TRANSBOUNDARY WATER EQUITY: MAKING RIVER COOPERATION FAIRER

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Transboundary water equity: Making river cooperation fairer

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Abstract
Shared river-basin planning often maximizes total benefits, without considering fairness. A new welfare-based optimization framework shows how equity can be made transparent, negotiable and operational in transboundary water and energy decisions.

Main article
Transboundary rivers connect countries through water, energy, food production, ecosystems and risk. They also connect them through difficult questions of fairness. Upstream and downstream states rarely face the same opportunities or vulnerabilities. Infrastructure might be located in one country but hydrological risks or environmental costs transferred to another. As climate change increases hydrological variability, and demand for water and electricity grows, the question is not only whether countries can cooperate, but whether cooperation can deliver outcomes that are perceived as fair.

This is a long-standing challenge in water resources planning. Transboundary water allocation is not only a matter of efficiency, but also of distributive justice among states and communities[1]. Power asymmetries, weak institutions and shifting political contexts can shape who benefits from shared waters and who bears the costs[2]. At the same time, transboundary water relations are not defined solely by conflict. Cooperative arrangements are frequent, but their existence does not necessarily mean that benefits and risks are distributed fairly[3].

Writing in *Nature Water*, Arnold, Giuliani and Castelletti[4] address this gap by bringing a classic idea from welfare economics into the analysis of transboundary water systems. They use Atkinson's welfare function to incorporate distributional equity directly into optimization. Atkinson's original contribution was to connect inequality measurement with social welfare, using an inequality aversion parameter to express how strongly priority should be given to those who are worse off[5]. In this water management setting, the parameter becomes a way to examine the balance between total system performance and a fairer distribution of benefits among riparian states.

The framework is powerful because it makes a normative choice visible. When inequality aversion is low, the model prioritizes total basin performance. When inequality aversion increases, it gives greater weight to improving outcomes for worse-off actors. This does not remove politics from water allocation. Rather, it makes explicit an important value judgement about how decision makers should weigh improvements in overall system performance against the need to reduce inequality among riparian states.

Arnold et al. apply this approach to the Zambezi watercourse, which links Zimbabwe, Zambia and Mozambique. Here, hydropower is central to electricity supply and future infrastructure choices will shape the distribution of benefits and risks. The authors examine cooperative reservoir operations and the expansion of floating photovoltaics, and their results show that more equitable hydropower operation can be achieved with relatively small reductions in total generation. More importantly, equity gains arise mainly through higher firm generation — meaning more reliable power during low flow periods, for more vulnerable riparian states. From a narrow efficiency perspective, this might look like a modest loss. From a resilience perspective, it can represent a meaningful improvement.

The floating solar application adds a further insight. When maintaining more natural delta flows reduces Mozambique's hydropower generation, an efficiency-oriented investment strategy does not necessarily compensate the country bearing the cost. By contrast, an equity-oriented solution redirects part of the floating solar investment towards Cahora Bassa — an artificial lake and dam on the Zambezi — and helps Mozambique recover part of the production lost from supporting the environmental objective. The model therefore adapts to changing distributional consequences, rather than requiring the analyst to decide in advance which country should be prioritized.

The broader value of this work is that it moves equity from an afterthought to a design criterion. Transboundary agreements often refer to equitable and reasonable utilization, but operational tools for translating this principle into planning decisions remain limited. The Atkinson framework offers one way to make distributional preferences explicit, testable and open to negotiation. This is especially useful where side payments are difficult, trust is fragile and long-term cooperation depends on whether outcomes are considered legitimate.

Several issues deserve attention, however, before such a framework can be used more widely. First, the analysis treats each country as a single actor. This is reasonable for interstate basin planning, but it can obscure inequalities within countries. A gain in national hydropower reliability does not necessarily mean improved access for poorer households, remote communities or groups already underserved by the electricity system. Future applications should therefore connect basin models with power-system, electrification and socio-economic models that can represent subnational outcomes. Integrated nexus assessments show how water, energy, land, economic and policy dimensions can be linked within a coherent modelling framework, offering a useful basis for extending equity analysis across sectors and scales[6]. Work on spatial electrification can further support this extension by representing access, infrastructure needs and distributional outcomes more explicitly[7,8].

Second, the inequality aversion parameter should not be treated as a purely technical calibration choice. Its value reflects ethical and political preferences about how much priority should be given to worse-off actors. This makes stakeholder engagement essential. Participatory modelling and science, policy and stakeholder interfaces can help translate abstract trade-offs into concrete alternatives that basin actors can understand, discuss and contest[9,10].

Third, transboundary water systems are embedded in broader economic, social and environmental systems. Hydropower, irrigation, ecosystem services, energy access and national development plans interact across sectors and scales. Future applications would therefore benefit from integrated approaches that can account for water management decisions, economic feedbacks, strategic behaviour and uncertainty within the same analytical framework[11].

Finally, not all objectives should be aggregated into a single welfare function. Environmental flows, biodiversity and ecological thresholds may behave differently from welfare measures that increase smoothly with benefits. The authors recognize this by treating delta-flow deficits as a separate objective. This distinction is important. Equity based aggregation should clarify value judgements, and not flatten all social and ecological concerns into one index.

Overall, Arnold et al.[4] offer a timely contribution to water resources planning. As climate pressures intensify, cooperation over shared rivers will depend not only on producing efficient solutions, but also on showing who gains, who loses and what societies are willing to trade for fairness. By making equity explicit within optimization, the Atkinson approach provides a promising step towards river basin planning that is not only more efficient, but also more legitimate.

References

1. Yalew, S. G., Kwakkel, J. & Doorn, N. *Front. Environ. Sci.* **8**, 590954 (2021).
2. Dinar, S., Katz, D., De Stefano, L. & Blankespoor, B. *Polit. Geogr.* **69**, 162–172 (2019).
3. Turgul, A. et al. *Water Int.* **49**, 274–288 (2024).
4. Arnold, W., Giuliani, M. & Castelletti, A. *Nat. Water* xxx–yyy (2026).
5. Atkinson, A. B. *J. Econ. Theory* **2**, 244–263 (1970).
6. Koundouri, P. et al. *npj Clim. Action* **4**, 113 (2025).
7. Mentis, D. et al. *Environ. Res. Lett.* **12**, 085003 (2017).
8. Egli, F., Agutu, C., Steffen, B. & Schmidt, T. S. *Nat. Commun.* **14**, 5066 (2023).
9. Alamanos, A., Koundouri, P., Papadaki, L. & Pliakou, T. *Front. Water* **3**, 744773 (2022).
10. Alamanos, A., Koundouri, P., Papadaki, L., Pliakou, T. & Toli, E. *Water* **14**, 2879 (2022).
11. Englezos, N., Kartala, X., Koundouri, P., Tsionas, M. & Alamanos, A. *Environ. Resour. Econ.* **84**, 975–1030 (2023).