u_{Ev} is positive, but there may exist a critical size beyond which its net effect becomes negative.

Lacking quantitative data from which to estimate Ev's preferences, we assign values to the weights $\mathbf{a}_{\mathsf{Ev}}$ that reflect in a qualitative way the relative importance that Ev assigns to different concerns as elicited from stakeholder interviews (Faysse). We proceed in the same way for the remaining three players hereafter described.

(3) A *downstream user* (Ds). There are stakeholders in the Adour Basin who are primarily concerned with minimizing demands on water flows in the three subbasins. These include downstream water users, recreational users of the river, and environmentalists concerned with downstream aquatic wildlife. We combine these stakeholders into a composite "downstream user," Ds. While Ds's utility has the same functional form as Ev's, he ranks water flows as significantly more important than preserving the rural landscape. (Recall that Ev, by contrast, was significantly more concerned about the rural landscape.) Specifically, we assume that $a_{\mathsf{Ds}}^1, a_{\mathsf{Ds}}^2 \gg a_{\mathsf{Ds}}^3, a_{\mathsf{Ds}}^4 \gg a_{\mathsf{Ds}}^5$ with $a_{\mathsf{Ds}}^5 \approx 0$. Since Ds has a higher "willingness to pay" for residual flows in terms of larger dams, the *net* effect of a unit increase in dam capacity for u_{Ds} is either more positive or less negative than for u_{Ev}.

[23] This maximum is attained when dams are built to their maximum capacity and farmers use no water.

(4) A *manager* (Mg). Mg administers the distribution of water in the district. For statutory reasons, he is equally concerned with avoiding budget deficits and budget surpluses. Further, he derives utility from increasing the scope of the water system he administers. That is, he prefers a larger operation and, therefore, higher dam capacities. Mg's CES utility is

$$u_{\mathsf{Mg}}(\mathbf{p},\mathbf{q},\mathbf{d}) = \left(a^0_{\mathsf{Mg}} \textstyle\sum_{k=1}^{2} a^k_{\mathsf{Mg}} \left(x^k_{\mathsf{Mg}}(\mathbf{d},\mathbf{p},\mathbf{q})\right)^{\rho_{\mathsf{Mg}}}\right)^{1/\rho_{\mathsf{Mg}}}$$

where $\mathbf{a}_{\mathsf{Mg}} \in \mathbb{R}^2_+$, $\mathbf{x}^1_{\mathsf{Mg}} = \phi(\mathbf{d})$ and $\mathbf{x}^2_{\mathsf{Mg}}$ decreases in the distance between the manager's realized and his target return on operations. In addition to his role as a player, Mg impacts the bargaining through the administrative budget constraint (see section 4.2).

(5) The *taxpayer* (Tp). The taxpayer in our model represents interests that are primarily nonlocal and nonagricultural.[24] This player's goals are to minimize the burden on French taxpayers by limiting expenditures on local dams and to maximize benefits to nonfarm users by increasing residual flows. Like Ev and Ds, Tp has a very weak positive preference for higher rather than lower local tax revenues. Formally, Tp's CES utility is

$$u_{\mathsf{Tp}}(\mathbf{r},\mathbf{c}) = \left(a^0_{\mathsf{Tp}} \textstyle\sum_{k=1}^{4} a^k_{\mathsf{Tp}} \left(x^k_{\mathsf{Tp}}(\mathbf{r},\mathbf{c})\right)^{\rho_{\mathsf{Tp}}}\right)^{1/\rho_{\mathsf{Tp}}}$$

with the following interpretation of symbols:

$$\mathbf{x}_{\mathsf{Tp}}(\mathbf{r},\mathbf{c}) = \left(\phi(r_{\mathrm{U}}, r_{\mathrm{M}}), r_{\mathrm{D}}, (3-\varphi(\mathbf{c})), \textstyle\sum_{i=1}^{3} p_i q_i\right)$$

where c_j is the construction cost of the jth dam expressed as a fraction of the cost of constructing the dam to its maximum admissible capacity and $\mathbf{a}_{\mathsf{Tp}} \in \mathbb{R}^4_{++}$ with $a^4_{\mathsf{Tp}} \ll a^1_{\mathsf{Tp}}$, $a^2_{\mathsf{Tp}} \ll a^3_{\mathsf{Tp}}$, and $a^4_{\mathsf{Tp}} \approx 0$.

Under this specification, all players have nondegenerate preferences over all classes of variables, with the qualifications that farmers care only about the quotas that affect their own subbasins and nonfarm players care only about the inner product of quota prices and quantities. With the addition of second-order preferences (footnote 22) to these first-order preferences, each player's preferences are strictly concave in all variables.

The preference profile specified here gives rise to a clear-cut conflict between farmers on the one hand and Ev, Ds, and Tp on the other. (For this reason, we sometimes refer to the latter group of three players as the *antifarmer group*.) Farmers prefer higher quotas and, when the hydrology constraints are binding, prefer greater dam capacity to less. Ev, Ds, and Tp prefer lower quotas because quotas and residual flows are negatively related and prefer less dam capacity either to preserve the rural landscape or to lower the tax burden. The relationship between the manager and the farmers is more complex. Like the farmers, the manager prefers higher quotas and more dam capacity but, in contrast to the farmers, he also prefers higher prices.

Projecting Preferences onto Price-Quota Space

Because the dimensionality of our bargaining space is so large ($\mathbb{R}^7$), it is difficult to obtain much intuition by studying players' full-dimensional proposals directly. Fortunately, one can gain a great deal of intuition for the comparative statics results discussed in section 5 by projecting players' preferences onto price-quota space. (This simplification does, however, obscure some interesting subtleties.) The projection is immediate for farmers, at least in regime CPCQ, and quite simple for Tp and Mg. For Ds and Ev, however, it is obtained indirectly through the constraint system since these players derive first-order utility from residual flows and landscape quality, caring barely at all about prices.

In order to understand how Ds and Ev's preferences are projected, consider regime CPCQ and assume that the ABC is binding.[25] Letting i denote either Ds or Ev, player i's concerns can be mapped into preferences over prices and quotas as follows. Starting from a given utility level $\bar{u}_i$, a unit increase in the common quota reduces residual flows; hence, i's utility declines and the only variables on the bargaining table that can perhaps increase it back to $\bar{u}_i$ are

[24] In actual negotiations, these interests might be represented by a bureaucrat from Paris charged with ensuring that the negotiation process is not captured by either farmers or by local political interests.

[25] As noted in section 4.2, the ABC is almost always binding when farmers make proposals.

dam capacities. (Recall that, *holding quotas constant*, if the initial capacity of dams is sufficiently small, the net effect of dam capacity increases on u_i is positive.) Now, consider a unit increase in quotas. An increase in dam capacity that exactly offsets the resulting loss in residual flows would leave *i*'s utility below its initial level, $\bar{u}_i$, since *i* dislikes dams. So dams must be increased by more than this level, to the point that the resulting *net increase* in residual flows is sufficient to compensate *i* for his utility loss due to larger dams. Since administrative operating costs increase with dam capacity and the ABC is binding, larger dams require higher quota prices. Thus, the ABC together with the technological relationships between quotas, dams, and residual flows induce utility levels for *i* in price-quota space, which decrease with quotas and, *provided that the derivative of* u_i *with respect to some dam capacity is positive*, increase with prices (that is, *i*'s indifference curves in price-quota space are positively sloped). If, however, dam sizes reach levels such that *i*'s utility declines with any further increase in their sizes, then farmers cannot "purchase" from *i* any further increase in quota levels at *any* price.

The shape of *i*'s induced preferences in price-quota space depends on his relative preference for residual flows and rural landscape. It follows from our earlier comparison of Ds and Ev that a unit increase in quotas hurts Ds less than Ev while, holding quotas constant, a unit increase in dam capacity benefits Ds more. Therefore, the range of dam sizes for which Ev's indifference curves in price-quota space will be positively sloped is smaller than the range for Ds and they will be more steeply sloped whenever they are positive. To summarize the preceding discussion, while there is no *economic* marketplace in which farmers can "buy" quotas from either Ds or Ev, there is, in effect, a *political* marketplace in which quotas can be "purchased" from either of these "suppliers" by increasing dam size (and residual flows) and a range of dam sizes for which the "political supply schedule" for quotas is upward sloping. Having made this distinction, we can now proceed *as if* farmers were buyers of quotas and nonfarmers were sellers.

The slope of the political supply schedule may become considerably steeper when hydrology constraints are binding, which in drought conditions is usually the case. For example, in section 5.2 we discuss in some detail the predicament facing farmers in regime IPCQ under drought conditions: (a) at the proposed quota and dam levels, the residual flow below either subbasin M or subbasin U is at its minimal admissible level; (b) player Ds's participation constraint is binding; (c) dams #1 and #3 are so large that Ds's utility declines with a further increase in either; (d) an increase in dam #2 increases Ds's utility. In this situation the only way a farmer can induce Ds to agree to "supply" still more quotas is to offer to expand the size of dam #2. However, an increase in the common quota decreases residual flows below *each* of the subbasins while the expansion in dam #2 increases only the flow below subbasin D (see Figure 2). Consequently, to restore the flows below the other subbasins to their minimal admissible levels, either dam #1 or dam #3 must be increased as well. But by (c), these secondary increases negatively impact Ds's utility so that dam #2 must be increased still further to compensate him. That is, because of the hydrology constraints, a unit increase in quotas requires three "rounds" of dam increases rather than the single one that would be required under normal conditions. Because each additional increase in dam size raises operating costs and part of each increase in dam capacity must be "bought" by devoting part of the capacity increase to increasing residual flows, three rounds of quota price increases are required as well. In this way, the hydrology constraints steepen the slope of the political supply schedule facing farmers.

5. COMPARATIVE STATICS ANALYSIS

In this section the institutional setting described in section 4 provides a context within which we explore a number of questions relating to bargaining power. To obtain the results reported in this section, we solved our computer simulation model for a variety of benchmark specifications and then successively increased one parameter (e.g., some player's access probability) and re-solved the model to obtain numerical comparative statics properties. We summarize the results of three *simulation experiments*, each consisting of a large number of individual simulations. Our primary objective in this monograph is to provide intuitions for our key findings. Accordingly, we suppress all but essential details of our numerical results and focus almost exclusively on the effect of perturbing certain parameters on the final rounds of bargaining. (Many of these suppressed details are documented in the papers cited in section 4.2.) In section 5.1 we introduce our method of analysis with a stripped-down model in which only three players participate. In section 5.2 we compare the performance of the farmer coalition when farmers participate independently in the bargaining process versus when the coalition is represented by a spokesman charged with maximizing the joint interests of all farmers. Finally, in section 5.3 we consider how the specification of the bargaining space affects player utilities. In particular, we examine whether farmers' bargaining power is increased if the maximum permissible degree of heterogeneity across water prices or quotas is restricted.

5.1. Shifting Access: An Heuristic Example

To introduce our method of analysis, we begin with a simple example. The example serves an heuristic purpose but also makes a substantive point. As an instructive device, the example illustrates in a simplified context how comparative statics exercises are conducted and analyzed in this monograph. In particular, it illustrates the role that backward induction plays in the MB model and demonstrates how effects in the last rounds of the game "build on each other," creating a "snowball effect" that becomes magnified as we move backwards through the game tree. The substantive contribution is to highlight a striking characteristic of the Rausser-Simon model that distinguishes it from axiomatic models of bargaining, such as the Nash bargaining model, and strategic models, such as Rubinstein's, that implement the "Nash program" (Osborne and Rubinstein). In all of those models, there is a monotone, increasing relationship between a player's equilibrium payoffs and his traditional, exogenously specified measures of bargaining power: his bargaining weight and his "default payoff," i.e., the payoff he receives if the bargaining phase ends without an agreement being reached. In the MB model there are additional, less transparent sources of bargaining advantage so that the relationship between payoffs and traditional measures of power is more delicate. In particular, the relationship between payoffs and power as traditionally measured need no longer be monotone.

The example in this section compares the equilibria of two games that are identical except for the players' access probabilities. In both games, farmers as a group have the same aggregate access but in the second, the distribution among them is shifted in favor of a farmer who has a strategic advantage relative to the others arising from his "location" in preference space. To reduce the problem to its barest essentials, we strip down our model by excluding four of our seven players from the bargaining process, leaving only Fu, Fm, and Ds. Assume also that there is only one dam (#1) for which size is being negotiated. The comparative statics experiment we consider is a shift in access from Fu to Fm in the CPCQ regime.[26] (Recall that access probabilities were introduced in section 2 and that regime CPCQ is defined by the condition that prices and quotas must be equal across subbasins.) To further simplify the exposition, we project all players'

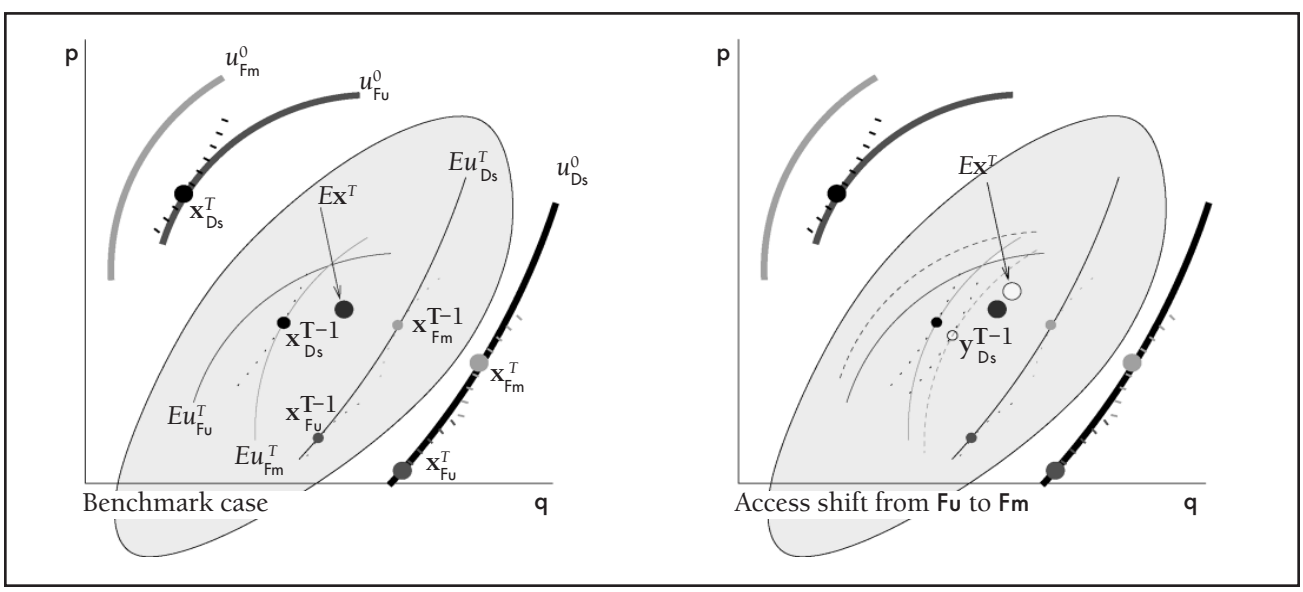
[26] Note that we use the word "shift" for expositional convenience: We are not suggesting that the access probability vector is a variable over which farmers have some control. The exercise considered here is a routine comparative statics one in which one exogenous parameter of the model—the distribution of power between farmers—is varied.

preferences onto price-quota space in the manner described in section 4.2. Intuitively, one would expect that a shift in access from Fu to Fm would increase Fm's utility while decreasing Fu's. In fact, the outcome is that *both* Fm and Fu benefit from the shift! The key to the argument is that Fm's participation in the negotiations generates, in effect, a positive externality for Fu. When Fm gains access at the expense of Fu, there are multiple effects on Fu's payoff in all but the last round of bargaining. In all rounds of bargaining, there is a "direct" effect, which reduces it. In round T-1 there is an "indirect" effect—the externality—that increases it. In rounds T-2 and earlier, there are multiple indirect effects, which further increase Fu's payoff. Under certain conditions, the indirect effects dominate, resulting in an inverse relationship between Fu's equilibrium payoff and his access probability.

Consider the impact of an access shift from Fu to Fm in the final round of bargaining. In this round, players' proposals depend only on default payoffs and, hence, are independent of access probabilities. Consequently, the *only* impact of the change in access is what we call the direct one: Fu strictly prefers his own proposal to Fm's and the latter is now more heavily weighted so that Fu's expected utility, conditional on reaching the final round, is negatively impacted.

Matters become more complex as we move backward through the game tree. We explain the argument underlying the result with the aid of Figures 3 and 4, which represent, respectively, rounds T-1 and T-2 of the bargaining in a T-round game. In each figure the shaded area highlights the region of the bargaining space that is relevant for that round; curves outside the shaded region are relevant for the round that follows. We begin with Figure 3. The left panel represents the bargaining for our benchmark vector of access probabilities. The three solid thick curves (labeled u_r^0) outside the shaded region represent the three players' participation constraints in the round T of bargaining, i.e., any price-quota pair on u_r^0 yields player r the same payoff as the disagreement outcome. Note that Fm's constraint is steeper than Fu's, reflecting Fm's higher willingness to pay for the marginal quota (for the reason explained in section 4.2). The players' T-round proposals are indicated by x_r^T. The large dot in the center of the left panel denotes the weighted average, Ex^T, of these proposals where the weights are the players' access probabilities. The three solid thin curves (labeled Eu_r^T) in the left panel represent participation constraints in round T-1, i.e., any price-quota pair on Eu_r^T yields player r the same payoff as r's expected payoff from the lottery in round T generated by the x_r^Ts. Note in particular that, while the relative locations of u_{Fm}^0 and u_{Fu}^0 are determined by the exogenously specified disagreement payoffs, the locations of curves Eu_{Fm}^T and Eu_{Fu}^T, relative to point Ex^T, depend on agents' risk aversion. The more risk averse agent r is, the greater will be the *minimum* distance between Ex^T and the curve Eu_r^T. Unless Fm is significantly more risk averse than Fu, Fm's participation constraint in round T-1

Figure 3. Access Shift Tightens Fm's Participation Constraint in Round T-1

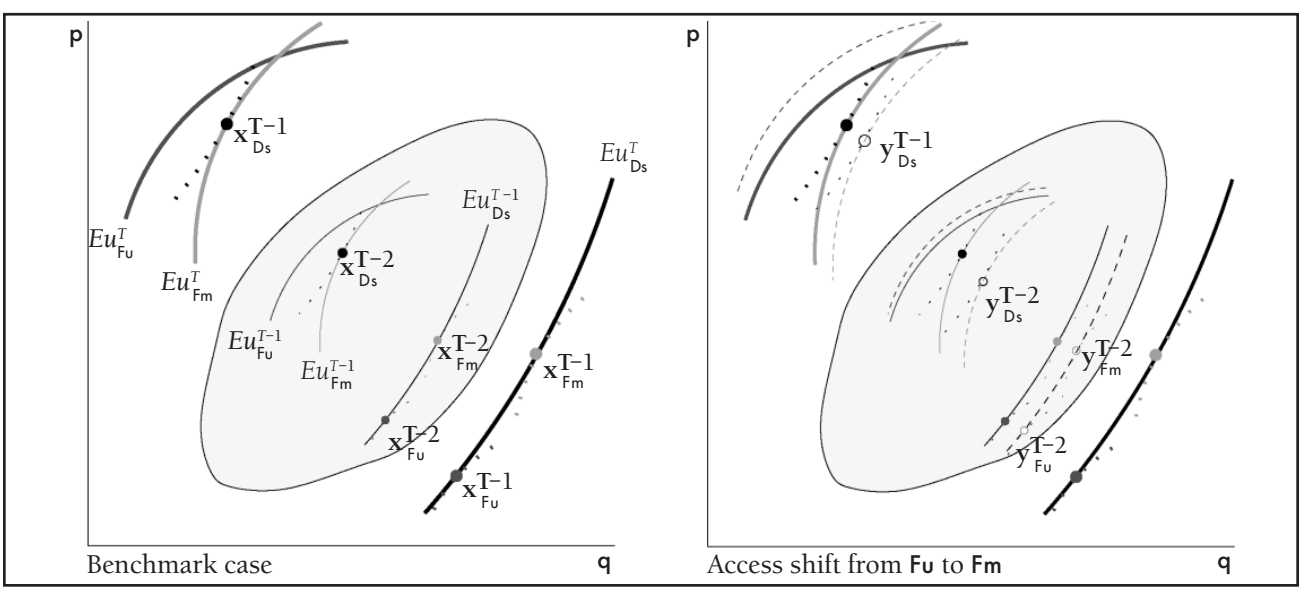


must lie, as it does in the figure, to the southeast of Fu's in the region of the figure to the south of Ex^T. The level sets of Ds's payoff function are relatively steep; in fact, they are almost vertical. (This means that, if the size of dam #1 is increased by one unit, the resulting increment in water flows when *holding quotas constant* raises Ds's utility by an amount only barely greater than the amount by which Ds's utility declines because dams despoil the landscape. The gap between these two amounts is the "surplus utility" generated by the dam increase, which can be "soaked up" by an increase in quota allocation, leaving Ds indifferent. In this instance the surplus amount is tiny.) Now, since Fm's level sets are steeper than Fu's, Fm's participation constraint must be binding on Ds while Fu's must be slack. It follows that Ds's proposal in round T-1 will be independent of the precise location of Fu's participation constraint in round T (Eu^T_{Fu}) but will be affected by any small change in the location of Fm's (Eu^T_{Fm}).

The right panel of Figure 3 indicates schematically the effect of a shift in access from Fu to Fm on the bargaining in round T-1. The expected price-quota pair in round T shifts to the northeast (i.e., from the solid dot to the open dot), reflecting Fm's relative preference, now more heavily weighted, for higher quotas at higher prices. To reduce clutter in this panel, we have omitted the labels on the lines representing participation constraints. The *dashed* lines parallel to the two farmers' thin solid lines represent their participation constraints after the access shift: Necessarily, Fm's constraint tightens while Fu's slackens. The widely spaced dotted curves represent the proposers' indifference curves through their respective optimal proposals. Since Ds is bound by Fm's constraint and unaffected by Fu's, the effect of the access shift is that Ds now proposes the open dot, $\mathbf{y}^{T-1}_{\mathsf{Ds}}$, rather than the (unlabeled) solid dot representing $\mathbf{x}^{T-1}_{\mathsf{Ds}}$. Thus, relative to the benchmark case, the lottery now facing players, conditional on reaching round T-1, is unambiguously more favorable for Fm and less favorable for Ds. For Fu, the net effect is indeterminate. Once again, the direct effect of the access shift is negative: Fu prefers his own proposal to Fm's and weight initially assigned to the former is now assigned to the latter. But in this round there is an additional indirect effect associated with the shift in Ds's proposal. Because the perturbed proposal is preferred by Fu to Ds's original proposal, this effect benefits Fm.

These changes in round T-1 impact the locations of players' participation constraints in round T-2. Figure 4 depicts the bargaining in this round; we include the participation constraints for round T-1 as well for reference. The left panel represents the benchmark case; the participation constraint for player *r* in round T-2 is represented by the thick curve, Eu^{T-1}_r. The right panel indicates the cumulative effect of the access shift by round T-2. As in the right panel of Figure 3, participation constraints in the benchmark case are represented by solid lines and those after the access shift by dashed lines. Once again, each widely spaced

Figure 4. Additional Effects in Round T-2



dotted curve represents the indifference curve through some player's optimal proposal. Reflecting the preceding remarks, Ds's participation constraint is slacker than in the benchmark case while Fm's is tighter. As we have noted, Fu's constraint could be slacker or tighter than in the benchmark. For this illustration, we have drawn it as slightly slacker, i.e., we have assumed that in round T-1 the loss to Fu resulting from the access shift dominates the gain to Fu due to Ds's weaker performance.

In this round, there are additional indirect effects that have no counterpart in round T-1: As in round T-1, y_{Ds}^{T-2} is southeast of the unlabeled solid dot, x_{Ds}^{T-2}. But, in this round, so too are y_{Fm}^{T-2} and y_{Fu}^{T-2} relative to the unlabeled solid dots x_{Fm}^{T-2} and x_{Fu}^{T-2} (cf., in Figure 3, y_{Fm}^{T-1} and y_{Fu}^{T-1} were in the same locations as x_{Fm}^{T-1} and x_{Fu}^{T-1}). As a result, Ds's participation constraint in round T-3 is further slackened relative to the original case since in this round *all three* proposals now yield him less utility. On the other hand, relative to the original case, each farmer benefits from these movements so that, other things being equal, each farmer's participation constraint in round T-3 will tighten. Once again, of course, these positive effects on Fu's participation constraint are offset by the usual, negative direct effect of the access shift.

It will now be apparent how the snowball we have been describing builds momentum as we induct backwards through the game tree. The impact of the access shift on Fm's equilibrium payoff is the limit, as T increases without bound, of the impacts on Fm's participation constraints in the first round of the bargaining in the game with T rounds. Without additional restrictions on parameters, given our functional form specifications, we cannot *guarantee* that these constraints will all tighten; however, our simulation results confirm that this property is extremely robust over a wide range of parameters.

5.2. Combining Forces: Impact of a Common Spokesman for Farmers

In section 5.2 and section 5.3, we return to the complete specification of our model. We consider the effect on farm coalition performance of introducing a *spokesman* charged with the role of representing farmers' collective interests. The spokesman is similar to other players in that he has a nonzero access probability; he differs in that his approval is not required in order for a proposal to be accepted. Formally, there is no participation constraint associated with the spokesman. (Think of him as an attorney hired to represent the interests of his clients: Ultimately, the clients themselves, not the attorney, must decide whether or not to accept any proposed deal.) The utility function that the spokesman maximizes is defined as the simple average of the three farmers' utility functions. We refer to this as the *average farmer utility function*. In this section we consider the effect of transferring access from farmers to the spokesman, holding constant the absolute access vector for nonfarmer parties and the individual access probabilities of farmers *relative to each other*.

Our goal is to explore the natural conjecture that farmers will negotiate more effectively as a group the more they can present a "united front" at the bargaining table. When an individual farmer makes a proposal, his objective is to advance his own interests, typically at the expense of other members of the farmer coalition. When farmers' proposals are weighted according to their access probabilities, farmers collectively suffer because each farmer fails to take account of other farmers' interests. The spokesman, on the other hand, will internalize any externalities that result from farmers' pursuit of their individual self-interest, subject to his objective function's equal weighting of the three farmers' utilities. We would expect, therefore, that the equilibrium value of the average farmer utility function will increase with the spokesman's access.

A number of questions arise in the context of our particular model: Does the spokesman always improve coalition performance? Under what conditions will the spokesman's contributions have the greatest impact? Which farmers benefit from the spokesman's participation and which, if any, lose and why? The "why" question is, in our view, particularly interesting because it focuses attention on the precise nature of the externalities that are internalized by the spokesman—how these externalities differentially affect the different members of the farmer coalition and, most important, how they impact the bargaining performance of the farmer coalition.

We address these questions for six specifications, varying both the issue space (CPCQ, CPIQ, IPCQ) and hydrological conditions (normal vs. drought). Throughout section 5.2 (and section 5.3 as well), we focus on the case in which Ds is *default strong* across all six specifications. (We say that a member of the antifarmer group (as defined in section 4.2) is default strong if his participation constraint is binding on all farmers and the spokesman in the final round of negotiations.[27]) The results of our simulation experiments are summarized below. Most striking is the counterintuitive result that, under normal conditions in regime IPCQ, all farmers' utilities actually decline as the spokesman gains access! Our other results are as follows: (1) Comparing his effect on farmer coalition performance in regime CPCQ relative to the other two regimes, the spokesman has a negligible effect under normal conditions and no effect whatsoever under drought conditions. (2) As the spokesman gains access in regimes IPCQ and CPIQ, Fu's equilibrium utility always declines; Fm's, Fd's, and the average farmer's equilibrium utilities increase *except* in regime IPCQ, normal conditions; and equilibrium utilities for all members of the antifarmer group move in the opposite direction from the change in the average farmer's utility.

One can obtain intuition for each of these results through a detailed study of players' final-round proposals. Once these final-round details are well understood, most of the equilibrium comparative statics properties can be deduced readily by applying the usual backward-induction logic, taking into account the snowball effects illustrated in section 5.1. To illustrate how this logic works, we shall see that in the final round (round T) the spokesman discriminates against Fu to the benefit of other farmers so that Fu's participation constraint in round T-1 becomes slacker as the spokesman gains access. In the penultimate round, typically, the spokesman again discriminates against Fu for the same reason. (The degree of discrimination will typically be less dramatic in round T-1 than in T because participation constraints become tighter as we move backward through the inductive chain, leaving the spokesman with less room to maneuver.) Thus, in round T-1 there will be *two* reinforcing effects—his slacker participation constraint and the discrimination against him by the spokesman—that contribute to a weaker performance by Fu. Typically, this weakness will compound as we work back through the inductive chain to the solution: The result, typically, will be that Fu's expected solution payoff will decline as the spokesman gains access. We emphasize the qualification "typically" because, for some parameter values, countervailing effects can reverse the impact of the last-round effects. Since no such reversals arise in the experiments reported in this monograph, the details we overlook by focusing on the final round, though interesting, are not critical.

Regime CPCQ

In this regime, the farmer coalition's welfare increases with the spokesman's involvement under normal conditions. Under drought conditions, it makes no difference whatsoever. The explanation for this difference is as follows. In the absence of hydrology constraints, farmers maximize their utilities subject to a common political supply schedule for quotas (see section 4.2). Because farmers have different optimal locations along this schedule, their proposals will differ. If hydrology constraints bind sufficiently tightly, however, the lowest quota level on the schedule that will satisfy these constraints will exceed even the level that would be optimal for Fm, who has the highest willingness to pay for quotas. Under these circumstances, all preference differences between farmers will be suppressed at the bargaining table since all farmers will be obliged to propose the same, super-optimal quota level. When the spokesman participates, he will be subject to exactly the same constraints; hence, his proposal will be indistinguishable from the common proposal offered by farmers. For this reason, if the drought is sufficiently intense, the transfer of access to the spokesman will have no impact at all. (For the same reason, the bargaining outcome will also be independent of the distribution of access across farmers.)

Under normal conditions, when the hydrology constraints do not bind, the preference variation between farmers is no longer suppressed and the spokesman can make a difference. Not surprisingly, however, his

[27] Surprisingly, we find that changing the identity of the default strong player has little impact on our results.

role in regime CPCQ is relatively insignificant since farmers in this regime are *constrained* to treat themselves and other farmers equally; there are simply no opportunities for self-promotion at the expense of the group. The spokesman's role is limited to merely reducing risk. As noted previously, in the absence of hydrology constraints, farmers' final-round proposals will differ in accordance with their willingnesses to pay: Fm proposes the highest quotas, prices, and dam capacity levels and Fd proposes the lowest. When the spokesman's access increases, farmers' expected utilities increase somewhat because their risk exposure is reduced: Their utilities from the spokesman's proposal exceeds the average of their utilities from all three farmers' proposals. For the model specifications we consider, this reduction in risk translates into an increase in farmers' solution payoffs. We should not expect, however, that this property will be robust across a wide range of parameter specifications since other parties at the bargaining table also benefit from the spokesman's participation. As his access increases, the variance of farmers' proposals decreases to the benefit of all risk-averse parties. Had the other negotiators been significantly more risk averse than the farmers, their gain from the reduction in risk might have exceeded the farmers' gain, inducing, possibly, a *decline* in farmers' solution payoffs as the spokesman's access increased.

In contrast to CPCQ, each farmer in regime CPIQ or IPCQ has ample opportunity to pursue his own interests at the expense of other farmers. He does so by proposing either low quotas (in CPIQ) or high prices (in IPCQ) for other farmers and either a high quota or a low price for himself. We refer to this individually rational pursuit of self-interest as *beggar-thy-neighbor* behavior. Its implications, explored hereafter, are subtle and diverse and vary depending on the regime and hydrological conditions. As noted earlier, much can be learned by comparing the spokesman's proposal in the final round of bargaining to the average of farmers' individual proposals in that round.

In the discussion of regime CPIQ that follows, we consider three kinds of averages. For a given *farmer*, we consider the mean of the three subbasin quota proposals made by that farmer and refer to this as the *farmer's mean quota*. For a given *subbasin*, we examine the average of the three farmers' quota proposals *for that basin* and refer to this as an *average subbasin quota proposal*. Each average subbasin proposal is compared to the spokesman's proposal for that basin. Finally, we examine the average of these subbasin averages and refer to this as the farmers' *overall average* quota proposal. This last scalar is compared to the average of the quotas that the spokesman proposes for the three basins.

Regime CPIQ

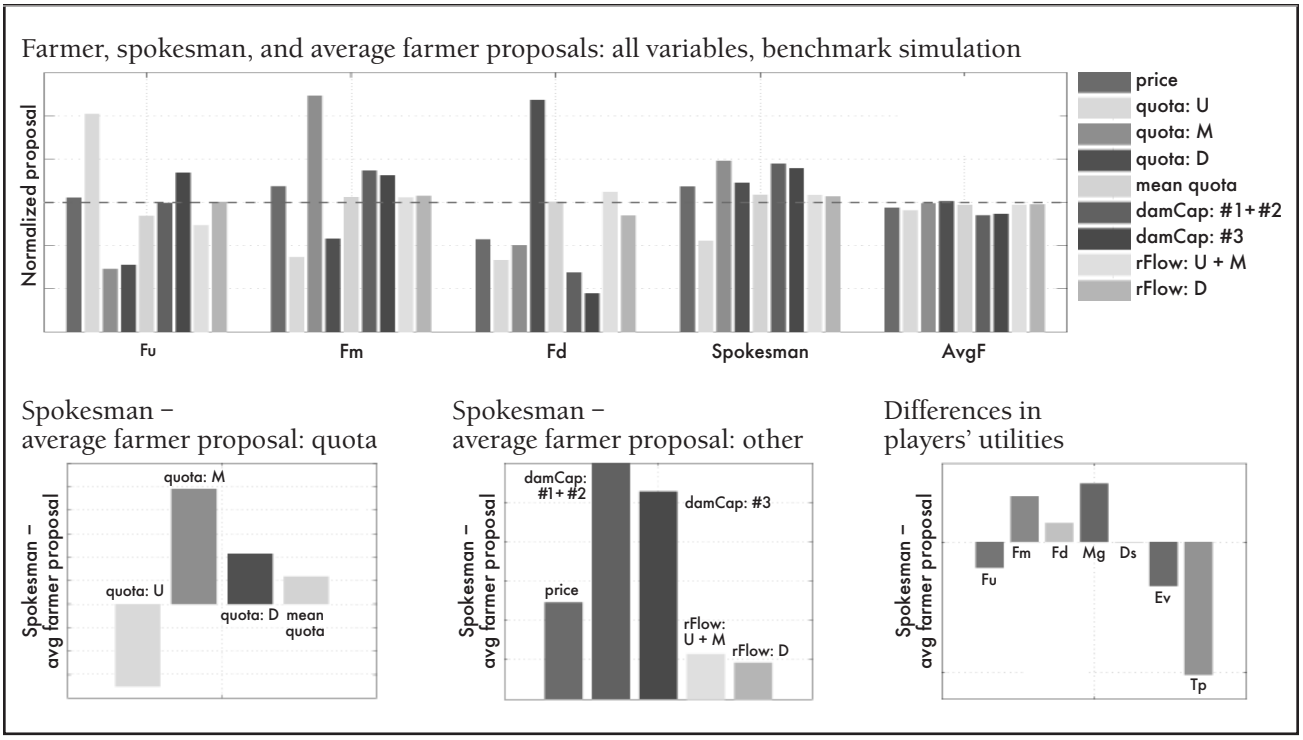
In regime CPIQ we focus exclusively on normal conditions since in this regime the spokesman's role is independent of hydrological conditions. In both cases the overall average quota proposal in the final round is inefficient from a coalition perspective because the differences between the average subbasin proposals do not efficiently reflect the different costs that quotas in different subbasins impose on the environment. To illuminate this inefficiency, Figure 5 compares the proposals made by farmers and the spokesman in the final round of bargaining under normal conditions. The upper panel of Figure 5 depicts graphically, from left to right, the final-round proposals made by each of the three farmers, the spokesman's proposal, and the average of the three proposals by farmers. The bar heights are normalized so that the height of each class of variable represents the player's proposal *relative* to the average of four proposals, consisting of the three proposals by individual farmers and one by the spokesman, e.g., farmer *i*'s quota for his own subbasin is represented as his proposal divided by the mean of all quota proposals by either farmers or the spokesman. Thus, a proposal is above (below) average if the corresponding bar is taller (shorter) than 1. From left to right, each cluster of nine bars represents the common price, three subbasin quota levels, the mean farmer quota, the average capacities for dams #1 and #2, the capacity of dam #3, the average of upstream and midstream residual flows, and downstream residual flows. (Recall that, while players do not explicitly propose residual flow levels, they are implied by the variables that are proposed.) Utility levels for Ds and Ev are determined, at least to a first-order approximation, by the right-most four bars in each cluster.

The lower left and middle panels of Figure 5 depict the difference between the spokesman's proposal and the average of the three farmers' proposals. In the lower left panel, the right-most bar compares the average of the quotas proposed by the spokesman to the farmers' overall average quota proposal. Each of the other bars compares the spokesman's proposal for some subbasin to the corresponding farmers' average subbasin proposal. The lower middle panel reports the differences for the remaining variables. The lower right panel reports the difference between players' payoffs from the spokesman's proposal and the average of their payoffs from the farmers' proposals. Since the experiment involves a shift in access away from farmers toward the spokesman, a player's participation constraint in the penultimate round will tighten (slacken) if and only if the player's bar in this panel is positive (negative).

Figure 5 illustrates a number of significant points. First, Fd's proposal is much more "efficient" than Fu's and somewhat more efficient than Fm's in terms of its impact on dam capacities and, therefore, prices. Specifically, while Fd's mean quota proposal is almost as high as Fm's and much higher than Fu's, the residual flows implied by Fd's proposal are roughly comparable with those implied by the other farmers' proposals; moreover, Fd's proposed dam capacities and, consequently, proposed common price are *much* lower. These differences arise because, whenever residual flows are reduced at some location along the river, flows at every measurement point downstream from that point are reduced as well. Thus, flow reductions from subbasin U imply matching reductions in subbasins M and D while reductions from subbasin D have no impact on the flows through subbasins farther upstream. For this reason, a unit of quota assigned to Fd has, very roughly, one-third the total environmental impact of a unit assigned to Fu. Consequently, Fd can "acquire" for his subbasin essentially the same total level of quotas as can the other two farmers but with much less dam capacity and, since prices rise with dam capacity, a much lower price as well. The remaining three points illustrated by Figure 5 are all closely related to the point just discussed.

Second, comparing the spokesman's proposal to the average of the farmers' proposals, observe that Fu is the clear loser: The spokesman's price is higher than the average price while the spokesman allocates a quota to Fu that is much lower than the farmers' average quota proposal for Fu. This difference can be traced

Figure 5. Farmer Proposals: Regime CPIQ, Normal Conditions, Final Round



to the relative environmental cost considerations noted previously: Quotas assigned to subbasin U are the most environmentally costly of all quotas.

Third, note from the top panel of Figure 5 that the spokesman can induce Ds to accept a higher overall average quota level than that proposed by the farmers at a slightly lower price. The spokesman can accomplish this because he allocates quotas across subbasins more efficiently than do the farmers. In particular, he discriminates against player Fu so that residual flows below the environmentally sensitive subbasin D are higher under his proposal than under Fm's proposal.

Fourth, while each farmer proposes a much larger quota for his own subbasin, there is little variation between the farmers' three average subbasin proposals. On the other hand, while the spokesman's quota allocation is more evenly distributed across farmers than is any individual farmer's, it is much less evenly distributed than the average subbasin proposals. Once again, this reflects the fact that the spokesman's proposal efficiently balances the relative environmental costs of assigning quotas to different farmers against the relative benefits that farmers derive from them.

The question arises: Why do individual farmers not take into account at least the relative environmental costs of assigning quotas to *other* farmers? For example, why does Fm assign roughly equal quota levels to Fu and Fd? The explanation can be traced to beggar-thy-neighbor behavior: Unlike the spokesman, each individual farmer assigns to himself the highest possible quota; as a result, the heterogeneity bound on individual proposals (section 4.2) prevents him from optimally differentiating the quotas assigned to the other two farmers.

Our final observation relates to the lower middle and right panels of the figure. Relative to the farmers' average proposal, the spokesman negotiates significantly higher levels of dam capacities in exchange for slightly higher levels of residual flows. This trade-off leaves Ds indifferent because his participation constraint is binding in the final round but negatively impacts Ev who, relative to Ds, is concerned more about dam capacities and less about residual flows. Similarly, while Tp derives some benefit under the spokesman's proposal from the increase in residual flows, his primary concern is to reduce the tax burden; consequently, this benefit is more than offset by the negative tax implications of the increase in dam construction under the spokesman's proposal.

The end result of all these considerations is that, as the spokesman's access increases, there is an increase in Fm's and Fd's expected utilities conditional on reaching the final round of bargaining. Mg's expected utility increases as well because of the additional dam construction under the spokesman's proposal. Because his participation constraint is binding on the spokesman as well as all farmers, Ds is unaffected in this round by the participation of the spokesman. (In earlier rounds, however, his utility declines.) Ev's, Tp's, and Fu's expected utilities decline. Under normal conditions, these qualitative effects are all reinforced as we move backward up the inductive chain to the solution of the game. Under drought conditions, the effect of the spokesman's participation on the solution is comparable except for a couple of relatively insignificant differences.

Regime IPCQ

In our discussion of regime IPCQ, we again refer to several different averages. We maintain a parallel terminological convention to the previous one, distinguishing this time between the average subbasin price, the farmer mean price, and the overall average price. We also compare the average common quota proposed by farmers to the common quota proposed by the spokesman.

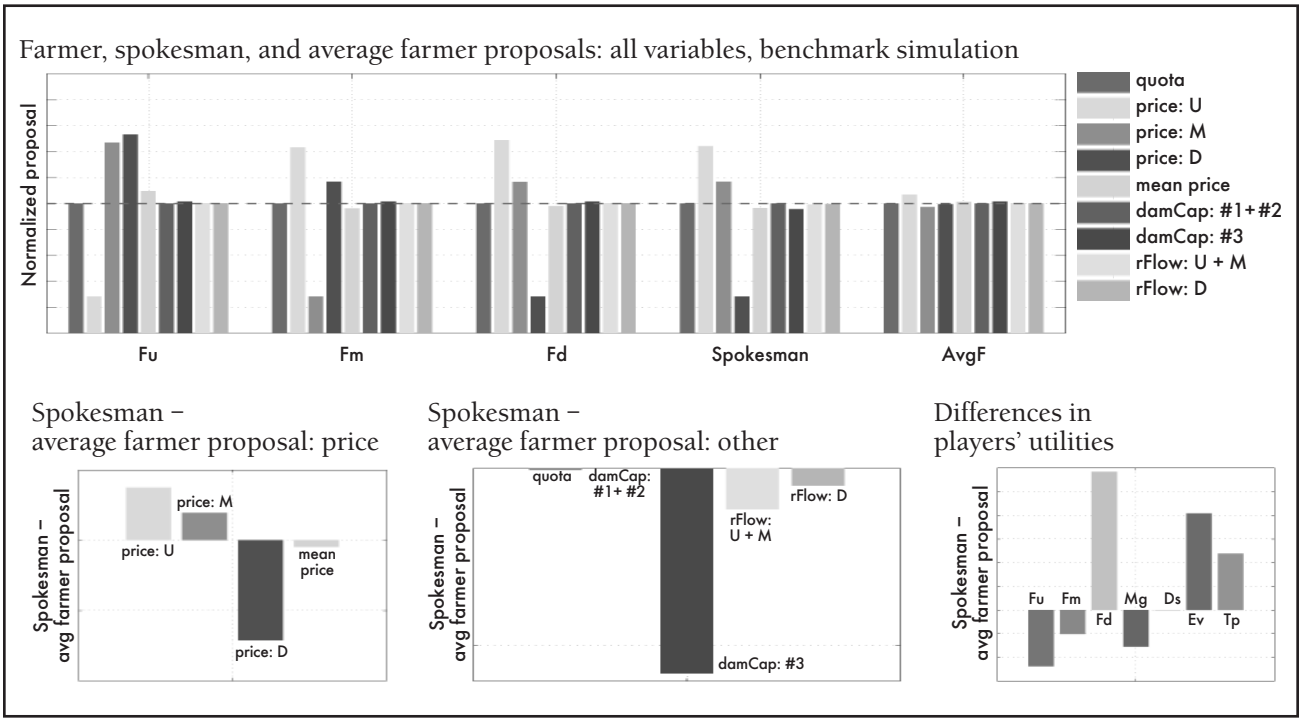
In contrast to regime CPIQ, the qualitative impact of the spokesman in this regime depends very much on hydrological conditions. Once again, the similarities and differences are revealed by an examination of the final round of bargaining. The details of the following discussion can be summarized as follows. Under both drought and normal conditions, individual farmers pursue collectively inefficient beggar-thy-neighbor strategies, proposing low prices for themselves and high prices for others. In both scenarios the spokesman's participation mitigates this inefficiency. There is, however, a second impact of the spokesman's involvement. In normal conditions it is a negative one for farmers that dominates the benefit of the first impact. Specifically, the spokesman's common quota proposal is greater than the farmers'

average common quota in drought conditions, while in normal conditions his proposal is less than this average. Since Ds's constraint is binding on all farmers and the spokesman and he dislikes the marginal quotas less than either Ev or Tp, these latter players are made worse off by the spokesman's participation in drought conditions and better off by his participation in normal conditions. Moreover, farmer Fm, who is strategically important in the sense we discussed in section 5.1, prefers the spokesman's proposal to the average of farmers' proposals in drought conditions while in normal conditions this preference is reversed. In each hydrological scenario, these attitudes toward the spokesman's involvement reinforce each other and initiate inductive chains that lead, ultimately, to diametrically opposed comparative statics effects for drought versus normal conditions.

To understand in more detail the differences between normal and drought conditions, compare Figure 6 with Figure 8. The two figures have the same structure as Figure 5 except that the locations of prices and quotas are exchanged. The bottom left panels of the two figures are qualitatively similar except for the price paid by farmer Fm. In both cases the farmers' overall average price proposal is higher than the spokesman's average price. On the other hand, the bottom middle panels of Figure 6 and Figure 8 are diametrically different. These panels depict the difference between the spokesman's and the average farmer's final-round proposals for quotas, dam capacities, and implied residual flows. Under normal conditions, the spokesman proposes lower levels for all of these variables; under drought conditions, his proposals are higher.

Our explanation of this difference begins with a detailed consideration of normal conditions (Figure 6). The difference between the average price proposed by the spokesman and the overall average price proposed by farmers can be attributed to beggar-thy-neighbor behavior by farmers. As discussed in section 5.1, farmers face an upward-sloping political supply schedule for quotas. As the top panels of the two figures indicate, each farmer assigns very high prices to others and proposes a common quota level that is individually optimal for that farmer to a first-order approximation[28] given the low price that he, himself, is required to pay. This behavior, while individually rational, creates negative externalities: Since each

Figure 6. Farmer Proposals: Regime IPCQ, Normal Conditions, Final Round



[28] A farmer does derive disutility from other farmers paying high prices. However, this disutility only arises as part of his second-order utility term. The results of this simulation demonstrate that the second-order utility term does not have a substantial effect.

farmer is more likely to be required to pay the high price assigned to him by some other farmer than the low price he has assigned to himself, he is, *on average*, trading quotas for prices at a rate that he would consider unacceptable if he were required to pay this rate with certainty. The spokesman internalizes this externality and purchases slightly fewer quotas. The qualitative properties of the lower middle panel now follow from the familiar linkage between quotas and prices: When quotas are reduced, the capacity of dam #3 can be reduced as well so that budget balance can be maintained with lower prices.

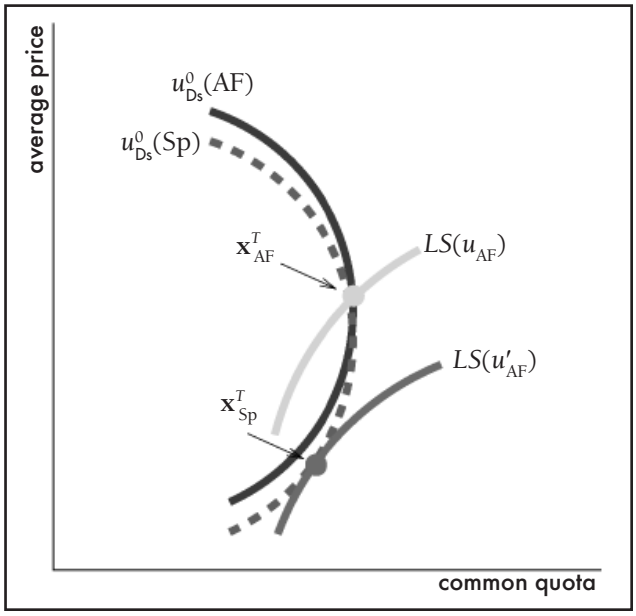
The comparison between the spokesman's proposal and the farmers' is illustrated by Figure 7, which depicts the level set, $LS(u_{AF})$, of the average farmer utility function passing through the overall average farmer proposal labeled as x^T_{AF}. Reflecting the fact that, on average, farmers are overpaying for the marginal quota, this level set is less steeply sloped at x^T_{AF} than the induced level set in price-quota space (see section 4.2) for Ds, whose participation constraint binds on farmer proposals in the final round. As it turns out, each farmer proposes the dam configuration that is globally optimal from Ds's perspective, given the common quota level, so that Ds's participation constraint, denoted by $u^0_{Ds}(AF)$, is vertical at the overall average farmer proposal.

Relative to the average farmer, the spokesman obtains efficiency gains in two respects. First, he rationalizes the distribution of prices across farmers: efficiency dictates a shift in the price burden toward Fu, who has the most irrigated area and, hence, the greatest revenue leverage, and Fm, who has the highest willingness to pay. With this adjustment, a given quota level can be achieved at a lower average price so that Ds's induced participation constraint in price-quota space, $u^0_{Ds}(Sp)$, shifts downward relative to $u^0_{Ds}(AF)$. Second, he internalizes the externality that farmers were imposing on each other by beggaring their neighbors, equating Ds's marginal rate of substitution (MRS) of prices for quotas with that of the average farmer. The net effect of these changes is that the spokesman proposes the vector x^T_{Sp} and thus obtains the higher utility level, u'_{AF}, for the average farmer.

The utility implications of these differences for each player are reflected in the bottom right-panel of Figure 6. While farmers benefit *on average* from the spokesman's involvement (a slightly lower quota at a significantly lower overall average price), the distribution of benefits is highly skewed: Fd benefits hugely from the spokesman's redistribution of prices while both Fu and Fm are negatively impacted. Mg's budget is unaffected by the spokesman's involvement (since his budget constraint binds), but his utility is negatively impacted because he prefers larger dams to smaller. Apart from Fd, the other beneficiaries from the spokesman's participation are Ev and Tp. Relative to the overall average farmer proposal, the spokesman reduces dam size (hence, lowering prices) in exchange for lower residual flows at an exchange rate that leaves Ds indifferent. Compared to Ds, however, Ev and Tp have a relative preference for smaller dams (steeper induced MRSs in quota-price space) so that, at the exchange rate that leaves Ds indifferent, both Ev and Tp benefit from the trade.

We now turn to drought conditions (Figure 8). Once again, farmers Fu and Fd beggar their neighbors. In this case, however, Fm's capacity to beggar *his* neighbors is limited by hydrological and technological constraints. As explained in section 4.2, farmers can acquire quotas in this regime *only* by increasing the size of dam #2; moreover, the "cost" of quota increases in terms of dam increases is significantly higher when the hydrology constraint on subbasin M binds. As a result, farmer Fm, who has the highest willingness to pay for quotas, is obliged to propose the

Figure 7. Regime IPCQ, Normal Conditions

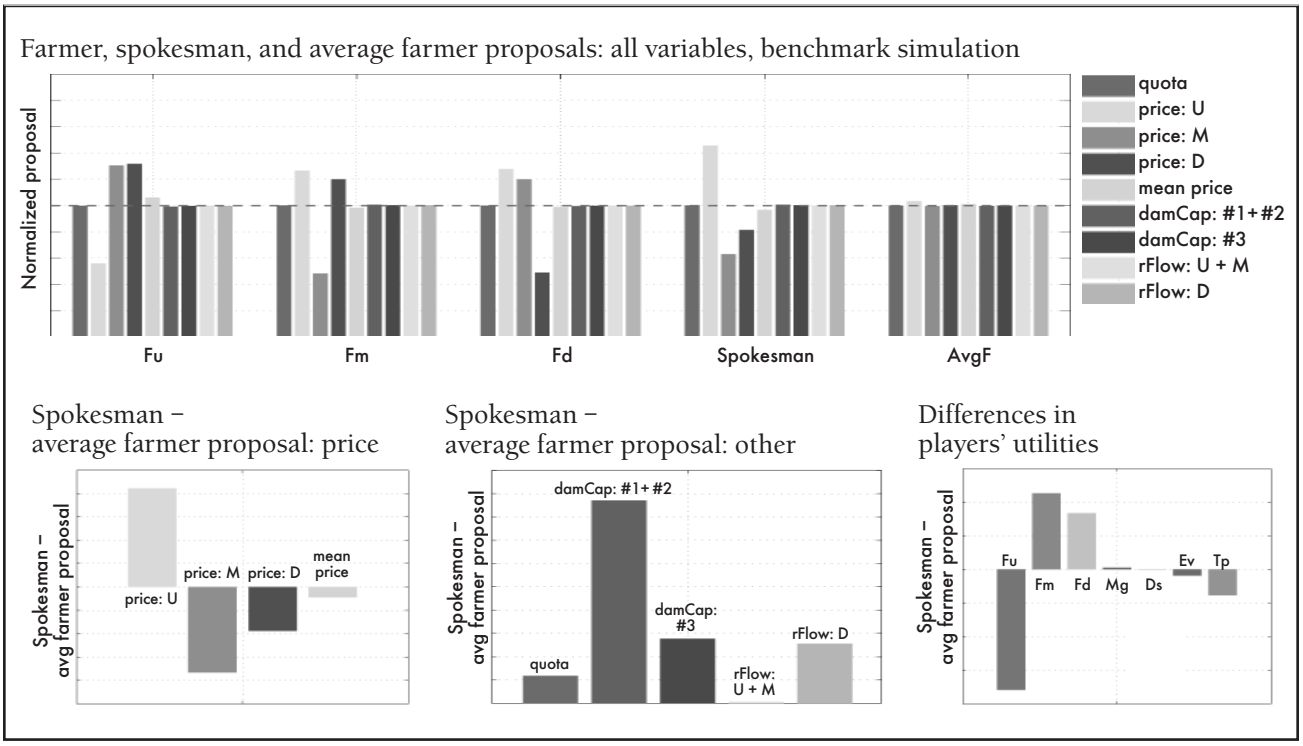


maximum feasible size for dam #2 in order to satisfy the hydrology constraint in drought conditions and is unable to achieve the quota level that is optimal for him when he beggars his neighbors, subject only to the heterogeneity constraint in normal conditions. Even though the other two farmers, who are not capacity constrained, overspend on quotas in the way we would anticipate, the capacity constraint on Fm binds sufficiently tightly that the farmers' overall average quota proposal is actually *suboptimal* from the average farmer's perspective.

In contrast to normal conditions, the result is that the indifference curve of the average farmer utility function passing through the overall average farmer proposal is *steeper* at this point than Ds's participation constraint. That is, because of Fm's technological constraint, the *average* farmer would in this instance choose to buy *more* quotas than he is purchasing under the overall average farmer proposal (see Figure 9). Once again, the spokesman achieves two kinds of efficiency gains relative to the average farmer. As in normal conditions, he rationalizes the distribution of prices across farmers so that a given quota level can be acquired at a lower average price. But, in contrast to normal conditions, he now proposes slightly *more* quotas than the average farmer.[29] The implications of these differences are reflected in the bottom right panel of Figure 8. In all critical respects (Fd and Fu are not critical), the signs are the reverse of those in Figure 6: Fm in this case prefers the spokesman's proposal to the average farmer's; Ds is unaffected by the spokesman's involvement because his participation constraint binds; Ev and Tp are negatively rather than positively impacted because quotas increase rather than decrease; and Mg's budget remains in balance but benefits from the increase in dam capacity.

Now compare the implications of the bottom right panels of Figure 6 and Figure 8 for the penultimate and earlier rounds of bargaining. We begin with normal conditions. Except for player Fd,[30] whose strategic

Figure 8. Farmer Proposals: Regime IPCQ, Drought Conditions, Final Round



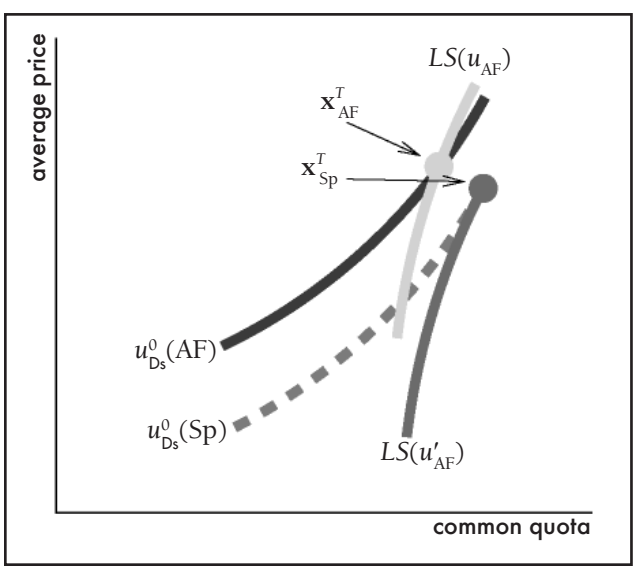
[29] Like Fm, Sp is unable to achieve a tangency with Ds's participation constraint because he has pushed dam #2 to its maximum feasible size.

[30] Fd is negatively impacted by the all of the changes in participation constraints; however, his benefit from the spokesman's rationalization of prices relative to the overall average farmer proposal is large enough to dominate all these negative effects. But, since Fd's participation constraint is never binding in the critical final rounds of bargaining, these effects do not impact the outcome of the bargaining.

role is minimal in this scenario, the qualitative effects reported on all of the players are reinforced by secondary effects in the penultimate round: Tp's participation constraint, which is binding on all farmers in this round, becomes tighter with the spokesman's involvement and this weakens all farmers' proposals. The constraints that bind Mg are Ev's and Tp's, so his proposal is weaker as well. Fm's constraint, which is binding on all nonfarmers, becomes slacker as the spokesman's access increases and this strengthens all nonfarmers' proposals. These qualitative penultimate-round net effects are all transmitted back to the solution of the game: As the spokesman's access probability increases, all nonfarmers gain while Mg and all farmers except Fd lose.

Under drought conditions, Fm's and Mg's penultimate-round participation constraints become tighter as the spokesman's access increases; since both players' constraints are binding on the antifarmer group, this group does worse in the penultimate round as the spokesman's access increases. On the other hand, Ev's constraint becomes slacker while Ds's is unchanged, and this benefits all farmers. For Fm and Fd, this effect reinforces the positive effects that occurred in the final round and occur in this round as well. For Fu, however, the negative impact of the redistribution of the price burden dominates the benefit from Ev's slacker constraint and the net effect of the spokesman on this player is negative. These effects are transmitted backward through the inductive chain so that in the solution to the game all members of the antifarmer group are negatively impacted by the spokesman's involvement while Fm and Fd benefit. Fu is negatively impacted. Because subbasin U has the largest irrigated area, the spokesman "sacrifices" Fu by assigning him a very high quota price.

Figure 9. Regime IPCQ, Drought Conditions



Summary and Discussion

The qualitative comparative statics results we obtain in this experiment reveal that, in negotiations where there is significant scope for divergent behavior among coalition members (i.e., our regimes IPCQ and CPIQ), the intervention of a spokesman will usually, but not necessarily, benefit the coalition as a group. In the experiments we consider, the impact of the spokesman's participation on the coalition's equilibrium payoff depends, basically, on two factors: his impact on the expected quota proposal and on Fm's expected utility conditional on reaching the final round of bargaining. The expected quota proposal is important because it impacts, through its effect on dam capacities and residual flows, the well-being of the nonfarmer players Ev and Tp, whose participation constraints are slack in the final round but bind in all earlier rounds. Any proposal that leaves Ds indifferent makes these two players better off. Fm's conditional expected utility plays a pivotal role for precisely the reason that we identified in the stripped-down context of section 5.1: Because Fm's constraint is binding on the antifarmer group in the penultimate round of bargaining, Fm's performance in the final round is a primary determinant of all farmers' expected performance in the penultimate and earlier rounds. In all the experiments we report here, these two effects reinforce each other. For other parameterizations, however, this need not be the case, at which point our analysis of the spokesman's impact would require much more delicacy.

It is significant that, when the coalition does benefit from the spokesman's participation, it does so only because he can discriminate against one of the coalition members. As we have observed, Fu is always the target of discrimination by the spokesman since the constraints that bind him will be relaxed by a mean-preserving perturbation in subbasin prices (quotas) involving an increase (decrease) in Fu's price (quota). In IPCQ, a unit increase in Fu's price raises

more revenue than a unit increase in either one of the other farmers' prices. In CPIQ a unit increase in Fu's quota requires a larger increase in dam capacity than a unit increase in either one of the other farmers' quotas. Hence, the spokesman, whose task is to maximize the sum of farmers' utilities, assigns a higher price and lower quota to Fu. Anticipating this discrimination, we would expect that Fu would not agree to the appointment of a spokesman of the kind we model. (Of course, whenever the farmer group does better on average with the spokesman, Fu could in principle be sufficiently compensated with side payments that all coalition members would benefit from the spokesman's participation.)

Our spokesman experiment illustrates dramatically the extreme sensitivity of our results to the importance of factors that one would not necessarily anticipate in the absence of a computational model. We observed that all of our comparative statics results are reversed in regime IPCQ when hydrological conditions change from normal to drought. We traced this reversal to the apparently inconsequential fact that, in the final round of bargaining under drought conditions, Fm proposes the maximum feasible capacity level for dam #2. This single technological constraint limits the extent to which Fm can squander the other farmers' money and a chain of significant consequences follows.

We emphasize this example because it highlights the complex, delicate, and highly nonlinear nature of player interactions when they negotiate with each other in an environment characterized by high dimensionality and multiple "sharp edges," such as the present one. This environment contrasts sharply with the smooth, low-dimensional, stylized characterizations of the world that one is obliged to construct in order to generate analytical comparative statics results. While environments of the latter kind are more elegant and transparent than ours and more likely to yield robust results, in many instances the cost of these positive attributes is that the simpler models fail to reflect the full richness of economic actors' interactions, either with each other or with the institutional contexts within which they must operate. In the experiment we have just discussed, a technological constraint that might have been assumed away in order to construct a simplified model with analytical comparative statics results proved to be an important determinant of the negotiated outcome.

Finally, our results in regime IPCQ provide a counterexample to the intuitively self-evident conjecture that the spokesman's participation will always benefit the farmer coalition. It is true that, when members of this coalition pursue their individual self-interests, the expected result of their activities will generally be suboptimal from the perspective of the coalition as a whole. For example, each farmer in IPCQ proposes a higher quota level than he would have proposed if he were required to pay his fair share of quota costs.[31] The conjecture mentioned is intuitively obvious precisely because we would expect the spokesman always to internalize any negative externalities arising from beggar-thy-neighbor behavior by individual farmers. Indeed, the spokesman does exactly this. Our conjecture fails in regime IPCQ, however, in part[32] because the externality that is negative in this narrow sense turns out to be positive in a broader sense—beggar-thy-neighbor behavior hurts Ds, Ev, and Tp more than it hurts the farmers and, in fact, *benefits* the manager—so that the farmer coalition's equilibrium performance actually declines when the spokesman internalizes it. On reflection, this result should not be at all surprising: A fundamental lesson from game theory is that behavior that is suboptimal by decision-theoretic criteria can, in a game-theoretic context, increase a player's equilibrium payoff relative to behavior that is decision-theoretically optimal.[33]

5.3. Limiting Dissention: Reducing the Degree of Proposal Heterogeneity

As we observed in section 5.2, the spokesman's role was essentially negligible in regime CPCQ but significant in the other two regimes. It seems probable, therefore, that, in regimes IPCQ and CPIQ, reducing

[31] We reiterate that it is the *political* supply schedule for quotas that is upward sloping.

[32] A second factor is that, while the spokesman enhances *average* farmer utility, in normal conditions he reduces Fm's utility and it is Fm's utility rather than farmers' average utility that matters in the final round of the game.

[33] See, for example, the vast literature on reputation building beginning with Kreps and Wilson and Milgrom and Roberts.

the degree of permissible heterogeneity among player proposals will have similar effects. As we have noted above in our earlier discussion of the bargaining space, players in our base-case scenarios for regimes IPCQ and CPIQ are constrained in the extent to which they can pursue their own subbasins' interests at the expense of other subbasins. Specifically, in regime CPIQ (IPCQ), the specification of the bargaining space includes an upper bound on the standard deviation of the three quotas (prices) proposed by any player. In this section we explore the impact of successively relaxing these bounds, again restricting our attention to the case in which, in the final round of bargaining, Ds's constraint is binding on all farmers and on Mg.

A natural conjecture arising from section 5.2 is that farmers' utilities will increase or decrease on average as these restrictions become tighter, depending on whether the average farmer benefits from the participation of the spokesman. In regime CPIQ, for example, we observed from the spokesman experiment that self-interested, beggar-thy-neighbor behavior by individual farmers served to weaken the performance of the farmer coalition. In the present experiment, we test the conjecture that, when we successively tighten our bound on the extent of heterogeneity among proposals and thus increasingly proscribe this kind of behavior, farmers will do better in equilibrium on average. It is less straightforward to make predictions for regime IPCQ since in this case the impact of the spokesman turned out to be counterintuitive under normal conditions. Even so, it still seems intuitive that, when we limit the extent to which each farmer can favor his own subbasin at the expense of the others, farmers will again do better on average.

Except for one of the four scenarios we discuss in this section—CPIQ, normal conditions—these conjectures are not supported by our simulation experiments. In regime CPIQ, farmers benefit on average when the heterogeneity bound is tightened under normal conditions but do worse when it is tightened under drought conditions. In regime IPCQ under both normal and drought conditions, the average farmer does monotonically worse as the bound tightens. Moreover, an analysis of our simulation results reveals that the forces driving our comparative statics results are quite different from the ones we anticipated.

Why in regime CPIQ are farmers positively impacted by a tighter bound in normal conditions but negatively impacted in drought conditions? To answer this question, we focus, as usual, on the final round of negotiations. We restrict our attention to farmer Fd, for whom the effect of hydrological conditions is most dramatic. In the discussion that follows, it is important to keep in mind the topography of the Adour Basin (see Figure 2 in section 4.2), noting in particular that both Fd's quota allocation and the capacity of dam #2 affect residual flows only below subbasin D.

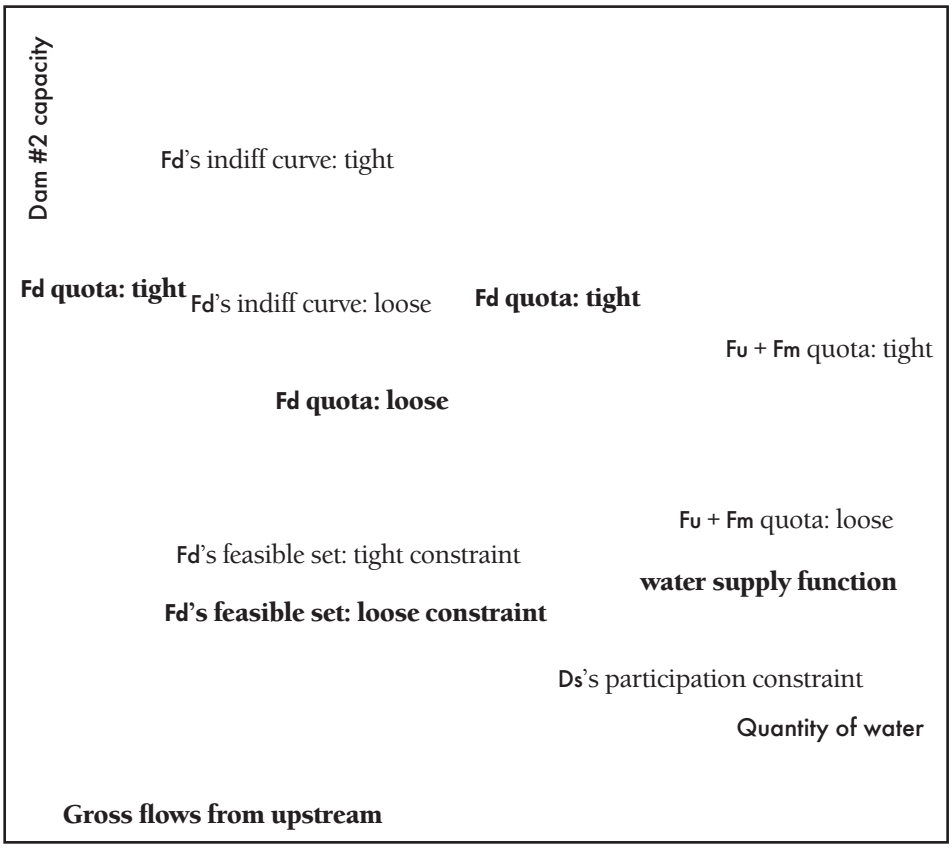
In section 4, we discussed how to project players' preferences onto price-quota space in regime CPCQ. We now extend this discussion to the more complex situation that arises in regime CPIQ. Figure 10 collapses Fd's optimization problem down to two dimensions. The curve labeled "water supply function" maps the proposed capacity of dam #2 (on the vertical axis) to water flows *gross of farm quotas* below subbasin D (on the horizontal axis). Nonfarmers care about *residual* water flows, which are gross flows minus any quotas allocated to farmers. The curve labeled "Ds's participation constraint" is the level set of Ds's utility function at his default utility, representing his willingness to trade off dam size against residual flow. The slope of Ds's level set is steeper than the slope of the "supply function" if and only if the increase in residual flows resulting from an expansion of the dam's size increases Ds's utility at a faster rate than the rate at which Ds's utility declines because he dislikes dams. For any given capacity for dam #2, farmer Fd can assign quotas that sum to the horizontal distance between Ds's level set and the water supply function. The heterogeneity constraint restricts the fraction of this distance that Fd can assign to his own subbasin. In Figure 10 the heterogeneity bound determines the lengths of the solid, horizontal, double-ended arrows (Fd's quota) *relative* to the lengths of the dotted arrows (Fm and Fu's quotas). As the constraint tightens, this fraction shrinks. The key point of the figure is that, since each farmer naturally assigns the largest fraction of total quotas to his own subbasin, a tightening of the heterogeneity bound means that *aggregate* quotas must be increased in order to deliver to a given farmer the same quota level he was receiving initially. It necessarily follows that as the heterogeneity bound tightens

there is an increase in the tension between farmers and those stakeholders who value residual flows.

Since, *ceteris paribus*, the capacity of dam #2 determines the common quota price through the administrative budget constraint, we can reinterpret Figure 10 to represent the trade-off facing farmer Fd, which is essentially between quota and price. When considering Fd's options, mentally relabel the vertical axis as the quota price implied by the given dam capacity and the horizontal axis as quotas and then interpret all curves associated with Fd as either opportunity sets or indifference curves in price-quota space. Assuming that quotas are optimally divided among farmers Fu and Fm from Fd's perspective, we can trace out the frontier of the choice set available to Fd. For our baseline case, this is indicated by the solid line labeled "Fd's feasible set: loose constraint" when the constraint tightens the feasible set contracts, as indicated by the dashed line labeled "Fd's feasible set: tight constraint." Note that the feasible set is "backward bending" if and only if, at the margin, Ds's dislike of dam #2 exceeds his fondness for residual flows. The solid and dashed lines labeled "Fd's indifference curve" indicate the indifference curves determining the location of Fd's optimal proposals both before and after the heterogeneity constraint tightens. The tangency points, indicated by oval-shaped dots, are characterized by the property that the marginal cost to Fd—incurred because the common quota price must increase to satisfy the administrator's budget constraint—of a further increase in the dam's size just offsets the marginal benefit to Fd from proposing additional quotas for his own subbasin, taking into account the increases in Fm's and Fu's quotas that he must also propose in order to satisfy the heterogeneity constraint. When the constraint tightens, Fd pays a higher unit price for fewer quotas, reflecting the fact that both quotas and the residual numeraire are normal goods.

It should be emphasized that the two-dimensional Figure 10 is only a partial representation of the problem being modeled. In particular, the location of Ds's participation constraint is *not* independent of the allocation of quotas among farmers. Consequently, it depends on the heterogeneity bound. Specifically, note in Figure 10 that pressure on upstream residual flows increases with the lengths of the horizontal dashed arrows but is independent of the lengths of the solid arrows. This implies that, when the constraint tightens while holding everything else in the figure constant, the line labeled "Ds's participation constraint" now represents a lower level of utility because Ds cares also about upstream flows. In other words, Ds's actual constraint moves to the right as the bound shrinks. Note also that, if farmer Fd were replaced in the figure by Fu, then the relationship between the heterogeneity bound and Ds's constraint would be reversed: In this

Figure 10. Farmer Fd's Problem, Normal Conditions



case, a tightening of the bound would shift Ds's constraint to the left.

We say that "drought conditions" apply when at least one of the hydrology constraints is binding. In our benchmark simulation of drought conditions, the hydrology constraints bind at the midstream and downstream measurement points; the upstream constraint is slack. When the heterogeneity bound tightens under these circumstances, farmer Fd is in an especially difficult position: To satisfy a tighter heterogeneity bound, he must reduce the quotas he assigns to himself and increase the quotas he assigns to upstream farmers. As we noted earlier, a one-to-one transfer of quotas upstream either doubles or triples the burden of satisfying residual flow requirements. Moreover, in our simulation, dam #1 is already at full capacity while dam #3 is already so large that the net marginal benefit to user Ds of increasing it still further is negative. Since dam #2 services only the downstream basin, farmer Fd cannot increase the supply of water to the upstream and midstream basins without *reducing* Ds's utility. (In contrast, in normal conditions, an increase in dam #3 creates a net surplus utility for Ds, which gives Fd room to maneuver.) Since Ds's participation constraint is binding, he must be compensated somehow for this loss. By a process of elimination, the only feasible way that Fd can provide this compensation is to reduce the mean quota allocation he proposes and to reduce the size of dam #2.

To summarize, Fd's response in normal conditions is to buy fewer quotas for his own subbasin at a higher price and to increase the size of dam #3 to accommodate the increased pressure on residual flows induced by the forced reallocation of the quotas he proposes. In drought conditions he has less room to maneuver and is obliged to *reduce* the size of dam #2. As we have discussed many times, when a farmer adjusts dam sizes and residual flows, he does it on terms that leave user Ds indifferent. But Ev and Tp dislike dams more than Ds—if they had been included in Figure 10, their participation constraints would have been flatter than Ds's—so that they benefit (suffer) whenever a farmer reduces (increases) a dam size.

We now broaden our discussion to include the other players, considering each scenario in turn. For the four cases we consider, the effects of the heterogeneity restriction in the final round of bargaining are summarized in Figures 11–15. The information conveyed by these figures parallels the information conveyed by the corresponding figures in section 5.2. The difference is that we compare farmers' proposals when we move from the tightest to the loosest specification of the heterogeneity bound instead of comparing farmer proposals to the spokesman's.

The Final Round of Bargaining: Regime CPIQ, Normal Conditions

Observe from the bottom left panel of Figure 11 that the overall average quota proposal declines as the bound tightens, although farmer Fu's mean quota proposal increases. From the lower middle panel, the mean common price proposal increases and there are increases in the means of farmers' proposed levels of both the capacity of dam #3 and the residual flow into the downstream subbasin. (In fact, Fu's proposed price declines while Fm's and Fd's increase, but these details are not apparent from the figure.) The utility comparisons are noteworthy: Farmer Fu benefits significantly, Fm moderately, and Fd slightly from the tightening of the constraint, while both Ev and Tp are negatively impacted. That is, each of the parties for whom the heterogeneity constraint binds actually benefits from a tightening of this constraint!

Why are farmers affected so differently by a tightening of the heterogeneity bound? The source of the difference has been alluded to already. When any farmer reduces the quota that he proposes for himself, residual flows increase at every monitoring point *downstream* of that farmer. Thus, when Fu is the proposer, a unit decrease in his own proposed quota generates, very roughly, three times the increase in residual flows that a corresponding decrease made by Fd would generate. Consequently, it is much less costly for Fu to satisfy the tightening heterogeneity bound than it is for either Fm or Fd. Indeed, it would be technologically feasible for Fu to satisfy the tighter constraint even leaving proposed dam capacities unchanged: He could do so by slightly reducing his own quota and significantly increasing the other two, thereby increasing residual flows at the upstream and midstream monitoring points and only slightly reducing the flow at the downstream point. Moreover, because this adjustment would increase the *aggregate*

number of quotas, the administrator's budget constraint could be satisfied at a *lower* common price. However, even this relatively minor adjustment is suboptimal for Fu. It is better for him to reduce his quota by a lesser amount, increase the other quotas by more, and offset the loss in residual flows relative to the previously discussed adjustment by slightly increasing the capacity of dam #3. For Fd, on the other hand, a quota adjustment exactly comparable to the optimal adjustment for Fu would result in very large losses in residual flows and, hence, would be infeasible. Fd must, therefore, significantly shrink his own quota, increase other quotas by much smaller amounts, and, to satisfy the budget constraint, increase the common price. Like Fu, Fd chooses to increase slightly the capacity of dam #3, which reduces slightly the amount by which he must shrink his quota, at the cost of an increase in the common price.

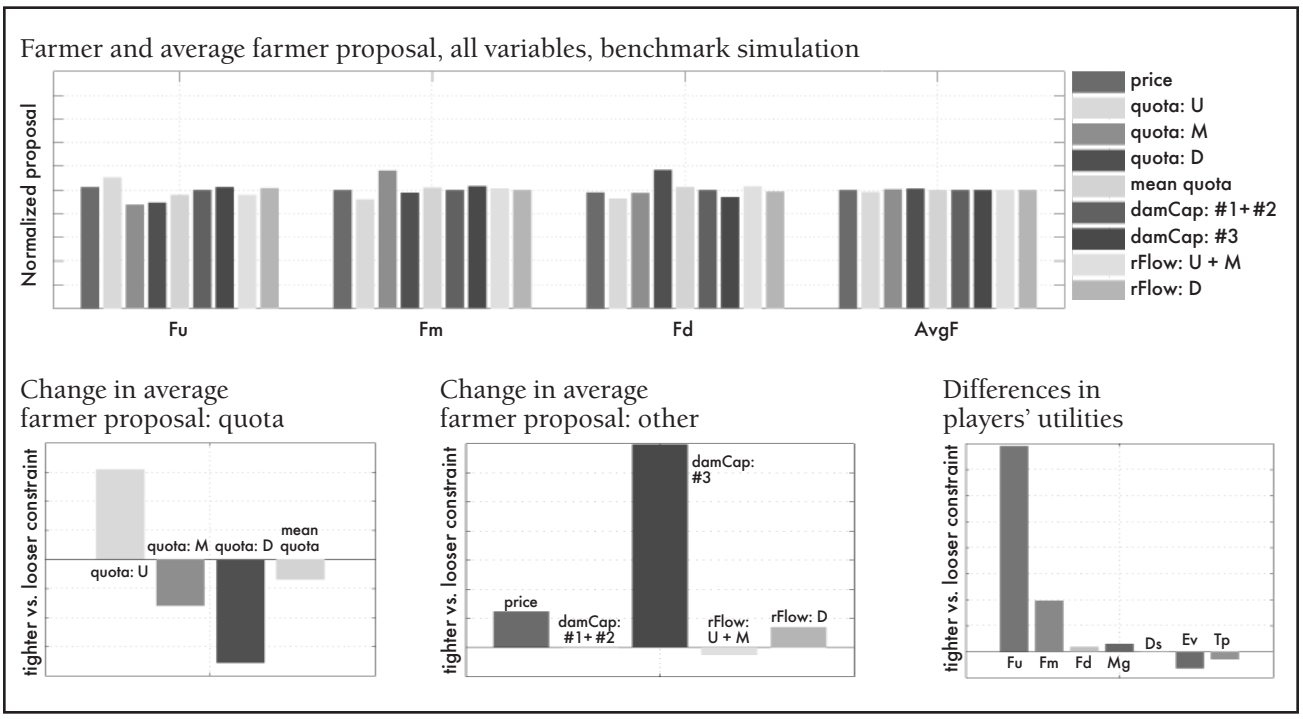
We now turn to the bottom right panel of Figure 11. Farmers benefit in expectation as the heterogeneity bound tightens because, as expected, they are *forced* to act in a less self-interested fashion. Each farmer fares worse from his own proposal but better from other farmers' proposals. The impact for a farmer is more favorable the farther upstream is his subbasin as explained in the preceding paragraph. It is difficult to infer either from the figure or from general principles why even farmer Fd should do better in expectation when the price he expects to pay increases and the quota he expects to receive decreases. We merely observe at this point that each farmer is negatively impacted by the tighter bound when he is selected to be the proposer but is positively impacted when another farmer is selected and that the gains are weighted more heavily than the loss because farmers are risk averse.

Since the tighter bound increases the average proposed size of dam #3 and residual flows below subbasin D, both Ev and Tp are negatively impacted for the usual reason. Thus, all of the effects observed in the final round reinforce each other as we move backward along the inductive chain so that, in the solution to the game, all farmers do better while all nonfarmers do worse as the bound tightens.

The Final Round of Bargaining: Regime CPIQ, Drought Conditions

Comparing the bottom left panel of Figure 12 with the corresponding panel of Figure 11, note that the average subbasin quota proposal increases by less under drought conditions than under normal conditions.

Figure 11. Farmer Proposals: Regime CPIQ, Normal Conditions, Final Round



The reason is that under drought conditions the tangency points represented by the dots in Figure 10 are now associated with impermissibly low residual flows. To satisfy the hydrological constraints in the benchmark case, the required dam capacities must be so high that even Ds derives negative marginal utility from further increases. When the heterogeneity bound tightens, the mitigation option that was

Figure 12. Farmer Proposals: Regime CPIQ, Drought Conditions, Final Round

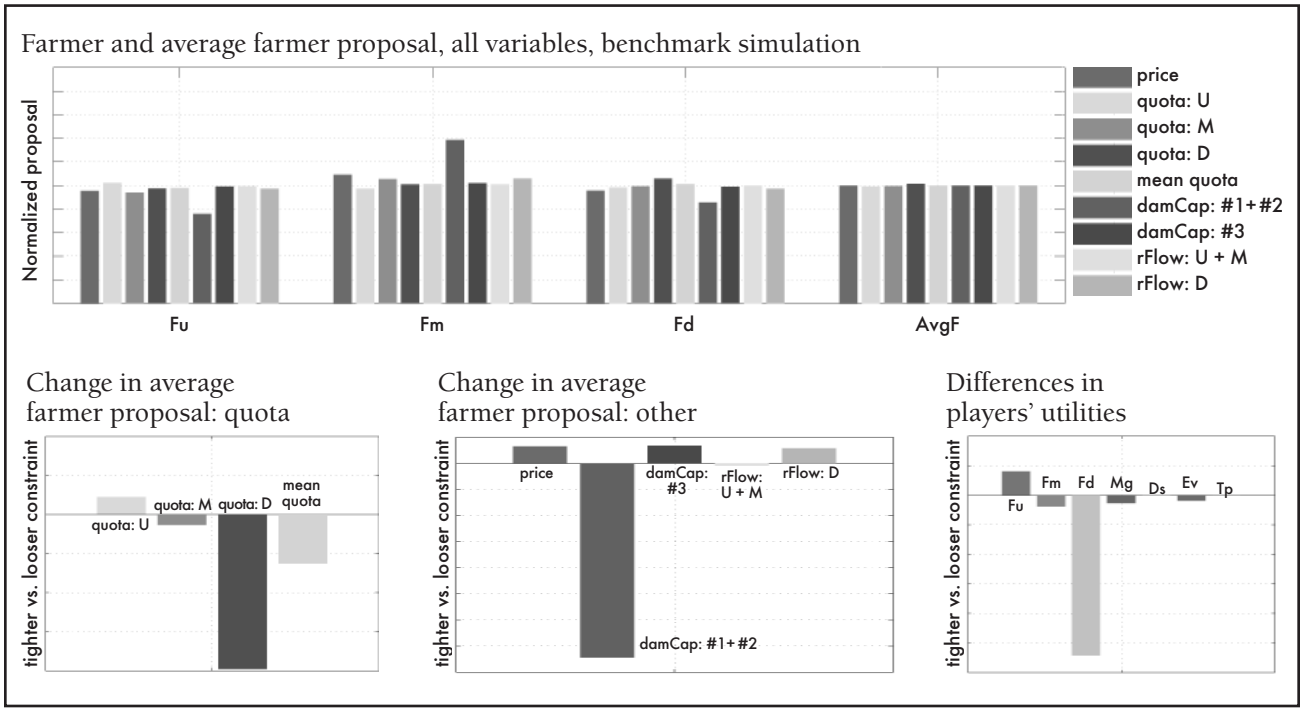
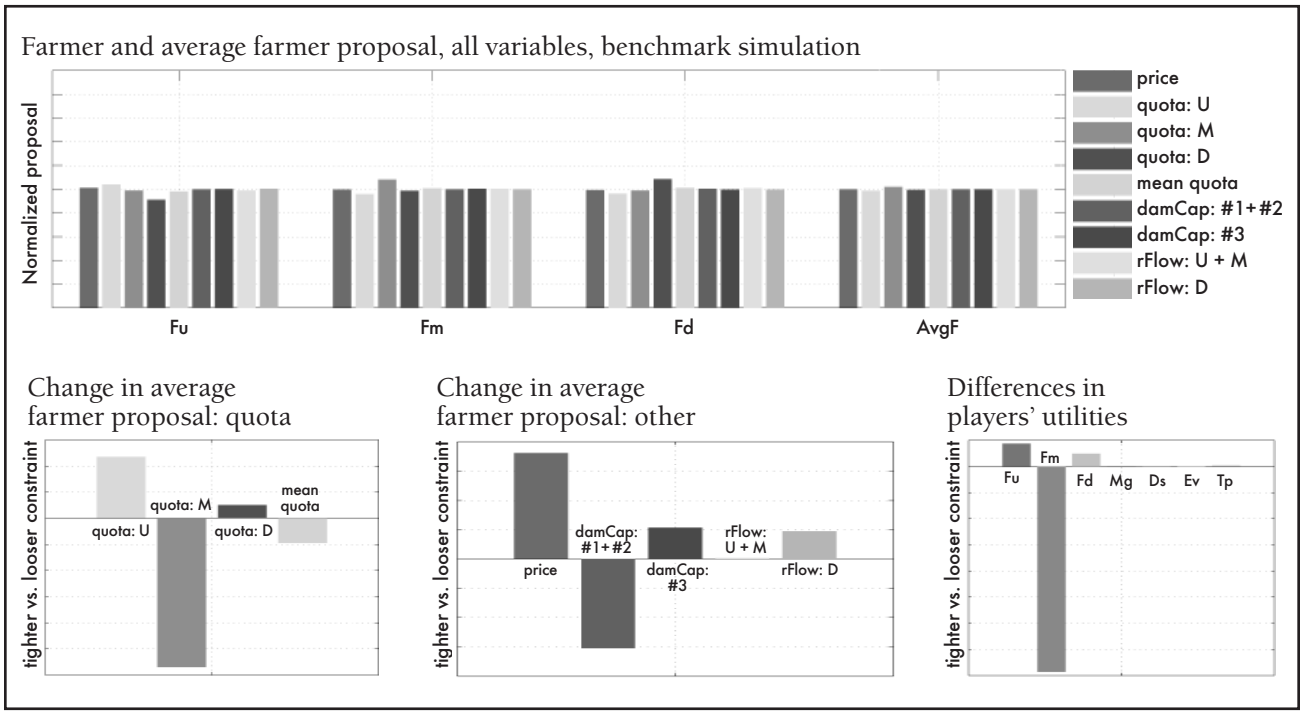


Figure 13. Farmer Proposals: Regime CPIQ, Drought Conditions, Third-to-Last Round

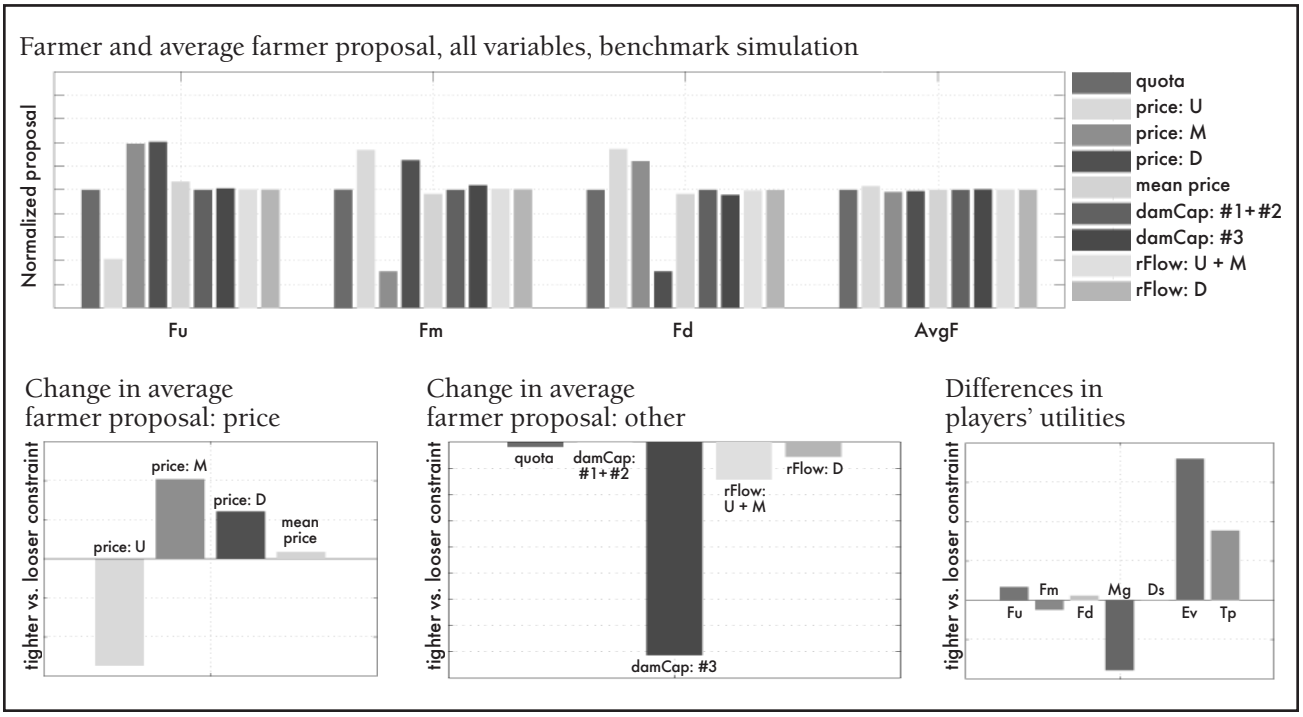


available under normal conditions—expand dams to accommodate Ds's residual flow requirement, thereby limiting the required reduction in mean quotas—is no longer such a readily available option for all farmers. In fact, as we have previewed already, Fd has no choice but to reduce his proposed size of dam #2 in order to satisfy Ds's participation constraint. The bottom right panel of Figure 12 reports the net effect of these changes on players' utilities, which is much less clear-cut than in the other cases we have considered. The key points to note are that all farmers' utilities are affected less positively (or more negatively) than under normal conditions (Figure 11) while the impact on nonfarmers is less negative. In this scenario the comparative statics impact of the change is indeterminate even in the penultimate round; by the third to last round, however, they are resolved (see Figure 13). The key characteristics of Figure 13 are that the overall average quota proposed by farmers is significantly lower and the common price is significantly higher when the bound tightens. Both the capacity of dam #3 and the residual flow in the downstream basin increase while the size of dam #2 is significantly smaller. Farmer Fm, who is strategically important in the sense we discussed in section 5.1, is significantly negatively impacted.

The Final Round of Bargaining: Regime IPCQ, Normal Conditions

It is interesting to compare the panels of Figure 14 to the panels of Figure 6, which summarize the corresponding scenario in the spokesman experiment. The lower middle panels of both figures are virtually identical. In both figures, the common quota level, dam capacities, and residual flows all decline, reflecting the fact that, as the extent of beggar-thy-neighbor behavior is limited either endogenously by the spokesman's behavior or exogenously by the tighter heterogeneity bound, farmers internalize to a greater extent the true cost of buying quotas. On the other hand, the overall average price declines in the lower left panel of Figure 6 while it increases in Figure 14. The reason for this difference is that, in contrast to the spokesman, each farmer is constrained by the heterogeneity bound from allocating prices efficiently even between the other two farmers, as in the discussion in section 5.2. In spite of this qualitative difference in the price effects, the effect on players' utilities (the bottom right panel of Figure 14) is qualitatively similar to the effect of the spokesman (Figure 6) in all respects except strategically unimportant ones. As the bound tightens, the strategically important farmer, Fm, pays a higher price

Figure 14. Farmer Proposals: Regime IPCQ, Normal Conditions, Final Round



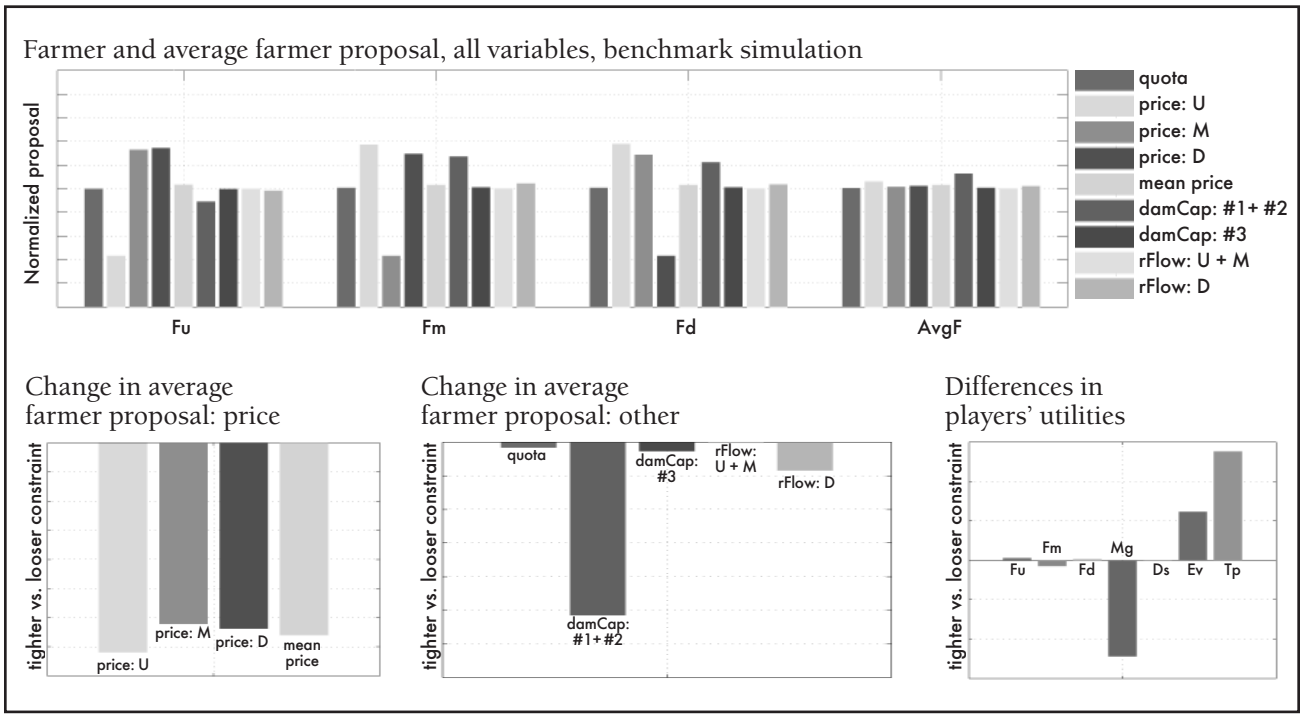
on average for a lower quota level and so is negatively impacted. Note also that, because dams and residual flows are reduced at a rate that leaves Ds indifferent, both Ev and Tp, who dislike dams more than Ds, once again benefit from these reductions. These effects all reinforce each other and are transmitted back to the initial round of the game. In the equilibrium, all members of the nonfarmer group benefit monotonically from the tightening of the heterogeneity bound. Farmer Fu, whose mean quota price declines significantly, benefits monotonically also while Fm, whose demand for quotas is the highest, and Fd both suffer monotonically. The *average* farmer's equilibrium welfare declines also.

To summarize, the comparative statics impact of tightening the heterogeneity bound in regime CPIQ depends on hydrological conditions. Ultimately, the decisive factor is the level of dam capacity in the benchmark case. Under drought conditions, significantly higher levels are required to meet hydrological constraints, to the point that Ds's aversion to dams at the margin dominates his appetite for residual flows. Consequently, when the heterogeneity constraint tightens in drought conditions and farmers are obliged to transfer quotas to their neighbors, the possibility of mitigating the impact by increasing dam size is no longer available. So dam sizes contract rather than increase, as in normal conditions, with the usual consequences. As we shall see hereafter, the role of the heterogeneity bound is quite different in regime IPCQ.

The Final Round of Bargaining: Regime IPCQ, Drought Conditions

The effect of the heterogeneity restriction under drought conditions is qualitatively similar to the effect under normal conditions. It is summarized in Figure 15, which is similar in many respects to Figure 14. One significant difference is that, under normal conditions, there is a slight increase in the overall average price proposed by farmers while this price declines under drought conditions. Another is that both dam capacities and quotas fall much more substantially under drought conditions than under normal conditions. However, these differences do not affect the end result. As in normal conditions, when beggar-thy-neighbor behavior is mitigated, the key beneficiaries are Ev and Tp, who benefit substantially from the reduction in dam sizes. The effects of these benefits are transmitted up the inductive chain and the solution impacts are the same as under normal conditions: All nonfarmers

Figure 15. Farmer Proposals: Regime IPCQ, Drought Conditions, Final Round



do better in equilibrium while all farmers except Fd, including the average farmer, do worse.

The equilibrium comparative statics in this case are the reverse of the ones we obtained in the corresponding experiment involving the spokesman (see section 5.2, especially Figure 8). In the current experiment, the primary impact of the tightening heterogeneity bound is to mitigate beggar-thy-neighbor activity and Fu and Fd both benefit from this. However, Ev and Tp both benefit also and to a considerably greater extent. By contrast, the spokesman not only mitigates beggar-thy-neighbor activity but also rationalizes the assignment of prices relative to the farmers' average assignment and, as a result, can obtain more quotas for less total expenditure as well as an increase in dam size. Though farmer Fu is sacrificed in the process, the strategically important farmer, Fm, benefits and Ev and Tp are both hurt.

Summary

There are quite striking and unanticipated differences between the comparative statics results in section 5.2 and section 5.3. We had expected both sets of results to be driven by the common design factor: The changes we introduced were each intended to mitigate, in expectation, the divisive tendency of each farmer to pursue his own self-interest at the expense of the farmer coalition. Indeed, this objective was accomplished in all of the experiments we considered: On average, in the final round of bargaining, the gap narrowed, at least in expectation, between the marginal benefit of acquiring an additional quota and the marginal cost of obtaining it. However, the equilibrium impacts of this accomplishment were quite different in the two sections. In all cases but one in section 5.2, the equilibrium payoff for the average farmer increased with the participation of the spokesman while those of nonfarmers decreased, providing a tentative confirmation of our conjecture that beggar-thy-neighbor activity would be a significant negative contributor to coalition performance.

The results of the experiment reported in the current section, however, suggest that determinants of bargaining success are in fact more subtle. When we tightened the heterogeneity bound, beggar-thy-neighbor activity was mitigated on average once again, yet in all but one case the average farmer's equilibrium payoff declined. Our comparison of the two sections revealed that the more significant contribution made by the spokesman was to rationalize the average allocation of quotas and prices across subbasins so that residual flows could be increased even as dam capacities were expanded. These increases in the final round proved to be important determinants of equilibrium improvement for the average farmer. Specifically, when both dam capacities and residual flows increased, the rates of increase were determined by Ds's preferences since, by construction, Ds's participation constraint was binding on all farmers in the final round. But rates of increase that leave Ds indifferent have a net negative impact on Ev and Tp, weakening the bargaining position of the nonfarmer coalition in the penultimate and earlier rounds.

6. CONCLUSION

This monograph presents a computational application of the Rausser-Simon MB framework to a rich environment that includes economic, hydrological, and strategic considerations. We used the model to explore the interactions between the structure of the bargaining process and the effective power of bargaining participants. Our results indicate a number of ways in which the structure of the negotiation process can be an important determinant of negotiation outcomes. For participants, there are a number of sources of bargaining power. The two direct sources are "access," modeled as the probability of being chosen to make a proposal, and "default strength," or how well the participant will fare if the negotiation does not result in an agreement. Our analysis identified a number of less direct sources of power, including "strategic location." In section 5.1, we showed in a stripped-down context that a coalition member's equilibrium performance is not necessarily monotone in increasing his access: There are circumstances in which a player can actually benefit in equilibrium when his access is transferred to another player whose strategic location is more favorable.

Our "spokesman" experiment demonstrated that the welfare of farmers as a whole typically increased when they were represented by a spokesman charged with the objective of maximizing farmers' average welfare. The spokesman improved average farmer welfare in three out of four scenarios. We identified two main reasons for this improvement. First, the spokesman mitigated, in an expected sense, the tendency of individual farmers to adopt beggar-thy-neighbor bargaining strategies: In our baseline parameterization for regime IPCQ, each farmer in effect purchased quotas with other farmers' money and consequently purchased more than he would have done had he been obliged to use his own money; in regime CPIQ, each farmer kept for himself a disproportionate share of the total number of quotas, thus lowering for himself the per-unit cost of quotas and raising it for others. Second, the spokesman rationalized the allocation of prices and quotas across subbasins. There were, however, winners and losers from this rationalization so that the spokesman's successes were always obtained at the expense of one of the farmers. This suggests that, in order to obtain the coalition's unanimous endorsement of a spokesman's participation, side payments would typically be required in order to compensate the losers.

Our "heterogeneity bound" experiment was designed to mimic the impact of the spokesman by limiting exogenously the extent to which farmers could engage in beggar-thy-neighbor behavior. Indeed, our exogenous restriction did limit this behavior; however, the equilibrium consequences of doing so were unexpected. We found in three out of four scenarios that farmers' equilibrium welfare actually declined as farmers were forced to act in a less selfish manner. The unanticipated lesson from this experiment was that, while farmers might collectively benefit from a restriction that obliged them to act less selfishly, "the opposition" might benefit even more so. (Recall that "acting less selfishly" meant purchasing fewer quotas and this benefited both Ev and Tp while leaving Ds indifferent.)

We conclude that the decisive contribution made by the spokesman was that he was more effective at distributing prices and quotas efficiently across subbasins than farmers were when they acted as self-interested individuals. A careful reading of section 5 suggests, however, that the implications for coalition performance of even this contribution are unlikely to be very robust. As we observed in section 5.2, farmer Fm was typically a beneficiary of the spokesman's efficiency improvements while Fu was typically a loser. Fortunately for the farmers, it was Fm rather than Fu who was strategically important in the sense we identified in section 5.1. Had the interrelationship between hydrological and agricultural conditions been different, Fu might have been the strategically important farmer, in which case the spokesman's participation might have had the opposite effect on equilibrium payoffs.

Linking our analysis to the real-world negotiation process it models, we can identify some potential reasons for the deadlock in the second stage of negotiations and some recommendations for altering the structure of the negotiation process in order

to increase the probability of its success. First, given that the interests of farmers are imperfectly allied, the selection of specific negotiation participants is an important consideration. However, the lack of robustness regarding the effects of the spokesman's participation on farmers' welfare does not provide firm recommendations regarding the selection process and the appropriate level of aggregation for farmers' heterogeneous interests. On the other hand, the results of the spokesman experiment suggest that the negotiation process should be expanded to allow for side payments among participants in order to increase efficiency while maintaining unanimity regarding the negotiation outcome. Second, an explicit specification of the permissible range of outcomes may facilitate agreement about allocating water across farmers in a manner acceptable to nonfarmer stakeholders; no such specification existed in the real negotiation process. Third, the only tool the water management agency can use in the real world to allocate limited water during a drought is to shut water off completely. This enforces consistency across farmers regarding their water use during a drought and likely was the primary cause of the failure to come to agreement regarding how to allocate limited supplies during a drought. If all irrigation was stopped in order to protect instream flows, the costs would vary widely across farmers, making it difficult for them to agree on any proposal that would simultaneously satisfy the other stakeholders. Our analysis illustrated the value of negotiating explicitly over quotas and prices for drought conditions separately from normal conditions. Doing so allows the farmers' quotas and prices to reflect the marginal value of the water in production they each have while simultaneously meeting hydrological constraints and satisfying the other stakeholders.

Overall, our analysis suggests that indirect sources of bargaining power may critically influence the outcome of a negotiation process. Comparing our results to the stalled Adour negotiation suggests that, when designing a negotiation process, policy makers must pay attention to the structural details that interact with these indirect sources of bargaining power in order to ensure that the structure will guide the stakeholders to an agreement.

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