TOWARDS OPTIMAL TREATIES FOR TRANSBOUNDARY WATERCOURSE MANAGEMENT

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Overview

It is common for riparians sharing a transboundary watercourse to have competing uses for the water, such as hydroelectric power generation, agriculture, industry, or commercial or residential requirements. The decisions of riparians seeking to allocate a limited quantity of water, by nature, are interdependent. In jointly managing the transboundary watercourse, riparians may decide to enshrine the water allocations in a treaty. The risk of inadequate or excessive allocations potentially arises from a poorly designed or implemented treaty, yet is hardly addressed systematically in the literature on treaty formation or execution. Our objective in this paper is to propose a tool for optimising the design or implementation of a treaty managing transboundary water allocations. First, using a calibrated mixed complementarity model ("MCP"), we characterise the optimal allocations based on the economic welfare for each of the riparians under an "infinite" or unconstrained amount of water. Then, using game theory, we explore the strategic implications of alternative allocations under a "finite" or constrained amount of water. If, under the set of constrained allocations, cooperation does not Pareto dominate defection, there is no incentive to write a treaty. As a potential solution to the impasse, we calculate the transfers required to transform the game in such a manner that cooperation is not only a dominant strategy Nash equilibrium, but also Pareto-superior. We draw lessons for the rational establishment or operation of transboundary watercourse treaties, including the use of money damages to enhance the prospects of treaty compliance.

Methods

Our approach has two stages. In the first stage, we develop an MCP characterising the optimal allocations for each of the riparians. A water market in one riparian is connected, through a transboundary watercourse, to an electricity market with hydroelectric and thermal generation in another riparian. We derive the optimality conditions, and prove two propositions. One, the optimal water allocations are a function of the economic welfare individually accruing to each of the riparians but jointly determined by them. And two, even if there is slack watercourse capacity, a riparian has no economic incentive to take more than its Pareto-efficient allocation.

In the second stage of our analysis, we deploy game theory to demonstrate the strategic implications of alternative allocations. We perform a calibration involving an upstream riparian U requiring water for various non-energy purposes, and a downstream riparian D requiring water for hydroelectric generation to supplement its thermal generation or electricity importation. We simulate the behaviour of riparians under two cases: there is an "infinite" amount of water (i.e. abundant enough to prevent the watercourse capacity constraint from ever binding), or the constrained amount of water available is less than the sum of their optimal allocations under an "infinite" amount of water. The second case may lead to a strategic game amongst the riparians. In a Prisoner's Dilemma ("PD"), defection is a dominant strategy Nash equilibrium but is Pareto-inferior to socially optimal cooperation, and thus the players have an incentive to write a treaty in order to obtain the benefits from cooperation. However, if the riparians are not in a PD and if cooperation does not Pareto dominate defection, there is no incentive to write a treaty. Given the game, we optimise the level of transfers ensuring that cooperation is the dominant strategy equilibrium, is a Nash equilibrium, and Pareto dominates the other profiles.

Results

There are four sets of results and implications. Firstly, our proof for the first proposition proceeds as follows. At a Pareto efficient allocation, the marginal rate of substitution ("MRS") between the two water uses must be the same. The MRS not only measures the inter-riparian value of an incremental unit of water, but also reflects the value of hydroelectric generation relative to thermal generation. Thus the valuations for the relief of capacity constraints of either the shared watercourse or the thermal generation plant are jointly determined by the riparians. One implication is that, if the equilibrium is Pareto efficient, there is no economic basis to deviate from the optimal levels of water allocations and thermal generation. Otherwise, the MRS would differ between riparians, or the valuations for the relief of any capacity constraints would be inconsistent.

Secondly, our proof for the second proposition proceeds as follows. If there is slack capacity, given a massive amount of water available, the shadow value of water is zero. This implies that there is an incentive to use the water for production, and the optimal allocations are positive. The sum of the optimal allocations is obviously far below the extraordinarily high watercourse capacity. Given the first proposition, deviating from the Pareto optimal levels of output for the riparians would cause a divergence in their MRS or their valuations for the relief of any capacity constraints would be inconsistent. As a consequence, a riparian has no incentive to take more than its optimal allocation just because there is slack. In short, more water is not necessarily better.

Thirdly, our calibrations simulate the behaviour of riparians under two cases: an unconstrained amount of water, and a constrained amount of water. Under the first case, we determine the Pareto optimal water allocations and their efficiency properties (the implications of the first proposition), and demonstrate the decline in the marginal benefit and the distortion in the MRS condition if more than the optimal allocations are taken (the implications of the second proposition). Under the second case, there is not enough water for each of the riparians to take the allocation that each would have obtained under an unconstrained amount of water. If they cooperate, they each receive their optimal allocation (and economic welfare). If a riparian defects (i.e. takes more than its optimal allocation), it has an incentive to take only up to its rational limit, but could still enjoy an increase in economic welfare. If both defect, their payoffs depend on the allocation rule, and the resulting game may not be a PD.

And fourthly, our calibrations enable us to study the behaviour of riparians, assuming that indeed the resulting game, due to some arbitrary allocation, is not a PD. Defection is a strictly dominant strategy for U or D, and simultaneous defection is a dominant strategy equilibrium and a Nash equilibrium. Simultaneous cooperation does not Pareto dominate simultaneous defection, however, because D gets a worse pay-off under simultaneous cooperation than under simultaneous defection. Thus, there is no incentive to write a treaty. Given the game, we calculate the transfers ensuring that simultaneous cooperation not only is the dominant strategy Nash equilibrium, but also Pareto dominates the other profiles. The transfers, which may be positive or negative, are estimated in such a manner that their sum is less than or equal to zero (i.e. riparians cannot "create money"); and that the resulting payoffs are "as close as possible" to the original ones. The transfers may be interpreted as supplemental incentives representing valuations of physical, commercial, or governance conditions, or as devices for implementing a damage clause invoked in the unlikely event that a riparian fraudulently obtains any gains through misrepresentation or deceit.

Conclusions

We have three main conclusions. First, even if there is extraordinarily abundant water, it is still sensible to perform an optimisation estimating the Pareto-efficient allocations. This matter is likely to increase in importance, as the energy transition (from fossil fuels to renewable energy, especially flexible hydroelectric power) intensifies in the coming years or across international jurisdictions. Second, in the unlikely event of fraud, a Pareto-superior benchmark is a prudent starting point for the determination of economic damages and the compensation for a harmed riparian. Indeed, even if riparians do not trust each other, they could enter into such arrangements with the assurance that they would be compensated if there happens to be non-compliance. And third, in the event a new treaty is established or an existing one is re-assessed, the process can focus on well-defined parameters for which information is readily or can be made available on a sustained basis.

References

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