

Pathways to Social Inequality

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1 **Social inequality is now pervasive in human societies, despite the fact that humans lived in rel-**
2 **atively egalitarian, small-scale societies across most of our history. Prior literature highlights**
3 **the importance of environmental conditions, economic defensibility, and wealth transmission**
4 **for shaping early Holocene origins of social inequality. However, it remains untested whether**
5 **the mechanisms that drive the evolution of inequality in recent human societies follow a sim-**
6 **ilar trajectory. We conduct the first global analysis of pathways to inequality within modern**
7 **human societies using structural equation modeling. Our analytical approach demonstrates**
8 **that environmental conditions, resource intensification, and wealth transmission mechanisms**
9 **impact various forms of social inequality via a complex web of causality. We further find that**
10 **subsistence practices have a direct impact on some institutionalized forms of inequality. This**
11 **work identifies drivers of social inequality in the modern world and demonstrates the appli-**
12 **cation of structural equation modeling methods to investigate complex relationships between**
13 **elements of human culture.**

14 **1 Introduction**

15 Social and economic inequality are ubiquitous in contemporary human societies, a trend that has
16 been linked to a number of detrimental consequences for the environment, the stability of political
17 and economic systems, and the well-being of individuals (e.g. 1; 2; 3). This inequality has been
18 formalized and reinforced in well-documented societies by cultural institutions like social class
19 hierarchies, caste systems, and slavery. However, human social organization is commonly char-
20 acterized as having consisted of essentially egalitarian, small-scale societies for the majority of
21 human history (4; 5; 6). While both external and intentional leveling mechanisms may have con-

22 tributed to the pervasiveness of egalitarian, small-scale social organization earlier in human history,
23 in contrast to the strict social hierarchies common in other primate species (e.g. 7; 8), a different set
24 of mechanisms has been proposed to explain the emergence of social inequality and its widespread
25 occurrence in modern cultures. Here we investigate institutionalized forms of inequality in mod-
26 ern human societies and potential causal relationships with a set of mechanisms that represent a
27 possible trajectory for the evolution and maintenance of inequality in recent human history.

28 Literature on the evolution of social inequality has focused primarily on reasons for the rise
29 of inequality around the dawn of the Holocene (e.g. 5; 6; 9). Somewhat less attention has been
30 paid to the processes that have caused this element of human social organization to continue to
31 emerge, persist, and evolve in societies during the intervening millennia of human history, or its
32 occurrence in a diverse and geographically widespread range of modern human cultures. Our cur-
33 rent understanding of the evolution of social inequality does not extend to whether mechanisms
34 and pathways associated with the *de novo* origin of human social inequality might also shape the
35 subsequent evolution and persistence of inequality in modern societies. We might expect facets
36 of environmental suitability, investment in resources, and wealth transmission patterns to impact
37 inequality in recently documented societies, just as they are hypothesized to shape the early evolu-
38 tion of inequality (10). We test one potential extension of a generalized pathway for the evolution
39 of inequality to the generation and maintenance of three specific types of institutionalized inequal-
40 ity in modern societies, using cross-cultural data collected in the Ethnographic Atlas and linked to
41 environmental information in the D-PLACE database (11; 12; 13; 14; 15; 16).

42 The timing of the earliest evidence of human social inequality has been linked to patterns of

43 climate change, and specifically a decline in climate variability around 12,000 years ago (9; 17; 18).
44 This ecological shift is theorized to have made risk mitigation strategies that previously leveled
45 social hierarchies less necessary, changing the relationships between humans and natural resources
46 in the process (10; 19; 20; 21; 22). Though this sort of global shift in climatic conditions may have
47 opened the door to incipient inequality at one specific point in human history, where conditions
48 persist that make resources dense or predictable we might expect to find ongoing evidence for
49 environmental impacts on the mechanisms that shape inequality. In particular, local environmental
50 conditions may play an important role in the intensification of subsistence activities, a cultural shift
51 that we expect to have consequences for the distribution and accumulation of wealth, and thus on
52 the development of cultural institutions that reinforce inequality.

53 Economic defensibility has been ascribed a key role in the emergence of inequality in early
54 Holocene small-scale societies. This principle of resource management entails a comparison be-
55 tween the costs of defending a resource patch through actions such as monitoring and preventing
56 intruders, and the resulting benefits (23). Dense, predictable resources are more defensible, as they
57 are associated with relatively small areas to defend, they are easy to locate and monitor, and the
58 reliable and abundant resources they produce counter-balance the cost of defense. Behaviours and
59 norms that are focused on the defense of natural resources, like territoriality and land ownership,
60 are theorized to arise when their benefits outweigh their costs (24). In early Holocene human
61 groups, the scales may have tipped toward the adoption of these resource defense strategies when
62 increasingly stable environmental conditions led to highly reliable or concentrated resource patches
63 (10). Over the subsequent millennia of cultural evolution, human innovations such as cultivation of
64 agricultural resources and intensification of production have further enhanced the density and pre-

65 dictability of resources, and thus their defensibility, in some societies (25). Though research on
66 early Holocene origins of inequality focuses on defensibility, we note that the sort of extraordi-
67 nary global climate shift that led to enhanced defensibility at the dawn of the Holocene has not
68 happened since. Thus we hypothesize that the intensification of subsistence resources may play a
69 particularly important role in shaping the use, defense, and distribution of resources. Rather than
70 simply implementing proxies for a mechanism associated with early Holocene inequality, we pre-
71 dict that more intensive production technologies and the associated property ownership will lead to
72 unequal accumulation of wealth, and ultimately a greater likelihood of institutionalized inequality.

73 Intergenerational transmission of wealth allows unequal distributions of resources in a soci-
74 ety to accumulate and persist over time, and is widely believed to play a role in social inequality
75 in both ancient and modern societies (e.g. 5; 26; 27). Wealth includes material assets like land and
76 tangible property, as well as social wealth (e.g. support networks, power) and embodied wealth
77 (e.g. physical health, knowledge) (27; 28). Material wealth is hypothesized to be particularly
78 closely linked to inequality (25; 26; 29), especially in agricultural or pastoral societies (25; 27).
79 Inheritance of finite resources, like land, whose productivity does not generally increase rapidly
80 without major environmental or cultural shifts, may magnify asymmetries in resource distribu-
81 tion, and thus may be particularly important to the genesis of inequality (25). Although unequal
82 wealth itself in the form of property rights may emerge before agriculture (19), the impacts of
83 wealth transmission on social mobility may play an important role in linking subsistence activities
84 to institutionalization of inequality.

85 Though inequality can be operationalized in a number of ways, we focus on a small set of

86 outcomes that represent rigid and persistent institutionalization of inequality. Social stratification in
87 general may be characterized by heritable differences in the level of access to resources and power
88 enjoyed by members of a society. Some level of social and economic inequality may have existed
89 throughout human history merely due to individual variation in economic success and differences
90 in the resources controlled by different families or lineages (4). However, the persistent, institu-
91 tionalized inequality that is the focus of this study occurs only when differences in resources and
92 power become entrenched in a society's norms and practices to the extent that social status persists
93 across generations. We focus on a narrow set of observable institutions which require widespread
94 acceptance of persistent social hierarchies, are unequivocally associated with social inequality, and
95 can be reliably coded as present or absent across a wide range of societies. We acknowledge that
96 inequality takes many forms in human society, and that alternative characterizations of inequality
97 (e.g. Gini coefficients) are important for understanding other dimensions of inequality. We propose
98 that investigating a limited and cohesive set of variables across a global sample of societies pro-
99 vides a perspective not already captured in nation-level economic studies or detailed case studies
100 of individual cultures.

101 Using this framework, we examine the extent to which empirical evidence supports the hy-
102 pothesis that the evolution and maintenance of persistent, institutionalized social inequality in mod-
103 ern human societies follows a trajectory that parallels the pathway by which inequality is thought
104 to have taken hold earlier in human history. Recent work has described the set of mechanisms
105 involved in this pathway as causal links between environmental conditions, resource defensibil-
106 ity, wealth transmission, and inequality (10). We propose an analogous trajectory for more recent
107 development and maintenance of inequality that focuses not on economic defensibility but on the

108 intensification of subsistence practices and the role these practices play in shaping human use
109 of environmental resources and the ownership and transmission of property. This trajectory can
110 be schematized as a path model (Fig. 2a). We investigate the details of each of the theoretical
111 constructs in this framework using a large, global cross-cultural data sample from the D-PLACE
112 database of places, languages, culture, and environment (11), and examine both incremental and
113 direct effects of the associated variables on institutionalized inequality by applying a structural
114 equation model (SEM) approach.

115 In testing whether the factors linked to inequality in modern societies mirror the mechanisms
116 proposed to explain the evolution of inequality in early Holocene cultures, this approach employs
117 normative data at the society level to test predictions which are often derived from individual-level
118 within-population phenomena. To the extent that we expect such phenomena to be detectable in
119 population-level patterns, we see cross-cultural tests of behavioural ecology theory as an important
120 source of evidence about these predictions (30). By taking advantage of the large global sample of
121 society-level data for a complex set of variables, we are able to simultaneously consider multiple
122 facets of the generalized pathways and specific associations identified in prior literature (e.g. 10;
123 28; 31).

124 **2 Results**

125 Our study compares three alternative models, which vary the number of variables and paths in-
126 cluded on a standardized structure that reflects the general sequence and directionality of causal
127 links proposed in prior literature to explain the emergence of inequality (10). In each path model

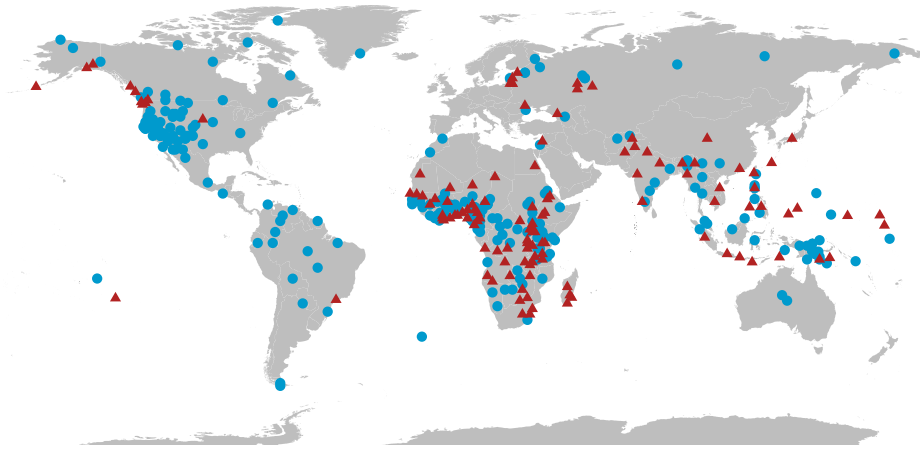


Figure 1: Societies included in the study (n=367). Red triangles represent societies that are identified as having heritable social class systems. Blue dots represent societies with an absence of heritable social class.

128 the direction of causality in relationships between variables is assumed to follow a trajectory from
129 environmental conditions to resource intensification to wealth transmission, resulting finally in in-
130 equality. Across these three models we vary only the inclusion of a population variable and the
131 presence of individual pathways. The first alternative (Fig. 2b) restricts the paths in the model to
132 a stepwise trajectory that includes only those direct effects that represent sequential links between
133 constructs in the aforementioned order, with no additional direct paths (Fig. 2a). The second,
134 more elaborate model (Fig. 2c) includes all potential direct effects whose directionality is consis-
135 tent with the overall trajectory of the schema, as well as possible effects of population. A third
136 model (Fig. 3) preserves well supported paths in Fig. 2c, but eliminates poorly supported paths,
137 creating a more parsimonious model to fit these data.

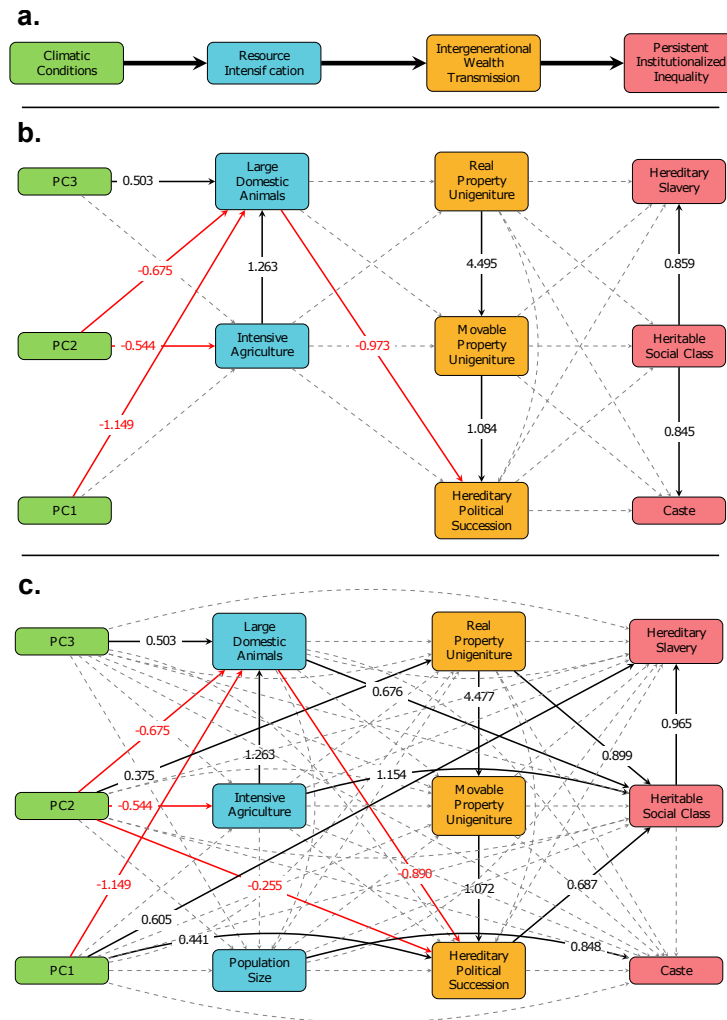


Figure 2: Path diagrams representing a) generalized trajectory, b) empirical SEM test of mechanisms on a strictly stepwise trajectory, interpreted through variables derived from D-PLACE, and c) loose implementation of the hypothesized pathways using variables from D-PLACE, in which a population size variable and additional direct paths that deviate from the discrete steps in the schema have been included. Red arrows indicate negative relationships identified in PiecewiseSEM model. Black arrows represent positive relationships identified in PiecewiseSEM model. Dashed arrows represent paths not found to be significant ($p < 0.05$). Significant paths are labeled with standardized coefficients. Individual variables represented by boxes in the diagram can be interpreted as *increasing* for continuous variables and *present* for categorical variables. See Methods for interpretation of PCA-derived environmental variables. Model 2c is better supported by the data than 2b (AIC: Model 2b = 185.51, Model 2c = 162.48). $n=367$.

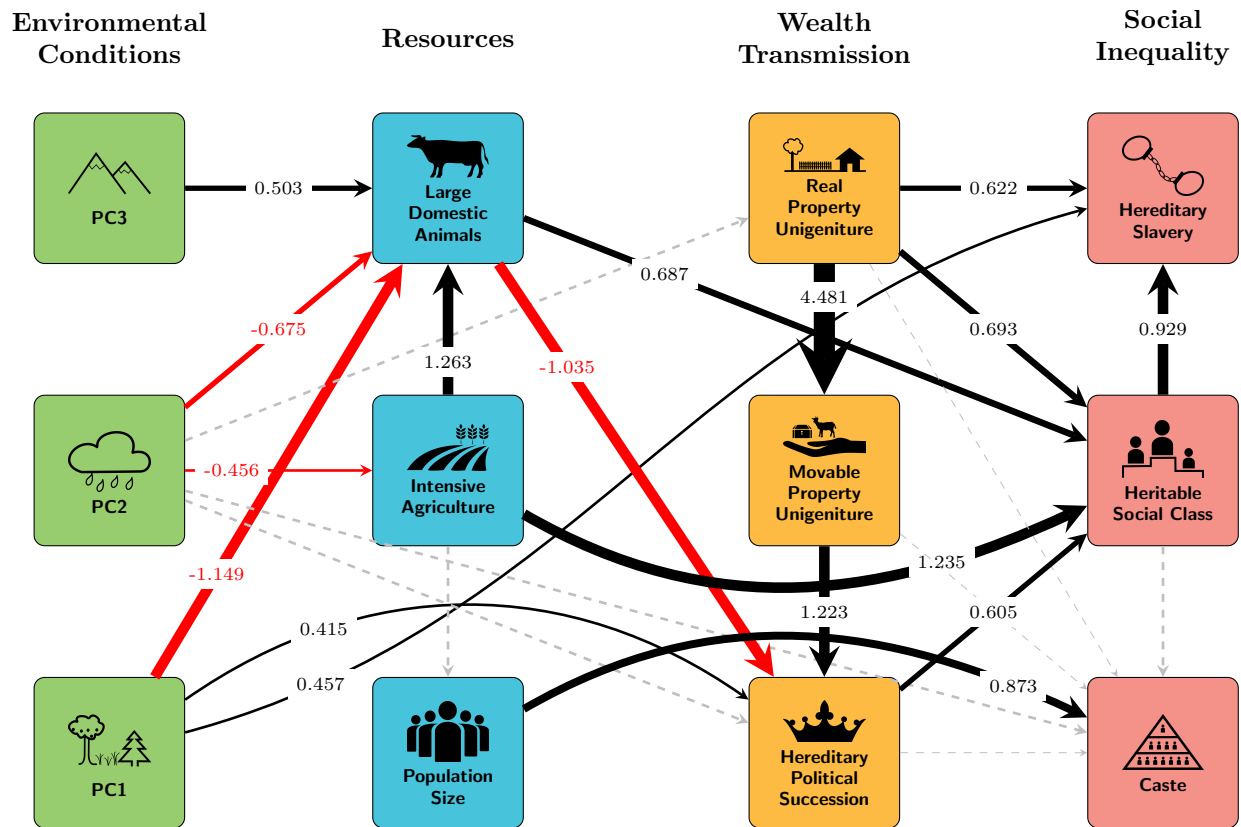


Figure 3: Most parsimonious model identified by Piecewise SEM analysis. Black arrows represent positive relationships. Red arrows represent negative relationships. Dashed arrows represent paths not found to be significant ($p < 0.05$) Line weights indicate the estimated magnitude of effects, and paths are labeled with standardized coefficients. Individual variables represented by boxes in the diagram can be interpreted as *increasing* for continuous variables and *present* for categorical variables. This model is better supported by the data than 2b or 2c (AIC: Model 2b = 185.51, Model 2c = 162.48, Model 3 = 150.30). $n=367$.

138 Shipley's test for directional separation indicates that paths are missing from the model that
139 implements a strictly stepwise progression of mechanisms on the pathway to inequality (Fig. 2a,
140 Fisher's $C=99.51$, $df=50$, $p<0.0001$) (32). Akaike Information Criterion comparison also suggests
141 that the highly restricted path model in Fig. 2b ($\Delta AIC=35.21$, $AIC=185.51$) does not account for
142 the data as well as the more elaborate model in Fig. 2c ($\Delta AIC=12.18$, $AIC=162.48$). The third
143 model (Fig. 3) eliminates non-significant paths that are not identified as missing by Shipley's test
144 and reduces unnecessary model complexity ($AIC=150.30$). AIC comparison suggests that of the
145 models under consideration, this final model provides the best characterization of the relationships
146 between variables in our dataset.

147 The model in Fig. 3 includes both direct and indirect effects of subsistence variables on
148 inequality outcomes. Six pairs of variables are linked by both direct and indirect effects, including
149 the links from intensive agriculture, large domesticated animals, and real property unigeniture to
150 heritable social class that are hypothesized to be particularly important pathways. Table 1 provides
151 a comparison between the direct effect and net indirect effect of each predictor on every inequality
152 variable.

153 We find that the environment has important impacts on the activities that relate to resource in-
154 tensification, namely intensive agriculture and keeping large domesticated animals. Environments
155 with less seasonal climate variation are more likely to be associated with these two variables, both
156 of which represent subsistence activities that may increase resource defensibility. We also find a
157 direct link between environmental productivity and slavery, with hereditary slavery more likely to
158 occur in more productive environments. Although this relationship is not mediated by the other

Table 1: Comparison of the direct and indirect effects in structural equation model in Fig. 3 (standardized coefficients). Net indirect effects are calculated by multiplying coefficients along each indirect path that connects the predictor and the ultimate response and computing the sum of all indirect paths between predictor and response. For relationships that are comprised of both direct and indirect effects, bold text indicates the effect of greater magnitude.

Response	Predictor	Direct	Indirect
Caste	Population Size	0.873	
Class	Intensive Agriculture	1.235	0.077
Class	Large Domesticated Animals	0.687	-0.626
Class	Movable Property Unigeniture		0.739
Class	PC2		-0.640
Class	PC1		1.689
Class	Real Property Unigeniture	0.693	3.312
Class	Hereditary Political Succession	0.605	
Class	PC3		0.031
Slavery	Intensive Agriculture		2.182
Slavery	Large Domesticated Animals		0.101
Slavery	Heritable Social Class	0.929	
Slavery	Movable Property Unigeniture		0.687
Slavery	PC2		2.120
Slavery	PC1	0.457	0.168
Slavery	Real Property Unigeniture	0.622	3.720
Slavery	Hereditary Political Succession		0.561
Slavery	PC3		0.028
Succession	Intensive Agriculture		-1.308
Succession	Large Domesticated Animals	-1.035	
Succession	Movable Property Unigeniture	1.223	
Succession	PC2		1.296
Succession	PC1	0.415	1.189
Succession	Real Property Unigeniture		5.478
Succession	PC3		-0.521

159 cultural variables in our study, it is likely cultural in nature, reflecting the use of slave labor in
160 exploiting abundant resources, or potentially a more complex cascade of economic and political
161 developments arising from resource surplus. Though the role of environmental conditions in the
162 early origins of inequality has been characterized primarily in terms of large-scale patterns in cli-
163 mate stability that created better conditions for resource defense in the early Holocene (22), we find
164 that climatic predictability and environmental productivity may play complex roles in determining
165 strategies for subsistence, shaping social and political processes, and even directly influencing the
166 cultural institutions that formalize and reinforce inequality.

167 Our results also include strong evidence that wealth transmission norms, and particularly
168 those that concentrate power and real property holdings, are associated with the institutionaliza-
169 tion of social inequality through class systems in which social status is inherited. The associ-
170 ation of both real property unigeniture and hereditary political succession with heritable social
171 class supports the hypothesis that many types of wealth contribute to the generation of inequality
172 (10; 27; 28). Of the wealth transmission variables included in this analysis, real property uni-
173 geniture (transmission of land holdings to a single heir) has the strongest net effect on heritable
174 social class. In contrast, movable property unigeniture has no independent direct effects on social
175 inequality variables, though it does participate in a relationship with class mediated by political
176 succession patterns. These findings support the notion that real property is central to the effect
177 material wealth transmission has on inequality, while movable material property inheritance may
178 serve primarily to support the accumulation and transmission of social wealth (10; 25; 26; 29).
179 We note that unigeniture may be a particularly potent mechanism for concentrating wealth and en-
180 couraging formal systems of inequality. We test the same models with intergenerational property

181 transmission encoded simply as the presence or absence of any inheritance rules for real and mov-
182 able property. Because these models result in poorer fit for two of our three inequality variables,
183 and because a parsimonious model offers no improvement on the full model with this data, we
184 retain unigeniture coding and report the alternative implementation of wealth transmission in the
185 supplementary materials.

186 We also find a direct effect of real property unigeniture on hereditary slavery. Although the
187 magnitude of this effect is smaller than indirect effects of real property inheritance rules on slavery
188 through heritable social class, it serves as further evidence of the importance of real property
189 inheritance in shaping inequality. The use of slave labor as a means of cultivating large parcels
190 of land, which are owned and inherited, explains this relationship to some extent, though it is
191 perhaps surprising that we find no evidence that intensive agriculture participates in this pathway
192 as a driver of real property unigeniture and an indirect driver of the link between real property
193 inheritance patterns and slavery.

194 Other components of the most parsimonious model also depart from the expected trajectory.
195 The expected stepwise link between resource intensification and wealth transmission occurs in the
196 selected model only in the form of an effect of large domesticated animal keeping on hereditary
197 political succession, and our model predicts that societies that make use of large domesticated
198 animals are, in fact, less likely to have systems of hereditary political succession. If the use of
199 large animals is positively linked to the development of inequality, as Kohler et al. have suggested
200 for agriculturalists (33) and Smith et al. have proposed for pastoralist societies (25), the negative
201 association we find between large animals and transmission of social wealth trends in the opposite

202 direction than we might expect for our sample of modern societies. This result also contrasts with
203 prior research that demonstrates positive links between pastoralism, intergenerational of multiple
204 types of wealth, and inequality (31).

205 Because the data we employ does not distinguish between animals used as a food resource
206 and animals used for labor, we report the results of the same modeling task using a dataset that
207 excludes societies that obtain a majority of their subsistence through pastoralism. The results
208 of this supplementary analysis, which focuses more narrowly on non-pastoral animal husbandry,
209 are qualitatively similar to those reported in Fig. 2, suggesting that the surprising direction of
210 the relationship between large domesticated animals and inequality is not merely an artifact of
211 how animal husbandry has been operationalized. Even in consideration of the limitations of this
212 study, such as the narrow focus on a small subset of the manifestations of social inequality, it
213 is difficult to interpret this apparent contradiction without further, more detailed examination of
214 wealth transmission and inequality in individual pastoralist and agropastoralist societies and in
215 targeted cross-cultural samples.

216 While intensive subsistence activities might be expected to have primarily indirect impacts
217 on social inequality through positive associations with wealth transmission, we find evidence for
218 stronger direct impacts of subsistence practices on inequality (see Table 1). Though we know that
219 inequality can arise even in the absence of agriculture (4; 10; 25; 29), our results suggest that sub-
220 sistence activities themselves are important contributors to the social and economic mechanisms
221 out of which rigid inequality structures can arise, independent of wealth transmission patterns
222 that consolidate resources and status for the few. This finding implies that inequality in modern

223 societies may arise through multiple pathways, some of which are not dependent on differen-
224 tial accumulation of property and power through wealth transmission practices. Specialization
225 and division of labor in economies associated with intensive agriculture, for example, might cre-
226 ate occupation-based stratification in wealth and prestige, regardless of how property or political
227 power are transmitted across generations.

228 Our failure to perfectly replicate the sequential progression of mechanisms that are thought to
229 have generated early Holocene social inequality might be explainable through alternative, population-
230 focused theories (34). We might expect a population-driven explanation to be manifested in a
231 trajectory like the one modeled here through effects of population size on wealth transmission or
232 institutionalized social inequality. If the links we find between resource intensification and inequal-
233 ity are artifacts of demographic pressures or the politics of large scale societies, we would expect
234 population size to participate in these pathways. However, we find that population size is linked
235 only to caste, and this association is not particularly strong. While this analysis is not designed
236 to test any particular demographic pressure model in great detail and lacks the statistical power to
237 explore the vast web of cultural, political, and economic pressures at play in its entirety, we find
238 no evidence that suggests our results are driven by the scale of the societies involved.

239 In addition to testing expectations derived from prior theory, our approach also allows us to
240 examine the independent and interrelated effects of individual observable phenomena associated
241 with the general constructs of environmental conditions, resource intensification, wealth transmis-
242 sion, and institutionalized social inequality. While selecting a parsimonious model of the pathways
243 that link our variables, we are simultaneously able to examine the complexities of these pathways.

244 We find, for example, that both real property unigeniture and hereditary political succession are
245 significantly positively associated with heritable social class, but not caste, while movable property
246 unigeniture has no significant direct impacts on any of our institutionalized inequality variables.
247 Furthermore, within the realm of wealth transmission we find evidence that movable property in-
248 heritance serves as a link between real property unigeniture and hereditary political succession.
249 This creates a strong indirect effect of real property unigeniture on heritable social class and high-
250 lights the complexity of interactions within the domain of wealth transmission.

251 Our results also point to heritable social class as the measure of institutionalized social in-
252 equality that is most strongly associated with the effects of wealth transmission and intensive
253 subsistence practices in modern human cultures. Subsistence and wealth transmission variables
254 are directly and positively associated with heritable social class, while the direct impact of real
255 property unigeniture on slavery is dwarfed by a net indirect effect of real property unigeniture on
256 slavery that is mediated by social class. We find no evidence that caste participates in the path-
257 ways linking subsistence or economic defensibility and wealth transmission to inequality. Rather,
258 caste is predicted only by population size in this model. Although this could potentially be inter-
259 preted as support for population-based theories or an impact of population size on the development
260 of inequality-reinforcing norms, we propose that this relationship may in fact be an artifact of
261 the highly restricted distribution of caste to societies in a small number of language families in
262 population-dense regions, namely the Indian subcontinent and parts of Africa. The language fam-
263 ily random effect in this model is the best predictor of caste, as evidenced by the marginal model
264 fit estimate for this variable (including only fixed effects) of 0.016, and the conditional fit estimate
265 (including language family and fixed effects) of 0.963 (See supplementary materials). It may be

266 difficult to systematically identify the drivers responsible for the origin of caste, given that the
267 caste systems of the world may reflect a very small number of independent origins and a strong
268 signature of shared histories.

269 **3 Conclusions**

270 The complex network of effects we identify between environmental, subsistence, inheritance, and
271 social inequality variables suggests that how we measure each of the core cultural constructs as-
272 sociated with a theoretical evolutionary trajectory for social inequality matters to our ability to
273 investigate the processes that create and maintain the institutions that most rigidly support social
274 hierarchies. A priori assumptions might have emphasized intensive agriculture as a means of in-
275 creasing economic defensibility, and thus a likely predictor of real property inheritance patterns
276 and inequality in turn (35), which could have been tested in a simpler model. However, the inclu-
277 sion of several variables to represent each component of the theory enables us to identify pathways
278 that deviate from expected trajectories in addition to those that support prior hypotheses.

279 Our ability to measure the relevant characteristics of societies is limited in practice by the
280 availability of cross-cultural data. With the data used in this analysis we may not be able to capture
281 all of the complexity in the phenomena discussed in great detail in a large body of prior literature,
282 or to capture additional phenomena that may contribute to the modern evolution of inequality. The
283 results presented here do not, in other words, rule out other possible pathways. Many causal rela-
284 tionships have been proposed that may impact individual cultural traits and mediate relationships
285 within this set of variables. For example, though our results do not support the potential importance

286 of real property inheritance as a link from agriculture to social inequality, such a pathway might
287 be detectable if specific other variables were included in the analysis. One proposal suggests that
288 metallurgy might arise in agricultural societies and subsequently have an effect on social inequality
289 (36).

290 There are also numerous other theories about the evolution of slavery (e.g. 37; 38). Due
291 to limitations of data availability we are unable to address every possibility outlined in prior re-
292 search, and instead focus on whether the influences on contemporary inequality mirror the set of
293 mechanisms for generating inequality that are supported by a large body of literature and distilled
294 in a recent review of that work (10). Because this approach focuses on a specific set of general,
295 society-level phenomena, we urge caution in interpreting results of this type of analysis; our model
296 helps us understand influences on cultural evolution but does not represent a singular, inevitable
297 trajectory for the evolution of institutions of social inequality. Other facets of human culture and
298 behavior are of vital importance in understanding individual systems of slavery, caste, and social
299 class.

300 Though no analysis can address all hypotheses in light of current data constraints, the re-
301 sults we present here answer several questions and illuminate others that are deserving of further
302 research. For example, the absence of an expected path from intensive agriculture to real property
303 inheritance patterns defies a strong prior expectation and points out a need for further research on
304 the relationship between agricultural practices, land tenure and real property inheritance.

305 The methods we implement here represent a novel but rigorous way to explore the complex
306 relationships between cultural phenomena that may interact both directly and indirectly, while also

307 controlling for shared histories. The structural equation approach illustrated in this analysis makes
308 it possible to examine in detail the empirical evidence for bold theories that have been proposed to
309 explain the evolution of human culture.

310 **4 Methods**

311 This study employs Ethnographic Atlas and environmental data for 367 societies available in the
312 D-PLACE database (11; 12; 13; 14; 15; 16) that are referenced to both specific times and places.
313 This sample of 367 societies is the maximal sample size for which all of the variables included in
314 our study were available. While this sample is distributed around the globe, no special effort was
315 made to control for cultural relatedness through sampling (as in, for example, the Standard Cross-
316 Cultural Sample). Instead, we control for genealogical relationships explicitly in the design of our
317 mixed effects path models. Although the current lack of a reliable, global cultural phylogeny pre-
318 vents us from using phylogenetic methods to control for shared histories, we use a random effect of
319 language family in the SEM framework to control for well-established genealogical relationships
320 between societies.

321 The variables in the study serve as proxies for the more abstract constructs that are central
322 to the hypothesized sequential evolution of early Holocene social inequality, and represent these
323 societies as they were observed at a single point during or near the early 20th century. These data
324 largely result from coding of ethnographic sources, which limits to some extent the ways in which
325 we can test evolutionary hypotheses. For example, the variables selected for this study reflect
326 not only a translation of central theoretical constructs to observable society-level phenomena, but

327 also the availability of data describing those phenomena in a large sample of societies around the
328 world. While the data and model we use do not explicitly reconstruct historical states of cultures
329 and their changes over time, the relationships we identify in this empirical data enable inferences
330 about the processes involved in the rise and maintenance of institutionalized social inequality in
331 modern human cultures.

332 We represent environmental conditions using three variables derived from a principal com-
333 ponents analysis (PCA). Although work on early Holocene inequality has characterized the envi-
334 ronment largely in terms of temporal trends toward stability immediately prior to that time, the
335 environmental variables included in this analysis allow us to characterize the productivity and
336 predictability of local environments, which are likely to impact the spatial variation we find in
337 human economic activity and cultural norms across a relatively narrow slice of history. Raw data
338 used in this study describe the mean, variance, and predictability of temperature, precipitation,
339 and net primary productivity (NPP) at each location, as well as measures of elevation and slope
340 (see supplementary information). Because this set of environmental variables is known to to be
341 highly correlated, we reduced it to three composite variables through principal components anal-
342 ysis (PCA) to avoid multicollinearity in the downstream SEM analyses (see Table S2). Higher
343 values of PC1 and lower values of PC2 may be expected in productive environments with pre-
344 dictable climates, conditions which may enhance economic defensibility. Higher values of PC3
345 are associated with topographic complexity, which can increase the patchiness of resources and
346 may thus also contribute to some extent to defensibility.

347 Domestication of plants and animals has been described as insufficient to spur the develop-

348 ment of inequality (25), and evidence for inequality that predates agriculture suggests that it is also
349 not a necessary condition for the emergence of inequality (4; 29). Yet empirical work has found
350 evidence that agriculture – particularly intensive agriculture – and the keeping of large domesti-
351 cated animals is associated with the wealth distribution and transmission practices that shape social
352 hierarchies (27; 28; 33; 39).

353 The observed link between subsistence and inequality has been explained as an association
354 between intensive agriculture and property rights, and a resulting concentration of material wealth
355 and political power in agricultural societies (e.g. 19; 25; 28; 39; 40). The presence of large domes-
356 ticated animals represents a similar pattern that has been identified for pastoralist societies (31),
357 and also an association between plow agriculture, the maintenance of draught animals, and dif-
358 ferential distribution of material wealth (33). We include both the presence of large domesticated
359 animals and the presence of intensive agriculture in our study to represent subsistence activities that
360 have been linked to inequality in prior empirical studies and are likely to impact the economics of
361 resource defense.

362 We focus on resource intensification as a technological and economic link between environ-
363 mental conditions and wealth accumulation. While prior research has portrayed this link more
364 broadly as a function of economic defensibility, targeting this mechanism allows this analysis to
365 ask a specific question about the human activities that may have resulted in institutionalized in-
366 equality in modern human societies.

367 Our analysis represents wealth transmission primarily as it relates to material and social
368 wealth. Material wealth transmission is characterized for the purposes of this study by variables

369 representing the presence or absence of inheritance rules that bequeath real property (land) and
370 movable property, respectively, to a single heir (unigeniture). Social wealth transmission is charac-
371 terized here by the presence or absence of hereditary political succession. Although we recognize
372 the importance of embodied wealth in shaping cultures, data limitations prevent us from exploring
373 that component of wealth transmission in this analysis.

374 Real property has been ascribed a particularly prominent role in differential wealth distribu-
375 tion due to practical limits on its subdivision and productivity (25; 26; 41). Movable property is
376 considered to be relatively indefensible by Mattison et al. (10), however possession and inheri-
377 tance of animals has been linked to inequality (31; 33). We include both real and movable property
378 to investigate the roles of each in the generation of institutionalized inequality. We hypothesize
379 that these two types of wealth may interact in different ways with intensive agriculture and with
380 the keeping of large animals. Our characterization of material property inheritance in terms of
381 unigeniture reflects an expectation that an inherently unequal pattern of wealth transmission across
382 generations is particularly likely to concentrate resources and power and thus lead to institution-
383 alized inequality. In using a variable that describes hereditary political succession to represent
384 social wealth inheritance, we consider political power to be a reflection of social influence, and its
385 hereditary assignment to be a manifestation of the intergenerational transmission of social wealth.

386 Persistent, institutionalized inequality, defined clearly by Mattison et al. (10), includes a
387 number of structures of varying levels of formality that emerge in societies to create and maintain
388 stratification. While inequality exists in many forms, at many scales, in many parts of society, it
389 is characterized in this study by the presence or absence of three forms of institutionalized social

390 hierarchy that are well described by cross-cultural data: class, caste, and slavery. Each of these
391 variables is encoded in a separate binary (presence/absence) variable, so that relationships between
392 individual types of wealth transmission and specific inequality outcomes may be investigated. For
393 each of these variables, we restrict the presence category to instances where the social stratifica-
394 tion system may persist across generations, namely heritable social class, hereditary slavery, and
395 caste. These response variables represent a small subset of the outcomes that can be considered
396 to exemplify persistent, institutionalized, inequality. However, they have the advantages of being
397 reliably identifiable as persistent and institutionalized forms of inequality, of being recoverable for
398 a maximally large, globally distributed sample of societies, and of representing particularly rigid
399 and entrenched mechanisms for enforcing social hierarchies.

400 Our coding of slavery is complicated by a large number of societies which are coded as
401 “slavery reported but not identified as hereditary or nonhereditary” in the Ethnographic Atlas. We
402 have included these societies in the “hereditary slavery absent” category in the analysis presented
403 here. Results using the alternative binarization (with these societies coded as “hereditary slavery
404 present”) differ from the results presented above in having a significant direct effect of intensive
405 agriculture on slavery but no direct effects of PC1 or real property unigeniture on this outcome.
406 Full results of the analysis including the alternative binarization of the slavery variable are reported
407 in the supplementary materials.

408 Not all approaches to the evolution of inequality focus on resources, their defense, and the
409 transmission of the resulting wealth. One competing family of theories ascribes the rise of inequal-
410 ity to pressures associated with growing populations and the organization of large-scale societies

411 (18; 34; 42; 43; 44). Examining the complexities of theories that center on carrying capacity, popu-
412 lation pressure, and the roles of individual-level competition and cooperation in creating inequality
413 in detail is beyond the scope of the current analysis of group-level phenomena. However, we are
414 able to incorporate population size into our model and test whether this measure of society size
415 is a significant driver of inequality, as might be predicted by this set of theories. Johnson's scalar
416 stress theory (34), for example, associates hierarchical organization, including social status hier-
417 archies, with the organizational pressures present in larger population. Under such a theory we
418 might expect population size to mediate impacts of agriculture or to serve as an independent driver
419 of inequality. Population size may also impact economic defensibility in complex ways through
420 its effects on within-group coordination and between-group competition (24). Incorporating pop-
421 ulation size in the model and assessing both its direct and indirect effects on inequality allows us
422 to examine whether resources and population work independently or in concert to impact wealth
423 and social hierarchy, and whether one or the other of these is a more important driver of institu-
424 tionalized inequality. This variable is encoded as a continuous variable that estimates the number
425 of individuals in each entire ethnic group. More information about the coding of all variables can
426 be found in the supplementary information.

427 We analyzed the data described above for 367 societies in the R statistical computing envi-
428 ronment, using the packages PiecewiseSEM and lme4 for structural equation modeling (45; 46).
429 Language family was included as a random effect to control for potential non-independence of data
430 that may result from common cultural inheritance, following Botero et al. (47). Because no widely
431 accepted global phylogeny of languages or cultures currently exists, we are unable to implement
432 phylogenetic path models, and instead use a less complex but more widely accepted method of

433 controlling for historical relationships through the inclusion of well established language family
434 classifications as a random effect in a mixed model framework (48; 49)

435 An initial model presents a very simple implementation of a stepwise pathway to inequality,
436 modeled to parallel the trajectory for early Holocene inequality origins outlined by Mattison et
437 al. (10) (Fig. 2b). In this model, environmental conditions are represented by our derived PC
438 variables. These have direct effects only on subsistence (large domesticated animals and intensive
439 agriculture). Subsistence variables represent modern use of resources and technologies to intensify
440 subsistence, and these variables in turn have direct effects only on wealth transmission variables.
441 The three wealth transmission variables have direct effects only on the three social inequality
442 variables. Any relationship between environmental or subsistence variables and inequality can
443 be characterized in this model only by an indirect path through one or more wealth transmission
444 variables.

445 We may not expect the chain of causal links modeled as a simplistic set of sequential effects
446 in Fig. 2b to serve as the only pathway for inequality to arise, exclusive of any direct impacts
447 of the environment or defensibility-enhancing subsistence practices on inequality. Prior literature
448 presents a more complex picture than the strictly stepwise schema is able to capture, and the
449 trajectory outlined in Fig. 2a does not explicitly rule out additional, direct links. For this reason
450 we also consider a more elaborate model that adheres to the same assumptions about directionality
451 and ordering of causal links, but includes a more complete set of direct paths between variables.

452 In this second model (Fig. 2c), the directionality of all estimated paths moves from envi-
453 ronment to subsistence/population, then inheritance, and finally inequality. Additional paths were

454 added to the set in Fig. 2b to allow for the possibility of direct effects of predictors on variables
455 farther to the right in the diagram. These direct paths extend from environmental variables to inher-
456 itance and social inequality variables, reflecting the possibility that the environment impacts wealth
457 transmission and institutions of inequality independently of agricultural practices and/or popula-
458 tion size. Direct paths from agricultural variables and population to social inequality variables are
459 also included. In this model population is treated as an additional potential predictor of wealth
460 transmission and inequality variables, reflecting hypotheses that link inequality to demographic
461 factors and the possibility that resource intensification and society scale have non-independent
462 impacts on inequality outcomes.

463 Finally, we use the support for individual paths in the full model (Fig. 2c) to develop a
464 more parsimonious model that retains well supported pathways but eliminates unnecessary model
465 complexity (Fig. 3).

466 **5 Data Availability**

467 All data are available online at <https://d-place.org/>. See supplementary materials for detailed infor-
468 mation on variables and societies included in this study.

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