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Kohler, Timothy, Green, Adam Stuart and Ortman, Scott (2026) Kuznets at -7000:Is there a really long-term relationship between growth and inequality? Structural Change and Economic Dynamics. pp. 207-217.

https://doi.org/10.1016/j.strueco.2026.01.007

Structural Change and Economic Dynamics 77 (2026) 207–217

Contents lists available at ScienceDirect

Structural Change and Economic Dynamics

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

Kuznets at -7000: Is there a really long-term relationship between growth and inequality?

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A R T I C L E I N F O

JEL classification:
B00
B52
C11
C31
D63

Key words:
Economic inequality
Economic growth
Prehistory
Eastern hemisphere
Western Hemisphere

A B S T R A C T

We use archaeological data on house sizes to generate estimates for economic inequality and economic growth from the Early Holocene to about the first millennium AD. At worldwide scales these variables are positively but loosely related; patterns are more divergent at regional levels. Cross-sectional regression shows that the formation of central-place hierarchies and development of landesque capital (indicating land-limited production) were positively linked to both economic growth and inequality; development of bronze smelting, animal management, and farming were also positively linked to growth. Iron smelting was linked to reduced inequality whereas presence of copper smelting and animals for portage were linked to reduced growth. We track the dynamics of inequality and growth through time in SW Asia/SE Europe, Britain, and SE North America, and analyze the first two with general additive models. Examination of three well-known interaction zones (Bronze Age West Asia, the Classic Maya world, and first-millennium-AD Britain) shows surprisingly regular transformations of the relationship between economic growth and inequality on millennial time scales. Overall our findings emphasize a strong cumulative component to both economic growth (productivity) and economic inequality over the substantial portions of the pre-capitalist Holocene that we analyze.

1. Introduction

Understanding factors affecting economic growth, economic inequality, and the relationship between them has long been a core concern in economics. The paper we commemorate in the studies collected here, published by Simon Kuznets (1955), seems particularly interested in framing this task through comparisons over long periods: decades if not centuries. The famous and highly tentative conclusion reached by Kuznets in that paper was that the 'early developing' countries of western and northern Europe and their economic and cultural descendants in the USA, Canada, Australia and New Zealand, as they underwent industrialization and urbanization, experienced a long-term trend of first increasing, and later decreasing, income inequality in conjunction with continued economic growth. Kuznets himself was uncertain how generalizable this pattern was, even whether this sequence applied to "late-developing" countries in the contemporary world. And of course, we know now that the pattern of increasing income equality he identified in the mid-20th century in developed countries would begin to reverse within three decades. With the resurgence of inequality studies following the 2008 recession, many researchers have re-engaged with the assumptions that drove Kuznets' hypothesis, including Thomas Piketty (2014) and Branko Milanovic (2016). In this paper we examine the very long term relationship between economic growth and economic inequality using data on house sizes accumulated over the last few years by a number of archaeologists, including those of us in the GINI Project (Bogaard et al., 2024). This requires adding analyses of economic growth (productivity) to the considerations of wealth inequality previously published in a PNAS Special Feature (Kohler et al., 2025a).

By contrast with economic history, the relationship between economic growth and inequality has not been central to archaeological research. We see at least two reasons for this. First is the conspicuous (and automatic) lack—for all of *pre*history—of documents detailing the levels and trends in income and wealth that can be found, and assembled, for many societies over the past few centuries. These gaps are almost as severe for the literate societies of the ancient world, though they are slowly being filled (Morris, 2010; Scheidel, 2017). Most research in archaeology dealing with economic growth, economic

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https://doi.org/10.1016/j.strueco.2026.01.007
Received 15 April 2025; Received in revised form 31 October 2025; Accepted 10 January 2026
Available online 11 January 2026

inequality, and their relationship has focused on archaic states (Moreno Garcia, 2016; Smith, 2008; van de Mieroop, 1999) or their immediate precursors (Hoffman, 1979). Although interest in these topics also extends to Celtic societies (Cunliffe, 2008), Bronze Age Europe (Kristiansen and Larsson, 2005) and even the Neolithic (Hayden, 2014; Hodder, 2006), the results usually do not lend themselves to a quantitative comparative framework. The second, more fundamental issue is a questioning of the degree to which contemporary and ancient economies are comparable. In both anthropology and economic history, researchers have tended to see a radical disjuncture between past and present economies. Anthropologists (and anthropological archaeologists) became caught up in a debate between researchers who assumed that past economies were too embedded to describe in mathematical terms, and others who attempted to do just that. Many anthropologists have failed to grapple with emerging ideas in economics, such as Piketty's (2014) analysis of capital or Mazzucato's (2024) investigation of entrepreneurship. Archaeologists have a lot to gain by updating their engagement with economics. Arguing that there are large-scale and long-term patterns that have shaped human economies in the past and present, Green and colleagues (2024) draw on a range of heterodox economic theories to advocate a set of theoretical propositions they call 'critical paleoeconomics' marked by a willingness to explore big patterns in ancient economies while recognizing that systems of production and consumption were subsumed in institutions that were variable in form (Green et al., 2024).

The proxy for economic inequality we use here is Gini coefficients calculated from residential building areas in archaeological sites. Our assumption is that larger houses index greater household resources, whether these were embodied in people, stored as goods, or maintained through social interchanges, and whether they are imagined as flows per unit time (income) or accumulated stocks (wealth). We substantiate this assumption elsewhere (Kohler et al., 2025a, 2025b; Kohler, T.A., M.E. Smith, 2018) and accept arguments by Ortman and colleagues (2025) that this proxy produces a minimal estimate of wealth differentiation.

Because we want to apply the same approach to sites that may date early in the Holocene, or as late as the Anglo-Saxon period in Britain, and that may have been occupied by hunter-gatherers, horticulturalists, farmers, or city-dwellers, we need a measure that responds appropriately to economic differences that arise for many different reasons. Following Borgerhoff Mulder and colleagues (Borgerhoff Mulder et al., 2009; Bowles et al., 2010) we argue that wealth differences among hunter-gatherers and horticulturalists are instantiated as somatic and relational differences among households. They emerge due to differences in characteristics such as the number of offspring, number of allies in conflicts, and importance of ritual obligations. Number of offspring in particular leads to larger residences, but ceremonial centrality may also require space to store paraphernalia or temporarily house participants. These factors continue to be relevant considerations among agriculturalists, but in such societies material goods become increasingly important to measuring wealth. More stuff to store (grain, livestock, tools and so forth) inevitably leads to larger residences. The important thing to note is that although different cultural contexts generate larger houses for somewhat different reasons, all of these differences in residential building area reflect socioeconomic differences to some extent. A particular advantage of calculating Gini coefficients using house-size measurements from specific sites (or small regions) is that this method automatically holds constant a great deal of inter-household variability due to cultural differences (including variability in construction materials and techniques) and climate.

Of course houses are composite goods, offering their occupants refuge from weather, predators, crime, and prying neighbors, signalling aspects of social and economic standing, and through their location offering variable degrees of access to natural resources and public services. For contemporary societies it is possible to develop hedonic regression models estimating the individual contributions of many such possible factors to housing prices or rents. An influential early example, for St. Louis and its county, found that size characteristics (number of rooms, number of bathrooms, area in square feet of first floor) are consistently significant and tend to have larger slope estimates (measuring market value) than the quality characteristics (e.g., structural condition and quality), though both are important. "The monthly rent of a dwelling unit one standard deviation larger than average as measured by number of rooms, number of bathrooms, and lot size, is about $16 more than that of an average unit. On the other hand, the additional rent for a unit one standard deviation better than average in basic residential quality and dwelling unit quality is more than $13 (Kain and Quigley, 1970, pp. 546–547).

Contemporary debates about income and consumption provide strong theoretical and empirical support for our claim that economic inequality can be assessed using ancient housing. In *A Theory of the Consumption Function* (Friedman, 1957), Milton Friedman defined the concept of "permanent income" as the expected long-term average income on which people base their consumption decisions — rather than using their current (possibly transitory) income.[1] Subsequent economic research has found a strong link between a household's permanent income and how much it is willing to pay for housing (Goodman and Kawai, 1982). Of course, permanent income and total lifetime wealth are expected to be strongly related in general (Meghir, 2004, p. F297)—and likely even more so in the smaller-scale, non-financialized economies making up the bulk of our sample. These economists have highlighted the ability of "permanent income" to explain quantitative patterns in contemporary economic evidence, conceptualizing housing as the ultimate consumer good. (We note that in anthropology the tendency has been to argue that production and consumption do not exhaust the possibilities of social life (Graeber, 2011)). Houses are sites of social reproduction, non-alienated labor, and indeed sometimes production for markets, all uses that help explain why they are so desired, and thus invested in.

2. Returning to our Childe-ish roots

No early archaeologist expressed an interest in economic growth, economic inequality, and their relationship more clearly as V. Gordon Childe (1936). There is also reason to believe that he would have appreciated our quantitative approach (Childe, 1951) which we describe in more detail elsewhere (Kohler et al., 2025a, 2025b). The GINI project, on whose data this paper is based, assembled a team of regional experts who constructed a database containing measurements of residence sizes that currently includes >4600 sites with >58,000 residential units spanning >10,000 years in all major world regions except Australia. We ourselves are not very impressed by these large numbers because important areas in Africa, South America, and central and east Asia, for example, remain under-represented; but we believe we have made a good-enough start on a comprehensive database to permit informed estimates about large-scale trends in growth and inequality for a substantial portion of the Holocene. We continue to add data to this database as it becomes available. Major additions since publication of the papers in Kohler et al. (2025b) include datasets for the Neolithic and Bronze Age in Great Britain (Bullmore, 2022), Denmark and Southern Norway (Bunbury et al., 2023; Sand-Eriksen, 2025), and the Carpathian Basin of central Europe (Duffy et al., 2025). Since we calculate proxies of economic inequality from house-size distributions, it follows that we can also use estimates of the changing central tendency for residence size through time as a measure of economic function (performance, or growth when positive) (Ortman et al., 2025).

These measures of economic growth and inequality can be calculated at any scale; Childe was particularly interested in what happened in Europe, but he recognized that it was also essential to understand how

[1] We thank Bob Allen for suggesting the relevance of this concept to our analysis.

Europe's patterns were linked to those in SW Asia. Economists contemporary with Childe were more interested in providing a framework for how "underdeveloped" economies could move toward prosperity. Kuznets thought that economic growth could provide a pathway through a succession of different economic phases. His proposition that economic inequality was merely a phase that had to be endured to achieve prosperity became enshrined in modernization theory (Lancaster and van de Walle, 2015). In fact, though, the economic trajectories that many embarked upon confounded the predictions of Kuznets, resulting in prolonged phases of increasing economic inequality, and structural economic changes that made reductions in that inequality difficult (Hout, 2016). Wallerstein (e.g., 1974) argued by contrast that the role an economy played in the broader capitalist world system better explained differentials in access to resources than did progress toward modernization. Since both modernization and dependency theory saw economic growth as the key variable of analysis, studies of wealth and income distribution declined during the latter half of the 20th century (Milanovic, 2023). Still, the debate underscored that economic development was the product both of the *internal* relationship between economic growth and economic inequality, and of *external* interactions between different economies.

In this paper we begin by examining inequality and growth at the largest possible scales, and then narrow our focus to particular regions. Recognizing that the modernization/dependency debate identified the need to investigate economic trajectories within larger world systems of interaction we close the paper by sketching such an analysis, reported in more detail elsewhere (Green et al., 2025).

2.1. *Economic inequality and economic growth at large scales*

Fig. 1 presents these estimates separately, for individual archaeological sites, across the entire world sample. Two conventions used in this figure need to be explained, each of which we developed to clarify distinctive characteristics of these data. First, we found that concurrent regional variability in house sizes was greatly reduced if we controlled for the time elapsed since the development of agriculture in each region. Consequently, in Fig. 1 we present site dates relative to the time of the local arrival or development of agriculture (Δyears). Thus, a date −1000 indicates that the measured structures were constructed about a millennium before the local appearance of agriculture. (The same data are graphed by calendar year in Kohler et al. (2025b, fig. S4)). Second, we also noticed that much variability in structure size was related to the position of the site containing the structures in its local hierarchy of central places (if any; see Berry and Garrison, 1958 on settlement hierarchies generally and Adams, 1966; Childe, 1950; Wright and Johnson, 1975 on early use of these concepts in archaeology). Consequently in Fig. 1 we control for this effect using a variable called SA (Social Advantage). SA is merely the sum of two more basic variables: NOfLevels (the number of levels in the central place hierarchy, ranging from 1–6 where 6 represents a system such as found in the Roman Empire), and WhichLevel, the level occupied by the focal site (ranging in these data from 1–5). Thus a small hamlet in a chiefdom might have an SA value of 3 or 4 (WhichLevel = 1 and NOfLevels = 2 or 3). We also characterize the location of sites within a settlement hierarchy in a way that provides a consistent descriptor even as the number of levels in the

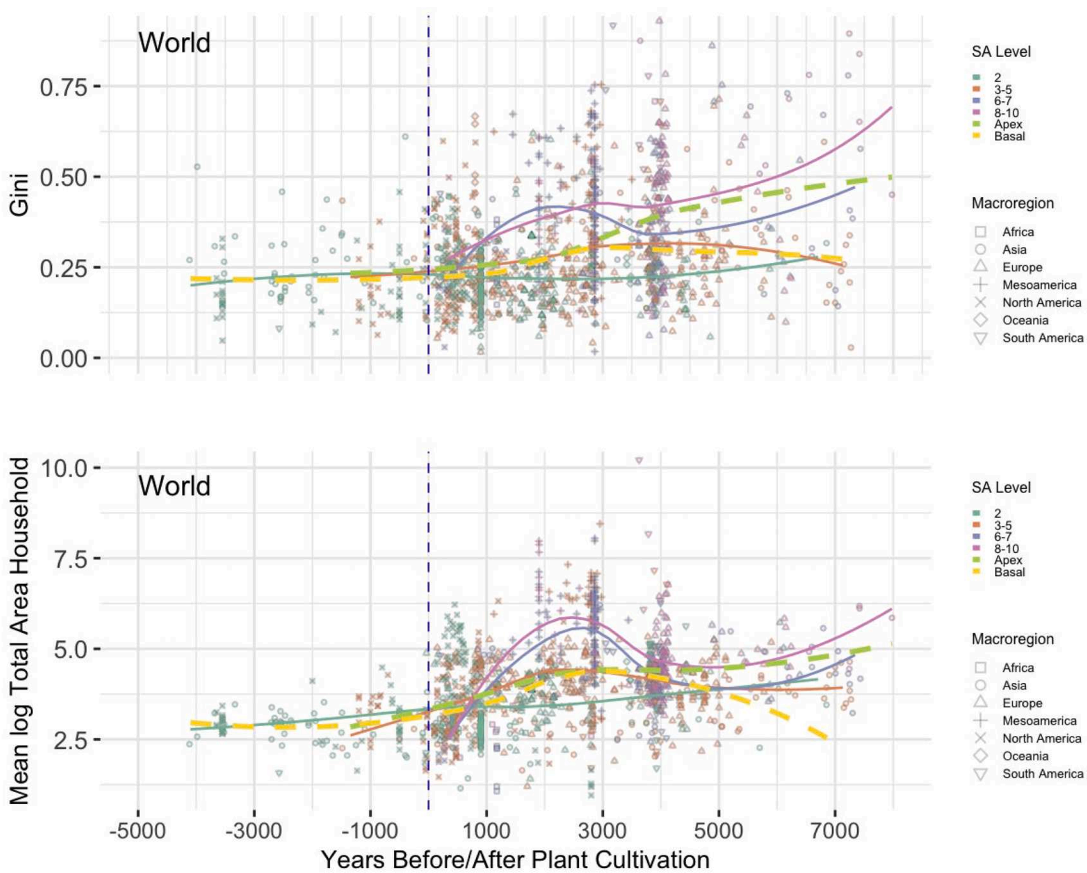

Fig. 1. Distributional statistics computed by site through Δyears, controlling for SA level and designation as Basal or Apex.
Note: Years Before/After Plant Cultivation (Δyears) are structure dates relative to the date when agriculture became locally common. Dashed vertical line marks onset of common plant cultivation locally. Seven sites from Asia pre-dating Δ−5000 are not plotted. Smoothing is by loess (span=0.9). Sample size: 50,170 structures in 1272 sites. Top: Gini coefficients measuring housing inequality (interpreted as inequality in wealth or permanent income). Bottom: mean logs of house size, interpreted as representing typical living standards or wealth. Source: authors' illustration based on data as described in Kohler et al. (2025b) with additions noted in text.

system (and thus the value for SA) changes. This is done by differentiating between 'Basal' and 'Apex' sites. Basal sites are those where WhichLevel = 1, regardless of the number of levels in the relevant settlement system. Such sites are thus always at the bottom of any hierarchy. Apex sites are those at the top of the hierarchy, whatever the size of the hierarchy. For more details see Kohler et al. (2025b).

Fig. 1 shows that at these very large scales, measures of economic inequality (Ginis) and economic growth (mean of the log of residence area) both show an increasing trend over the nine millennia represented. Comparing the top and bottom panels reveals that the mean log of the total house area (bottom panel) considered as a measure of economic function tends to increase prior to housing inequality (top panel), though this possibility needs to be more carefully examined on a by-region basis. The cumulative growth in both measures, though admittedly slow, is at odds with the assumption by some economists that, prior to the Industrial Revolution, 'increases in available resources will, in the long run, be offset by increases in the size of the population. Countries with superior technology will have denser populations, but the standard of living will not be related to the level of technology, either over time or across countries. The Malthusian model's predictions are consistent with the evolution of technology, population, and output per capita for most of human history. For thousands of years, the standard of living was roughly constant and did not differ greatly across countries' (Galor and Weil, 2000). This does not seem to be an idiosyncratic view, as the same perspective was echoed by the committee awarding the recent Nobel Prize in Economics (Committee for the Prize in Economic Sciences in Memory of Alfred Nobel, 2025). An obvious objection to Fig. 1 though is that the world was not an effective interacting unit during the times depicted here, so growth and inequality cannot have plausible functional relationships at the scales plotted.

Explaining growth and inequality at large scale

Before examining the inequality-growth relationship at less-global scales it's interesting to explore the factors that contribute to (or detract from) economic growth and inequality at global scale, since they

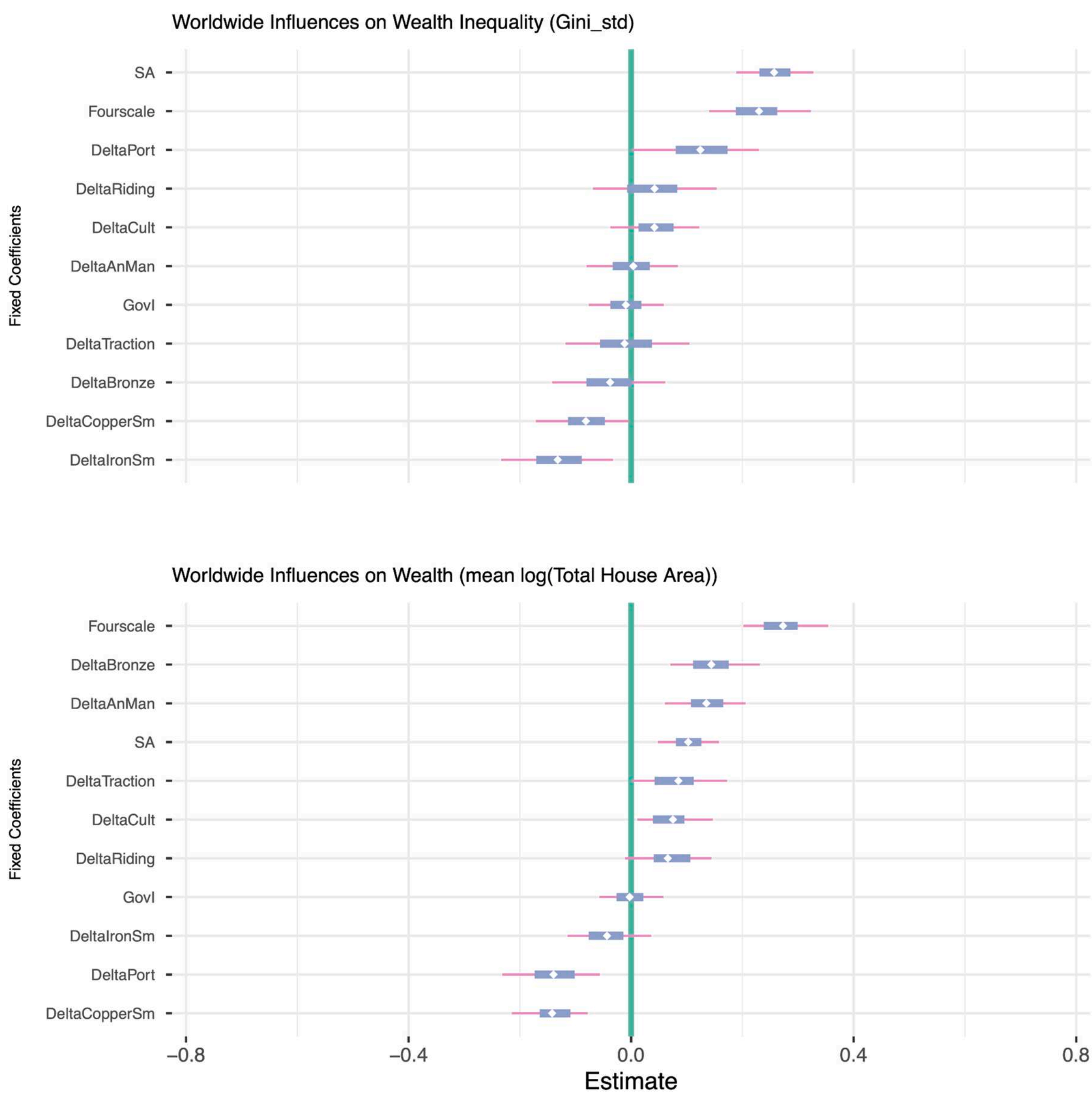

Fig. 2. Fixed effects from Bayesian multilevel regression models for the World sample with 24 regions and 1164 sites treated as cross-sectional data.
Note: credible intervals (CIs) for fixed coefficients are displayed as blue (50 %) or red (90 %); fixed coefficients ordered by median estimates displayed as white diamonds. Both models use random intercepts for regions. Top: Influences on Gini coefficients computed on household residence sizes by site; Bayes $R^2 = 0.33$. Bottom: Influences on typical wealth (mean of log of total residence size) by site; Bayes $R^2 = 0.63$. Source: authors' illustration based on data as described in Kohler et al. (2025b) with additions noted in text.

represent what all the regional sequences assembled here tend to have in common. Fig. 2 reports regression analyses considering the World sample cross-sectionally, taking the measures of inequality and wealth from the top and bottom panels of Fig. 1 as the dependent variables. The top panel shows that high values for SA (Social Advantage) and Fourscale (measuring extent of landesque capital development and pressure on land) are linked to increased inequality at high confidence. Amy Bogaard and colleagues (2025) explain the Fourscale variable, which measures the extent to which farming was land-limited, in detail. Higher values indicate increasingly land-limited, vs. labor-limited, production. At lower confidence, presence of animals for portage (DeltaPort), and use of cultivated plants (DeltaCult) are both associated with increased Gini values. (All variables prefixed by Delta are coded as 1 when present and −1 when absent for this analysis.) Iron smelting (DeltaIronSm) is associated with reduced Gini values (high confidence) as is copper smelting (with low confidence). Kohler et al. (2025b) report and discuss these results in more detail, though the database here is slightly larger leading to slightly different results.

For this paper we add an analysis of the correlates with economic growth, taking the wealth estimates in the lower panel of Fig. 1 as the dependents. The results bear some similarity to the results for wealth inequality, with interesting differences. Three variables in the analysis most connected to increasing wealth at these scales are Fourscale, DeltaBronze (presence of bronze smelting), DeltaAnMan (presence of animal management), SA, and DeltaCult (presence of farming). Use of animals for ploughing (DeltaTraction), and horseback riding, (DeltaRiding) are both connected with increased wealth at lower probability. Copper smelting and use of animals for portage (DeltaPort) are associated with decreased wealth at high probability, whereas iron smelting is linked to decreased wealth at low probability. The Bayes r^2 for wealth (0.63) is considerably higher than that for wealth inequality (0.33). This suggests either that variables other than those considered need to be brought into the analysis of wealth inequality, or that the processes producing wealth inequality are more regionally specific than those producing growth.

The advent of metal working is connected with growth and inequality in ways we did not anticipate. Copper is likely connected with *decreased* wealth inequality according to our proxy, and iron smelting is very likely connected with low levels of wealth inequality. Copper smelting, and likely iron smelting, also connect to low levels in our measure of wealth (average house size). Disregarding reversed causality, two possible explanations for these effects come to mind, which need not be mutually exclusive. First, the appearance of these metals may be having narrow effects on our proxies themselves. Reasons for large residences in farming societies include space for storing grain or housing animals. These results suggest that making or storing metals is an alternative path to wealth (and wealth inequality), and one that relaxes the need for a large residence. Alternatively (or additionally) the results for iron and for wealth inequality specifically are anticipated by the theory that iron, being cheaper than bronze, makes it possible for the first time to arm large numbers of men in warfare. Since such large numbers cannot be drawn from a noble class, this gives (bargaining) power to lower social strata, eventually increasing their social standing and decreasing wealth inequality. This argument was advanced by Axel Kristinsson (2010) specifically for Europe, but in light of our results may apply somewhat more broadly.

Despite our admiration for V. Gordon Childe we must point out that portions of these analyses contradict views expressed in *Man Makes Himself* (1936/1951). Here Childe noted that bronze production demanded specialized skill and long-distance trade, given the highly localized raw materials on which it depends, and produced weapons and ornaments consumed by the wealthy. In his view then bronze metallurgy should increase wealth inequality. We find it to be associated with *low levels* of wealth inequality, though with high levels of wealth (at least considering these cross-sectionally and worldwide, see Fig. 2). These differing effects could be explained if bronze implements were more widely owned than anticipated by Childe. On the other hand, according to Childe, the abundance and broad distribution of iron ores made production monopolization unlikely, "cheapen[ing] implements and weapons" and "br[eaking] down the exclusive privileges of the warrior aristocracy" (Childe, 1936, p. 189). Here our results agree with Childe but go further; we find iron smelting associated with both low levels of wealth inequality (strongly) but also (weakly) associated with low levels of wealth. In *What Happened in History* (Childe, 1942), Childe suggested that over longer sweeps of history, iron technology was connected with the rise of empires and tributary systems, thus playing a role in *increasing* inequality; if so we do not see this effect in our data. We raise the possibility that the surprising connection of iron with low levels of wealth might be indirect evidence that reductions in the "after-tax wage" in the large polities made possible by iron and horses (Turchin, 2009) lowered labor supply via a substitution effect making non-work activities relatively cheaper (Stantcheva, 2016). As a possible countervailing force, Graeber (2011a) has argued that the rise of armies paid in coin helped transform more fluid and transient social inequalities into permanent class boundaries.

The strong connection between variability in levels of SA with variability in both wealth and wealth inequality—documented in Figure 2—reminds us that the urbanization and structural changes in employment invoked by Kuznets to explain the growth and increasing inequality in industrial societies were not in fact new processes, though they resembled processes experienced in antiquity about as much as a fire resembles the slow oxidation of an iron blade. Still, we must keep in mind that the curves graphed in Fig. 1 are highly smoothed and it is possible that some of the trends they pick out were much more rapid, even step-like, in the event.

2.2. *Economic inequality and economic growth at regional scales*

To further evaluate the Kuznets relationship—how growth and inequality are related over time—we need to reduce the scale of observation to regions whose size makes internal interactions plausible. Although this relationship is typically evaluated in contemporary societies using some measure of income inequality versus a measure of economic performance such as GDP per capita (e.g., Milanovic, 2016, fig. 2.18), the proxies available to us in archaeology are not precise analogues, and map better onto ideas of permanent income, as discussed above, or wealth, which is ironically more difficult to measure in a contemporary context where future income is unknown and where wealth may not accurately assessed.

In this paper we limit ourselves to describing levels, recognizing that a presentation in terms of first differences will be necessary to strengthen inferences of causal directions. In this section we first describe the growth—inequality relationship by region and phase for three regions for which our data are relatively complete, highlighting the diversity of regional dynamics in this relationship. (Lumping sites by regions and phases prior to computing Gini indices allows us to retain even those sites with fewer than 5 houses.) Reverting to the site database, we then analyze the economic growth—inequality relationship for two of those regions (those with the densest sampling) modeling Ginis as a function of time and wealth (productivity) using tensor-product models (Wood, 2017). This analysis highlights overall trends within regions. Because the spatial scope of analysis is smaller we can now keep track of time using the more straight-forward calendar years measure (negative years indicating BCE).

What sort of relationship between growth (or productivity) and inequality might we expect in the regional economic systems examined here? Branko Milanovic has found that in historical societies with a steadily rising income—such as the developed world has enjoyed since the early/mid 19th century—inequality will first increase, and then later decrease, as growth proceeds. The mechanisms for increase suggested by Milanovic follow closely those originally suggested by Kuznets: movement from lower-income, lower inequality rural areas to urban areas offering the possibility of higher income produced by jobs in the industrial sector. But since such employment is not universal in urban areas these destinations also experienced higher inequality. Eventually however (in the USA beginning around WWI) inequality began to decrease under pressure from 'processes like wars, social strife, and revolutions' brought on by the unsustainability of high inequality (Milanovic, 2016, p.98). Inequality ceased to decrease in these countries around the mid-1980s, when 'a second technological revolution' (still following Milanovic) driven by great improvements in information, communications, and transport technologies led to high-skill-biased wage differentiation and globalization. Milanovic suggests (not too convincingly given the self-perpetuating tendencies of autocracy: (Nord et al., 2025)) that political and economic forces will eventually cause this wave to peak, and more generally that countries with steadily rising

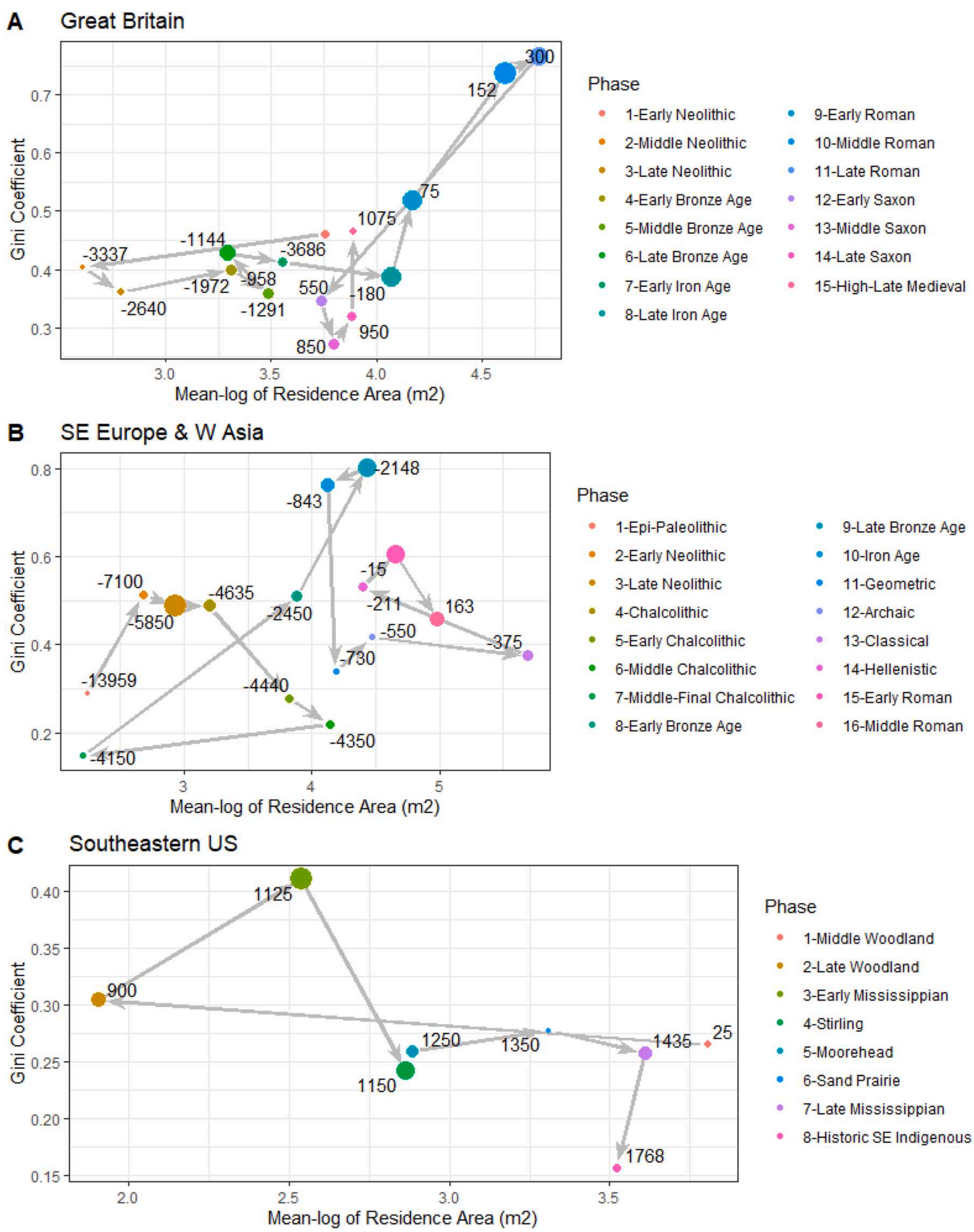

Fig. 3. Phase plots of productivity (mean of the log of house size, by archaeological phase) vs. economic inequality (Gini coefficient across all residences, by phase) for three world regions.

Note: Symbol sizes reflect relative sample sizes for phases within regions, labels represent the mean age (years CE) of sites assigned to that phase; phases are listed in chronological order in the legend and the sequence is marked using arrows in the plots. Source: authors' illustration based on data as described in Kohler et al. (2025a) with additions noted in text.

incomes will experience repetitive secular waves of inequality increase and then decrease.

But what is the expected pattern of the Kuznets relationship in a society with no or very slow increases in income? The tendency among economists has been to assume that such relationships will be random, or irregular, driven primarily by external events such as plagues or wars (see Milanovic, 2016, fig. 2.4). Yet Fig. 1 above suggests that in fact both economic inequality and average wealth were slowly rising throughout significant portions of the Holocene, although the pace of such increases when averaged over the time scale in Fig. 1 may seem insignificant to observers trained on the last two centuries.

In Fig. 3 we present the inequality vs. productivity relationship through time as phase plots for three well-sampled regions. The measure of productivity is the mean of the log of residence size across all residences assigned to a given region and phase; the measure of inequality is the Gini coefficient calculated across these same residences.. Symbol sizes are proportional to the log of sample size of residences for a phase within a region. The direction of time (in years CE) in these plots is indicated by arrows along each trajectory at their terminations, and labels represent the mean age of the settlements assigned to each region and phase.

These phase plots summarize a great deal of information in compact form; we nominate them as fundamental tools for comparison of archaeological societies and regions, like the plots of regional trajectories suggested by Peterson and Drennan (2011, fig. 6.14). They also allow us to pose and preliminarily answer questions such as, 'are increases in inequality more likely to spring from times of increasing wealth?' This would correspond to a counter-clockwise trajectory through the phase space. The plots do show that sometimes, but they also sometimes show the opposite. Perhaps one could label counter-clockwise trajectories as Kuznetian, and clockwise trajectories as anti-Kuznetian? More generally, counter-clockwise movement through phase space tends to suggest that changes in inequality are led by changes in production (at least within the limits of the phase-based chronology); clockwise movement suggests that changes in distribution (monitored by the Gini coefficients, dictated by political economy) lead changes in production or average wealth. This possibility constitutes an exciting step forward in the analysis of ancient economies.

In the sequence for Great Britain (Fig. 3A), for example, changes in inequality are mostly due to production changes through the Late Iron Age; after that changes in production seem to follow prior changes in social distribution of surpluses. The British sequence appears to have 3 regimes (or basins of attraction) in fact: a pre-Roman regime of generally improving production; a Roman regime characterized by a step change to high production and high inequality, and a Medieval regime, somewhat intermediate, but overall led by changes in political economy (distribution). In the SE Europe and W Asia diagram (Fig. 3B) by contrast changes in inequality early in the sequence are predominately anti-Kuznetian (led by changes in distribution) until late in the third millennium BC, after which the directions in the phase plot are mixed but feature a step increase in production following the 8th century BCE. This coincides with the widespread adoption of iron for tools (ploughshares, sickles, and mattocks) and weapons, the rise of territorial monarchies and imperial states, and mass-production of items such as storage jars and amphorae, signaling surplus management and long-distance trade in commodities such as olive oil and wine (Bevan, 2014; Graeber, 2014). In the spirit of this journal's title we suggest that movement from one regime (or basin of attraction) to another represents structural change whereas movement within a basin represents dynamics.

It is clear from these plots that regional trajectories can move in any direction over time, indicating that the relationship between changes in productivity and inequality at this level of spatial and temporal granularity is dynamic. There are several transitions in which the trajectory is down and to the right, indicating positive productivity growth combined with negative inequality growth. Notable examples include the Late Bronze Age through Late Iron Age in Britain; the Late Neolithic through Middle Chalcolithic and Archaic through Classical periods in SE Europe and West Asia; and the Early Mississippian through Stirling Phase in the Southeastern US. However, of the sequences described here only the Southeastern US (Fig. 3C) shows this pattern of change following a period of rising productivity and inequality, as the Kuznets relation would suggest, and there are other examples where episodes of increasing productivity and inequality are followed by strong declines in both, as in the transition from the Late Roman to Early Saxon phase in Great Britain. In short, these phase plots suggest that analyzing through-time changes in productivity and inequalityjointly is likely to yield greater insight than analyzing either in isolation from the other.

Many readers will be familiar with phase plots from their use in studying solutions to systems of differential equations or for characterizing simple dynamical systems such as predator-prey relations. They will note (by contrast) the absence of fixed points or limit cycles in Figure 3; instead the societies in these regions were usually exploring new portions of this phase space. These behaviors—the novel and contingent histories tracked by the productivity/inequality relationship—are typical of open, self-organizing systems of adaptive behavior. And yet these plots are not without some regularities. Accounting for these will likely require use of many local models that work for limited portions of the temporal or social spectra, and a plurality of paradigms (Krakauer, 2024). Such plots should be regarded as providing well-posed points of departure for explanatory journeys, not their destinations.

Turning from these temporally localized dynamics, we now investigate the overall patterns in the relationship between Ginis, wealth, and time in SW Asia/SE Europe, and in Britain, using general additive models (GAMs). Time is used here as an index for a smooth latent process that the model estimates; we don't assume a fixed functional form but allow time's effects to emerge flexibly. Results are reported in Fig. 4 and Table 1.

Beginning with the top left panel for SW Asia/SE Europe (Fig. 4A), the partial effect of wealth on inequality (i.e., the shape of the relationship holding other variables constant) becomes less positive (or more negative) as average wealth increases. Holding time constant, then, inequality declines with increasing wealth, suggesting that in contemporaneous time slices, wealthier sites tend to be more equal (or perhaps that equal societies generated more wealth). In either case, widespread access to productivity or collective institutions may be buffering inequality. To the right, the partially countervailing effect of time shows that inequality tends to increase from ~20,000 BCE to CE 1. The effect of time does not contribute positively to Gini values until around 5000 BCE. (In their analysis of much the same region, Bowles and Fochesato (2024) propose this date for the emergence of enduring economic inequality.) Below both panels is shown the surface describing the interaction between these main effects which is relatively smooth, monotonic, and without pronounced nonlinearities. In sum, the increase in inequality in this region suggests multiplicative reinforcement of wealth and time on inequality — not much curvature or complexity, likely reflecting a more coherent (continuous) institutional evolution compared with the next sequence.

In Britain (Fig. 4B) the U-shape (with its minimum at middle) of the partial effect of wealth on inequality shows that this effect depends heavily on levels of wealth. At low average wealth, increasing wealth slightly increases wealth inequality. At high average wealth, increasing wealth increases wealth inequality more strongly. At levels of wealth near the average in this sequence, increasing wealth has no effect on wealth inequality. The time main effect slopes upward, as for SW Asia/SE Europe, though with a slight downward deflection after its midpoint reflecting the influence of some late, low Medieval values. The surface describing the interaction between these main effects is complex, nonlinear, and curved, in marked contrast to that for SW Asia/SE Europe. A notable wedge emerges in the isopleth pattern coincident with the Roman invasion indicating a flattening of the modeled relationship between wealth and inequality. In this period increasing mean wealth

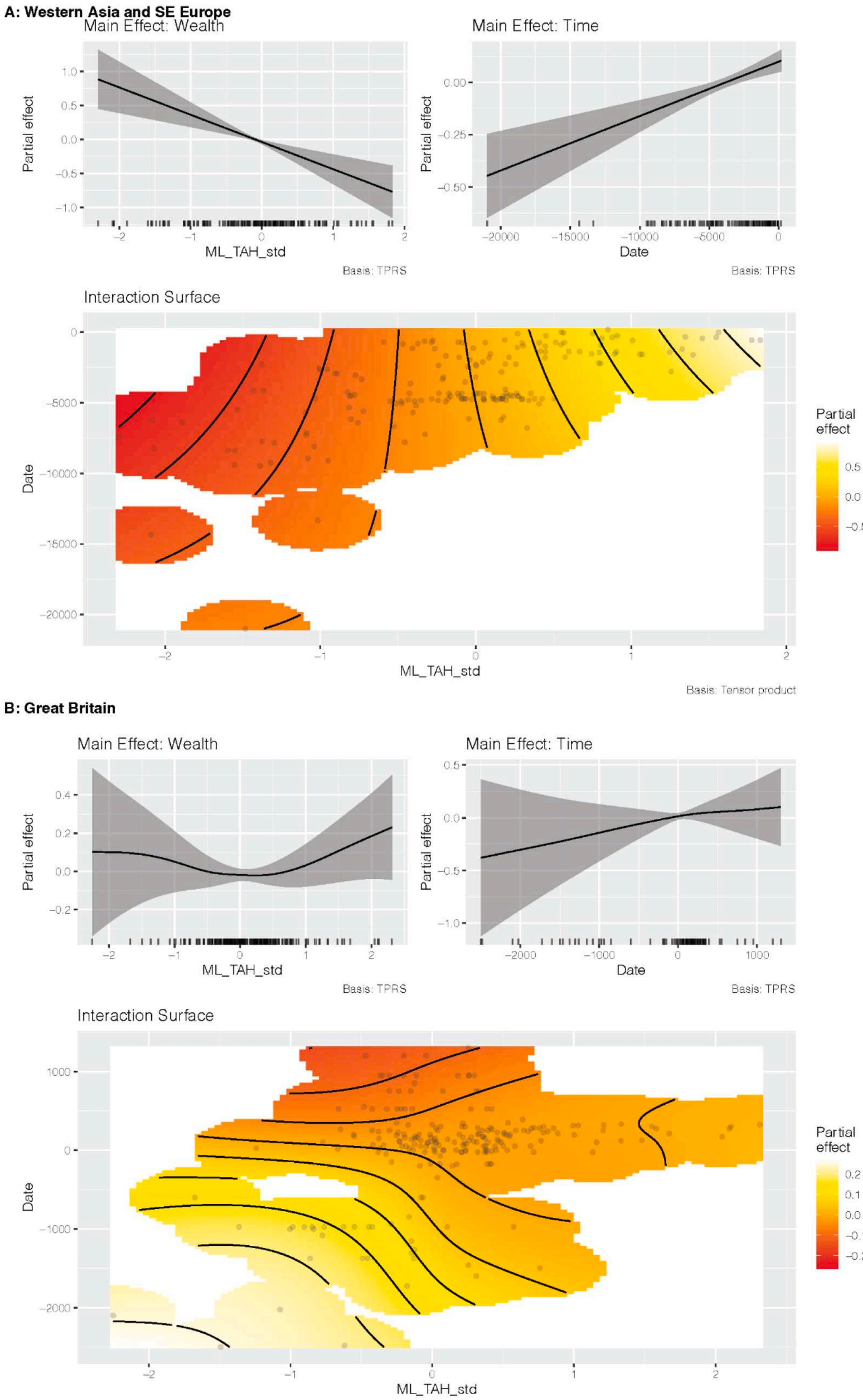

Fig. 4. Generalized Additive Model Results for the Relationship Between Wealth and Inequality with Time as a latent variable. A: Western Asia and Southeastern Europe; B: Great Britain. Each panel displays the estimated effects from a GAM modeling Gini coefficients (wealth inequality) as a function of standardized mean wealth (ML_TAH_std) and time (Date). The upper plots in each region show the main effects of wealth and time independently, with shaded 95 % confidence intervals. The lower plots present the tensor-product interaction surface, illustrating how the joint effects of wealth and time influence predicted inequality. Warm colors indicate higher predicted partial effects on inequality. Observed data points (sites) are overlaid. White areas indicate regions of low data density, where

extrapolation is not supported.
Source: authors' illustration based on data as described in Kohler et al. (2025a) with additions noted in text.

Table 1
Summary of GAM Results for Western Asia/SE Europe and Britain.

Region	Term	EDF[a]	Ref. DF[a]	F	p-value	Adj. R^2	Deviance Explained
A: Western Asia & SE Europe	s(ML_TAH_std)	1.03	1.06	15.97	0.0001	0.18	19.3 %
	s(Date)	1.00	1.00	19.49	0.0000		
	te(ML_TAH_std, Date)	1.00	1.00	17.77	0.0000		
B: Great Britain	s(ML_TAH_std)	3.23	4.08	1.59	0.1780	0.17	20.6 %
	s(Date)	2.38	2.90	1.21	0.3790		
	te(ML_TAH_std, Date)	3.10	4.05	0.51	0.6700		

[a]Estimated Degrees of Freedom: indicate the flexibility of each smooth term; values near 1 imply linearity; higher values indicate more complex nonlinear effects.
[a] Reference Degrees of Freedom: used to compute the F-statistics.

had a diminished marginal effect on inequality. The wedge appears to show a temporary decoupling of wealth and inequality: before CE 1 there's a stronger gradient — inequality varies more with wealth (see isopleth curvature). During the Roman domination and for some time afterwards that relationship flattens out — additional wealth measured at the level of the settlement doesn't lead to clear shifts in inequality. (We suggest that the extensive Roman economic network freed local elites from much dependence on the local economy.) Around CE 1000, the isopleths tighten again, especially at higher wealth levels — the stronger positive marginal effects of wealth on inequality resume. Of course the GAM does not "know" about the Roman imperial domination of this area from CE 43 to around CE 410 but presumably a variety of laws and taxation practices imposed by the empire preempted autochthonous patterns with significant ramifications for the relationship between wealth and wealth inequality; these likely worked in tandem with the extensive networks of the elite households mentioned above. In any case these effects do not disappear quickly following the withdrawal of the legions.

Each of these models explains about 20 % of the deviance in Gini in their regions; for SW Asia/SE Europe each of the model terms is significant and all are linear or near linear (Table 1). For Britain none of the individual terms is significant and all are non-linear.

In sum, we are in the early phases of discovering the most productive ways of analyzing the long sequences of wealth and wealth inequality generated by these new approaches to the archaeological record. The two approaches applied in this section yield somewhat different sorts of insights. Whereas both underscore the existence of both inter-regional and through-time variability in our data, the GAM reveals some underlying patterning among variables (such as the shared positive partial effect of time on inequality) despite the complicated internal dynamics regions display through time. We now sketch an analysis of what seems to happen when some of our regions become linked through historical processes such as trade.

2.3. Detecting kuznets 'Tides' in the relationship between economic growth and economic inequality

We now report the preliminary results from an analysis in which the GINI dataset allows us to compare trajectories of change in economic growth and economic inequality within areas where the archaeological record attests to the emergence of zones of interaction within or between regions. This project also entails interpolating changes in economic inequality to poorly sampled areas. Green et al. (2025) developed an inverse-distance-weighted interpolation which they applied to Britain between 1025 BCE and CE 1225, portions of Bronze Age Eurasia between 2625 BCE and 1125 BCE, and portions of the Maya area (Chase et al., 2023) between 125 BCE and CE 875. Each of these areas is marked by dense exchanges internally.

Initial findings include the fact that the relationship between inequality change and productivity change reverses after long periods of time in surprisingly regular ways. In the early phases of zonal interaction, productivity tends to rise while economic inequality drops, driven perhaps by an uptick in interaction among masses of everyday communities, such as when the earliest urban travelers forged networks of exchange in Bronze Age West Asia. However, as zonal interaction continues, and becomes increasingly geared toward extractive economic activities like imperial expansion, economic inequality rises and the relationship between economic growth and economic inequality reverses. After a phase of extraction, economic growth declines and economic inequality continues to rise, until eventually both decline together. Given the nature, scale and duration of these undulations in the relationship between economic growth and economic inequality, we call these 'Kuznets' Tides' (Green et al., 2025). As with the drivers of economic growth above, a wide range of variables likely shapes the relationship between these variables, and more data is needed to better reconstruct their shape, and new theories are needed to understand their drivers. However, just as economic growth often appears to be tied to Δyears across a range of different economic changes (Figs. 1 and 2), tides appear to begin with the introduction of weight metrology into different world systems. This pattern requires further investigation, but may be related to the fact people first began to make weights so they could quantify value and transfer it across cultural boundaries. They are, thus, a "metrological regime", which empowers new communities of long-distance merchants and, later, attracts state intervention. This cyclical power dynamic sees merchants gain wealth, states push back with new rules for quantification (e.g., by standardising weights or coinage).

3. Discussion and conclusions

Our goal in this paper has been to show that the book of prehistory need not be so closed as economists — with exceptions prominently including Bowles and Choi (2019), Dow and Reed (2023), Allen (2024), and Bowles and Fochesato (2024) — have tended to believe. Treating it as one-dimensional, dismissed with a Malthusian epithet, places most of human history beyond the reach of economic analysis. Here we show that reasonable, if tentative, estimates are possible for basic economic constructs such as economic inequality and economic growth through time. This extends the purview of economic history for thousands of years and makes possible examination of models, such as proposed by Kuznets (1955), over periods that not only pre-date the Industrial Revolution, but even the appearance of states and writing.

Any examination of the Kuznets (or other) model using the data presented here is nevertheless tentative and partial. We hope this example will provoke our colleagues to extend the dataset and help sharpen the concepts employed. It's hard though not to note that the world sequences in Fig. 1 trend upward, and the partial effects of time on wealth inequality in those regions analyzed with GAMs are strongly positive overall (Fig. 4), though subject to sharp reversals in particular times and places (Fig. 3). Despite great temporal and spatial heterogeneity, the world history of both wealth and wealth inequality contains a cumulative component over the long stretches of the Holocene examined here.

If we had the ability to plot regional sequences of both variables at high temporal and regional precision over the course of a couple centuries (as more data would allow) would these look like Kuznets 'waves' (Milanovic, 2016)? The fact that archaeological data, in principle at least, can generate many more examples of these than the one-and-a-half cycles available to traditional economic historians suggests that archaeology may be able to contribute to a more general explanation for the Kuznets relationship than those currently on offer. Perhaps such contributions might even have benign contemporary applications in helping promote growth without increasing economic inequality, extending the relevance of archaeology in new directions (Ortman, 2019) while reinforcing the utility of economic history.

Although plots such as Fig. 3 tersely speak volumes they present only the economic side of the social-evolutionary narrative. They reflect processes acted upon by, and in turn constraining or promoting, essentially all other aspects of human life. A broader and more satisfying view of life in these regions would need to consider physical health (Harper, 2021), life expectancy and population growth rates (Kohler and Reese, 2014), political organization, civil rights, and personal security (Ortman, 2016), institutional arrangements facilitating or impeding economic growth and economic inequality (North, 2010), growth of usable knowledge as well as technological progress (Mokyr, 2005), and climates facilitating or impeding production and commerce (Fagan, 2005). The research directions promoted here shed light on only a small part of the human story, but its centrality does not suit its neglect to date.

CRediT authorship contribution statement

Timothy A. Kohler: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Adam Green:** Writing – review & editing, Writing – original draft, Visualization, Software, Investigation, Formal analysis, Conceptualization. **Scott G. Ortman:** Writing – review & editing, Supervision, Software, Resources, Project administration, Funding acquisition, Data curation, Conceptualization.

Acknowledgements

We thank Ravi Kanbur, Andrew Sumner, and Sen Kunal for the invitation to present an earlier version of this paper at the UNU-WIDER/Cornell/Kings College London Symposium 'Kuznets at 70: Inequality and Structural Transformation', Helsinki; colleagues hearing a short version of these results at the WEHC in Lund, Sweden, at CSH in Vienna, Austria, and at SFI in Santa Fe, NM; our GINI Project colleagues on whose data we draw; the US National Science Foundation for support of the GINI Project (#2122123); two careful reviewers for this journal; and the Office of the Provost, Washington State University.

Data availability

We will deposit our data and code for analyses on article acceptance

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