Transboundary water resources allocation using bankruptcy theory; Case study of Euphrates and Tigris Rivers

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ABSTRACT

One significant problem of trans-boundary rivers, which has been causing various challenges and disputes throughout the world, is that the amount of demand and need of riparian states is larger than the available water. Hence, one of the main challenges in trans-boundary rivers management problems is that how we can allocate the limited and shared available water among riparian states when it is not sufficient to satisfy the claims of all riparian states so that it would be more equitable and reasonable. In this study, we survey the application of bankruptcy theory to solve this problem in trans-boundary rivers. Furthermore, we propose a new bankruptcy rule to help solving conflict in trans-boundary reallocation problems and investigate its application in a real case study. The results reveal that this method is potentially helpful to solve conflict over trans-boundary water resources problems.

KEY WORDS: *Transboundary water resources, conflict management, shared water allocation, bankruptcy rules.*

INTRODUCTION

"Fair" and "efficient" natural resources reallocation among stakeholders and states is a complex conflict problem, which is likely to depend One significant problem of trans-boundary rivers which has been causing various challenges and disputes throughout the world is that the amount of demand and need of riparian states is larger than the available water. Hence, one of the main challengeable issues in trans-boundary rivers management is how we can allocate the limited and shared available water among riparian states when it is not sufficient to satisfy the claims of all riparian states? Therefore, "equitable" and "reasonable" water resources reallocation faces this question that which criteria and mechanisms should be considered for this "equitable" and "reasonable" reallocation?

Bankruptcy theory is one of the applicable methods for conflict management in resources allocation problems.The final aim of this method is a fair division of assets or a common resource (*E*) in face of scarcity among some creditors when their claims (*C*) exceed *E*. Bankruptcy theory has been numerously applied for resources allocation problems. Grundel *et al*. (2011) used it for multipurpose resources allocation situations (MPRA). Ansink & Weikard (2012) and Ansink & Marchiori (2010) used it in water resources management. In addition, Beard (2011) discussed a comprehensive review of the connection between the bankruptcy and river sharing literature.The frequent application of bankruptcy method reveals that it is a popular tool for resolving conflict and achieving agreement on water resources allocation problems.

The bankruptcy rules redistribute an asset *E* when it is not sufficient to meet all claims *C*. Many different bankruptcy rules have been developed. Some of these rules are based on the associated cooperative bankruptcy game (Grundel et al., 2011). An overview on bankruptcy rules is given by Thomson (2003). In addition to the proportional rule (PRO), which is the simplest method of bankruptcy, there are some classical bankruptcy rules such as constrained equal awards (CEA), constrained equal losses (CEL) and the Talmud rule (TAL) (Herrero & Villar, 2001). PRO, CEA and CEL are the most useful bankruptcy rules which have strong theoretical and empirical support (Ansink & Marchiori, 2010) and have been used in many practical studies such as Sheikhmohammady *et al*. (2010), Ansink & Weikard, (2012) and Herrero *et al.* (2009).

One of the most significant problems of using these methods, such as PRO, is that they do not take into account the amount of the contribution that agents have made to *E*. This does not seem to be fair. In this paper, we propose a new bankruptcy rule that does consider the contribution as an important factor to reallocate water resources. Reallocation of Euphrates and Tigris rivers is used as a case study to illustrate the application of the proposed rule to a real reallocation problem. This paper is arranged as follow. The new proposed rule is explained in the next section. In section 3, Euphrates and Tigris rivers reallocation as a real case study will be introduced and analyzed to find the most satisfying allocation. Section 4 concludes the paper.

METHODOLOGY

There are three reasons for solving water resources reallocation problems using bankruptcy rules (Ansink & Weikard, 2012). First, both reallocation problems and real bankruptcy problems have the common feature that claims exceed the available resources. Moreover, the properties of bankruptcy rules are well understood; hence, they can easily be put to use. Thirdly, many two-agent water rights disputes are solved using variants of bankruptcy rules (Ansink & Weikard, 2012). However, in spite of this, it should be taken into account that water resource allocation problems differ from a simple bankruptcy problem. In a bankruptcy problem, claimants are characterized by their claims *C* only, but in a water resource allocation problem, claimants are defined by the contribution they make to the assets E as well as their claim C to the resources. Moreover, the position of agents can be important in some water resource allocation problems, such as in river sharing problems, while the agents' position does not affect the final outcome in the standard bankruptcy problem.

Consider a set *N* of *n*≥*2* agents are claimants whose claims are $c_i \geq 0; c = (c_1,...,c_n)$ and their contributions are $a_i \geq 0; a = (a_1,...,a_n)$. The aim of bankruptcy method is to determine the allocation of each agent, denoted by $x_i \geq 0; x = (x_1,...,x_n)$. For a resource allocation problem, we have:

$$\sum_{i=1}^{n} a_i = \sum_{i=1}^{n} x_i \qquad (1)$$

$$0 \leq x_i \leq c_i \qquad (2)$$

The first equation assumes that all assets (*E*) are fully allocated but not over-allocated. In that case the sum of the allocations equal E; the sum of the contributions always equal *E*. The second equation simply says that the allocation an agent receives cannot be negative and never exceeds its claim.

1 – The proportional rule (PRO): is defined as follows:

$$x_i^{PRO} = \lambda c_i \quad \text{where} \quad \lambda = \frac{E}{C} \qquad (3)$$

in which *C* and *E* are the total amount of claims and assets, respectively. PRO allocates each agent the same proportion λ of its claims.

2 – The constrained equal award (CEA) rule: is defined as follows:

$$x_i^{CEA} = \min(\lambda, c_i) \quad \text{where} \quad \sum_{i \in N} \min(\lambda, c_i) = E \qquad (4)$$

3 – The constrained equal losses (CEL) rule: is defined as follows:

$$x_i^{CEL} = \max(0, c_i - \lambda) \quad \text{where} \sum_{i \in N} \max(0, c_i - \lambda) = E \qquad (5)$$

CEL allocates each claimant a share of the asset such that their losses in comparison with their claims are equal, subject to no claimant receiving a negative allocation.

As mentioned before, the problem with these bankruptcy rules is that they do not consider the contribution (a_i) that the agents make to the resource (*E*). The SSR rule developed by Ansink (2009) considers the contribution of agents, but it favors downstream agents, who always receive larger proportions of their claims in contrast with upstream ones (Ansink & Weikard, 2012). Accordingly, we propose a new division rule to cover the problems of these methods.

The proposed rule is based on this principle that the total deficit - the difference between *C* and *E*- should be divided inversely proportional to the agents' contribution to E: the bigger their contribution, the smaller the difference between their claim and the allocation they get. For instance, in a trans-boundary river problem, agents are countries and the agents' contribution is the proportion of total inflow of river which originates on the territory of each agent. So, the total deficit (*D*) is denoted as follow:

$$D = C - E \qquad (6)$$

which C and E are the total amount of claim and the asset or total resources, respectively.

The total deficit (*D*) should be proportionally divided according to agents' contribution and subtracted from their claims. Thus, the deficit or loss for each agent (d_i) is calculated as follow:

$$d_i = \frac{1 - \left(\frac{a_i}{\sum a_i}\right)}{n-1} * D \quad \text{where:} \quad d_i \leq c_i \qquad (7)$$

in which c_i and a_i are the claim and asset of agent. *n* is the number of agents and *D* is the total deficit evaluated using equation 6. The allocation of each agent (x_i) is then calculated using follow equation:

$$x_i = c_i - d_i \;;\; 0 \leq x_i \leq c_i \qquad (8)$$

or:

$$x_i = c_i - \left[\frac{1 - \left(\frac{a_i}{\sum a_i}\right)}{n-1} * D \right] \;;\; 0 \leq x_i \leq c_i \qquad (9)$$

The merit of this method is compared to SSR is that the upstream or downstream position of agents has no effect on the agent's allocation. In an exceptional situation, If $d_i > c_i$ then $x_i = 0$. For example, if a_i=0 and c_i be small, d_i will be greater than c_i. Moreover, if both the contribution and allocation of an agent *i* is zero (a_i=0 and x_i=0), we should repeat the calculation without considering him. The water resources allocation of the Euphrates and Tigris rivers is used as a real case study to illustrate how to implement the proposed technique.

CASE STUDY

The Euphrates and Tigris Rivers both originate in the Anatolian Highlands of Turkey and flow through Syria and Iraq and finally join the sea at the head of the Persian Gulf. Turkey contributes 88 percent of the water flow of the Euphrates River and 43 percent for the Tigris, making Syria and Iraq heavily dependent on these transboundary supplies of water (Lupu, 2002). Relations regarding the rivers were generally peaceful and cooperative in nature until the 1960's when Turkey, Syria, and Iraq began developing the Tigris and Euphrates Rivers, including water storage, irrigation, and hydropower dams for their industrial and agricultural developments as well as for addressing their Kurdish ethno-political concerns. In particular, the construction of the major development project known as the Southeastern Anatolia Project (or GAP) of Turkey (and to a lesser extent the Euphrates Valley Project of Syria, for irrigation) has served to increase tensions (Korkutan, 2001; Zentner, 2010). The equitable and reasonable use of these rivers lies at the heart of political disputes among the riparian states. With respect to these challenges, the respective projects of each state for using the rivers have caused great tensions among them. For example, in 1975, Syria and Iraq came very close to a full-scale war when Syria blocked the water flow in the Euphrates River (Schulz, 1995).

Figure 1. Tigris-Euphrates basin (UNEP/DEWA/GRID-Geneva, 2000).

Turkey, Syria and Iraq realized early after the announcement of the GAP development plans that coordination and cooperation were necessary to manage the Tigris-Euphrates waters effectively (Zentner, 2010). Several scholars have surveyed the hydro-policy of each riparian country for both the Euphrates and Tigris rivers such as Beaumont (1978), Kliot (1994); Altinbilek (1997); Lupu (2002), and Kucukmehmetoglu (2009). Most of these researches concluded that there is not sufficient water in these rivers to satisfy the demands of the three riparian countries (Table 1). However, most of them did not propose any mechanism to reallocate the flow of these transboundary rivers among riparian countries.

It can be clearly seen that the amount of claims are almost 49% and 12% more than the total resources *E*. It should be mentioned that we used the data related to composition of length, contribution of flow, and water claim of each riparian state in Table 1 from Kliot (1994), TMFA and Ministry of Foreign Affairs (1996), Ibrahim & Sonmez (2002), Lupu (2002), and Kucukmehmetoglu (2009).

RESULT

We reallocate the resources of these rivers using four bankruptcy rules: PRO, CEA, CEL and the proposed rule. Table 2 shows the results and compares them.Comparison of the results shows that CEA rule seems to prefer the agents with smaller claims and they would get a relatively higher portion of their claims. In contrast, CEL rule seems to favor the agents with larger claims and higher priority are given to them in the reallocation. PRO is located between CEA and CEL (cf. Herrero and Villar, 2001; Ansink and Marchiori, 2010). Furthermore, CEA corresponds to equal sharing when claims are sufficiently high, whereas CEL corresponds to equal sharing when claims are equal (Ansink & Weikard, 2012). The proposed method favors countries with a large contribution to the water resources.

Table 1. Contribution and water demand of riparian states on the Euphrates and Tigris rivers.

Rivers	Riparian	Composition of Length	Contribution of Flow (MCM/y)	Water Demand and Claim (MCM/y)
Euphrates	Turkey	1230 km (41%)	31580 (89%)	18420 (52%)
	Syria	710 km (23%)	4000 (11%)	11300 (32%)
	Iraq	1060 km (36%)	0 (0%)	23000 (65%)
	Total	3000 km (100%)	35580 (100%)	52720 (148%)
Tigris	Turkey	400 km (22%)	25240 (52%)	6870 (14.1%)
	Syria	32 km (1%)	0 (0%)	2600 (5.4%)
	Iraq	1418 km (77%)	23430 (48%)*	45000 (92.5%)
	Total	1850 km (100%)	48670 (100%)	54470 (112%)

Table 2. Reallocation of the Euphrates and Tigris rivers among riparian states.

Rivers	Riparian	PRO		CEA		CEL		Proposed method	
		x_i	λ_i	x_i	λ_i	x_i	λ_i	x_i	λ_i
Euphrates	*Turkey*	12430	67.5%	15790	86%	9850	53%	17457	95%
	Syria	7630	67.5%	9895	88%	7015	62%	3693	33%
	Iraq	15520	67.5%	9895	43%	18715	81%	14430	63%
Tigris	*Turkey*	6140	89.4%	6870	100%	3970	58%	5330	78%
	Syria	2320	89.4%	2600	100%	1150	44%	0	0%
	Iraq	40210	89.4%	39200	87%	43550	97%	43340	96%

It is noticeable to mention that we assume that all relevant effective factors including social, population, natural and ecological characters, economic and sustainable development criteria are considered in determining the demands of each riparian country. Moreover, political and military power of each state does not affect to overestimate the states' claims.

CONCLUSION

In this paper, the application of bankruptcy rules for conflict management of trans-boundary rivers is surveyed and we developed a new bankruptcy rule trans-boundary water resources allocation. The considerable feature of this rule is that the assets are allocated with respect to agents' contribution to the total resources, which seems to be more equitable and reasonable. Moreover, we used the water resources allocation problem of the Euphrates and Tigris Rivers as a real case study to illustrate the application of the proposed method in the water resources allocation problems. We compared the proposed method with three alternative bankruptcy rules (PRO, CEA, and CEL) to transboundary river resources allocation problem. The results reveal that this method is more powerful and reasonable to manage conflict and dispute over water resources allocation problems.

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