

## ***Interactive comment on “Endogenous change: on cooperation and water in ancient history” by S. Pande and M. Ertsen***

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Response to anonymous referee #4 by Saket Pande and Maurits Ertsen

We thank the referee for her critical review of our manuscript. We are grateful that she has brought in the perspective of a historian on the topic that is transdisciplinary. Given the interesting discussion that the paper has generated, we also take this opportunity to thank the editors of the special issue for facilitating such a discussion.

If we understand the comment on the use of secondary data correctly, it refers to our description of the chronology of the civilizations. Given the scale at which our analysis, we fail to see how any additional data on social structure would change the conclusions that we have drawn. Further, the use of secondary data to understand

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the evolution of societal complexity (and/or its link with climate) at the scale of our analysis appears to be a standard practice based on our review of relevant literature. See for example the work of Jonathan Kenoyer, an archaeologist well-respected for his pioneering work on Indus civilization, published in 2011 in *Puratattva*. The chronology that he presents based on a wide variety of archaeological evidence is well accepted in archaeological literature and is at the scale of our analysis. We have been careful in not calling the Indus a centrally planned state. But the pattern of organization based on the chronology indicates the scale at which cooperation evolved as the Indus rose to maturity and then declined.

We have refrained from providing archaeological evidence that support the chronologies discussed in the paper just as we have kept the definition of cooperation coarse. This is done to keep the flavor of the paper fairly general so that it is accessible to audiences of all backgrounds. The notion of cooperation is borrowed from economic theory. Cooperation in a society composed of dispersed population centers exists at a certain spatial scale if no population center exists in isolation from any other population center. By scale here we mean the spatial extent and by a population center we imply a settlement of any size (from small to large cities such as Harappa). Cooperation at a scale larger than the scale of the population centers is the (mathematical) complement of non-cooperative organization of society. Thus any evidence that reasonably demonstrates that two population centers were communicating (for eg through trade, common cultural practices) is sufficient evidence that they were not living in isolation.

Our theory does not rely on climate determinism to predict (cautiously or in a proximate manner) an onset of cooperation at some scale of a study area. Even if the climate was stationary in mid to late Holocene (which it was not), the demographic pressure of individual population centers would have forced the centers to either seek additional resources or efficiently use locally available resources. There is no ‘strong’ evidence in Harappan civilization that large scale conflict led to its demise. Thus if the population was rising and that the civilization, most probably, did not disperse due to conflict, it

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might have been able to sustain population growth by cooperating at largest possible scale since cooperation (through trade or by succeeding in establishing a stable central authority) increases the efficiency with which total available resources can be used.

Finally on climate determinism in explaining the rise and the dispersal of the Indus, climate played an important role in the region. Archaeologists/cultural anthropologists and paleoclimatologists, the two sides of the debate on climate determinism and Harappa, in our opinion agree on this (see for eg. Madella and Fuller, 2006). What they disagree on is whether the 4.2k singularity led to the dispersal of the civilization. Archaeologists argue that the Harappa rose to its maturity in the midst of increased dry condition and that the society was able to cope with such extreme dry conditions. However, even they agree that Harappa dispersed soon (on archaeological time scale) afterwards. It appears that the society was able to cope but only to a certain extent.

We must emphasize here that our theory is based on how scarcity conditions may lead to conditions conducive for rise and/or dispersal of societies in resources scarce regions. Our theory supports the argument that, probably, the conditions were conducive for Indus to cope with increasing dry conditions by forming larger scale cooperative structures. Scarcity conditions are driven not only by exogenous climatic conditions or but also endogenous conditions (such as demography) that are a function of past evolution of societal complexity. The innovation of the presented theory and its application in context of change in coupled human-hydrological systems is accurately captured by the term 'endogenous'. While we appreciate the concern of the referee that it is an annoying jargon, we intend keep it for the reasons stated above. We however intend to remove other mentioned jargon to the extent that it does not excessively dilute the rigor of the presented theory. In doing so, we hope to further clarify the underlying theory.

On the final remark of the referee, we would like to clarify that we focused on the rise to maturity and dispersal of both the civilization because we believe that the 'signal of' the need to cooperate is probably the strongest as a society is approaching its maturity. Given the paucity of data, this is important if we wish to draw any credible evidence for

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or against the theory of endogenous change.

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