Quaternary Science Reviews 314 (2023) 108217

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Combining social sciences, geoscience and archaeology to understand societal collapse

Giacomo Benati [a], Carmine Guerriero [b,*]

[a] Department of Economic History, Institutions, Politics and World Economy, Faculty of Economics and Business, University of Barcelona, Diagonal 690, Barcelona, 08034, Spain

[b] Department of Economics, University of Bologna, Piazza Scaravilli 2, Bologna, 40126, Italy

ARTICLE INFO

Article history:
Received 6 June 2023
Received in revised form
4 July 2023
Accepted 5 July 2023
Available online xxx

Handling Editor: Mira Matthews

Keywords:
Climate change
State-building
Time inconsistency
Collapse archaeology

ABSTRACT

Despite its apparently obvious conclusion that adverse environmental conditions must produce economic and institutional crises, the "collapse archaeology" literature has been criticized for its lack of a formal theory, a credible measurement strategy and a proper understanding of the roles of environmental shocks. To tackle this issue, we propose to combine a time inconsistency theory of state formation and evolution—i.e., state-building, institutional proxies based on this model and highly granular simulated climate data. To clarify our proposal, we apply it to the study of state-building in Bronze Age Mesopotamia, and we show that moderate droughts shaped these economies directly via deteriorated production conditions as well as indirectly via institutional resilience.

1. Introduction

To clarify how environmental crises shape state-building and, thus, inform public policies in developing countries, a pioneering archaeological literature has amassed growing evidence that droughts triggered economic and institutional crises (e.g., Kennett et al., 2012; Manning et al., 2017; Sinha et al., 2019; Fleitmann et al., 2022). Yet, the credibility of this "collapse archaeology" research program is undermined by three key limitations (D'Alpoim Guedes et al., 2016). First, it lacks an underlying theory identifying the strategic determinants of institutional resilience (Degroot et al., 2021). Second, it relies on proxies whose measurement is not theoretically informed (Butzer and Endfield, 2012). Finally, it focuses on the single impact of environmental conditions overlooking both their combined and indirect effects (Benati and Guerriero, 2023). We consider these issues in the context of a structural empirical model blending an economic theory of state-building (Benati et al., 2022), institutional proxies informed by this framework and highly granular simulated climate data. We first describe the application of our proposal to the study of state-building in Bronze Age Mesopotamia. Next, we exploit these results to evaluate the limitations of the collapse archaeology literature and propose a general strategy for future research.

2. A structural model of state-building and its application to Bronze Age Mesopotamia

BGZ (2022) study the possible cooperation between non-elites and time-inconsistent elites, i.e., elites unable to commit to direct transfers and, thus, assure the non-elites' participation. The elites can, however, incentivize investment by enacting a more inclusive political process, which entrusts the non-elites with control over fiscal policies. While adverse production conditions force the elites to grant to the non-elites strong political rights to convince them that a sufficient part of the returns on joint investments will be shared via public good provision and, thus, to cooperate, a large investment return allows the elites to garner cooperation and keep control over fiscal policies. Since Bronze Age Mesopotamia was mainly involved in farming investments whose return was never tiny (BGZ, 2022), the model produces for this study case two key predictions. First, the non-elites' political rights become stronger the more adverse the climate turns. Second, reforms towards a more inclusive political process foster public good provision, easing, in turn, societal resilience.

* Corresponding author.
E-mail address: c.guerriero@unibo.it (C. Guerriero).

https://doi.org/10.1016/j.quascirev.2023.108217

Following BGZ (2022), we assess these predictions by studying 44 Mesopotamian polities for which we can observe all relevant information for each half-century between 3050 and 1750 BCE. We capture the degree of societal resilience with the estimated settled area of each polity in ha over the previous half-century, i.e., *Polity-Size*. Obtained from walled area, artifact scatters, and settlement remains, this variable is correlated with urbanization (BGZ, 2022). Turning to public good provision, we record the number of public and ritual buildings, i.e., *Public-Buildings*. Regarding the inclusiveness of the political process, we build on the events in a 40-year window around each time period and we construct a score rising with the division of the decision-making power, i.e., equal to one for mostly dominated polities, two in the absence of institutionalized decision-maker—i.e., temple, palace and town elites, three (four) when only one (two) was (were) active, and five when political power was contested among all institutionalized decision-makers, i.e., *Political-Institutions*. Both *Public-Buildings* and *Political-Institutions* are based on historical analyses of the single periods and polity-specific secondary sources informed by royal inscriptions (BGZ, 2022).[1] Finally, to pick the farming return, we follow a large botanical literature suggesting that climate extremes explain most of yield anomalies (Vogel et al., 2019), and we construct the Palmer drought severity index—i.e., PDSI—by combining temperature and precipitation simulated by Armstrong et al. (2019),[2] latitude and available water storage capacity,[3] all averaged over the previous 50 years and a 30 km radius (Jacobi et al., 2013). This was the maximum distance between the fields and the settled center (BGZ, 2022). Different from its components, the PDSI—inversely—captures the inability of the supply of soil moisture to meet its demand. The PDSI ranges between −10—i.e., extreme droughts—and 10—i.e., fully wet conditions, with negative values above - 4 picking intermediate severity (Redmond, 2002). Thus, we gauge negative, but not unbearable, climatic shocks favoring state-building with the share of previous half-century during which PDSI lied between −4 and 0, i.e., *Drought-I*.[4]

Conditional on polity and half-century fixed effects,[5] OLS estimates unveil three patterns (Table 1). First, droughts of intermediate severity favored reforms covering half of the range between a fully extractive and a fully inclusive political process (column (1)). Second, these reforms were accompanied by a significantly larger public good provision (column (2)). Finally, *Drought-I* has two significant effects on the polity size and, notably, the direct and negative impact of decreasing it of 92.4 ha and the indirect and positive effects of increasing it of 26.3 and 5 ha via, respectively, a more inclusive political process and larger public good provision (column (3)). Hence, roughly a third of the direct and negative impact of droughts is compensated by its indirect institutional effect.

To evaluate if our results are attenuated by measurement errors or are capturing reverse causation and/or unobserved heterogeneity, we perform several tests available upon request. First, we reach similar conclusions when we evaluate the possibility that *Political-Institutions* has no cardinal meaning and thus only discrete switches towards some form of protection of the non-elites' political rights matter. Second, the independence from human effort and institutions of *Drought-I* excludes reverse causation in our analysis of institutional formation, whereas the fact that *Public-Buildings* (*Polity-Size*) is unrelated to lead values of *Political-Institutions* (and *Public-Buildings*) is inconsistent with the former driving the latter given the lag with which institutions would adjust over time. Finally, our results remain similar if we also consider other key determinants of institutional resilience identified by the extant literature and, notably, the returns on long-distance trades, degree of environmental circumscription and severity of internal and external conflicts.

3. Qualifying collapse archaeology

Our estimates allow us to qualify the limitations of the collapse archaeology program. First, its lack of game-theoretical foundations makes it difficult to specify the estimating equation and, thus, distinguish extreme droughts inducing collapse from moderate droughts favoring state-building and societal resilience. Second, its focus on coarse proxies undermines the credibility of its results. Starting from the institutional metrics, this literature studies the presence of hierarchies, dynastic cycles, monuments, and/or settlements, none of which captures the institutions garnering the non-elites' cooperation. Turning to environmental proxies, this line of research relies on proxies based on the still limited hydro-climatic records, which, in turn, might misrepresent the climatic conditions of—possibly distant—polities. Benati and Guerriero (2023) clarify this point by comparing for our 44 polities the Armstrong et al.'s (2019) simulated temperature with the closest hydro-climatic records obtained from cave speleothems and lake sediments (Palmisano et al., 2021). There are three key remarks. First, proxy data do not replicate the inverted U-shaped evolution of the temperature discussed by the historical literature and captured by simulated data. Second, they inefficiently proxy the farming return being negatively and significantly linked to coeval cereal yields. Third, proxy data display lower between variation and their partial correlation with simulated data is larger in the locations of the hydro-climatic records than in the 44 polities. Finally, the collapse archaeology literature focuses on the direct impact of climate extremes, ignoring not only their indirect—institutional—effects, which we discussed in section 2, but also the combined impact of temperature and rainfall, which is instead gauged by the variable *Drought-I*.

4. Conclusions

Our proposal can be rephrased as a three-step approach to future research. First, such projects should build on game-theoretical models clarifying the incentives linking exogenous conditions to social evolution. Second, they should rely on up-to-date statistical methods. Finally, they should adopt measurement strategies informed by social sciences, geoscience and archaeology. This mix will help minimize the errors introduced by differential data quality and their aggregation process.

[1] The quality of the settlement data is homogeneous across polities (Palmisano et al., 2021), and we take into account the possible impact of asymmetries in excavation techniques by controlling for year fixed effects. Finally, our focus on the middle chronology induces errors which range between 8 and 30 years and are, thus, limited given our aggregation choices (Sallaberger and Schrakamp, 2015).

[2] These data span the 60,000-0 BP period and the northern hemisphere at a 0.5° spatial resolution.

[3] This equals the mm/m of water that a soil can store for plants and is available from the HWSD dataset.

[4] Armstrong et al. (2019) validate time series and spatial variation of their simulations employing the available proxy and observational climatic data. The partial correlation between *Drought-I* and the natural logarithm of coeval cereal yields in liters per ha reported by cuneiform administrative texts is negative and significant.

[5] Including these controls assures that the estimates are not driven by time-independent or predetermined determinants of institutional resilience, like the land suitability for agriculture and pasture and the timing of the agricultural revolution, as well as macro-shocks such as epidemics and farming innovations (BGZ, 2022).

Table 1
Climate change and state-building.

	(1)	(2)	(3)
	The dependent variable is		
	Political-Institutions	*Public-Buildings*	*Polity-Size*
Public-Buildings			7.046 (1.089)***
Political-Institutions		0.302 (0.044)***	11.051 (1.646)***
Drought-I	2.381 (0.930)***	0.784 (1.383)	- 92.366 (50.302)*
Estimation	OLS		
Number of Observations	1188	1188	1188
R^2	0.09	0.18	0.15

Notes: 1. Standard errors in parentheses; *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include polity and half-century fixed effects.

Author contributions

Giacomo Benati and Carmine Guerriero have equally contributed.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

We wish to thank Amin Gholami Oskuyi for the outstanding research assistance, Miryam Bar-Matthews and two anonymous readers for insightful comments and both the 2015 Rita Levi-Montalcini and 2021 Maria Zambrano programs for funds.

References

Armstrong, E., Hopcroft, P.O., Valdes, P.J., 2019. A simulated northern hemisphere terrestrial climate dataset for the past 60,000 years. Sci. Data 6, 265.
Benati, G., Guerriero, C., 2023. A Multidisciplinary Approach to Identify the Impact of Climate Change on State-Building. Unpublished.
Benati, G., Guerriero, C., Zaina, F.—BGZ, 2022. The origins of political institutions and property rights. J. Comp. Econ. 50, 946–968.
Butzer, K.W., Endfield, G.H., 2012. Critical perspectives on historical collapse. Proc. Natl. Acad. Sci. U.S.A. 109, 3628–3631.
D'Alpoim Guedes, J., et al., 2016. Twenty-first century approaches to ancient problems: climate and society. Proc. Natl. Acad. Sci. U.S.A. 113, 14483–14491.
Degroot, D., et al., 2021. Towards a rigorous understanding of societal responses to climate change. Nature 591, 539–550.
Fleitmann, D., et al., 2022. Droughts and societal change: the environmental context for the emergence of Islam in late antique arabia. Science 376, 1317–1321.
Jacobi, D., et al., 2013. A tool for calculating the palmer drought indices. Water Resour. Res. 49, 6086–6089.
Kennett, D.J., et al., 2012. Development and disintegration of Maya political systems in response to climate change. Science 338, 788–791.
Manning, J.G., et al., 2017. Volcanic suppression of nile summer flooding triggers revolt and constrains interstate conflict in ancient Egypt. Nat. Commun. 8, 1–8.
Palmisano, A., et al., 2021. Holocene regional population dynamics and climatic trends in the near east: a first comparison using archaeo-demographic proxies. Quat. Sci. Rev. 252, 106739.
Redmond, K.T., 2002. The depiction of drought: commentary. Bull. Am. Meteorol. Soc. 83, 1143–1148.
Sallaberger, Walther, Schrakamp, Ingo, 2015. Associated Regional Chronologies for the Ancient Near East and the Eastern Mediterranean 3: History & Philology. Brepols, Turnhout, BE).
Sinha, A., et al., 2019. Role of climate in the rise and fall of the neo-assyrian empire. Sci. Adv. 5, eaax6656.
Vogel, E., et al., 2019. The effects of climate extremes on global agricultural yields. Environ. Res. Lett. 14, 054010.