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Discussions

Interactive comment on "Endogenous technological and population change under increasing water scarcity" *by* S. Pande et al.

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We are grateful to the referee for her thoughtful and detailed review of our manuscript. Following is a point by point response to the referee's general comments.

1. My first main .. short section that describes such models and where they differ from the Limits of Growth models to which the paper's model results are compared.

Response: We agree. We will add a section that describes such models and where they differ from Limits to Growth models. This will also provide some background in the theory that most hydrologists do not have.

2. Like many papers relying on highly stylized . . .the predictions from the model are

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rather dire outside of the technological singularity case which the authors deem to be unlikely. Is a growth stabilization trajectory really outside the realm of possibility? And if so, why?

Response: We are thankful to the referee to point this out. We will expand the closing paragraph of the discussion that the referee has mentioned into another section that will further discuss the modeling assumptions, such as the parameter values used and provide justification for it. Further, this additional section will provide critical self-reflection on the parameter values used and on the robustness of the results. We would additionally provide a more detailed interpretation of results and discuss its sensitivity to the modeling assumptions.

We appreciate the referee's comment on the possibility of growth stabilization trajectory. It may be possible for another parameter configuration. We would highlight this possibility in our revised submission. However, the choice of various parameters with respect to water availability and relative productivity of different types of labor and water was made to reflect a water scarce society that crucially depends on water for production and human well-being. Further we assumed that the production technology is such that a skilled worker produces more per unit labor than an unskilled worker (as one may expect).

We believe that a rigorous sensitivity analysis (of model results with respect to water availability, relative productivity of different types of labor and water and the assumptions about population growth relative to consumption) is fit for a separate technical note, which we intend to follow up on. Nonetheless, we will discuss in our revised manuscript that different choices of parameters conceptualize different (some may be unrealistic, such as a society where skilled labor productivity is lower than unskilled labor productivity) societies under different water availability scenarios.

3. The model does not account for endogenous .. considered catastrophic.

Response: We agree with the referee that the model does not sufficiently account for

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endogenous migration in the face of declining consumption per capita. We however have considered a very simple endogenous migration conceptualization by having a step change in population growth rate as a function of consumption per capita. But indeed we agree that such a simple conceptualization is a limitation of the model. We intend to highlight it in our self-critical evaluation.

Please note that we, like the referee, do not see a decline in population as catastrophic. The decline may be a story of comparative advantage. The threshold on consumption per capita conceptualizes the notion of comparative advantage (though in a limited manner). It is implicitly assumed that there are always places outside the basin that allow for consumption per capita larger than this threshold. We will incorporate this discussion in our revised manuscript.

4. Building on this point, .. that population growth is tied to consumption thresholds (rather than change) is therefore problematic.

Response: We agree with the referee that equivalence between population and success of a society may be misleading. Our model associates success of a society with aggregate production (which is equivalent to gross domestic product at basin scale). We also agree with the referee that population change in itself is endogenous. We have modeled, though in a limited manner, endogenous change in population by varying it with consumption per capita. Thus we can model positive population growth even under declining aggregate production.

Please note that the resource availability, (endogenous) productivity changes and (endogenous) human capital development endogenously affect (amongst other internal variables) the wage rates (the income of the agents) and hence consumption per capita. Thus consumption per capita captures some, if not all, effects of the variables that the referee points to.

However we agree that the endogenous behavior of population growth is modeled in a limited manner. This limitation is partly due to the need to preserve a parsimonious

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construct of society within the model. For example, to introduce the effect of increasing aggregate production on fertility rates and hence on population growth may require the modeling of leisure (free time) alongside labor (time spent on work), which may further complicate the model. We will however discuss this and other limitations highlighted in our additional section of critical self-evaluation.

5. Related to point 1 above, . . .if technological change is assumed to be endogenous rather than exogenous, and why do these make the theory more credible in the context of water?

Response: We again thank the referee for her insightful comment. While we wish not to take a position on it, we will discuss which dynamics can be explained by endogenous technological change when we discuss the limitations and strengths of endogenous growth theory. We would like to highlight here that the dynamics that assumes endogenous technological change is more restricted, i.e. the co-evolutionary paths of the endogenous variables are more restricted, than when technological change is assumed to be exogenous. Underlying the assumption of endogenous technological change made in the paper is a belief that water dependent societies have shaped water related technology to suite their development needs and that the technology in turn shaped its organization. Meanwhile, an assumption that technological development is exogenous is equivalent to the assumption that technological growth is accidental (in context of societal development). It may be a valid assumption for a society that does not intensively depend on water but probably not for a water dependent society.

6. How realistic is the assumption .. human innovation and technology? What are the implications of this?

Response: We attempt to model a societies in water scarce regions. We therefore assumed that all the water that is available is used up for production since its supply would always be binding in water scarce regions. The model at present does not allow agents to choose the amount of water. The model however can be extended

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further to allow for it that then may yield some other interesting dynamics (a topic for a technical note on sensitivity analysis). We will discuss the point raised here in our revised manuscript.

7. How sensitive are the model results to various assumptions .. assumptions about ever-declining water availability

Response: Please note that the rate of return is an endogenous variable. The choice of various parameters such as with respect to water availability and relative productivity of different types of labor and water was made to reflect a water scarce society that crucially depends on water for production and human well-being. Further we assumed that the production technology is such that a skilled worker produces more per unit labor than an unskilled worker (as one may expect). Please also see our response to comments 2-4 on our limited representation of possible dynamics that population growth can take in relation to consumption per capita.

We agree that a discussion of various assumption pointed out by the referee should be discussed (and will be discussed in our revised manuscript, please see our response to comments 1 and 2). As we stated in our response to comment 2, we will also provide justification of the assumptions made (as well as critically evaluate its limitations). A detailed sensitivity analysis is however a subject matter for a technical note, which we intend to pursue in the future.

On Specific comments / technical corrections: Response: All the specific comments/ technical corrections suggested by the referee will be incorporated.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 13505, 2013.