Economic and Political Considerations in Regional Cooperation Models

Ariel Dinar and Aaron Wolf

Cooperation among players requires a realization of economic benefits to all players and a meeting of efficiency requirements through economically driven allocations. Cooperation among political (and sometimes hostile) players may not meet these requirements. Political considerations, usually ignored in economic analyses, can hinder or even block possible arrangements. A framework is proposed that includes both economic and political considerations for evaluating transfers or trades of scarce resources. This method quantifies both the economic payoffs using n-person game theory and the political likelihood of any of the coalitions actually forming, using the PRINCE Political Accounting System. The economic-political approach is applied to a case of a potential water transfer in the western Middle East. Results suggest that incorporating political considerations in the analysis stabilizes the regional solution suggested by economic-related allocations.

In evaluating joint actions among individuals, organizations, or countries, economists usually assume that players are economically rational, have freedom of choice, and, in the case of organizations or countries, that each "speaks with one voice." Then, economically optimal solutions to allocation problems, under rational behavior of the agents, can be found. Approaches include competitive, noncooperative, and cooperative solutions. For example, using n-person cooperative game theory in the characteristic function form, cooperation among players occurs if and only if there are economic benefits from cooperation realized by each player, by subcoalitions of players, and by the grand coalition that includes all players. This approach also fulfills efficiency requirements through economically driven allocations. Such analyses usually refer to a just and fair distribution of scarce resources or to gains from a transfer (redistribution) of scarce resources, or to construction of joint facilities and allocation of their costs among users.

Cooperation among political (and sometimes hostile) players may or may not follow the same lines suggested in game theory models. For example, Shubik (1982) concludes that modeling aggregates as a single player presents difficulties, especially in international politics, where representing a country as a single player can be dangerously misleading. Also, if the allocation is to be conducted among players with some level of hostility, political considerations, which are usually not incorporated in economic analysis, can hinder or even block the most efficient arrangement. These political considerations can impact relations among individuals, economic sectors, groups within a nation or state, or the nations themselves.

Often, particularly when a level of hostility exists among players, economic and political analyses of a possible transaction will reach different, and sometimes diametrically opposite, conclusions. For example, a suggested solution to the Ganges River Basin water allocation problem between India, Bangladesh, and Nepal (Rogers 1993) demonstrates the big economic advantages in regional cooperation. Perhaps political considerations not included in many of the suggested solutions, such as that of Rogers (1993), may explain in part why the continuous regional dispute over the Ganges water still has not been fully resolved among all riparians.

Dinar and Wolf (1994a) examined a possible international water transfer in the western Middle East. While economic findings suggested that greater welfare was associated with the participation of a larger number of players, a political evaluation suggested not only that the formation of

Ariel Dinar is senior economist at the Agriculture and Natural Resources Department,World Bank, Washington, D.C., and Aaron Wolf is assistant professor, Department of Geography, University of Alabama.

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larger coalitions was highly unlikely, but also that the most likely political course of action was the status quo, with no cooperation at all.

When acknowledging each other at all, economists and political analysts have usually sufficed with a passing comment or a footnote recognizing the concerns of the other. Here we distinguish between the "economic"—the efficient allocation of water in consideration of its benefits and costs—and the "political"—the organization of power to achieve some action in relation to the resource (often resulting in "inefficient" distribution). This paper proposes a framework by which both economic and political considerations are included in a unified model for evaluating allocation, transfer, or trade of scarce resources. This method quantifies both the economic payoffs of a number of possible coalitions and players, using n-person cooperative game theory, and the political likelihood of any of the coalitions actually forming, using the PRINCE Political Accounting System (Coplin and O'Leary 1983). By doing so, it might be possible to adjust the measure of efficient distribution by incorporating both the economic and political considerations of a potential transaction.

The next section discusses political considerations and their quantification. The following section presents several n-person game theory allocation concepts, used for resource allocation, and their rationales, drawbacks, and applications. The combined political-economic approach is developed in the fourth section and applied in the subsequent section to a case study wherein a potential water transfer in the western Middle East is considered. In order to alleviate detrimental water deficits among the riparians of the Jordan River, we examine the possibility of one or a series of water transfers from the Nile basin, where water-saving technology might be exchanged for the water that is saved. In this setting, we investigate both the political considerations that would lead to the coalitions necessary to implement the transfer and the economic results of each possible coalition.

While water is examined in the international setting, it should be noted that the method has potential application to a wide variety of resource allocation problems, regardless of the resource in question, the number or classification of players, or the political relations among them.

Water Conflicts and Politics

This section reviews the interaction between economic methods and some of the noneconomic tools that have been used in the literature to evaluate water scarcity issues. Noneconomic tools emphasize the importance of political or even aesthetic and emotional aspects of water allocation. The vast literature associated with the political aspects of water transfer is mainly restricted to specific case studies, with a limited economic interpretation regarding the water conflict.

LeMarquand (1977) provides a general conceptual framework for handling international river cooperation. The model identifies three sets of factors that establish general patterns of incentives and disincentives for cooperation. The three sets are the hydrologic-economic relations among the potential cooperators, the foreign policy of each potential cooperator (regarding relevant issues), and the domestic policy and consensus of each potential cooperator. The hydrologic-economic set can be viewed as a necessary condition for cooperation. Then foreign policy, which is affected by domestic policy and consensus, may decay or enhance this cooperation. This framework does not include an important set of factors: the power of a potential cooperator to prevent the establishment of other coalitions. Another potential drawback of this approach is its lack of quantitative measurements for the various factor sets and variables used. The model has been applied to four case studies.

Endtner (1987) measured differences in water-related cultural ideologies of Native Americans and Mormon anglers in order to explain the political economy of water development in Utah. Using a vector of cultural symbols and meanings of water for both parties, Endtner estimated the Robinson-Brainerd coefficient of similarity for nine topics concerning water ideology. The results suggest that the Mormons and the Native Americans agree to some extent on most practical uses of water but show dramatic differences on cultural and legal topics. The study concludes that the cultural ideologies of both Native American and Mormon anglers have biased their responses to reforms in water laws (e.g., water projects or water markets) in directions that are not economically desired by them.

An approach employing differences in beliefs and attitudes regarding water on the part of water users and regulatory-agency personnel is developed and applied in a case study of water-permit allocation in Florida (Lynne, Shonkwiler, and Wilson 1991). The model consists of several belief and attitude statements that provide measures on a Likert scale. The differences between the responses of the water-permit applicants and those of agency personnel to the belief and attitude statements are used to measure potential conflict. Although the approach provides a cardinal rating of conflict levels, it does not assign economic values to the activities of the players involved in the water allocation.

A Political Accounting System (PAS) to quantitatively and qualitatively predict interactions among entities (Coplin and O'Leary 1974, 1976, 1983) is also used in the political science literature. The first element of this system is the issue position, which expresses the strength of each participant's (player's) position for or against each of the issues. A second element is the power of a player to influence an issue, that is, the ability of each player to accomplish or to prevent the occurrence of particular outcomes on each issue. The third element in the PAS is salience, the importance each player attaches to a particular issue.

Two problems may affect the application of the PAS approach. First, the measure of the values to be included in the PAS is, in many cases, subjective, ordinal (although normalized), and possibly inconsistent. Second, this approach does not consider coalitional arrangements among the players. The approach does not guarantee an outcome that will satisfy all potential players since each player implicitly maximizes its own objectives (issues). However, the PAS does provide a baseline for comparison between possible political likelihoods of coalitional formations and is used here.

Naff and Matson (1984) and Frey and Naff (1985) apply a similar approach to water conflicts in the Middle East. Their approach consists of three components: (1) motivation to participate (potential benefits); (2) riparian position regarding the water; and (3) power to prevent any coalitional arrangement. Subjective weights ranging from one (weak) to five (strong) are assigned to each component for each party (player). A summation over the weights by entity provides the total ranking for the players involved. Interpretation of the results suggests that the more uniform the ranking, the higher the potential for conflict.

None of the approaches incorporates economic considerations into the cooperation process. There is also no attempt to evaluate the cooperative agreement (allocation of the joint cost or benefits) among the participants. Such approaches are therefore limited in their application.

We suggest here an approach that combines economic and political considerations while evaluating potential for regional cooperation. The suggested approach allows us to assess quantitatively both the likelihood of a given cooperative project to occur and the allocation of the associated benefits among the cooperators. The suggested approach combines game theory principles with political science assessment methods.

n-Person Cooperative Game Theory Approaches to Resource Allocation

Game theory is one approach extensively used to determine a fair and efficient allocation of common resources, costs, or payoffs. Fairness is addressed by allocating according to the contribution of a player to the incremental gains of the common (group, region, etc.).[1] The relevant game cost allocation methods have been discussed in many publications. Shubik (1982) provides a thorough review of various solution concept applications and their relevance to real world situations. He concludes that applications of game theoretic solutions may face difficulties in cases where there are diseconomies of scale, or where the price system does not exist. Dinar, Ratner, and Yaron (1992) evaluate the reasonableness and acceptability of cooperative game allocation solutions based on two extensive water resource case studies. Their main conclusions are that use of utility functions may lead to problems in gains allocation, and that the allocations are heavily dependent on probabilities of coalition formation in the case of the Shapley value and the generalized Shapley value.

Allocation schemes suggested in the literature on cooperative game theory in the characteristic form include the core (Shubik 1982), the Shapley value (Shapley 1953), and the generalized Shapley value (Loehman and Whinston 1976; Loehman et al. 1979). These schemes are relatively easy to implement (Young 1985) and were selected to be used in the case study discussed in this paper.

To set the theoretical framework for a regional allocation game, assume a resource such as a river or a groundwater aquifer that may be shared, under certain arrangements, among different users in the region. Using game theory terminology, the potential users are players, groups of the players are coalitions, and the various possible allocation arrangements are a game. Let N be the set of all the players in the regional game, S the set of all feasible coalitions in the game, and s ($s \in S$) a feasible coalition in the game. The noncooperative coalitions are $\{j\}, j = 1, 2, \ldots, n$, and the grand coalition is $\{N\}$.

Games may be of a cost nature or of a net income allocation nature. In both cases the incentive to cooperate is the lower cost or the higher net income to the player that is associated with cooperation. In the case of cost allocation, the objective is to minimize the joint cost, and in the case of

[1] The interested reader can find a comprehensive discussion on the application of game theort in Shubik (1982, ch. 12).

income allocation, the objective is to maximize the joint net income. In both cases the value of the game objective function is called the "value." Let f^s be the value of any coalition s of the region's players. In practice, f^s is maximized over the sum of all j players in coalition s and in any noncooperative coalition $\{j\}$ subject to available endowments of the joint resource:

(1) $$\max f^s = \sum_{j \in s} R^j \quad \forall s \in S.$$

Here f^s is the value of the objective function of coalition s, and R^j is the payoff function of player j while participating in coalition s. Arrangements can be made in the game to allow a player to use more of the resource and to compensate other players by side payments.

Regional cooperation, according to the above principles, is economically feasible if

(2) $$f^s - \sum_{j \in s} R^j \geq 0 \qquad \forall s \in S.$$

The Regional Cooperative Game

The regional optimization model in equation (2) can be interpreted as a cooperative game, with side payments, and described in terms of a characteristic function. The value of a characteristic function for any coalition expresses the coalition's gains, assuming efficient behavior of coalition members.

Equation (3) defines the characteristic function of a normalized game in which players of coalition s allocate only the additional net income derived from cooperation:

(3) $$v(s) = f^s - \sum_{j \in s} f^{(j)} \qquad \forall s \in S,$$

where $v(s)$ is the value of the characteristic function for coalition s in terms of incremental net income. It is assumed that $v(\{j\}) = 0$ for $j \in N$.

Allocation Schemes

The purpose of this section is to evaluate, using different allocation schemes, the acceptability, to the players, of the outcomes of the regional game when reallocation of regional cooperative gains is considered. At this stage no ideological or political considerations affect the creation of any coalition arrangement. Three allocation schemes will be considered: the core, the Shapley value, and the generalized Shapley value.

The Core. The core of an n-cooperative game in the characteristic function form is a set of game allocation gains that is not dominated by any other allocation set. The core provides a bound for the maximum allocation each player may request. In this respect, it is an overall solution for many allocation schemes (such as the ones considered later) that are contained within the core. Let ω_j be player j's allocation of the incremental net income from the regional game. The core fulfills requirements for individual and group rationality; that is, the core solution for each player is preferable to the noncooperative outcome and to participation in partial coalitions. The core also fulfills requirements for joint efficiency (Shubik 1982); that is, all costs or gains are allocated:

(4) $$\omega_j \geq v(\{j\}) \qquad \forall j \in N,$$

(5) $$\sum_{j \in s} \omega_j \geq v(s) \qquad \forall s \in S,$$

(6) $$\sum_{j \in N} \omega_j = v(N).$$

The system (4), (5), and (6) has more than one allocation solution. A method of calculating the extreme points of the core (Shapley 1971) calculates the incremental contributions of each player when joining any existing coalition, and assigns these contributions to that player.

The Shapley Value. While the core may contain more than one allocation, the Shapley value is a unique allocation scheme. The Shapley value scheme allocates θ_j to each player based on the weighted average of its contributions to all possible coalitions and sequences. In the calculation process, an equal probability is assigned for the formation of any coalition of the same size, assuming also all possible sequences of formation.

(7) $$\theta_j = \sum_{j \in s \in S} \frac{(n - |s|)!(|s| - 1)!}{n!} [v(s) - v(s - \{j\})] \quad \forall j \in N,$$

where n is the number of players in the game, and $|s|$ is the number of members in coalition s.

The Generalized Shapley Value. The Shapley value has been criticized for assuming equal probabilities to all coalition formations. The generalized Shapley value refers to a subset of practical coalitions only, and the probability of a coalition occurring depends on the logical sequence of its formation. Like the Shapley value, the generalized Shapley value assigns to each player the weighted average of its contributions to all coalitions realistically formed. The generalized Shapley allocation to player j, $\hat{\theta}_j$, is

(8)

$$\hat{\theta}_j = \sum_{j \in s \in S} P(s, s - \{j\}) [v(s - \{j\})] \qquad \forall j \in N,$$

where $P(s, s - \{j\}) = P(s \mid s - \{j\}) \cdot P(s - \{j\})$ is the probability ("physical-economic" probability) of player j joining coalition s.

It is assumed so far that the players in the game are economically rational. This means that the decision of each player to join a given coalition is based only on the incremental net income it receives by joining that coalition. However, in view of the literature reviewed earlier, ideological and political considerations should be included in the modeling framework. The probabilities used in the Shapley value and in the generalized Shapley value allocations ignore these aspects. They do not include players indirectly involved in the game, and they also do not address ideological and policy considerations that affect the political agenda of a given player.

Political Probabilities of Coalition Formation

It is recognized that economics and politics play interactive roles—sometimes complementary, sometimes contradictory—in the evaluation of resource allocations, yet neither paradigm is autonomous. Just as political considerations can effectively veto a project with an otherwise favorable economic outcome, a project with potential regional-welfare improvements might influence the political decision-making process to allow the necessary cooperation. Although the process of interaction between economics and politics is dynamic in nature and evolves over time, it will be analyzed here in a static framework. Furthermore, we examine only the political likelihood that any of the previously described coalitions may be formed for the purpose of the resource allocation.

We will use the PRINCE Political Accounting System (PAS) developed by Coplin and O'Leary (1974, 1976, 1983) to calculate political probabilities for the formation of different coalitions. The PAS is a technique for assessing the impact of a given player on joint policy decisions. Quantification of political projections has not been particularly prevalent in the academic world, although it seems to thrive when real-world political decisions need to be made. The PAS, for example, is the basis for an annual handbook of country and political risk analysis (Coplin and O'Leary 1994) and a comparative study of international political risk analysis (Howell and Chaddick 1994).

Particularly in the assessment of water resources conflicts, when quantitative political models do exist, they generally use the same parameters as those of the PAS. As noted earlier, Frey and Naff (1985) suggest a method for assessing water disputes through a like method, and Lowi (1993) lists similar parameters as those particularly relevant to riparians in her assessment of water conflicts in the Middle East and Southeast Asia.

While we recognize some lack of enthusiasm for quantitative political analysis in general, and the elementary and subjective nature of the PAS in particular, we feel that its performances are far better than other approaches.[2] Therefore, its inclusion in the model is a useful first step in an attempt to bridge the worlds of the economist and the political analyst. Since we are not using the PAS as a predictive tool, but are, instead, applying its results as guidelines to help unify economic efficiency and political considerations (determining what kind of redistribution of resources would be required for hostile players to overcome their reluctance to cooperate), we feel the inclusion of the PAS in this context is justified.

The PAS assumes that the political impact of players on joint decisions is affected by three factors: (1) the extent to which each player supports, opposes, or is neutral toward each joint decision (issue position); (2) how effective each player might be in blocking or enabling the joint decision (power); and (3) how important the joint decision is to each player (salience).

As described by Coplin and O'Leary (1974, 1976, 1983), players to be included in the political analysis should be those that directly and indirectly impact the joint decision.[3] Let $i \in N$ and $m \in M$ be, respectively, players likely to directly and to indirectly impact the joint decision. For each player $i \in s \subseteq N \cup M$, a value of each political factor ($k = 1, 2, 3$ for issue position, power, and salience, respectively) can be quantified.

Values for issue position (indexed by $k = 1$) are in the range $[-\lambda^1, +\lambda^1]$, where negative values express opposition, a zero value expresses neutrality, and positive values express support. Larger absolute values are associated with higher levels of support or opposition. Note that each value for power and salience (indexed by $k = 2$ and $k = 3$, respectively) is in the range $[1, \lambda^k]$ $\forall\, k = 2, 3$. Again, larger values represent higher levels of power and salience, respectively.

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[2] See, for example, Ascher (1989) for a thorough critique of the PRINCE method and other expert systems for political-economic forecasting, and Howell and Chaddick (1994) for another thorough analysis of several political models that concludes that the PAS performs best.

[3] Here we provide the mathematical notation to the textual description of the model in Coplin and O'Leary (1983).

A necessary condition for comparability is that every λ^k should be normalized so that

$$(9) \qquad \max|\lambda^k| = \bar{\lambda}^k \qquad \forall\, k = 1, 2, 3.$$

Actual values for each player are affected by its coalition environment. The individual values $\dot{\lambda}_i^k(s)$ satisfy $\gamma \leq \dot{\lambda}_i^k(s) \leq \bar{\lambda}^k$ where

$$(10) \qquad \gamma = \begin{cases} -\bar{\lambda}^k & \text{if } k = 1 \\ \bar{\lambda}^k > \hat{\lambda}^k > 0 & \text{if } k = 2, 3 \end{cases}.$$

To calculate the total effect each player has on a given joint decision, *s*, we obtain

(11)

$$Y_i(s) = \prod_k \dot{\lambda}_i^k(s) \qquad \forall\, i \in s \subseteq N \cup M,\ \dot{\lambda}_i^1(s) > 0.$$

To calculate the political probability of a joint decision being adopted, we obtain

(12)

$$\xi(s) = \frac{\sum_i Y_i(s)|_{Y_i(s)>0} + \frac{1}{2}\sum_i Y_i(s)|_{\dot{\lambda}_i^1(s)=0}}{\sum_i |Y_i(s)|} \qquad \forall s.$$

The nominator includes the sum of the total effect of the players in support of the joint decision and half of the effect of those who are neutral. In the absence of other information, neutral players are assumed to be equally likely either to support or to oppose *s* in the future (Coplin and O'Leary 1983). Therefore, $Y_i(s)$ in the case of $\dot{\lambda}_i^1(s) = 0$ is given a weight of $\frac{1}{2}$. The denominator includes the absolute value of all players' effects.

Since the numerator is less than or equal to the denominator, we obtain $0 \leq \xi(s) \leq 1$, which is defined as the political probability that a joint decision *s* will be adopted, or, in our case, that coalition *s* will be formed.

Reallocation of the Regional Gains

The generalized Shapley value is modified to account for the likelihood of political formation of the possible coalitions. This is done for each coalition by multiplying the physical-economic probabilities $P(s, s\text{-}\{j\})$, calculated in the generalized Shapley value, by the political probabilities $\xi(s)$. The resulting allocation $\tilde{\theta}_j$ is given by the generalized Shapley value with modified probabilities (GSVMP):

(13)

$$\tilde{\theta}_j = \sum_{j \in s \in S} \xi(s) \cdot P(s, s - \{j\}) \cdot [v(s) - v(s - \{j\})] \qquad \forall\, j \in N.$$

Evaluating Possible Water Transfer in the Western Middle East

The combined game theory and PAS approach has been applied to a case of water transfer in the western Middle East. The western Middle East is facing a gloomy future regarding water resources. The data used here are based on analysis in Dinar and Wolf (1994a) of a regional water transfer under a cooperative framework. The parties (players) that might be involved in a regional arrangement are Egypt (EG), Israel (IL), the Gaza Strip (GS), and the West Bank (WB). Calculations in Dinar and Wolf (1994) suggest that the region will face water shortages under a variety of demand scenarios.

Following the plan suggested by Kally (1989)[4] (extract in Ben-Shachar, Fishelson, and Hirsh 1989), water from the Nile River will be diverted through the eastern Sinai Peninsula to southern IL (the Negev Region). According to Dinar and Wolf (1994), a water-saving technology[5] will be sold by IL to EG in exchange for part of the water that will be saved in EG. Part of this water will replace the amount originally conveyed from northern IL through the Israeli National Carrier to the Negev. Part of the water saved in northern IL will be sent to the WB. Another part of the saved Nile water will augment the demand for water in the GS. For simplicity, assume also that allocation of this water has been determined exogenously to the system (say, by an international committee, or by a treaty); that is, a fixed, agreeable amount of water[6] will be sold (in the case of a regional arrangement) by EG to GS and IL, and by IL to WB. The price is determined endogenously in the model, using calculated values of marginal productivity for water.

The potential number of coalitional arrangements in the region is $2^4 - 1 = 15$. They include: (a) the current noncooperation case {EG}, {IL}, {GS}, {WB}; (b) partial-cooperation cases {EG;

[4] For simplification we exclude several countries, such as Jordan, that could potentially participate in a more comprehensive regional arrangement (Kally 1989).

[5] By technology we mean a package of hardware, training, and maintenance.

[6] Some water market models leave quantity and price to be determined endogenously.

Table 1. Characteristic Function Values for Different Coalitions

Coalition	Incremental Net Income per Player (millions of dollars) EG[a]	IL	GS	WB	Value for Coalition s f^s	$\sum_{j\in s} f^j$	Incremental Net Income for Coalition s $v(s)$
{EG}	0.00				0.00	0.00	0.00
{IL}		0.00			0.00	0.00	0.00
{GS}			0.00		0.00	0.00	0.00
{WB}				0.00	0.00	0.00	0.00
{EG; IL}	5.00	85.70			90.70	0.00	90.70
{EG; GS}	4.00		4.00		8.00	0.00	8.00
{IL; GS}		0.00	0.00		0.00	0.00	0.00
{IL; WB}		0.00		0.00	0.00	0.00	0.00
{EG; IL; GS}	6.60	85.70	4.00		96.30	0.00	96.30
{EG; IL; WB}	5.00	112.55		3.35	120.90	0.00	120.90
{IL; GS; WB}	0.00		0.00	0.00	0.00	0.00	0.00
{EG; IL; GS; WB}	6.60	112.55	4.00	3.35	126.50	0.00	126.50

[a]EG ≡ Egypt; IL ≡ Israel; GS ≡ Gaza Strip; WB ≡ West Bank.

GS}, {EG; WB}, {EG; IL}, {IL; GS}, {IL; WB}, {GS; WB}, {EG; GS; WB}, {EG; IL; GS}, {EG; IL; WB}, {IL; GS; WB}; and (c) the grand coalition case {EG; GS; IL; WB}.

Because of physical conditions in the region (and only for these considerations), at least three coalitions—{EG; WB}, {GS; WB}, and {EG; GS; WB}—can be excluded a priori because of economic inferiority (e.g., an inability to support expensive energy costs to pump water from the Negev to WB). Therefore, for practical purposes the number of coalitions in the regional game is 12.

The characteristic values of the coalitions are the incremental gains to a particular coalition in the game (see table 1 for regional gains distribution). These gains are to be distributed among the players participating in the game. As the major player (it holds the water in the regional game), EG is not likely to favor such distribution of the regional gains because it does not fully reflect EG's political power over the Nile water. If redistribution of these gains is not considered, the regional solution may not be stable enough, or may not exist at all. In order to "correct" for the instability embodied in the regional optimization solution, and to make cooperation more attractive to some players, the incremental regional net income is considered for redistribution using alternative allocation schemes.

The Core. The core equations for the regional game are

$$\omega_j \geq 0 \qquad j = \text{EG, IL, GS, WB}$$

$$\omega_{EG} + \omega_{IL} \geq 90.70$$

$$\omega_{EG} + \omega_{GS} \geq 8.00$$

$$\omega_{EG} + \omega_{IL} + \omega_{GS} \geq 96.30$$

$$\omega_{EG} + \omega_{IL} + \omega_{WB} \geq 120.90$$

$$\omega_{EG} + \omega_{IL} + \omega_{GS} + \omega_{WB} = 126.50.$$

This system of equations has more than one allocation. A method of calculating the extreme

Table 2. Extreme Points of the Core in the Regional Game

Maximum Incremental Net Income Allocation to Player j (millions of dollars) EG	IL	GS	WB	Coalition Formation Sequences Leading to This Allocation						
0.0	90.7	5.6	30.2	1234	1243					
0.0	88.3	8.0	30.2	1324						
0.0	118.5	8.0	0.0	1342						
90.7	0.0	5.6	30.2	2134	2143					
96.3	0.0	0.0	30.2	2314	3214					
120.9	0.0	5.6	0.0	2413	4123	4213				
126.5	0.0	0.0	0.0	1423	2341	2431	3241	3421	4321	4231
0.0	126.5	0.0	0.0	3412	4312	4132	1432			
8.0	88.3	0.0	30.2	3124						

points of the core (Shapley 1971) was applied (table 2). The extreme points of the core are interpreted as the players' preference. Each of the players will prefer allocations that are closer to the extreme points of the core. The four left-hand columns of table 2 are the maximum possible allocations to the players, while the right-hand side of the table shows the coalition formation sequences leading to these allocations. The results shown in table 2 suggest that the negotiation set in this game is quite large. EG and IL can each claim up to $126.5 million; the maximum value for GS is $8.0 million, and for WB it is $30.2 million.

The Shapley Value. Using equation (7) and the results shown in table 1, the Shapley allocation of the regional gains is $\theta_j = (57.7, 56.4, 2.4, 10.0)$, to EG, IL, GS, and WB, respectively (values are in millions of dollars). The Shapley allocation is contained within the core of the game and is also consistent with the maximum claim values computed in table 2. That is, EG and IL receive similar allocations, and GS receives an allocation that is 24% of that for WB, which is consistent with the core maximum value allocations (8.0 compared with 30.2 for GS and WB, respectively).

The Generalized Shapley Value. Figure 1 depicts the conditional physical-economic probabilities of coalition formation. Coalitions initiated by each player are identified, and the conditional probabilities of each coalition formation are calculated and presented along the branches. The identified coalitions are those that appear in table 2. Using equation (8), the data in table 1, and the values in figure 1, the generalized Shapley allocation of the regional gains is $\hat{\theta}_j = (53.8, 49.5, 5.2, 16.5)$ to EG, IL, GS, and WB, respectively.

The Generalized Shapley Value with Modified Probabilities (GSVMP). The PAS is used now to estimate the probability that a given coalition will be established. The PAS will be used here to evaluate a player's level of support for or opposition to joining a given coalition. The PAS components, which were described generally earlier, are as follows. (1) *Issue position,* which summarizes all internal forces of a player, is scored on a scale of −3 to +3 (including 0). When applied to hydropolitics, this measure is equivalent to a quantitative summation of LeMarquand's factors (1977). (2) *Power,* which summarizes a player's ability to enforce or implement its position, is scored on a scale of 1 to 3. When applied to hydropolitics, power reflects legal water rights and riparian positions as well as more traditional aspects, such as military or economic strength. (3) *Salience,* which reflects the importance to a player of being in a given coalition, is scored on a scale of 1 to 3.[7] This measure also includes a summation of internal forces, many of which are described by Endtner (1987).

Developing reliable values for the Political Accounting System is a complicated task. Any estimate of political viability is, by nature, subjective. Coplin and O'Leary (1976) suggest only that by dividing overall political viability into the components of issue position, power, and salience, as described earlier, one can make a more systematic and perhaps as a consequence more objective assessment. They do not, however, offer a systematic methodology for assessing each component λ^k. These values can be estimated in various empirical ways (surveys, referendums, committees) or can be left to the subjective decision of the analyst.

Several political analysts have tackled the question of quantifying political viability in a similar manner. Meltsner (1972), for example, argues for breaking viability into its components, but allows that "the investigation of political feasibility . . . depends on the role of the analyst, his political knowledge, and the scope of his policy problems." In their discussion of "strategic management," Nutt and Backoff (1987, p. 237) present a matrix to help guide the analyst in determining similar parameters, offering a ranking system to identify stakeholders as "low priority," "antagonists," "problematic," and "advocates," but suggest only that arriving at such categories requires "extended discussions."

The values assigned to the political components of the PAS in this paper are our best quantitative assessment of an elusive quantity. We recognize the need to develop more objective measures for each component of political viability. One option might quantify a combination of military might and legal bearing as a gauge of power, for example, or the amount of public posturing over an issue as manifested in news releases as a measure of either issue position, or salience. Another, more common option, used particularly in the absence of data necessary for a quantitative assessment, is to substitute iterations of "expert opinions," first described by Gordon and Helmer (1964) as the Delphi method.[8] Experts familiar with the technical and political landscapes of a particular issue might be asked to rank the viabilities of available options

[7] The scale of 1 to 3 indicates low, medium, and high values. In the case of issue position, the range also includes 0, which means indifference. Different scales could have also been chosen (e.g., 1 to 5), but the relative values of the PAS results would not be affected.

[8] See Linstone and Turoff (1975) for a good summary of the strengths, weaknesses, and applications of the Delphi method; and Needham and de Loë (1990) for its applicability to water resources planning.

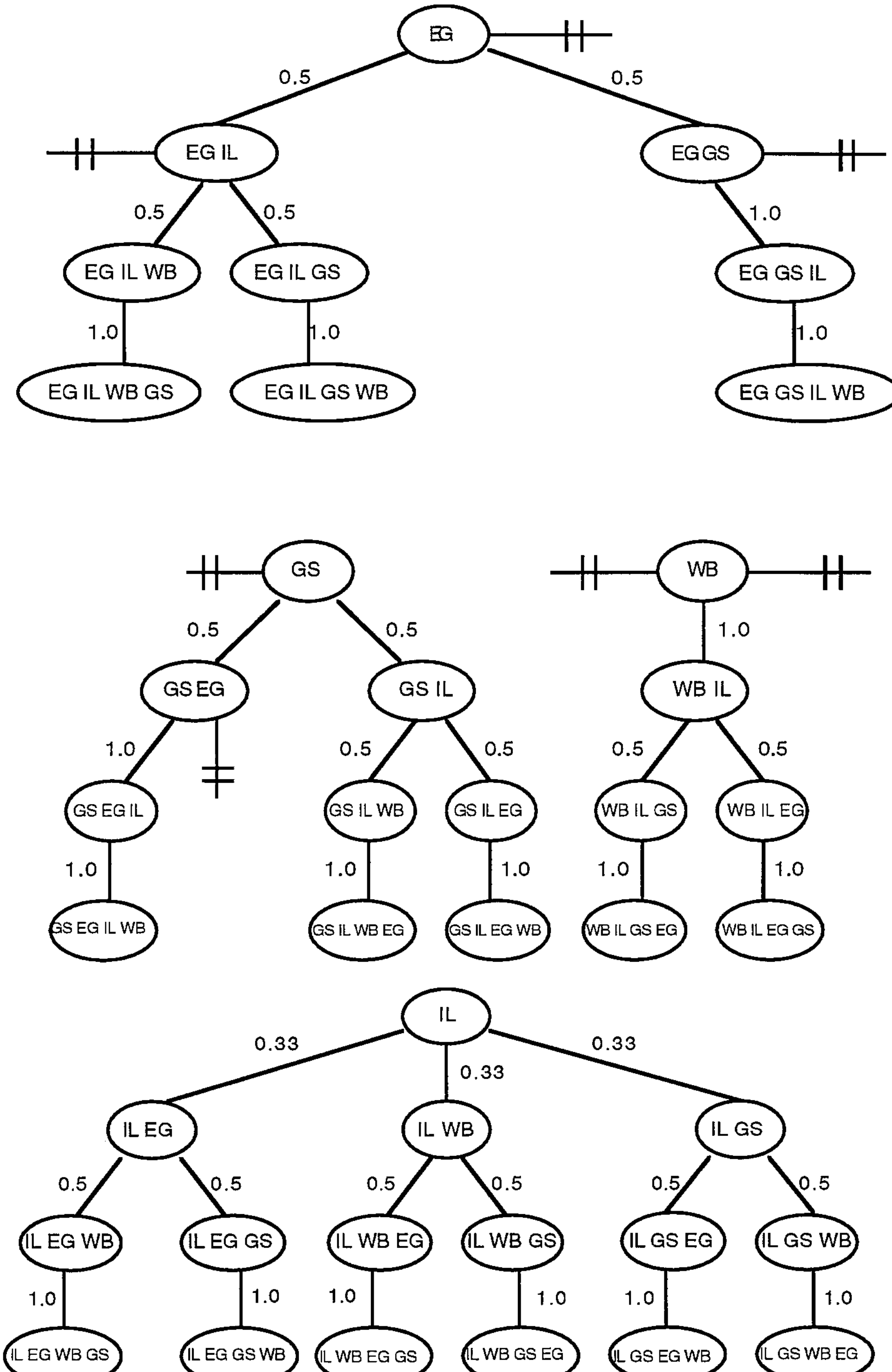

Figure 1. Coalition Formation Sequence in the Regional Cooperative Game. (Numbers along the branches denote the conditional physical-economic probabilities of moving from one coalition to another.)

on a consistent scale. The relative importance of the viability measures themselves should also be weighted for that particular issue during a particular time frame. A variation on the weighting process is first described in detail in Kepner and Tregoe (1965). However, one should keep in mind that the experts' findings are stylized in the sense that the experts are not the players directly involved in the particular problem.

Using the PAS approach, once every component is evaluated for each player participating in each coalition, multiplication across rows in table 3 will give a measure of a player's overall level of support or opposition to a proposed coalition. Adding these values for each actor involved will provide a ranking value for the coalition as a whole, which can be compared with the values for other coalitions. A higher number reflects greater likelihood of support.

Using the same approach, the PAS provides an absolute measure for estimating the likelihood that a coalition will be established (equation [12]). Table 3 also presents the political probabilities associated with each coalition. For purposes of this analysis we use the information in Dinar and Wolf (1994b) for determining these values. The resulting political probabilities of 0.23, 0.89, 0.64, 0.64, 0.73, 0.0, 0.0, and 0.0 represent, respectively, the probabilities for formation of the coalitions {EG; IL}, {EG; GS}, {EG; IL; GS}, {EG; IL; WB}, {EG; IL; GS; WB}, {IL; WB}, {IL; GS}, and {IL; WB; GS}. The last three coalitions have been assigned probabilities of 0.0 since there is no physical possibility for cooperation among them in terms of water surplus. Likewise, it is recognized that among hostile actors, the most likely scenario is for players not to overcome their hostility. Therefore, each status quo noncooperation coalition—{EG}, {IL}, {GS}, and {WB}—is given a probability of 1.00.

The conditional political-physical-economic probabilities are then calculated by multiplying the physical-economic probabilities in figure 1 by the corresponding political probabilities in table 3. The modified probabilities are shown in figure 2. It should be noticed that the modified probabilities (figure 2) are smaller than those in figure 1. The probability values in figure 2 should be interpreted in the following way: values along the branches emanating from the same root indicate the probabilities that the subcoalitions will be created. Subtracting the aggregated probability value from 1 indicates the probability of remaining in the root coalitional stage. For example, the probability that the branch coalition {IL; EG; WB} will be formed from root coalition {IL; EG} is .32, and the probability that the coalition {IL; EG; GS} will be formed from {IL; EG} is also .32. Therefore, the probability that these coalitions will not be formed but will remain at the root coalition {IL; EG} stage is .36 [= 1 − (.32 + .32)]. Using equation (13), the data in table 3, and the values in figure 2, the reallocation of the regional gains, according to the GSVMP, is $\tilde{\theta}_j$ = (77.3, 35.6, 4.1, 9.5) for EG, IL, GS, and WB, respectively.

In attempt to validate our findings for political viability, we compared our values for the options described here with the values arrived at by the five members of the Middle East Water Commission for similar water resources alternatives.[9] The commission assessed alternatives to increase supply and decrease demand for water resources in countries riparian to the Jordan River watershed. Those values were derived through a modified Delphi process, averaging subjective values assigned by the members of the commission at a meeting in June 1994, as described in Wolf and Murakami (1995). The Nine–Gaza/Israel water pipeline alternative was assessed by the commission members at a rate of more than 50% for technical and economic feasibilities, but at only 7% for political feasibility. While the methodologies used are different, the findings in our study were similar to these in Wolf and Murakami, so that we feel that our assessments of political viability were corroborated.

In comparing the different allocation schemes (see table 4), one observes that all are included within the core of the regional game and are therefore considered to be efficient allocations. The changes in the allocations of the regional gains from cooperation—starting with the regional economic model (6.6, 112.55, 4.00, 3.35) and moving through the Shapley value (57.7, 56.4, 2.4, 10.0), the generalized Shapley value (63.7, 45.8, 2.8, 14.2), and finally the generalized Shapley value with modified probabilities (77.3, 35.6, 4.1, 9.5)—suggest that the GSVMP allocation is the most likely to be stable of all the allocations.

Based on the GSVMP allocation, EG gets closest to the maximum payoff allocation it considers fair, according to the core allocations. IL's allocation drops significantly compared with its allocation in the regional economic solution, but few could believe that IL's share in the regional gains should be so high, even higher than those allocated to EG.

Given the role of WB in the regional game, it is

[9] The work of the Middle East Water Commission, a research body of the International Water Resources Association, is described in Biswas and Wolf (1994).

Table 3. Modified Political Accounting Systems for the Regional Game

Riparian and Target Entities	Issue Position	Power	Salience	Total	Probablity
Coalitions	{EG}, {IL}, {GS}, {WB}				1.00
Coalition	{EG; IL}				0.23
Nile Basin					
Egypt	−2	3	3	−18	
Sudan	−3	2	2	−12	
Ethiopia	−2	2	2	−8	
Targets					
Israel	+2	2	3	+12	
Gaza	−1	1	1	−1	
West Bank	−1	1	1	−1	
			Total	−28	
Coalition	{EG; GS}				0.89
Nile Basin					
Egypt	+2	2	3	+12	
Sudan	+2	1	2	+4	
Ethiopia	−1	2	2	−4	
Targets					
Israel	+1	2	3	+6	
Gaza	+3	1	3	+9	
West Bank	+2	1	1	+2	
			Total	+29	
Coalition	{EG; IL; GS}				0.64
Nile Basin					
Egypt	+1	2	3	+6	
Sudan	−2	2	2	−8	
Ethiopia	−2	2	2	−8	
Targets					
Israel	+2	2	3	+12	
Gaza	+3	1	3	+9	
West Bank	+2	1	1	+2	
			Total	+13	
Coalition	{EG; IL; WB}				0.64
Nile Basin					
Egypt	+1	2	3	+6	
Sudan	−2	2	2	−8	
Ethiopia	−2	2	2	−8	
Targets					
Israel	+2	2	3	+12	
Gaza	+2	1	1	+2	
West Bank	+3	1	3	+9	
			Total	+13	
Coalition	{EG; IL; WB; GS}				0.73
Nile Basin					
Egypt	+1	2	3	+6	
Sudan	−2	1	2	−4	
Ethiopia	−2	1	2	−4	
Targets					
Israel	+2	2	3	+12	
Gaza	+1	1	2	+2	
West Bank	+1	1	2	+2	
			Total	+14	
Coalition	{IL; GS}				0.0
Coalition	{IL; WB}				0.0
Coalition	{IL; WB; GS}				0.0

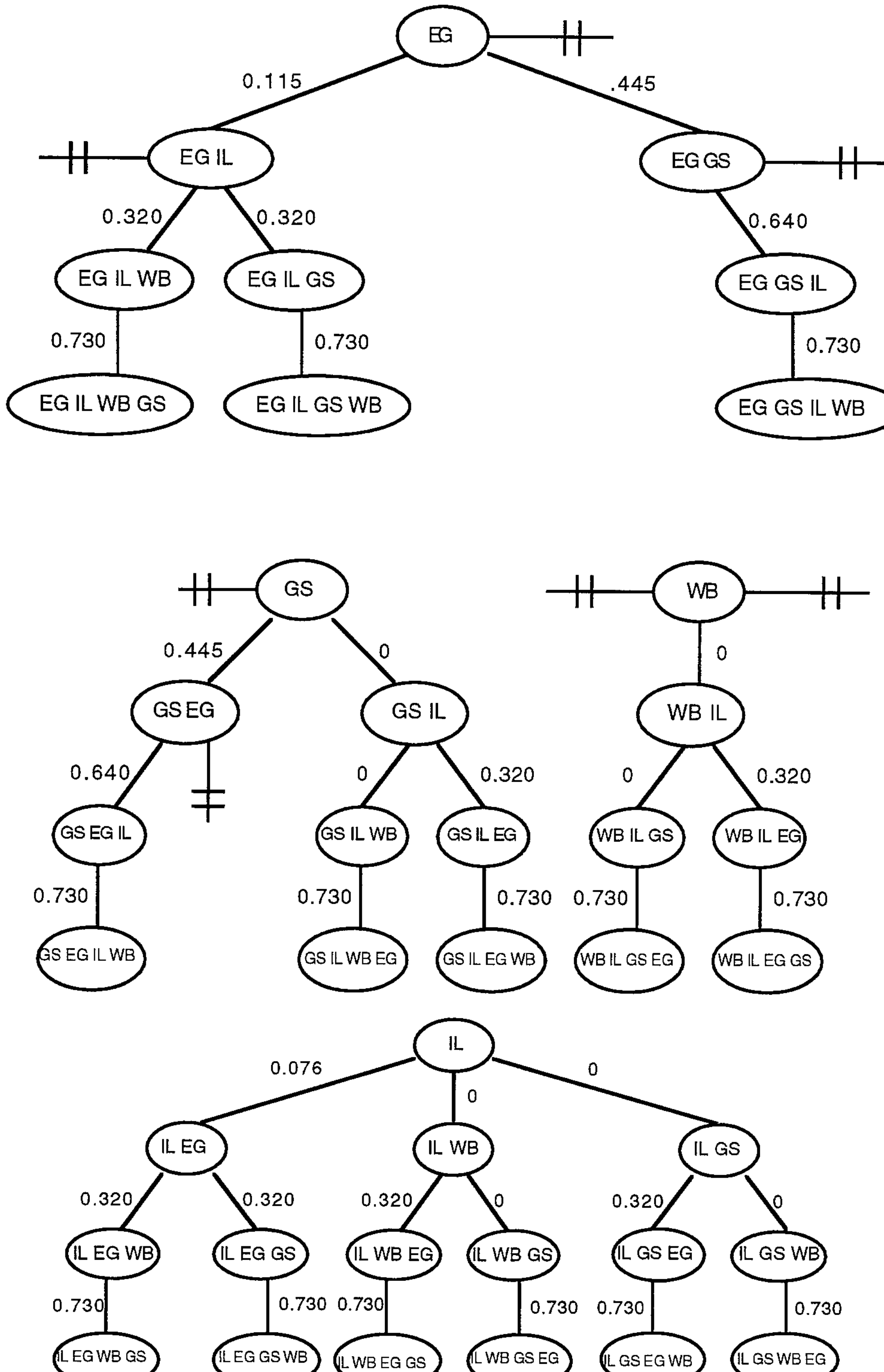

Figure 2. Coalition Formation Sequence in the Regional Cooperative Game, using baseline political assumptions. (Numbers along the branches denote the conditional political-physical-economic probabilities of moving from one coalition to another.)

Table 4. Results of Different Allocation Schemes for the Regional Gains

Allocation Scheme	EG	IL	GS	WB
Regional economic model	6.6	112.55	4.00	3.35
Shapley	57.7	56.4	2.4	10.0
Generalized Shapley	63.7	45.8	2.8	14.2
Generalized Shapley with modified probabilities (GSVMP)	77.3	35.6	4.1	9.5
Sensitivity analysis of GSVMP:				
Highest values	76.9	33.4	3.9	11.3
Lowest values	78.5	34.1	3.6	10.3

surprising that its allocations are always higher than those for GS. The main reason is that WB's participation allows IL to save a substantial electricity cost, which would otherwise be required to send water from northern Israel to the Negev. The GS allocation determined by the GSVMP is better than the one determined by the regional economic model.

Sensitivity Analysis of the $\lambda_i^{;k}(s)$ *Values Used in the Calculation of the Political Probabilities.* The integration of measurable economic variables with the subjective political factors is not without partial remedy, at least. To evaluate the effects of the values presented in the analysis for the political variables, on the final GSVMP allocation, and to establish respective bounds on the results, a sensitivity analysis was conducted. The sensitivity analysis referred to the issue position component in the PAS matrix. Issue position is the component that can most easily be affected by coalitional setup, while the power and the salience components are less likely to be affected by a coalitional setting. Egypt and Sudan's values were selected for demonstration of the sensitivity analysis. Among the players involved, Egypt is the most likely to be associated with a range of issue position values, given both its important role in the game and its opportunities for gains from the game, on one hand, and the domestic politics situation it faces, on the other hand. Sudan has both an existing water allocation and claims for more water from the Nile. Sudan's issue position may vary based on its general relationship with Egypt and Ethiopia. For these reasons, the issue positions range of values for Egypt and Sudan will be used in the sensitivity analysis.

The sensitivity analysis is based on values in table 3. Modifications have taken into account the range of possible issue position values. Then the low and high values of the political probabilities (table 5) have been incorporated into the coalition formation sequence (as was the case of the base values in figure 2) and used to calculate the allocation of the regional gains. The resulting coalitional formation probabilities are not presented.

Allocation results in table 4, for the lowest and highest values in the sensitivity analysis, suggest that the allocation according to GSVMP based on the range of values evaluated in the sensitivity analysis is still acceptable and reasonable.

Stability and Reasonableness of the Various Allocation Schemes. Although all allocation schemes provide results that fulfill the necessary core requirements for acceptability, some players may view some allocations as not fair, which can lead to unstable results.

To assess the stability of the allocation solutions we follow Dinar and Howitt (1997) and apply the Shapley-Shubik power index (Shapley and Shubik 1954):

$$\alpha_i = \frac{x_i - v(i)}{\sum_{j\in N} x_i - v(i)}. \qquad (14)$$

The power index compares the gains to a particular player with the gains to the coalition. A more harmonized power distribution is more likely to yield a stable coalition. Therefore, the coefficient of variation of the power distribution $S_\alpha = \sigma_\alpha/\overline{\alpha}$ is a measure of stability for each allocation, where σ_α is the variance and $\overline{\alpha}$ is the mean value of α. The greater the value of S_α, the larger the instability of the allocation solution. Table 6 presents the stability measures of the various allocation solutions.

As can be seen from the table, the allocation according to the economic model alone is the most unstable. The game theoretic allocations are far more stable, with the GSVMP being the most stable and the Shapley being the least stable.

In comparing the Shapley value with the GSV and the GSVMP when dealing with regional cooperation, one needs to address the reasonableness of the regional arrangements based also on the calculation of possible allocations of such arrangements. For example, using only the Shapley value, which assumes equal probability for the formation of each coalition, may result in allocations that overestimate the allocation of benefits to some players while underestimating it for other players. The GSV addresses this issue by taking into account coalition arrangements that are impossible, for example, because of physical constraints, such as in the case of water conveyance, a mountain that blocks a coalition among players on the two sides of that mountain. However, the GSV, assuming rational players, does not address wider political considerations, such as disagreement on other is-

Table 5. Sensitivity Analysis of the Political Probabilities of Coalition Formation[a]

Riparian and Target Entities	Issue Position Low	Issue Position High	Power	Salience	Total Low	Total High	Probability Low	Probability High
Coalition		{EG; IL}					0.20	0.34
Nile Basin								
Egypt	−3	−1	3	3	−27	−9		
Sudan	−3	−1	2	2	−12	−4		
Ethiopia	−2	−2	2	2	−8	−8		
Targets								
Israel	+2	+2	2	3	+12	+12		
Gaza	−1	−1	1	1	−1	−1		
West Bank	−1	−1	1	1	−1	−1		
				Total	−28	−11		
Coalition		{EG; GS}					0.87	0.91
Nile Basin								
Egypt	+1	+3	2	3	+6	+18		
Sudan	+2	+2	1	2	+4	+4		
Ethiopia	−1	−1	2	2	−4	−4		
Targets								
Israel	+1	+1	2	3	+6	+6		
Gaza	+3	+3	1	3	+9	+9		
West Bank	+2	+2	1	1	+2	+2		
				Total	+29	+35		
Coalition		{EG; IL; GS}					0.47	0.74
Nile Basin								
Egypt	−1	+2	2	3	−6	+12		
Sudan	−3	−1	2	2	−12	−4		
Ethiopia	−2	−2	2	2	−8	−8		
Targets								
Israel	+2	+2	2	3	+12	+12		
Gaza	+3	+3	1	3	+9	+9		
West Bank	+2	+2	1	1	+2	+2		
				Total	−3	+23		
Coalition		{EG; IL; WB}					0.47	0.84
Nile Basin								
Egypt	−1	+2	2	3	−6	+12		
Sudan	−3	+2	2	2	−12	+8		
Ethiopia	−2	−2	2	2	−8	−8		
Targets								
Israel	+2	+2	2	3	+12	+12		
Gaza	+2	+2	1	1	+2	+2		
West Bank	+3	+3	1	3	+9	+9		
				Total	−3	+35		
Coalition		{EG; IL; WB; GS}					0.50	0.88
Nile Basin								
Egypt	−1	+2	2	3	−6	+12		
Sudan	−3	+2	1	2	−6	+4		
Ethiopia	−2	−2	1	2	−4	−4		
Targets								
Israel	+2	+2	2	3	+12	+12		
Gaza	+1	+1	1	2	+2	+2		
West Bank	+1	+1	1	2	+2	+2		
				Total	+14	+28		

[a]Only the partial and grand coalitions are affected and presented.

sues, or long-term hostility between some players, that affects the probability of coalition formation. For example, although physical and economic prospects for cooperation over sharing water resources in the Ganges Basin exist among India, Bangladesh, and Nepal (Rogers 1993), it cannot materialize since there are both domestic opposition for such cooperation within one party and hos-

Table 6. Power Indexes and Stability Measure of the Various Allocation Schemes

	EG	IL	GS	WB	S_α
Allocation Method		α_i			
Economic model	.052	.889	.031	.026	.727
Shapley	.456	.445	.019	.079	.217
GSV	.503	.362	.022	.112	.195
GSVMP	.611	.281	.032	.057	.186

tility among some of the parties. If such considerations are not addressed properly, the coalition formation probabilities calculated by GSV will not reflect the actual relationships between the parties, which ultimately lead to no cooperation.

Using the same token, when only political considerations are included in the evaluation of possible cooperation arrangements, without identifying economic and physical feasibility, the cooperation between the parties involved either will be suboptimal (not related to the actual issue considered for cooperation) or will lead to the status quo. For example, five Central Asian states considered cooperating in order to reduce the negative environmental impact on the region of the diversion of the Amu-Darya and Syr-Darya Rivers. The heads of states, recognizing the need for action, agreed in 1992 to cooperate (World Bank 1994). However, so far only political considerations have been addressed (since no feasible projects with identified benefits to each state have been agreed upon yet). Therefore, the only allocation of the rivers' waters is still based on the former Soviet scheme, which is the inferior status quo solution.

Discussion

Economic efficiency alone is not a sufficient condition for cooperation, especially when that cooperation is related to the transfer of a scarce resource among hostile potential cooperators. Therefore, wider political considerations should be incorporated into the analysis as well. Existing political analyses do not provide quantitative tools for these kinds of analyses. A framework for analyzing economic and political aspects of cooperation was developed in this paper and applied to a simplified case study of water and technology transfer. A water-efficient technology was sold by one player to another, and part of the amount of water saved was released for sale to the regional participants. A more general case could also include a technology-related transaction between any regional player and "the rest of the world." This might change the regional outcome and might make the game more attractive to some players and less attractive to others when compared with the scenarios analyzed here.

The process of reallocating the regional gains, by using different game-theory allocation schemes and including political aspects, demonstrates the need for a massive income transfer from one player to another in order to keep the arrangement stable. In this case Israel needs to "bribe" Egypt and to reduce its initial allocation from $112.55 million in the solution of the economic model to $35.6 million in the case of the GSVMP. These results mean that the technology transfer component of the model is not necessary; an alternative might be to use the transferred income to improve water-use efficiency in Egypt.

A drawback of our approach is the use of "almost subjective" considerations for proposal evaluation. This problem results from the need to combine quantitative (economic) and qualitative (political) measures in the analysis. Although we showed by conducting a sensitivity analysis that the GSVMP results are reasonably stable as issue position values change, future research should focus on quantifying political and ideological considerations to be compatible with economic ones.

The Nile River is considered here as the only source of surplus water. The cost associated with the cross-desert canal are believed by some researchers to be high enough to allow the introduction of other new sources of water that were economically inferior to the alternative discussed in the paper. In addition, there is an emerging regional dialogue between Egypt, Ethiopia, Sudan, and seven other riparian countries on issues concerning reallocation of the Nile River water. Although such development may eliminate the exclusivity status that Egypt possesses in the game, it still leaves open many regional cooperation opportunities, some of which were discussed in this paper.

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