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GAME THEORETICAL APPROACH TO REGULATE THE PUBLIC-OWNED RIVER WATER UTILITIES: A CASE STUDY OF CAUVERY RIVER

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Abstract

Management of regulated water systems has become increasingly complex due to rapid socio-economic growth and environmental changes in river basins over recent decades. This paper focusses on the public-owned river water utility river basin conflicts that are increasingly marked by a heightened attention because of the political discourse surrounding it. In order to promote cooperation and resolve conflicts between states in a basin, policy makers must vigorously try to get the dialogue process on and avoid deadlocks in the process. Little theoretical and empirical research exists to understand when these negotiations are most effective and the mechanics behind these negotiations. Here we draw from diverse literature, economic and geographical, to capture and integrate the design elements associated with effective utility regulation along rivers on a national and international level. The utility sharing of waters of the river Cauvery has been the bone of contention of a serious conflict between the Indian states of Karnataka and Tamil Nadu. Decades of negotiations have not bore fruit till date. Even if treaties have been signed, they have been rejected and till date enforcement mechanisms are not put in place so as to hasten the negotiation process so as to avoid further escalation of irregularities in the water utilization. This study aims at defining few enforcement mechanisms based on the latest agreement brought out by the Cauvery Water Disputes Tribunal 2007 which was rejected and though appeals were filed by riparian states no amendments have been made so far. Non-Cooperative games have been used to model the regulation of the water utility and policy implications there on have been drawn out.

Keywords: *Water utility, Game Theory, Prisoner's Dilemma, Stag Hunt*
JEL Codes: *C72, D74, Q25, Q34, Q58*

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INTRODUCTION

Introduction to Water Conflicts

In the 20th century the world has experienced substantial growth in the demand for fresh water for agriculture and industry along with a decline in the uncontaminated supply of this source. International River basins historically cradles of modern civilization, have been transformed into arenas of competitive exploitation by neighbouring nations. The sharing of rivers across political boundaries is an area of both contention and conflict, be it at international, national, regional or local levels. Conflicts over water have steadily increased in number due to various reasons such as population growth, rapid industrialization, consumerism, pollution, environmental degradation, inequities in the access to and use of water, poor governance and complications arising out of managing multiple uses across multiple users. As a result it has become increasingly difficult to distinguish between water as an environmental issue or a national security issue.

Sharing gets even trickier when water sources cross international borders, and countries compete for often scarce resources in a confusing and fragmented legal and regulatory framework. Water stress often accompanies and can exacerbate other geopolitical tensions. Many of the world's simmering conflicts are in regions where water is shared and scarce. Some believe that water is likely to be a greater source of conflict in the 21st Century than oil or any other natural resource.

However, history shows that while international conflicts over water often inflame political tensions, most disputes are resolved peacefully. Despite the limitations of international law regarding control of water, disputes over international waters tend to induce cooperation rather than incite violence. Still, as water stress increases, conflicts are likely to become harder to resolve. Water security is likely to be of widespread concern among individual nations and the international

community as a whole. Water security is not just a matter of averting hot wars. Global trade depends on peace, and most global trade occurs via international shipping lanes. Countries around the world, individually and collectively, have incentives to keep these global flows moving.

The Cauvery River, the sacred Ganga of the South rises from the Talakaveri in the Brahmagiri hills of the Western Ghats and traversing through the states of Karnataka (Mysore) and Tamil Nadu (Chennai) finally discharges its waters into the Bay of Bengal near Cauvery-Patnam. The Cauvery is acclaimed as one of the best- regulated rivers of the country whose 90-95 per cent of the flow is utilised for irrigation 29 (1.0 million hectares) and hydel power generation bringing wealth and prosperity to its entire basin area. Prosperous towns line the banks of the river. It forms a number of waterfalls, rapids and cascades providing cheap sources of hydroelectricity and narrow gorges for constructing dams and reservoirs. It is because of these benefits that a dispute arose between Karnataka, Tamil Nadu and Kerala for the sharing of its waters. Initially, the dispute was confined to Karnataka (during the last part of the 19th century) but later on Kerala also joined the contesting parties. So the Cauvery issue is a historic issue which is yet to be resolved.

Conflicts can be resolved through game theory. Game theory is a tool that can help explain and address social problems. Some games, like some real situations are "winner-takes-all". These games are by their nature very competitive, as only one person can win (Chess would be an example of such a game). Other games, however, require cooperation to win. Many of the newer video games, for example, require cooperative strategies among multiple players in order for any single player to advance. In the real world, even during times of hostility, rivals generally have common interests and must cooperate to some degree.

LITERATURE REVIEW

In this context, game theory becomes an analogy to conceptualize the elements of conflict and cooperation in the relationship between two partners who participate in an exchange for some specifiable benefit in spite of their divergent interests. There is rich literature showing us various game theoretical mechanisms of sharing river water. Most of the water resource problems whether a benefit-cost allocation, transboundary water sharing scheme, water quality management or other water related issues can be modelled as non cooperative games be it a prisoners dillemma, chicken game or a stag hunt game. Identifying the model of the water game, is most important because the characteristics of an anti coordination game cannot be captured by a coordination game (say P.D. for example) (Madani, 2009).

Carraro *et. al.* (2005) believe that many natural resource management issues have the characteristics of a Prisoner's Dilemma game: players' dominant strategy is not cooperative, and the resulting equilibrium is not Pareto-optimal. Similarly, most papers dealing with sharing natural resources problems have made the same assumption about the game to be the Prisoner's Dilemma. However, all common resource problems might not be Prisoner's Dilemmas (Sandler, 1992). This would imply not all water games are rival in nature and sometimes coordination between players may be beneficial. Often non-cooperative game theory methods can help resolve the conflict based on the qualitative knowledge about the players' payoffs i.e. how the players order (rank) different outcomes (ordinal payoffs). This enables to handle the socio economic aspects of conflicts and helps in planning and designing a policy when quantitative information is not readily available.

As compared to the previous literature another technique of modelling benefit sharing is through cooperative game theory(Sheehan and Kogiku,1980). The cooperative technique is motivated by the fact

that in a non cooperative game such as prisoner's dilemma though its Pareto optimal to cooperate the conflicting nations would chose to non-cooperate because it falls in line with their Nash equilibrium. But this need not be true in all the cases as is shown in various other literature especially with respect to water resource problems. Bardhan (1993) believes that the literature usually jumps to the case of Prisoner's Dilemma in case of free-riders. Sometimes, the player might not be able to reach his objective on his own. Under that condition (Stag-Hunt game) a player cooperates when the other player also cooperates and defects when the other one defects. In some common resource examples consequences of defection might be so bad that a player prefers not to defect if the other player defects (Chicken game) (Bardhan, 1993).

For a cooperative game theoretic approach the allocation of cost and benefits of river sharing is modelled by comparing the net savings to a given player from joining a coalition. Though there is a propensity to disrupt, on application of Gately's rule* we can determine if the possibility of disruption tends to infinity or not. (Sheehan and Kogiku, 1980). Further in the literature few real examples are looked into -Case of 2 South Indian states which have to decide between producing electricity for self sufficient needs as against regional development by tapping the hydro-electric project which they have been differently endowed with. Here cooperation would have been the socially and financially best option but their political rivalry extends beyond all rationality and they refuse to cooperate. This provides motivation for my current research topic of formulating a non cooperative model between the South Indian states over the Cauvery dispute. Another example focused on the concept of core has been applied to the river sharing problem in Japan though, here too it was not clear how the core will sustain itself in the absence of mitigating institutional limitations on participant mobility.

Some geographical papers that motivated this study of water conflicts gives an insight into the other factors that we need to consider while looking at water conflicts. The papers in geographical journals try to establish the relationship between water conflicts and prevailing relations between the co riparian states (Alam, 2002). Rationale for water wars are based on 3 building blocks water scarcity, wider conflicts and bellicose public statements. Though it should be noted that India and Pakistan did not wage war against each other even if the above prevalent factors were present. But the reasons and conditions for an international water conflict and a national (inter-state) water conflict would differ substantially because of the presence/absence of an arbitrator, political set up etc. Hence even if India dealt with Pakistan in a cooperative manner, the same deal is very difficult to strike within India between conflicting riparian states.

*Gately's Rule describes the propensity to disrupt by each party. It is the ratio of party B's net savings of a joint action to party A's net savings of the same.

Giordano and Wolf establishes that in their study of water conflict and cooperation it is important to know the relation between the water related conflict at the national level and other non water related conflicts at the int'l level. And the nature of the relation would vary depending on each country. For example with respect to India-Pakistan, the Indus treaty has survived three wars. Both countries have remarkably kept other non water related conflicts out of the water conflict picture. While in Israel, though territorial issues lie at the heart of the Arab-Israeli conflict water is a contributing factor as well. The Arab League's decision to divert the head of waters away from Israel was a main factor that led to 1967 war. If water relations are to be clearly understood, intricacies of hydro political dynamics, their variation across geographic space and often distinct historical and political conditions within a region have to be considered (Giordano and Wolf, 2002).

War over water is neither strategically rational, hydrographically effective, nor economically viable. Alam (1997) has aptly dubbed this concept of water as a resource which transcends traditional thinking about resource-related disputes, "water rationality". Shared interests along a waterway seem to overwhelm water's conflict-inducing characteristics and, once water management institutions are in place, they tend to be consistently resilient. The more valuable lesson of international water is as a resource whose characteristics tend to induce cooperation, and incite violence only in the exception.

With respect to the River Cauvery, the main riparian states are Karnataka and Tamil Nadu. Over the years many agreements have been signed but an efficient solution has not emerged. Leave alone coalition of players, the coalition governments in the past years (years of the agreement) itself have been unstable. Active bipartisan politics in both states made an ultimate solution more difficult. No attempt was made to generate technical options to the sharing of Cauvery waters. Expert engineers were not able to work together for a common solution; rather they got involved in party politics (Wolf, 1998).

And so here lies the need to go ahead and model a non cooperative solution to the problem. The authors aim to execute an attempt to model a non-cooperative approach to resolve the sharing of Cauvery river water. Water is increasingly an important site of contestation between states in India because of the rapid pace of economic growth, growing populations and increasing urbanization. The growing importance of forging coalition governments at the national level and the related assertion of regional identities add to the intractability of the problems. More often than not, such issues arise as a result of a focus on demand-side management. Many scholars have argued that supply-side management might be one way of dealing with such issues.

While there is merit in this argument, there is a need to undertake institutional innovations as well.

Given the changing political dynamics in the country, it should not be difficult to convince the states that the relationship between state governments and the Centre need not be a zero-sum game. An increasing role for central institutions in dealing with issues emerging out of sharing the waters of transboundary rivers does not necessarily mean a whittling down of the powers of the states. Moreover, one needs to creatively use existing tools (such as mediation and scenario building exercises) for managing water resources of inter-state rivers more effectively and democratically.

RESEARCH OBJECTIVE AND METHODOLOGY

The sharing of waters of the river Cauvery had been the bone of contention of a serious conflict between the Indian states of Karnataka and Tamil Nadu. The genesis of this disparity, itself, lies in two controversial agreements, one signed in 1892 and another in 1924, between the Madras Presidency and the Princely State of Mysore.

The state of Karnataka feels that it has not got its due share of water utilization vis-a-vis Tamil Nadu. Karnataka claims that these agreements were skewed heavily in favour of the Madras Presidency, and has since demanded a renegotiated settlement based on "equitable sharing of the waters". Tamil Nadu, on the other hand, pleads that it has already developed almost 3,000,000 acres (12,000 km^2) of land and as a result has come to depend very heavily on the existing pattern of usage. Any change in this pattern, it says, will adversely affect the livelihood of millions of farmers in the state. Decades of negotiations have not bore fruit till date.

The research objective is to shed light on some of the routes the negotiation process could take or into which it can be steered, given certain assumptions. Game theory has been widely used in solving all sorts of water resource management problems and conflicts. It is essentially the mathematical study of competition and cooperation. It illustrates how strategic interactions among players result in overall outcomes with respect to the preferences of those players. Such outcomes might not have been intended by any player (Stanford Encyclopedia of Philosophy, 2006). Game theory can be used to predict how people behave, following their own interests, in conflicts. In a typical game, decision makers (players), with their own goals, try to outsmart one another by anticipating each other's decision. The game is resolved as a consequence of the players' decisions. It analyses the strategies players use to maximize their payoffs. A solution to a game prescribes decisions the decision makers might make and describes the game's outcome.

Similarly taking the present scenario of Cauvery and based on its latest agreement, the study tried to see which model of the game best captures the essence of the conflict situation. Game theory has two approaches - Cooperative and Non - cooperative. This paper looks at few basic non cooperative solution concepts and checks the strategic changes that can be brought to the negotiation table thereafter.

MODEL DEVELOPMENT

The assumptions for the game were kneaded through the information provided by the CWDT and on the basis of the latest (rejected) agreement. The crucial points that would impact this study on each players strategy has been dealt with in detail below.

The CWDT Report

The report mainly consisted of leading experts study on the water requirements of the state, based on existing cropping patterns, other industrial and domestic uses etc. Also recommendations to economize on water have been included by the experts.

Cropping Patterns in Karnataka and Tamil Nadu

In Tamil Nadu, the normal pattern in the Cauvery basin is to raise the first crop of short duration paddy known as `Kuruvai' in June, with the waters of south-west monsoon flowing down the river, early enough, to be harvested before the onset of the north-east monsoon. After the harvest of `Kuruvai', a second crop of medium term paddy-known as `Thaladi' is grown in these areas with the benefit of north-east monsoon to be harvested by January-February. The rest of the areas grow only a single crop of long term paddy known as `Samba' commencing from July/August, to be harvested in December/January. In other riverline tracts too, subject to availability of supply, two paddy crops are grown, followed by a cash crop like green gram and black gram.

In Karnataka's side of the Cauvery basin ragi, jowar, sesame, groundnut, redgram and short duration pulses are the common kharif crops under rainfed conditions. In some areas, where there are pockets of retentive soils or where late rains occur, some rabi crops like jowar, Bengal gram and cotton are cultivated. However, in these areas failure of rains is very common and as such is severely drought prone. Appropriate doses of irrigation would also help increase the productivity and stability of the yield. In the Cauvery basin, particularly, in old irrigation projects in Karnataka, rice and sugarcane are the main crops under irrigation. This has been an old practice in Karnataka. In years of inadequate monsoons, rice is discouraged and light irrigated crops like ragi, groundnut etc., are grown in rabi/summer. In the new irrigation projects in Karnataka there is no provision to grow paddy even during kharif season except in limited areas to a limited extent. Light irrigated crops

like ragi, maize, jowar, pulses, groundnut, sunflower etc., are grown. On the other hand in Tamil Nadu, paddy is the major crop.

The National Commission on Agriculture in their report (Part V-Resource Development) have mentioned that in India ,rice is grown in about 40 percent of the irrigated area under all crops; rice crop is the largest consumer of irrigation water, accounting for 50 percent of the total irrigation supply. Next to rice comes the wheat crop followed by other cereals and these consume about 15 percent and 12 percent of the irrigation supplies respectively. Amongst cereals, rice has the lowest productivity per unit of water as is evident from the following table

Table 1: Productivity of Cereals per unit of Water

Crop (new strains)	Water requirement in a typical tract (mm)	Productivity per mm of water (kg/ha)
Rice	1200	3.7
Sorghum	500	9
Bajra	500	8
Maize	625	8
Wheat	400	12.5

Source: National Commission on Agriculture.

Tamil Nadu follows traditional irrigation methods which increases its scarcity of water. For example: water once released during a crop season continues uninterruptedly. There is no practice of running the canal system on rotational basis as also no Warabandi is enforced amongst the beneficiaries with the result that almost during the entire irrigation season, the waters let into the channels run to waste during night time. Also, even now in large areas, field to field irrigation practice is continuing. In view of the above situation, at least 5 percent improvement in the overall system efficiency can be easily achieved by proper management practices in all the existing schemes. Therefore,

system efficiency of 65 percent had be adopted for working out the crop water requirement and the same has been done in order to find out the actual crop water requirement in TN. Key witnesses to the CWDT like Dr.M.S.Swaminathan have mentioned before the Tribunal the need to protect the economy of Thanjavur which is heavily dependent on rice. He too advocates the use of new varieties of seeds, among other efficient cropping practices.

On observing Tamil Nadu's prevalent agricultural practices and water management techniques, the degree of wastage and inefficiency in the system is evident. There is scope for a lot of improvement.

The Committee has suggested that savings can be effected by:
(i) Restricting the double crop paddy area;
(ii)Introduction of a shorter duration variety in place of `Samba`;
(iii) Growing crops requiring less water.
These considerations would apply to all projects.

This does not mean Karnataka is completely free of inefficiency in their irrigation system. But the Committee found far lesser fault in their system compared to TN. But changes like restriction in the area of the Cauvery basin (Karnataka side) where they are allowed to plant sugarcane have been reduced to 40000ha.

Domestic and Industrial Water Requirement of Tamil Nadu and Karnataka from The Cauvery Waters

In general the Tribunal kept the following Indian standards in mind in computing the domestic and industrial requirement of both the states. Due to lack of detailed information regarding the population of various towns and cities etc. in the cauvery basin; as also the type of water supply delivery system, they considered the drinking water requirement of urban population as under:

(i) 25 percent of urban population at 135 lpcd
(ii) the remaining 75 percent of urban population at 100 lpcd

Also they do not have livestock figures separately for all the party States and U.T of Pondicherry, considering animal population to be equal to the rural human population - although this will be on a liberal side - they provided 30 lpcd for animals and 40 lpcd for humans aggregating to 70 lpcd as recommended above.

Since the drinking water requirement would be spread over the entire area of the basin, the Tribunal is of the opinion that it would be reasonable to assess that 50 per cent of the drinking water requirement would be met from the ground water sources as it is generally seen that wells and tube wells in urban and rural areas cater to substantial requirement of drinking water. It may be mentioned that while calling for information states were asked to project their population for working out drinking water requirement.

The industrial development depends on several other sectors as well – specially the energy, infrastructure and massive financial investments etc. Both the states projected their water requirement based on increased growth rate. The states' domestic and industrial requirement is tabulated in Table 2.

Table 2: Water Requirement of Tamil Nadu and Karnataka

	Karnataka	**Tamil Nadu**
In basin domestic water requirement	1.75 TMC	2.20 TMC
Industrial use	0.10 TMC	0.25 TMC
Water requirement for Thermal power	-	0.28 TMC

Note: Based on the water requirements of each state and other principles, CWDT came out with an agreement in 2007.

Highlights of the Final Agreement of 2007 (Related to Tamil Nadu and Karnataka)

Clause - II

The order would supersede –the agreement of 1892 between the then Government of Madras and the Government of Mysore so far as it related to the Cauvery river system and the agreement of 1924 between the then Government of Madras and the Government of Mysore so far as it related to the Cauvery river system.

Clause-IV

The Tribunal hereby determined that the utilisable quantum of waters of the Cauvery at Lower Coleroon Anaicut site on the basis of 50 percent dependability to be 740 thousand million cubic feet-TMC.

Clause-V

The Tribunal hereby orders that the waters of the river Cauvery be allocated in three States of Kerala, Karnataka and Tamil Nadu and U.T. of Pondicherry for their beneficial uses as mentioned hereunder:

(i) The State of Kerala - 30 TMC
(ii) The State of Karnataka - 270 TMC
(iii) The State of Tamil Nadu - 419 TMC
(iv) U.T. of Pondicherry - 7 TMC

In addition, we reserve some quantity of water for environmental protection and inevitable escapages into the sea as under:

(i) Quantity reserved for environmental protection-10 TMC
(ii) Quantity determined for inevitable escapages into the sea- 4 TMC

Total (726 + 14) 740 TMC

Current Status of the Agreement and Conflict

As soon as the agreement came out, Tamil Nadu wanted it gazetted. But Karnataka filed an appeal to the apex court of the country and filed Special Leave Petition as well. They opposed the allocations stated by the tribunal and refused to share that quantity of water with TN. The judgment to that was due in February 2012, but it has been postponed to April 23rd. Moreover the chief of CWDT quit earlier this month, which added to the delays. Since no final order has yet been passed, both states continue in their earlier path of sharing (limited water) and using water. Karnataka continues to draw and sanction plans of damming Cauvery citing power shortage and TN continues to raise hue and cry about Karnataka not sharing their stored water.

Keeping in mind that 2007 is the last official agreement that was released by the Tribunal in respect of the Cauvery issue, we formulate a game between the players noting the changes suggested by the Tribunal committee as well as the various uses of water for each state and the tradeoffs they deal with.

Characterization of the Game

- PLAYERS: Karnataka (Ka) and Tamil Nadu (TN)
- Karnataka's strategies are to share or do not share waters with Tamil Nadu (represented by ROW)
- Tamil Nadu's strategies are to alter cropping pattern or do not change cropping pattern (COLUMN)

Inspiration for TN's strategy is drawn from the suggestions in the Tribunal. In the summary of the report provided in the previous chapter, they explicitly stated about the inefficient cropping pattern prevalent in Cauvery Delta Zone (Thanjavur). Hence TN's shortage of water caused due to bad irrigation techniques can substantially be reduced if the state

agrees to alter cropping pattern and make changes with respect to its irrigation methods.

Karnataka's strategy by virtue of being the upstream riparian state is to share or not share waters of Cauvery. The conflict continues because Karnataka wants to dam Cauvery's flow in its state at various points in order to tap its hydel power and they would ideally want to route Cauvery waters for other industrial, agricultural and domestic purposes based on their requirement to other parts of their state.

In order to capture the payoffs each state gets with respect to their strategies, proxies are needed which would approximate the game as closely as possible to the conflict. Now, to Karnataka, sharing waters would imply lesser water for itself. Lesser water to the state would have a ripple effect in all the sectors -irrigation, power, industrial, domestic use-where they would face a water deficit. This can be either captured through power shortage alone and thus the revenue forgone due to sharing. Or we can include the effect of water deficits on the revenue of agriculture and industry. And to Tamil Nadu -changing cropping pattern would entail net benefits to its economy in terms of bringing about efficiency into their agricultural system and thus output (revenue).

Based on the above description of the game we take the conflict through 3 of the standard non-cooperative games and see which one renders itself to the conflict in the best manner and see the implications if the conflict takes that course of the game.

Table 3: Prisoner's Dillemma

	Don't Change(TN)	**Change (TN)**
Don't Share (Ka)	(1,1)*	(3,0)
Share (Ka)	(0,3)	(2,2)

In the Cauvery context, though we would be tempted to model it this way because the status quo as of now is the Nash equilibrium, we don't! Because in a PD, the Nash is necessarily the worst outcome with respect to payoff but in a river sharing context we can't justify that Karnataka and Tamil Nadu are absolutely worse off by not sharing and not changing cropping pattern (Table 3). That is both players need not be worse off by not sharing and not changing. So this type of the game in this context becomes void.

Table 4: Chicken Games

(Players are better off choosing rival strategies)

	Don't Change	**Change**
Don't Share	(0,0)	(3,1)*
Share	(1,3)*	(2,2)

The Nash Equilibria in this game are opposite actions by each player (starred ones) (Table 4). So being in (0, 0) by moving to the Nash of the game we do not achieve any overall welfare benefit. Hence the above logic renders it void too.

Table 5: Coordination Game

(Where players will do better if they chose the same strategy)

	Don't Change	**Change**
Don't Share	(2,1)*	(0,0)
Share	(0,0)	(1,2)*

In a static setup, the above coordination game has 2 Nash equilibria. Note from a welfare point of view, sum of their pay offs are the same so there is no difference between both the Nash', per se. But strategy wise a planner would prefer (1,2) to the other (Table 4).

Comparing the present situation Karnataka does not want to share and Tamil Nadu does not want to change cropping pattern, so the game is at (2,1). As a planner ,the need is to design a system which will persuade Karnataka and Tamil Nadu to move to (1,2) which is the outcome planner prefer in the long run. Given TN changes cropping pattern, it is in the best interest of Ka to share water, as she can earn a higher payoff of 1 as compared to 0. But at the same time we see that Karnataka has to get a drop from its status quo payoff of 2. If as a planner we validate such a move we are implicitly putting a value on Tamil Nadu's water deficit as compared to Karnataka's power deficit. In other words there is a value judgement here by the planner.

The mechanics behind such a move is possible if as planner we incorporate a punishment into the negotiation process that would make Karnataka move from (2,1) to (1,2). We can probably think of a punishment larger than the power deficit that Karnataka has to forgo by sharing waters ,only then can we persuade Karnataka to move to (1,2).

Say we move this to a sequential framework, do the Nash's still hold?
(By Backward Induction)
if TN moves first then (change, share) ie;(2,1)-here 2 for TN and 1 for Ka emerges.
if Ka moves first then (don't share, don't change) ie; (2,1)-here 2 for Ka and 1 for TN emerges.

So as a policy implication the planner can aim at persuading TN to commit to the strategy - changing cropping pattern which would prove crucial to moving the dialogue process forward, given the sequential set up is present and both players will act rationally. A better coordination game to capture the conflict would be the Stag Hunt game (Table 5).

Table 5: Stag Hunt Game

	Don't Change	**Change**
Don't Share	(2,2)*	(2,1)
Share	(1,2)	(3,3)*

Here there are two Nash equilibria but we can differentiate between them as one can be ranked above the other. So (2,2) is the Bad Nash and (3,3) the good one.

Then here the planner has to incentivize both the players TN and Ka to make a move to the better Nash. Note: here from Karnataka's POINT OF VIEW given Tamil Nadu changes it's cropping pattern, if we look at the payoffs: if Karnataka continues to remain at its, "Don't Share" strategy it still earns its status quo payoff of 2 (which is different from the earlier coordination game wherein if Karnataka did not share it would have incurred 0 payoff).

So the planner has to incentivize such that both the players are persuaded to move to (3,3). Planners justification to move to (3,3) is purely welfare oriented. Its Pareto optimal to do so. We should look at it from the point of overall development of India to which such a move would benefit, because Tamil Nadu's benefit contribution to the overall economy is more than Karnataka's losses (per se, in terms of power deficit and other losses thereafter).

If we look at a stag hunt in a sequential framework the study finds us arriving at the same Nash equilibrium which implies if one commits in sequential the other will follow suit. So if it's a sequential game it is enough if planner persuades one of the players.

Thus it is evident from the above discussions of the game that, water sharing problems need not always be modeled as a Prisoners

Dilemma or Rival games, because the dynamic structure of water resource problems and game evolution might affect the behaviour of stakeholders in different periods of the conflict. The above games are drawn assuming that politics does not raise its dirty head to collapse the negotiations, which is rarely the case. The power asymmetries among the riparian states have a big impact on the enforcement mechanisms thought of above.

CONCLUSION

Non cooperative game theory has been used to capture the conflict situation in Cauvery and to draw out options that would enable the dialogue process between riparian states to continue well. Game theory has provided insights for understanding or resolving water conflicts which often are multi-criteria multi-decision-makers problems. It sometimes can reflect and address different engineering, socio-economic, and political characteristics of water resources problems even without detailed quantitative information and without a need to express performances in conventional economic, financial, and physical terms. The study was able to predict if the optimal resolutions are reachable and explain the decision makers' behaviour under specific conditions.

Although, most water conflicts (games) have been previously modelled as Prisoner's Dilemma, other games with different structures and characteristics (i.e. Chicken and Stag-Hunt) support the idea that not all water resources games are Prisoner's Dilemma. It was also discussed how the structure of the games might be changed by third parties and regulating agencies to promote Pareto-optimal resolutions to water conflicts considering the non-cooperative behaviours of the stakeholders.

It is important for the policy maker to understand that in persuading parties to take a particular strategy route, adequate efforts must be taken to educate grassroots level citizens who will be directly

affected by such decisions. For eg: in case of Tamil Nadu ,more than any other obstacle it is the mental block of farmers that we ought to transcend in order for them to accept modern agricultural practices and changing cropping patterns, because there is the issue of ignorance and sentiment attached to ancestral property and plantations. Hence time and effort should be taken for this matter, so as to make a significant change in the level of water demanded by the state.

From the games, it is obvious that besides dialogue either a punishment or incentive must be used to get the parties to be on the track of cooperation. Water is, by its nature, an interdisciplinary resource -- the attendant disputes can only be resolved through active dialog among disciplines. Just as the flow of water totally ignores political boundaries, so too does its management strain the capabilities of institutional boundaries. In administering the punishment or incentive we should see that the politics of democratic coalitions do not interfere and mar its judgement of punishing a particular party or in incentivizing one. Also the opposition in each should not tap such a volatile conflict to garner votes by disrupting the negotiation process. They should look at the greater social good and act responsibly.

Water dispute amelioration is as important, and less costly, than conflict resolution. Most often, international attention, and resultant financing, is focused on a basin only after a crisis or flashpoint. In fact, the experience of the commission such as those of the Amazon, La Plata, or Mekong may suggest that when international institutions are established well in advance of water-stress they help preclude such dangerous flashpoints. As noted earlier, other basins have equally resilient institutions, which have survived even when relations on other issues were strained. Hence the authorities set up in monitoring the Cauvery conflict must be strengthened and their roles should be well defined, so that there is no wastage of government machinery.

Furthermore, it must be understood that once cooperative water regimes are established through treaty, they turn out to be impressively resilient over time, even between otherwise hostile riparian states, and even as conflict is waged over other issues. So every attempt must be made so that roadblocks to cooperation are removed for the welfare of the nation as a whole.

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