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Endogenous technological and demographic change under increasing water scarcity

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The ancient civilization in the Indus Valley civilization dispersed under extreme dry conditions; there are indications that the same holds for many other ancient societies. Even contemporary societies, such as the one in Murrumbidgee river basin in Australia, have started to witness a decline in overall population under increasing water scarcity. Hydroclimatic change may not be the sole predictor of the fate of contemporary societies in water scarce regions and many critics of such (perceived) hydroclimatic determinism have suggested that technological change may ameliorate the effects of increasing water scarcity and as such counter the effects of hydroclimatic changes. To study the role of technological change on the dynamics of coupled human-water systems, we develop a simple overlapping-generations model of endogenous technological and demographic change. We model technological change as an endogenous process that depends on factors such as the investments that are (endogenously) made in a society, the (endogenous) diversification of a society into skilled and unskilled workers, a society's patience in terms of its present consumption vs. future consumption, production technology and the (endogenous) interaction of all of these factors. In the model the population growth rate is programmed to decline once consumption per capita crosses a "survival" threshold. This means we do not treat technology as an exogenous random sequence of events, but instead assume that it results (endogenously) from societal actions.

The model demonstrates that technological change may indeed ameliorate the effects of increasing water scarcity but typically it does so only to a certain extent. It is possible that technological change may allow a society to escape the effect of increasing water scarcity, leading to a (super)-exponential rise in technology and population. However, such cases require the rate of success of investment in technological advancement to be high. In other more realistic cases of technological success, we find that endogenous technology change only helps to delay the peak of population size before it inevitably starts to decline. While the model is a rather simple model of societal development, it is shown to be capable of replicating patterns of technological and population changes. It is capable of replicating the pattern of declining consumption per capita in presence of growth in aggregate production. It is also capable of replicating an exponential population rise, even under increasing water scarcity. The results of the model suggest that societies that declined or are declining in the face of extreme water scarcity may have done so due to slower rate of success of investment in technological advancement. The model suggests that the population decline occurs after a prolonged decline in consumption per capita, which in turn is due to the joint effect of initially increasing population and increasing water scarcity. This is despite technological advancement and increase in aggregate production. We suggest that declining consumption per capita despite technological advancement and increase in aggregate production may serve as a useful predictor of upcoming decline in contemporary societies in water scarce basins.