“Sharing water and benefits in transboundary river basins” by D. Arjoon et al.

The authors would like to thank the reviewer for his/her interesting and insightful comments. Our responses and the proposed changes/corrections are detailed below.

Referee #3

3.1 P3 L 14–17. You implicitly state that axiomatic approaches ignore economic welfare. This is not exactly true. You may not be aware of some recent work in this area, e.g.: - Ambec, S., A. Dinar, and D. McKinney (2013). Water sharing agreements sustainable to reduced flows. Journal of Environmental Economics and Management 66(3), 639– 655. - Van den Brink, R., G. van der Laan, and N. Moes (2012). Fair agreements for sharing international rivers with multiple springs and externalities. Journal of Environ- mental Economics and Management 63(3), 388–403. These papers apply axioms on the welfare distribution resulting from the physical allocation of water. Actually, most axiomatic papers in the river sharing literature do so.

RESPONSE: We do not agree that we implicitly abstract from economic welfare. The text in question reads: “As discussed previously, the economically efficient allocation of water is not necessarily equitable. Conversely, axiomatic approaches may be considered equitable but do not necessarily maximize the total economic welfare over the basin and may be considered deficient as a result. Institutional arrangements that ensure maximum economic welfare, as well as the equitable sharing of these benefits over the basin, are required.”

We use the word “deficient” to mean that the axiomatic approaches may result in less than optimal water allocations from an economic perspective. For example, Madani et. al. (2014) uses bankruptcy rules to determine the allocation of water within the Qezelozan-Sefidrud river system in Iran. The resulting allocations are defined by the notion of fairness that are inherent in each rule, but these rules do not necessarily maximize the economic welfare over the basin.

In order to clarify this, we have changed the paragraph to read “*As discussed previously, the economically efficient allocation of water is not necessarily equitable. Axiomatic approaches, on the other hand, allow the characterization of an equitable distribution of welfare, but do not necessarily maximize the aggregated economic welfare over the basin. Institutional arrangements that ensure maximum economic welfare, as well as the equitable sharing of these benefits over the basin, are required.*”

3.2 You introduce, in Sections 2.1-2.3 a social planner that collects all information and derives an appropriate social cost of water and its related price. A tremendous task I would say, especially since water is not a regular good and this price will vary by quality, location, time, and possibly other aspects. What is more problematic is that the planner relies on all water users for its collection of information, a crucial step in the analysis. In Section 2.1 this process is described but this section ignores the problem posed by incentive compatibility: why would users truthfully reveal their demand curves (or make truthful bids) if they could benefit by pretending a higher demand curve (i.e. a higher bid)? Sure, the section mentions some methods to check the reliability of information, like remote sensing, but this does not eliminate the incentives to "cheat".

RESPONSE: We agree that the incentives to cheat will remain even if the river basin authority is able to audit the bids. For industrial uses, including hydropower generation, cheating might be more difficult because the market prices and production functions are often well characterized. In our opinion, the main challenge is to be found in the agricultural sector because (a) it is often the largest water use (and hence cheating might have serious basin-wide consequences), and (b) the heterogeneity in terms of cropping patterns and irrigation efficiency requires that significant data be collected and analyzed to audit the demands. However, due to river basin closure, there is a strong incentive to strengthen the monitoring of river basins, either directly (on-site measurement stations) or indirectly (remote sensing). Various initiatives, at different levels, demonstrate that significant effort and financial resources are being devoted to observations of water resources. For example, the Surface Water and Ocean Topography (SWOT) satellite mission (anticipated launch date 2020), The Sentinel-3 satellite mission, the Hydromet project in the Senegal River basin, etc. We argue that the incentives to cheat might not be eliminated but they can be suppressed, or at least kept within limits, through a robust monitoring system and a strong RBA to negotiate disputes. An example of how this has worked, with good success, is the Indus River basin. Zawahri (2009), in discussing the Permanent Indus Commission, states "The commission's ability to monitor development of the shared river system has permitted it to ease member states' fear of cheating and confirm the accuracy of all exchanged data. Finally, its conflict resolution mechanisms have permitted the commission to negotiate settlements to disputes and prevent defection from cooperation."

3.3 In general, it is not clear what the status quo / baseline situation is w.r.t. property rights over water, which makes it hard to interpret the model. I see three candidates for the status quo: - First, on P4 L26 an exogenous water price P_D is introduced. This suggests that there is a planner or a market active in the status quo, where users can buy their water. Second, expected net benefits (ENB) are derived assuming that a user can abstract any water unhampered by other (upstream) users' water use. This suggests that you take the principle of Unlimited Territorial Integrity as your status quo. - Third, the sharing of the RBA money seems to ignore any historical water use rights. This suggests that the status quo is one without any water use or where the RBA owns all water (since apparently water prices are paid to the RBA).

RESPONSE: The purpose of the presented methodology is to provide an alternative to the types of agreements on international river basins which attempt to define the rights to water. These agreements are often perceived as zero-sum games and can lead to distrust and tension between riparian countries, as is the case in the Nile River Basin. What we present is an entirely different perspective that may help to avoid the pitfalls and limitations of current agreements based on physical allocation. For example, with respect to the Nile Basin, the current agreement driving water allocation legally constrains Sudan to 18.5 bcm of water use. Sudan has available land resources to expand irrigation and use much more water than this (Allan et al 2013), but is limited due to the agreement. As well, uncertainty with respect to changing climate and the possibility of increased evaporation, uncertain hydrology and sea level rise could create an imbalance in water demand and supply in the basin (Whittington, 2014). For instance, a rise in sea level would result in the loss of agricultural land in the Nile Delta, and, subsequently, a large portion of Egypt's historic water use would no longer be required (Whittington, 2014). Therefore, as part of the application of this methodology to a river basin, the historical

water use rights are disregarded.

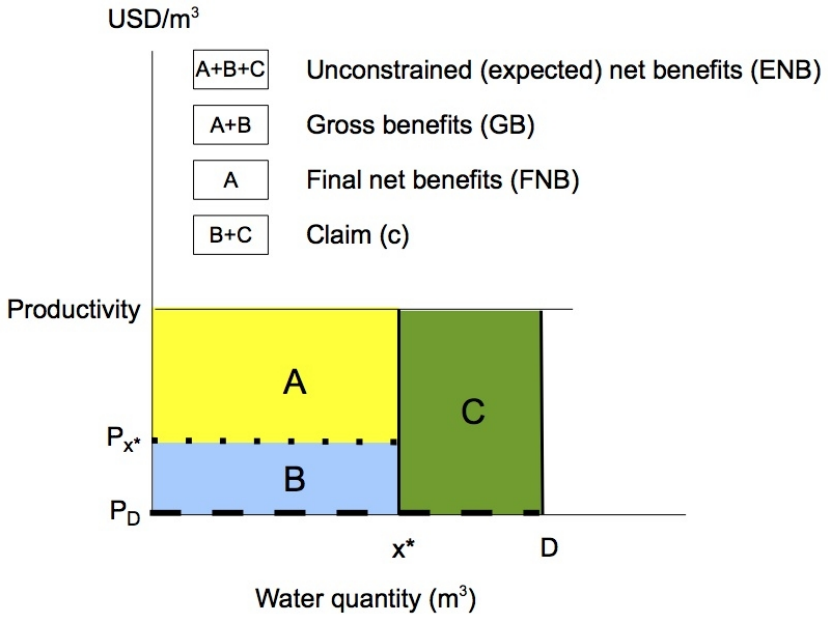
The institutional arrangement that we describe departs from traditional (physical) allocation mechanisms that are based on water rights and relies instead on a bidding process whereby all water users are granted equal access to the resource. Productive use and allocation decisions are separated. The benevolent water manager (RBA) is a non-profit, regulated organization that acts as a third party operator of the water resources system. It does not directly put water to productive use for its own benefit. Instead, it coordinates allocation decisions throughout the system based on the offers provided by water users, and tries to achieve allocative efficiency by ensuring that the water is consumed by those who value it most highly. The benevolent water manager is, in this case, the operator of an auction-based market. So, as part of the institutional arrangement, the RBA may be considered as the owner of bulk (raw) water in the basin. Since the RBA is a supranational institution, the riparian countries own the water. However, once the allocated water is diverted to the user, the water belongs to the user (who has paid for it). Note that price (P_D) is not exogenous; it is derived from the aggregate demand curve for water that results from the market operated by the RBA as part of the methodology.

As mentioned earlier, water users are invited to communicate basic economic information required to estimate their demand curve and to derive the expected net benefit (ENB), i.e. the benefit they would get without rationing. At this stage, we do assume that a user's benefits are maximized unhampered by other upstream users' water use or by the historical claims of downstream users. In a sense, the status quo, in this case, is a balance between two extreme principles: the principle of Unlimited Territorial Integrity and the principle of Absolute Territorial Sovereignty.

3.4 In Section 2.1, ENB was calculated as consumer surplus. In Section 3.2, however, ENB is calculated as unconstrained water use (Dj) multiplied by productivity (Pj). This seems to be a completely different measure. Where consumer surplus equals willing- ness to pay minus the water price for all consumed units of water and is measured in money terms, this new measure is a production measure: productivity of water times consumed units of water, probably measured in terms of physical output. This is very confusing (it is also confusing that P is used to denote both productivity and price). In section 3.3, Eq (2), again the production measure is used to calculate gross benefits. Gross benefits cannot be the product of water use and productivity.

RESPONSE: In section 2.1 of the paper, in Figure 1, we show the ENB as being the consumer surplus. Figure 1 is the demand function for conditional factors needed to produce a certain level of output. In our case, this is the demand for water needed to produce a certain amount of crop and there is unconstrained output. We disregard the fact that the WTP is, in fact, constrained by the final output level that one wishes to produce. In our case study (section 3), we implicitly assume that the input demand is horizontal (perfectly elastic) with the price (P) = marginal productivity. Underlying this assumption we suppose that the productivity remains the same for the producer and that the output can always be sold on the market. The gross consumer valuation is equal to the rectangle under the horizontal demand curve (or marginal productivity (USD/m3) x water quantity (m3)). For the ENB this is the whole area under the horizontal curve where the water quantity is equal to the water demand. For the gross benefits (GB), this is the area under the horizontal curve given the amount of water they are allocated. The final net benefits (FNB) are the GB minus the area under the horizontal curve representing the cost of

water. Please see the figure below which we will incorporate into the paper in section 3.



3.5 The innovative part of the paper is where you distribute the rents using the axiomatic approach. This method is postponed to Section 3.5. My main comment here is that there is no clear motivation for distributing E such that each user obtains an equal proportion of benefits (FNB+tp) to claims (ENB). There are many axiomatic solutions that are similar in spirit to yours, but I do not see a compelling motivation why this particular new rule is introduced and applied here. It seems standard to motivate a new solution in terms of its characterizing properties, but such a characterization is not provided here. There are some statements in the text that claim this rule satisfies the properties "solidarity" and "security of minimum benefits", but these properties are not clearly defined. Note that I am not saying that a full characterization should be provided here, as that is perhaps less relevant for the HESS audience, but I would expect a convincing motivation for introducing this new solution over any other (existing) solutions. Two additional minor comments: - By taking account of FNB in your bankruptcy rule, you have a problem that is more general than a standard bankruptcy problem (see e.g. work by Hougaard). - Your proposed solution does not take into account historical water use or any other property rights regime? (see my comment on the status quo).

RESPONSE: Please note our response to comment 3.3 regarding water rights.

As previously mentioned, section 2 describes the methodology while section 3 is an example of how this methodology can be applied using the Eastern Nile River Basin as the case study. In section 2.4 we describe the last step – transfer payments. We have added to this section, which should read: "*At this point in the methodology, the RBA has collected an amount of money, referred to as the estate (E), that can be shared among the water use agents. Using an axiomatic approach, a method of sharing this estate should be determined. The aim of the axiomatic approach is to find and capture the notion of fairness that water users could agree upon. The approach then sets out axioms (properties) that fairness should or should not satisfy. Finally, these properties are*

translated into a sharing rule that quantifies the particular definition of fairness. How the benefits are shared depends entirely on the definition of fairness as agreed to by water users. For example, a simple proportional sharing method may satisfy the properties of equity defined by the users, or an egalitarian method, or some other form of sharing may be required. Since each river basin will have a different definition of fairness (depending on conditions in the basin and the outcome of negotiations with the water users), each river basin will likely have its own unique sharing rule."

In section 3.5 we describe a possible solution to transfer payments, assuming that the agents have all agreed on the properties underlying this rule. It is important to note that there were no negotiations done to develop this rule (this was beyond the scope of the project), however, we do not believe that this weakens the impact of the methodology. We present an objective viewpoint and consider our analysis to be a benchmark or reference point. A paragraph has been added to section 3.5 which reads "*It should be noted that, for this study, the properties for this rule were not developed with stakeholder input as this was beyond the scope of this research project. Although stakeholder involvement is imperative in this institutional arrangement, in this case study, we are giving an objective viewpoint and this analysis serves as a benchmark or reference point.*"

The motivation for using this rule is that the cost of cooperation is divided equally among the agents. Again, we are certainly not saying that this solution is better than another, or even that this would be the solution to sharing the benefits for the Eastern Nile River Basin. Rather, we are giving an example of how the overall methodology could work when applied to a river basin. The rule or method used for the transfer payments would be based on the definition and properties of fairness that are developed through negotiations with the water users.

Allan, J. A., Keulertz, M., Sojamo, S. & Warner, J. eds. (2013). Handbook of Land and Water Grabs in Africa: Foreign Direct Investment and Food and Water Security. Routledge International Handbook. Routledge, Abingdon.

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