

# A comparison of income inequality in the Roman and Chinese Han empires

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The emergence of vast territorial empires is a recurring development in the history of human civilization. Their ability to extract resources from their subjects, and to redistribute them, also increases the potential of higher levels of economic inequality. Here we explore how imperial structures contributed to set the level of inequality in two ancient empires, the Roman Empire ca. 165 CE and the Chinese Han Empire ca. 2 CE. We estimate the overall levels of imperial inequality as the combination of inequality between and within regions. We find that the Han Empire was, overall, more unequal and extractive than the Roman Empire. Other empires, however, were even more extractive, as shown by a comparison with the Aztec Empire ca. 1492. We argue that higher inequality increased the potential for political instability and the collapse of empires.

It is generally assumed that more complex human societies also tend to be more unequal<sup>1–3</sup>. The rise of early states, able to extract resources from their subjects and to redistribute them unevenly across the population, is a particularly important step<sup>4,5</sup>. At a later stage, the development of extensive empires substantially increased the potential for inequality as they could achieve a higher level of redistribution, involving a greater amount of resources across a much larger territory<sup>6</sup>. And yet, very few attempts have been made to estimate economic inequality across ancient empires, and those which exist have almost invariably focused on building simple overall imperial social tables. But imperial structures and policies potentially played a key role in setting overall inequality levels, interacting with, and contributing to generate, regional variation in levels of development across the constituent regions of any empire. While empires appear to intrinsically have a high potential for inequality, they were not all the same and sometimes they showed a tendency to evolve towards a greater balance in the distribution of political clout, fiscal extraction, and general levels of development between provinces. A comparison of empires observed in specific phases of their development allows to highlight distributional mechanisms of more general import.

Here we focus on the Chinese Han Empire ca. 2 CE and the Roman Empire ca. 165 CE. The fact that the appearance, the development, and the final collapse of these polities mostly overlapped in time has led to many attempts at comparative study<sup>7–10</sup>. We build upon this research by

exploring the Roman and Han socio-economic structures and the internal variation in economic development and income per capita across provinces or regions. We then estimate the overall levels of imperial inequality as the combination of inequality between and within regions. This approach allows us to account for some features of imperial polities which contributed crucially to determining overall inequality levels. We find that the Han Empire was, overall, more unequal than the Roman Empire but that inequality and inequality extraction ratios varied considerably across the territories that they ruled over. Other empires, however, can be presumed to have been even more unequal and extractive, as shown by a comparison with the Aztec Empire on the eve of the Spanish Conquest. In the case of the Aztecs, high levels of imperial extraction and a very uneven treatment of subject provinces appear to have led some territories to rebel and to ally themselves to the Spaniards<sup>11</sup>. We argue that high internal inequality might help to explain the crisis faced by the Han dynasty from the first decade of the Current Era and the low resilience to exogenous shocks characterizing China in that period. This finding also speaks to recent debates about inequality and political stability in both modern and premodern societies.

## Results and discussion

### Historical context

At the beginning of the Current Era the Eurasian landmass hosted two enormous empires, each controlling over four million square

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kilometres of land and ruling over 60–70 million people at their peak<sup>7</sup>. In the West, the Roman Empire covered much of Europe, of the Middle East and of North Africa enclosing entirely the Mediterranean Sea. In the East, the Han Empire occupied much of present-day China and other territories in Vietnam, Korea and elsewhere. These empires existed in mostly the same period: from the end of the third century BCE to the third century CE for the Han, and from the first century BCE to the fifth century CE for the Roman. Han history is usually divided into a Western Han (202 BCE – 9 CE; simply Han in the following) and a Eastern Han (25 CE – 220 CE) phase, separated by a dynastic crisis, civil war and partial state collapse. Chronology is only one reason why the Roman and the Han empires have frequently been the object of comparative studies. Another aspect that has elicited much attention is their final collapse (limited to the western part of the empire in the case of the Romans), which has been attributed to a variety of institutional, climatic, and epidemiological factors<sup>7,12–14</sup>.

Both the Roman and the Han empires had a very well-developed imperial administration, which is one reason why relatively good-quality historical information survived. They conducted regular censuses, including for the purpose of gathering information about the number of taxpayers and their fiscal capacity in the different areas that they ruled over<sup>15–17</sup>. Connected to this, both empires had relatively efficient fiscal systems. The Roman imperial fiscal system presented many features that can be considered fairly advanced compared with those typical of medieval Europe<sup>18</sup>, including the recourse to municipal officials for tax collection (instead of tax farming, which however never entirely disappeared), the achievement of a relatively high fiscal pressure which can be estimated at about 5–7% of the total imperial product<sup>19</sup> and the ability to obtain substantial fiscal redistribution across provinces. Many resources were funnelled towards the very centre of the empire, both to fund the central administration of the state and to pay for the privileges of the population of the city of Rome such as the regular distribution of free grain or bread to hundreds of thousands of entitled beneficiaries. However, the balance between the resources extracted from the provinces and those used locally varied considerably, for two reasons. First, because fiscal pressure was uneven depending both on the relative economic development of a province (so, on its actual fiscal capacity) and on when and how it had become part of the empire; for example, Italy enjoyed the privilege of being exempt from direct taxation on land. Second, because local expenditure was also uneven. As usual in preindustrial states, most public expenditure (about two-thirds) was absorbed by the military and consequently the overall provincial-level expenditure depended crucially on where the legions and other auxiliary bodies were stationed<sup>19,20</sup>. The military focus of public expenditure went hand in hand with the limited size of the bureaucracy<sup>21</sup>.

The Han fiscal system appears to have shared some features of the Roman one, beginning with its relatively advanced character, but was much more centralized. As in the Roman Empire, the capital region benefited from long-distance redistribution of grain<sup>22</sup> and the main taxes were that on land and the poll tax. Differently from the Romans, however, the Han enforced a uniform land tax rate across the Empire, which in the period considered here was set at one-thirtieth of the (presumed) yield. Overall fiscal pressure was comparable to the Roman as it has been estimated that land and poll taxes together might have absorbed about 10% of the (notional) yield of the average Han farming household<sup>23</sup>. There were also some elements of progressive taxation for part of the richest commoners, as for instance merchants were charged double the poll tax rate and fivefold the property tax rate of free peasants<sup>24,25</sup>. This, however, might have reflected more a general mistrust of merchants and of the urban population<sup>23,26–28</sup> than an attempt to contain inequality. While on the surface the Han fiscal system might appear to have been less inequality-promoting than the Roman, in practice their overall policies went in the opposite direction.

Roman imperial authorities allied themselves with, and co-opted into the administration, the provincial elites. The prosperity and the resilience to crises of communities rested primarily on the ability and willingness of local elites to contribute to the common welfare<sup>29</sup>. Instead, the Han tried to weaken local political and economic elites who might have challenged the power of the ruling dynasty. The main means to achieve this end was not fiscal but consisted in the forced resettlement of wealthy families from subject areas to the capital region of the empire; the Han resorted to this expedient at least six times (see Supplementary Methods, Section 2.4 for additional discussion)<sup>23,30</sup>. This practice probably helps to explain the much larger gap in income per capita between centre and periphery that we estimate for the Han compared to the Roman. Another relevant difference between the two empires is the lower military expenditure of the Han<sup>31</sup>, at least in the period that we focus on (circa 2 CE), long after the end of the phase of territorial expansion under Emperor Wu (141–87 BCE). Arguably, low military expenditure limited fiscal redistribution towards frontier provinces, to the advantage of the capital region. Low military expenditure allowed to pay for an exceptionally large bureaucracy. As high-ranking (and high-income) officials were mostly concentrated in the capital province of Sili, Han public expenditure for the administration of the state tended to exacerbate income differences across the empire much more than it happened in the Roman Empire with its small bureaucracy.

### Income levels across empires

Compared to other ancient empires, the Han and the Roman empires, also due to their relatively advanced administration, left us substantial historical documentation which has been extensively used to estimate total product, total population and income per capita at the imperial level. However, attempts to measure these variables at the provincial/regional level are rare for the Romans<sup>32</sup> and (to the best of our knowledge) non-existent for the Han. Here we accept estimates of imperial total product in line with the most recent literature and proceed to regionalize them by exploiting the best information available, as clarified in the Methods section and as detailed step-by-step in the Supplementary Methods. While the procedure differs in some respects for the two empires considered, mirroring differences in the evidence available, a key assumption that we make is that in a pre-industrial context, urbanization rates are positively correlated with levels of economic development, hence with income per capita. This assumption is in line with a sizeable literature<sup>33,34</sup>.

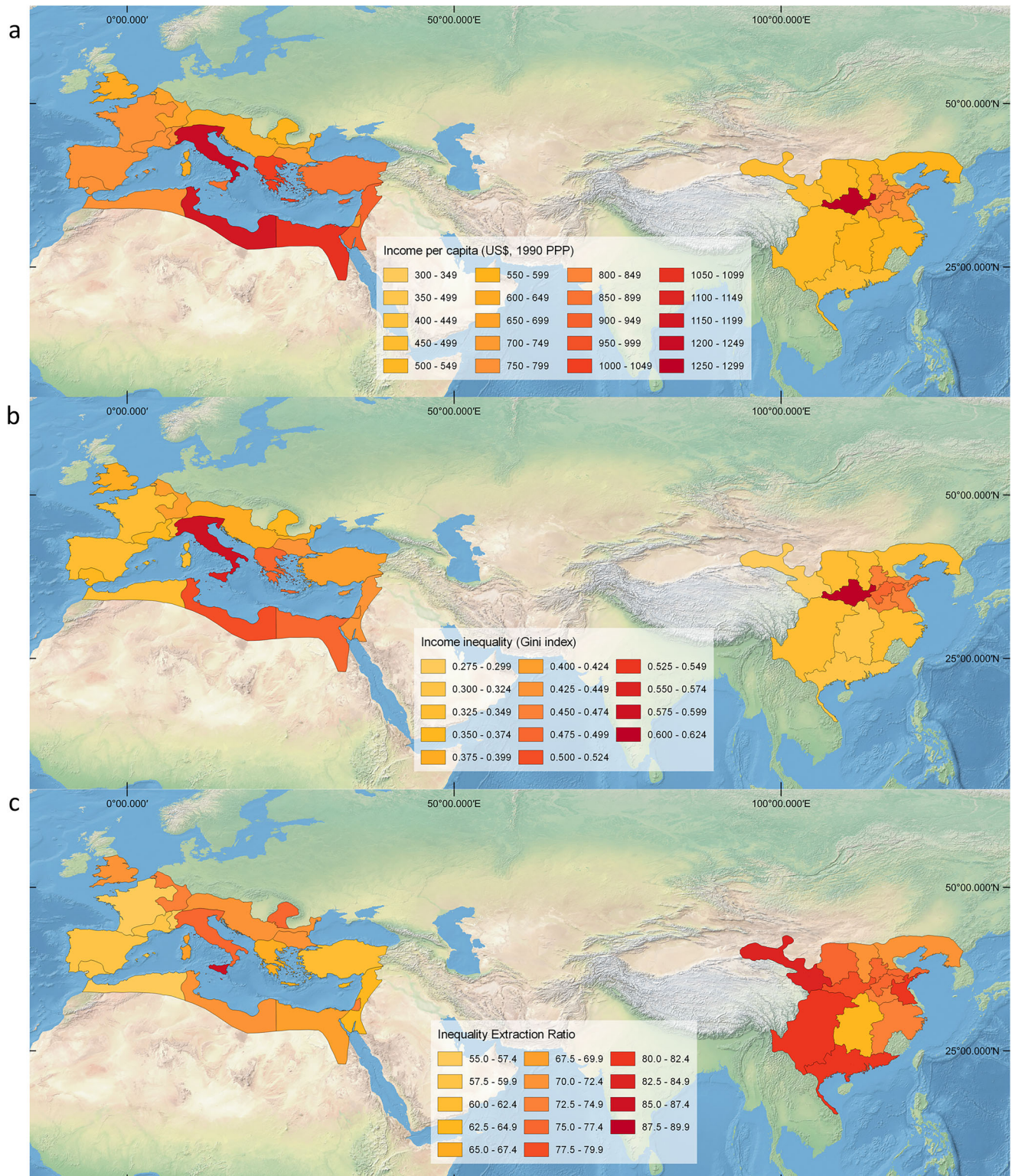
For the Roman Empire ca. 165 CE we accept an estimate of a total population of 75 million and of an imperial income per capita of kg750 of wheat equivalent, or 2.25 times the subsistence minimum of kg333 of wheat equivalent. This corresponds to a total economic product of 21.5 billion sesterces, which is a conservative estimate<sup>35,36</sup>. Note that the subsistence minimum that we use as a reference is above the physical subsistence minimum of kg250 of wheat equivalent and is meant to roughly correspond to the level of US\$400 (1990 Purchasing Power Parity, PPP) commonly taken as a reasonable social subsistence minimum, covering more than physiological needs<sup>2,11</sup>. The same rate of conversion implies an imperial income per capita of \$900.

For the Han Empire ca. 2 CE we accept an estimate of a total population of 57.7 million and of an imperial income per capita of 1.88 times the subsistence minimum, or \$750. This estimate matches one recently proposed for 100 BCE, when the Han Empire was closer to its peak<sup>37</sup> and might be considered slightly optimistic for year 2 CE (Supplementary Methods, Section 2.2). By assuming a conservative estimate for the income per capita in the Roman Empire and a possibly optimistic one for the Han Empire we are implicitly making more robust our conclusions regarding differences in income inequality and in inequality extraction ratios. Also note that the income levels of both the Roman and the Han empires were markedly above the 1.72 subsistence minima (\$690) recently estimated for the Aztec Empire

ca. 1492<sup>41</sup>. For the Byzantine Empire ca. 1000, an income level comparable to the Aztec has been proposed<sup>38</sup>.

While the Han empire-wide income level was lower than the Roman one, that for the central regions of both empires (Italy for Rome, Sili for the Han) was comparable: 3.1 subsistence minima in Italy, 3.2 in Sili. The Han central region was richer than the Roman central region both compared to the imperial average, and in absolute terms. However, in the Han Empire there were no other regions with an

income per capita nearly as high. The closest were some regions in the North China Plain with about 2 subsistence minima, 35–40% lower than Sili's. In contrast, in the Roman Empire three regions had an income per capita above 2.5 subsistence minima, not very far from that of peninsular Italy. This structural difference between the empires is clearly visible in Fig. 1a, and we argue that it is the long-run consequence of the different way in which imperial policies interacted with pre-existing differences in economic conditions. While the Roman



**Fig. 1 | Per-capita income and inequality in the Roman and Han Empires. a** Income per capita. **b** Income inequality (Gini index). **c** Inequality extraction.

Empire relied heavily on the support and cooperation of local elites and actively spread urbanism in the peripheries, the Han Empire was generally mistrustful of local, and especially of urban, elites. The recurring forced removal of the elites from the provinces to the central region can reasonably be expected to have stifled the economic development of the provinces, while at the same time boosting the wealth of Sili.

Another important difference concerns public expenditure. In the Roman Empire, it mostly comprised military expenditure. The deployment of legions and auxiliary bodies in frontier provinces led to a systematic and substantial redistribution from some of the rich internal regions to frontier ones which tended to be relatively poorer. Arguably, this reduced inequality between regions and contained excessive concentration of economic resources in the capital region. In the Han Empire military expenditure probably absorbed a much smaller share of public expenditure<sup>23,31</sup>: in the absence of external enemies much of the military force was conscribed when needed, so that the Han army was overall less professionalised, less well-paid and much less intensely deployed in frontier provinces compared to the Roman. A larger share of the budget was probably spent on local public expenditure in the Han empire compared to the Roman, especially if we account for the much more intensive recourse to conscripted labour services for infrastructure projects and similar<sup>31,39</sup>, but this was mostly funded by tax revenues collected locally among peasants<sup>23,25</sup>. Potentially more relevant for fiscal redistribution was the Han bureaucracy, which was larger than the Roman and presumably absorbed a larger share of the overall fiscal revenues<sup>25,31</sup>. However, the size of the Han bureaucracy was much smaller than that of the Roman army (some 130,000 officials compared to almost 400,000 soldiers) and high-ranking officials were disproportionately concentrated in the capital region (see Supplementary Methods, Section 2.5.1). Overall, these factors point to a stronger concentration of public expenditure in the central region in the Han Empire compared to the Roman.

Some clarifications are needed. First, our income estimates, like all those ever developed for preindustrial societies, must be understood as an approximation as producing them requires many assumptions (see Supplementary Methods, Section 2.3). However, they are informative of orders of magnitude and can be reasonably expected to properly reflect differences between empires as well as between regions of each empire. Note that per-capita income of regions relative one to the other, not the exact region-by-region income estimate, is the most important factor when measuring imperial inequality. Second, when comparing the Roman Empire to the Han Empire, we are in fact comparing their situation in two specific moments in time. For Rome, 165 CE (the early reign of Marcus Aurelius) can be considered to have been the peak of the empire. But Han China in 2 CE, while experiencing a demographic peak, was probably not experiencing its economic peak as well, although this is difficult to establish due to the scarcity of information (see discussion in Supplementary Methods, Section 2.2). At the same time, the forced relocations of the local elites all occurred before the mid-first century BCE, so we have no reason to think that the rather extreme differences in income levels between centre and peripheries that we report for 2 CE might have been lower 50 or 100 years earlier.

### Income inequality

Our estimates of per-capita income allow us to keep track of between-region inequality. To account for within-region inequality we developed a full set of regional social tables. For the Roman Empire we started from pre-existing attempts to produce simple, empire-wide social tables<sup>2,32,40</sup> and adapted them to properly reflect variation in provincial socio-economic structures. For the Han Empire we produced regional social tables by means of a novel approach which makes good use of the available information and maximizes comparability with the Roman Empire. For both empires, our social tables

reflect a highly hierarchical society. At the top we place the imperial household, followed by a set of elite categories. To exemplify, in the Roman empire two property-based social categories existed which also enjoyed political privileges, the senatorial and the equestrian order, to which a lower (in terms of per capita income and of social prestige) category can be added: the decuriones, members of the local town and city councils who constituted the bulk of the Roman social, economic and political elite. Other groups with elite-level incomes included wealthy freedmen who could not accede to the previous orders. In the Han Empire, even more clearly than in the Roman Empire, the richest families gained social recognition by achieving the highest-ranking posts in the bureaucracy, although officials were by no means the only members of the economic elite. In both empires, elite households were disproportionately concentrated in the capital city (Rome and Chang'an, respectively) and the surrounding capital regions (Italy and Sili), which is in keeping with the much higher per-capita incomes that we have estimated for such regions compared to all others.

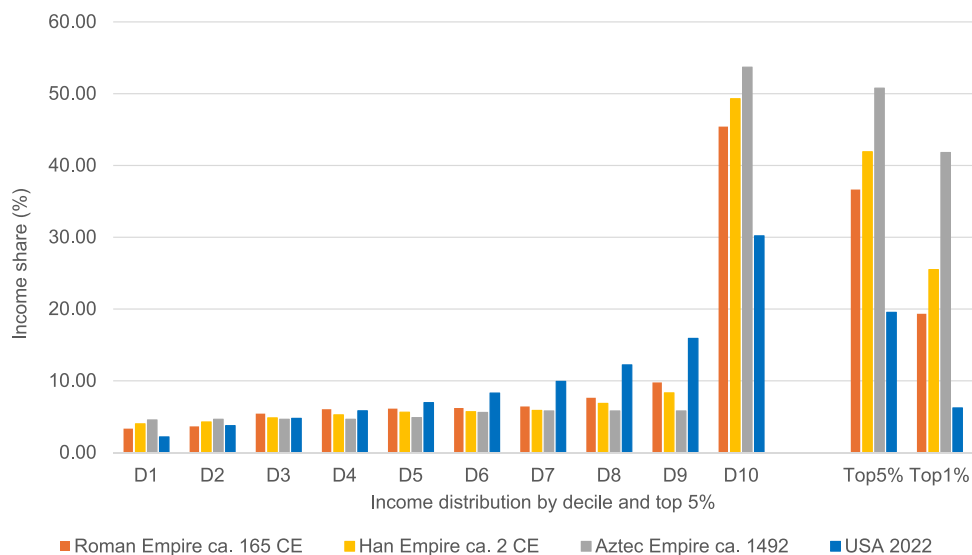
Below the elite we define various categories of middling-income households (many artisans and merchants, middling landowners, etc.) followed, for both empires, by two low-income categories which concentrated the bulk of the population and comprised most of the peasants. Finally, we define a category of very poor households surviving at a level of mere physical subsistence (conventionally placed at kg250 of wheat equivalent or \$300). While we do not single out a class of slaves, who in the Roman context could have very varying incomes, most slaves can reasonably be expected to have belonged to the two lowest categories. For the Roman Empire we also distinguish the households of legionaries and of members of auxiliary bodies who earned good incomes in-between those of the middling groups and of the commoners. We do not do this for the Han Empire in part because of the lack of information, and in part because by this omission we model the deeply different distributive impact that the army might be reasonably expected to have played in this empire compared to the Roman. The Supplementary Methods reports examples of our regional social tables for both empires (Supplementary Tables 8, 22). Imperial social tables can simply be obtained by merging the regional social tables. Table 1 reports the corresponding summary tables.

Our social tables allow us to immediately measure income inequality by means of the Gini index (Fig. 1b and Supplementary Tables 9, 23). For the Han Empire as a whole, we estimated that the richest 1% earned 26% of the total income, growing to 42% if the richest 5% is considered. At the other extreme of the distribution, the poorest 50% earned just 24%. The Roman Empire showed a somewhat less skewed distribution, with the top 1% and 5% earning 19% and 37% respectively, against the 25% of the bottom 50%. A third ancient empire, the Aztec, shows a markedly more uneven distribution than both the Roman and the Han, with a 42% income share for the top 1% and a 23% income share for the bottom 50%<sup>41</sup>. Figure 2 provides a visual comparison of the entire distributions. Of course, any kind of comparison between Eurasian empires, such as the Roman and the Han, and the Aztec empire, which developed in a much later period and in a deeply different natural, social and cultural environment, needs to be done conservatively. However, some general features of the income distributions of these three empires can be safely compared, particularly regarding the income earned by the bottom strata of society. This was very similar in the three empires, reflecting a situation in which a large part of the population survived at levels close to subsistence. More substantial differences are to be found in the income share of the richest. In particular, the much larger share of income that was seemingly earned by the top 1% in the Aztec empire (even allowing for a greater incertitude in the estimates compared to our Roman and Han cases, also due to a much more limited availability of usable written records) can be understood as reflecting the conditions of an empire in quick and violent expansion, extracting heavy tributes from recently

**Table 1 | Summary social table for the Roman Empire and the Han Empire**

Roman Empire				Han Empire			
Income category	Income per capita (in minimum subsistence) <sup>a</sup>	Population share (%)	Income share (%)	Income category	Income per capita (in minimum subsistence)*	Population share (%)	Income share (%)
Emperor	117,900.00	0.00	0.28	Emperor	159,932.23	0.00	0.65
Other wealthy 1	17,743.95	0.00	0.42	Elite 1	12,201.86	0.00	0.45
Senators 1	9825.00	0.00	0.23	Elite 2	4632.25	0.00	0.67
Senators 2	1965.00	0.00	0.42	Elite 3	1855.75	0.00	1.08
Senators 3	943.20	0.00	0.34	Elite 4	742.25	0.00	1.73
Senators 4	471.60	0.00	0.39	Elite 5	296.79	0.02	2.76
Equites 1	471.60	0.01	1.12	Elite 6	118.78	0.07	4.42
Equites 2	235.80	0.01	1.12	Elite 7	47.38	0.28	7.06
Equites 3	117.90	0.05	2.79	Elite 8	18.95	1.12	11.30
Equites 4	58.95	0.09	2.38				
Decuriones 1	58.95	0.01	0.28				
Other wealthy 2	60.46	0.01	0.29				
Decuriones 2	35.37	0.16	2.52				
Other wealthy 3	36.28	0.16	2.58				
Decuriones 3	17.69	0.52	4.11				
Other wealthy 4	18.14	0.52	4.21				
Middle 1	11.82	0.60	3.15	Middle 1	9.46	0.46	2.31
Middle 2	9.67	0.90	3.87	Middle 2	7.68	0.73	2.97
Middle 3	7.52	1.40	4.68	Middle 3	5.93	1.19	3.78
Middle 4	5.37	2.10	5.02	Middle 4	4.20	1.94	4.35
Middle 5	3.22	5.00	7.17	Middle 5	2.52	4.69	6.29
Legionary	2.36	0.84	0.88				
Auxiliary	2.33	1.19	1.23				
Bulk 1	1.88	13.39	11.18	Bulk 1	1.44	14.36	11.01
Bulk 2	1.34	57.03	34.03	Bulk 2	1.03	61.14	33.56
Physical subsistence	0.75	16.00	5.33	Physical subsistence	0.75	14.00	5.60
Total	2.25	100.00	100.00	Total	1.88	100.00	100.00

Notes: The table reports point estimates produced as the combination of region-level estimates, as per sheets Summarized Empire distribution in RomanEmpireReplicationFile.xlsx and Summarized Empire distribution in HanEmpireReplicationFile.xlsx. \*Incomes per capita are expressed as multiples of a subsistence minimum of kg333 of wheat equivalent or \$400 per capita. <sup>a</sup>Incomes per capita are expressed as multiples of a subsistence minimum of kg333 of wheat equivalent or \$400 per capita.



**Fig. 2 | Income distribution in the Roman Empire, the Han Empire and the Aztec Empire.** D1 = First decile (poorest 10%), D10 = Tenth decile (richest 10%).

conquered provinces, to the almost exclusive advantage of the ruling elites based in the original cities of the Triple Alliance<sup>11</sup>. To provide a modern term of comparison, Fig. 2 also reports the income distribution for today United States. The income share of the richest was much higher in ancient empires than in a modern democracy, even a relatively unequal one like the United States.

Overall, the Gini index of income inequality was 0.46 in the Roman Empire ca. 165 CE, 0.48 in the Han Empire ca. 2 CE and 0.50 in the Aztec Empire ca. 1492. These levels are all higher than those estimated for different medieval polities, including the Byzantine Empire with its estimated Gini of 0.41–0.43 around 1000 CE, but lower than those of the most economically advanced areas of Europe at the beginning of the early modern period (the northern Low Countries had a Gini of 0.50 ca. 1500 CE and the southern Low Countries one of 0.52 ca. 1550 CE)<sup>11,38,41,42</sup>. This comparison, however, could be misleading as early modern northern European societies were much richer than either the Roman or the Han Empire, let alone the Aztec. To assess this analytical issue, we employ inequality extraction ratios which measure how close a society is to the maximum inequality that it could theoretically experience without pushing all its members, except for a single super-rich individual or household, below subsistence<sup>2,42</sup>.

The inequality extraction ratio was 69% in the Roman Empire, 80% in the Han Empire and 89% in the Aztec Empire. Roman extraction was substantial, but not unusual and comparable to that achieved in rich European regions such as the northern Low Countries ca. 1500. The Han can be considered a highly extractive society while the Aztec was an exceptionally extractive one, although for some other polities even higher extraction ratios have been proposed, for example 113% for the Moghul Empire ca. 1750 CE<sup>2,11,42,43</sup>. Inequality extraction ratios well above 100% have been proposed also for sub-Saharan Africa during 1870–1929 and must be interpreted conservatively, as they would not be sustainable in the long run and could simply result from over-estimation of inequality and/or underestimation of income per capita. Interestingly, by the end of the twentieth century inequality extraction ratios in sub-Saharan Africa seem to have declined to levels in-between those reported above for the Han Empire and the Aztec Empire<sup>44</sup>. Note that our conclusions, and especially those regarding the characterization of the Han Empire ca. 2 CE as substantially more extractive than the Roman Empire ca. 165 CE, are robust even to substantial changes in the estimates of the imperial per-capita income levels, as shown by several robustness checks in the Supplementary Methods and by the probabilistic sensitivity analysis of the estimates introduced in the Methods section.

### Imperial extraction and political (in)stability

Higher inequality extraction ratios imply a social organization which, empire-wide, was strongly tweaked in favour of a small elite. This surely has to do with the tendency which (we argue) was typical of, but not necessarily limited to, ancient empires of actively promoting the concentration of resources in the central region which hosted the imperial seat. However, inequality extraction ratios could be high also in the peripheries (Fig. 1c). Indeed, in the Han Empire many peripheral regions suffered from an inequality extraction higher than the central region, due to relatively high local inequality and per capita incomes much lower than those of Sili. This suggests an important difference in the economic and political situation experienced by the Han and the Roman empires.

For the Aztec Empire ca. 1492, higher local levels of imperial extraction single out those provinces that opted for rebellion against the central power and to ally themselves with the Spaniards<sup>11</sup>. Along similar lines, high between-region inequality, which reflects at least in part the predatory attitude of imperial elites mostly residing in the capital regions, coupled with high regional inequality extraction ratios, which reflect the predatory attitude of local elites, might have fostered empire-wide social instability. This might have been the case for the

Han Empire as, shortly after the period that we focus on, it was disrupted by almost two decades of rebellion and civil war. A dynastic crisis culminated in the rise of Wang Mang, formerly the highest-ranking Han official and nephew of the empress dowager, to the position of emperor. Wang Mang established the short-lived Xin dynasty (9–23 CE) and launched a vast program of land reform aimed at reducing inequalities in land ownership. He also tried to introduce an income tax of 10% for skilled labourers and professionals. These and other social reforms attempted in this period match well our findings about the high levels of extractiveness characterizing much of China at the beginning of the Current Era – as does the fact that these reforms rapidly failed, largely due to the resistance of the great landowning families and of local officials kin to them<sup>26,27</sup>. This failure at social and economic reform probably helped to trigger peasant rebellions, most famously the Chimei (Red Eyebrows). While these rebellions are usually considered to have been caused by the inability of the central Xin government to react to a series of major famines and floods<sup>45</sup>, we argue that high inequality extraction had made some parts of China less resilient against crises. This is in line with a recent literature about catastrophes both in the past<sup>46–48</sup> and in today societies<sup>49,50</sup>. On the contrary, the Roman Empire ca. 165 CE was still benefiting from a long period of relative peace and stability (the *pax romana*) which, we argue, was also bolstered by relatively mild inequality between centre and periphery and by moderate levels of overall and local extractiveness.

### Final considerations: from ancient empires to modern democracies

Empires, being characterized by a strong political and socio-economic internal hierarchy with a dominant central region and subject territories with various juridical status, and by the presence of a specialized imperial ruling elite with an incentive to maximize its own benefit, intrinsically have a high potential for inequality. However, this potential differs depending on the overall context and it is not always fully exploited. Accordingly, our estimates suggest a substantial variation in the level of inequality and of inequality extraction across ancient empires. Such estimates characterize the Roman Empire ca. 165 CE as relatively egalitarian (by the standards of such premodern societies), the Han Empire ca. 2 CE as an intermediate case but on the high-extraction side and the Aztec Empire ca. 1492 as exceptionally unequal and extractive.

This graduation appears to empirically match a potential for political instability and social unrest growing with overall inequality levels. This finding places in a somewhat different light recent arguments about the inequality-reducing potential of state collapse<sup>5</sup>, as it might be that the sharp decline in inequality reported after the ultimate fall of both the Han and the (western) Roman empires (in 220 CE and 476 CE respectively) was also the consequence of the exceptionally high levels of inequality and/or of inequality extraction reached in the pre-fall period. This, both because high inequality can make state collapse more probable, and because inequality itself can fall by a larger margin when it starts at a higher level. While this remains a speculative argument, our study also speaks to the debate about the relationship between economic inequality and socio-political instability in modern societies. First, because it offers some historical support to the finding that there is a positive relationship between inequality levels and socio-political instability<sup>51,52</sup>, or even simply the individual preferences for revolt against the established order<sup>53,54</sup>. Second, because high between-region inequality in per capita income is not limited to ancient empires but is also found in some modern democracies. A well-known case is that of Britain, where the relative rise of the south-east around the city of London, together with deindustrialization and economic stagnation in northern England and in other areas, led to widespread resentment and contributed to determine a geography of discontent that corresponds closely to that of the vote in

favour of the Brexit in 2016: a political development which many have interpreted as being against London<sup>55</sup>. Recent research has shown that within-Britain divergence has ancient roots, dating from at least the late Middle Ages<sup>56,57</sup>. We argue, then, that the destabilizing effects of high territorial unbalances might also be of a kind that slowly accrues across the centuries (as might have been the case for the Han and the Roman empires) but ultimately favours sudden and unexpected developments, in the past as today.

## Methods

In the following we provide an overview of the procedure used to produce overall inequality estimates across the Roman and the Han empires, as the combination of inequality between provinces/regions and of inequality within each province/region. The Supplementary Methods file provides a more detailed, step-by-step discussion.

### Inequality between provinces or regions in the Roman Empire

Starting with the estimate of the average real income across the Roman Empire introduced in the main text and discussed further in Supplementary Methods, Section 1.2, we regionalize it based on the reasonable assumption that there exists a general positive relationship between levels of urbanization and average incomes, which we exploit while also accounting for the specificities of the capital region (Italy) and of different groups of provinces.

For Italy, we start with a recent assessment of the real income of the components of the Roman elite provided by Scheidel and Friesen<sup>40</sup>. Based on this estimate, across the Empire 290,600 elite households (1.55% of the total) captured about 23% of the total income (see Supplementary Table 1 for the breakdown by elite category). Based on the general information about the province of residence of members of the Roman elite, we assume that peninsular Italy captured the real income of the emperor, 75% of that of the senators, 50% of that of the equites, and 25% that of other components of the wealth elite. Following<sup>58</sup> we also assume that the real disposable incomes of elite households in peninsular Italy were 7% higher than those for the empire as a whole and those of non-elite households were 2.5% higher. Overall, we estimate that the real disposable income per capita in peninsular Italy was about 3.1 subsistence minima, or 1026 kg of wheat equivalents. Note that cereal equivalents are a unit of measure in which everything is expressed in terms of wheat or another relevant cereal (husked millet for the Han Empire), allowing for relatively easy cross-cultural comparison<sup>59</sup>. As detailed in the main text and in the Supplementary Methods, Sections 1.5 and 2.2, our subsistence minima are established based on cereal equivalents. Also note that the use of cereal equivalents as a starting point in our estimates allows to avoid the index number problem arising from the use of alternative approaches, and particularly that based on estimates expressed in PPP dollars. While in the main text we sometimes refer to \$PPP to connect to current debates in the literature, all comparisons of societies very distant in time based on this metric must be interpreted conservatively.

We adapt the population estimates for peninsular Italy and the provinces from ref. 60, as reported in Supplementary Table 3. After having subtracted the income of Italy from the overall imperial income, we divide the rest based on urbanization rates, also considering other relevant historical circumstances. For example, ca. 165 CE some regions were experiencing economic decline while their urbanization rates remained relatively high due to previous historical trajectories. This was the case of Sicily, which notwithstanding economic difficulties still had an urbanization rate over four times that of the wealthiest parts of Gallia and Hispania. Consequently, we proceed in two steps. First, we distinguish the majority of regions (group A) from the European frontier provinces and the economically backward or declining regions (group B), as per Supplementary Table 5. Importantly, group B accounts for only about 17% of the population residing

outside peninsular Italy, with an average (population-weighted) urbanization rate of about 13.3%, compared to about 17.6% in group A. Also note that for both groups urbanization rates are lower than the 17.9% characterizing the Empire as a whole (for towns with at least 5000 inhabitants). This is because they do not include peninsular Italy, where about 16% of the imperial population lived and which had an urbanization rate much higher than the imperial average. We use the ratio in the average urbanization rates of groups A and B to proxy the ratio in their real income per capita. We estimate the real income per capita in group A to be about 2.2 subsistence minima, compared to about 1.7 subsistence minima in group B.

As a second step, we estimate the average income on a region-by-region basis, unpacking the overall average for groups A and B introduced above. Regional incomes per capita are modelled differently between the two groups, but uniformly within the same group, according to the formulas detailed in the Supplementary Methods, Section 1.4. The results are also shown graphically in Fig. 1a.

### Inequality within regions in the Roman Empire

Our estimates of inequality within each region of the Roman Empire are obtained by developing a full set of detailed regional-level social tables. Social tables proxy the average income and the population share of relevant socio-economic categories. Consequently, they are commonly used to estimate levels of economic inequality in past societies, when more granular data about the individual- or household-level distribution are lacking<sup>2,11,40,43,61</sup>. An essential first step is establishing the physical subsistence minimum income, which is the level below which not even the poorest category could go for prolonged periods of time. We accept the estimate of 250 kg of wheat equivalent proposed by Hopkins<sup>62</sup> and Jongman<sup>63</sup> for the Roman Empire.

Income and prevalence of the poorest strata: to account for the presence of households in extreme economic distress, we assume that across the empire the poorest part of the population, that which lived at physical subsistence (250 kg of wheat equivalent), was 16% of the total: the mid-point of the 10%–22% range proposed by Scheidel and Friesen<sup>40</sup>. Based on ref. 64, we also assume that this category accounted for 25% of the population of cities with at least 5000 inhabitants, which implies that across the empire, 14% of the rural population earned a physical subsistence income. We then regionalize the estimate of the prevalence of the population at physical subsistence based on urbanization rates (Supplementary Table 6).

Income and prevalence of the elite: see above for the prevalence of elite categories in peninsular Italy. For the rest of the Empire, the prevalence of elite households and the presence of cities within a region were strongly connected, as those who sought to climb the social ladder, improving their formal rank or their actual social standing, would concentrate in the larger towns, where the institutional and socio-economic framework was more conducive to upward mobility compared to the countryside<sup>65</sup>. Consequently, we assume that in each region the share of the total elite households matched the share of the total urban population (both shares recalibrated by excluding peninsular Italy). To distribute the richest elite classes (senators, equites...) we use the urban threshold of 5000 inhabitants, while for the lower elite classes (decuriones, etc.) we consider the share of population residing in settlements with at least 1000 inhabitants. For the average real income of each category of the elite, which we adapt from<sup>40</sup>, see Supplementary Table 2.

Income and prevalence of military households: In the mid-second century CE, the imperial army consisted of approximately 380,000 men<sup>66</sup>. Of these, 157,200 made up the 30 legions that were active in 165 CE (5240 men per legion, excluding the officers), while the remaining 222,800 were enrolled in auxiliary regiments. The salary received by Roman soldiers under Marcus Aurelius is known. The legionary salary was 12 *aurei*, which can be converted to 3144 kg of wheat equivalent. The salary of auxiliary units was only slightly lower. We assign the

income of each legion and auxiliary regiment to the region in which it was stationed in 165 CE, as shown in Supplementary Table 6.

Income and prevalence of the middling strata and of residual categories: Roman middling strata, collectively defined as those below elite ranks but able to afford respectable consumption levels, included, in urban contexts, many merchants, traders, artisans and military veterans<sup>67</sup>, with wide-ranging incomes that could approach the lower elite levels<sup>64</sup>. We estimate that the prevalence of middling households in the whole empire was 10%, slightly above the mid-point of the 6 to 12% range envisioned by Scheidel and Friesen<sup>40</sup>. However, their prevalence was higher in urban centres, so we assume a share of 17% in urban centres with at least 5000 inhabitants, based on<sup>64</sup>. The implied prevalence for rural areas is about 8.5%. The overall prevalence of middling households in each region is determined by its urbanization rate. To account for stratification within middling households in the same region, we divide them further into five income categories, whose relative prevalence is established by assuming the same proportions introduced by Scheidel and Friesen<sup>40</sup> and shown in Supplementary Table 7. Right below the poorest of the middling strata, but above physical subsistence, we find the bulk of the population, which is not comprised in any of the previously defined categories. Region by region, the overall prevalence of these households is calculated as a residual, subtracting from the total population all other categories. We further stratify them in two categories, according to the proportions shown in Supplementary Table 7. Region by region, the collective income of the five middling categories and of the two residual categories is derived by subtracting from the total income that earned by the elite, by the military and by the poorest strata. This residual is then distributed across the middling and residual categories based on the proportions shown in Supplementary Table 7. The real income of the middling and residual categories does not have a predefined lower boundary, but in practice it always remains well above the physical subsistence minimum.

### Inequality between provinces or regions in the Han Empire

Starting with the estimate of the average imperial income introduced in the main text and discussed further in Supplementary Methods, Section 2.2, we regionalize it using a procedure analogous to that followed for the Roman Empire. However, for the Han Empire no data about provincial urbanization rates are available. Consequently, we focus on population density (based on information coming from the census of 2 CE), as it is generally accepted that in preindustrial times more densely populated areas tended to enjoy higher average incomes<sup>11,68–70</sup>. For Han China, a similar idea was also supported by historian Sima Qian (145 or 135–ca. 87 BCE), active during the reign of Emperor Wu<sup>71</sup>.

Analogously to what done for the Roman region of Italy, we account for the unique conditions characterizing the Han capital region of Sili by estimating its income separately from that of the provinces. This leads to a two-step procedure. First, we estimate the average income of the capital region and that of the rest of the empire; the income of the capital region is about 70% higher than the imperial average. Then, we distribute the income of the rest of the empire across the provinces. The exact estimation procedure and formulas are detailed in the Supplementary Methods, Section 2.3, and the results are shown in Supplementary Table 15 (and graphically in Fig. 1a).

### Estimation of elite incomes in the Han Empire

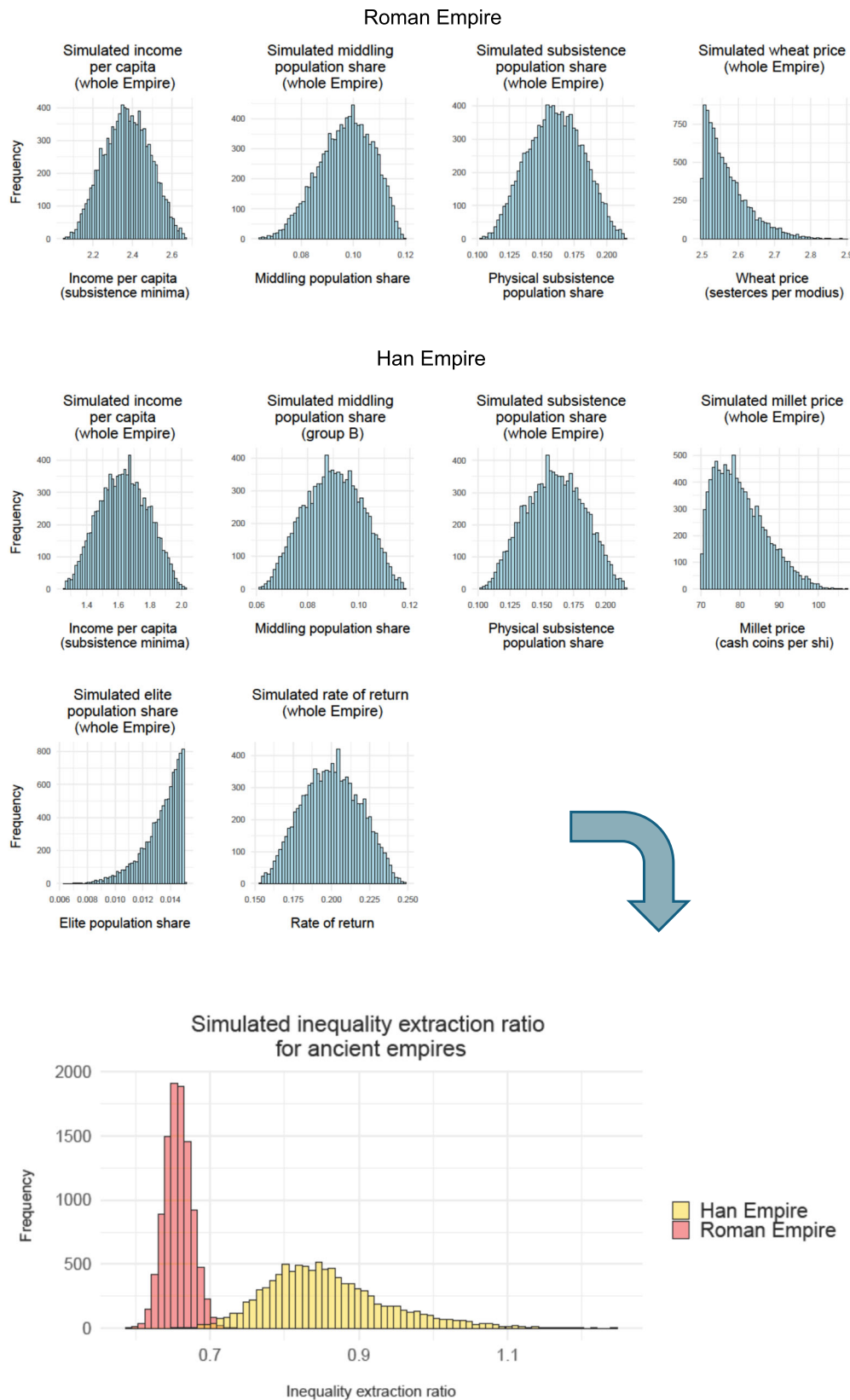
We assume that, across the Han Empire, elite households were 1.5% of the total (see Supplementary Methods, Section 2.4). As there are no previous estimates of the elite share of the total income, we produce our own based on a power-law distribution of wealth, following the same approach used by Scheidel and Friesen<sup>40</sup> to estimate the elite incomes in the Roman Empire that we rely upon. The use of power-law (or Pareto) distributions is commonplace in studies of the income or

wealth of the elite in both modern and preindustrial societies (for example<sup>37,61,72</sup>), and is grounded in substantial empirical evidence that elite income and wealth do tend to be distributed in such a way. To establish the parameters of our power-law distribution of wealth we begin by assuming 1 billion cash coins as the maximum level that could be achieved by households other than the emperor's. In Western Han times, historical sources estimate the largest fortunes in the hundreds of millions<sup>27</sup>, and we can reasonably assume that the emperor was the only billionaire. We also establish a minimum level of wealth necessary to belong to the Han elite, relying upon information concerning the forced relocations of the local elite that were repeatedly imposed by the Han imperial administration. While in 197 and 127 BCE the minimum wealth for being removed to the capital region was 3 million cash coins, in 73 and 65 BCE a lower threshold of 1 million cash coins was applied<sup>30,73</sup>. We take this lower threshold as the minimum wealth of the Han elite, also because it is the closest in time to the period that we consider (2 CE). Based on these parameters, we run different simulations applying a power law. We then select our preferred wealth distribution as the one which matches better the available historical information, as discussed in the Supplementary Methods, Section 2.4. Following<sup>40</sup>, the wealth distribution is transformed into an income distribution by applying a fixed rate of return to wealth; the results are shown in Supplementary Table 16.

### Inequality within regions in the Han Empire

We estimate inequality within each region of the Han Empire by building a set of regional-level social tables, following as closely as possible the methodology employed for the Roman Empire.

Income and prevalence of the elite: we allocate across regions the elite households (which include high-ranking officials) reported in Supplementary Table 16 based on differences in urbanism, employing a similar approach to that used for Rome. The literature on Chinese urbanization consistently qualifies settlements as urban if they exceed a conventional demographic threshold of 2000 inhabitants. For year 2 CE, Chao and Chen<sup>74</sup> estimate the urbanization rate at 18.7%. Unfortunately, no regional breakdown of this estimate is available. The Han Shu, Western Han's official dynastic history, reports the number of registered households in a selection of the largest cities of the empire, but the list is incomplete. However, the Han Shu also enumerates counties (*xiàn*). While their exact population is not reported and can only be estimated at the aggregate level, their spatial distribution conveys useful information. The Han Shu claims that the empire was divided into 1587 counties (including 241 marquisates)<sup>75</sup>. Counties usually consisted of a walled capital city surrounded by other villages and rural areas<sup>76,77</sup>. In the Han period, and up until the onset of industrialization in China, the local capital tended to be the county's largest settlement and economic centre, in addition to fulfilling administrative functions<sup>78</sup>. Yet the capital was not necessarily the county's only walled town<sup>75,79</sup>. We divide the provinces (*zhōu*) of the Han Empire into five groups (plus one composed only of the capital region of Sili) based on the information regarding the number of counties and that related to population density. Thereafter we assume that the prevalence of elite households differed across the 6 groups according to the proportions shown in Supplementary Table 19. However, based on the Han Shu and other sources, we know that the highest elite ranks were not distributed proportionally to the overall size of the provincial elite. The highest ranks of the bureaucracy entailed yearly salaries above 100,000 cash coins. Combined with additional revenues such as the returns from landed property or the gifts from the emperor<sup>73</sup>, such posts in the public administration likely allowed for incomes exceeding 200,000 cash coins – which is the lowest level in our elite income distribution. However, out of a total of about 130,000 public officials in the late Western Han period<sup>80</sup>, only a small minority held such high-ranking positions and mostly resided in the capital region (most public officials had low salaries and did not



**Fig. 3** | Probability distribution of the simulated inequality extraction ratios for the Roman and the Han empires.

belong to the economic elite). Due to the uneven distribution of the highest ranks of the bureaucracy across the provinces, we model separately the regional prevalence of the elite, and its composition by income classes, according to the procedure detailed in the Supplementary Methods, Section 2.5.1.

Income and prevalence of the poorest strata: to partly account for the presence of economically destitute households we assume that, in the capital region and in each province, 14% of the population survived at the level of physical subsistence (250 kg of husked millet equivalent: see Supplementary Methods, Section 2.2). Based on existing evidence,

we cannot confidently attempt to capture regional variation in the prevalence of the poorest strata, which is then kept constant across the Han Empire. Our estimate of 14% is conservatively set at a slightly lower level than the 16% assumed for the Roman Empire. Intuitively, if households living at the level of physical subsistence were at least as prevalent in Roman cities as in Han ones, and similarly prevalent in rural areas, the likely lower urbanization rate in the Han Empire would yield a lower proportion of such households compared to the Roman Empire.

Income and prevalence of the middling strata and of residual categories: sources from the Han period occasionally refer to middling families (*zhōngjiā*) and provide some indications about their incomes. However, the overall information coming from the surviving historical sources about the prevalence and the economic means of this group is contradictory and its interpretation is controversial<sup>22</sup>. Therefore, we follow a different path to consider the middling strata. As for the Roman Empire, we define middling households those right below the elite ranks, but still able to afford respectable consumption levels. We allow middling households to be richer in regions where the bulk of the population was richer, which reflects a relative (instead of absolute) concept of respectability. To estimate their regional distribution, we once again resort to regional variation in urbanism, as urbanization in Han times was positively linked with economic and social stratification<sup>81</sup>. Alongside middling farmers and officials, middling incomes were often achieved by those engaged in branch occupations (*mò yè*) such as craft and trade, despite their lower legal status compared to those engaged in root occupations (*běn yè*) such as farming and weaving<sup>22</sup>. In Han times, artisans still enjoyed a higher legal status compared to merchants, who faced sumptuary laws, legal prohibitions, and higher tax rates than other classes, but also benefited from the most profitable business<sup>73</sup>. Importantly, branch occupations flourished in urban centres. Consequently, we assume that middling households were more prevalent in more urbanized areas, and estimate their regional distribution based on the groups defined in Supplementary Table 18 and the proportions reported in Supplementary Table 20. This procedure leads to estimate that overall, middling households were about 9% of all households in the Han Empire. Middling households were more evenly distributed across the empire than elite households, as they were not targeted by the same resettlement policies. To account for stratification within middling households in the same region, we divide them further into five income categories, according to the procedure discussed in Supplementary Methods, Section 2.5.2. This procedure is analogous to that followed for the Roman Empire and the same is true for the two bulk categories which are placed immediately below the middling income levels, to account for the population which is not comprised in any of the previously defined categories. Region by region, the collective income of the five middling categories and of the two residual categories is derived by subtracting from the total income that earned by the elite and by the poorest strata. This residual is then distributed across the middling and residual categories based on the proportions shown in Supplementary Table 21.

### Managing uncertainty in the estimates of key parameters

As is inevitable in a study of inequality in an ancient empire, many of the parameters in our reconstruction are subject to a degree of uncertainty. To manage uncertainty, we proceed in three ways. First, our preferred point estimates of key parameters are conservative ones; see for example the discussion of our preferred estimates of income per capita in the main text. Second, in the Supplementary Methods we introduce and discuss several robustness checks which overall support our conclusions regarding the relative inequality levels and more importantly, the relative inequality extraction levels. Finally, we adopt a probabilistic approach<sup>82</sup>, allowing the estimates of several parameters to vary within a reasonable range which covers the various

estimates existing in the relevant literature. The procedure and the results are discussed in the Supplementary Methods, Section 3, and are also summarized graphically in Fig. 3. For both the Han and the Roman empires, the parameters that we allow to vary are the income per capita across the empire; the population share of the middling strata of society; the population share of the poorest stratum (those at physical subsistence); the price of the cereal of reference (wheat or millet). For the Han Empire, for which less information is available, we allow additional parameters to vary. As shown in Fig. 3, the distributions of the simulated Inequality Extraction Ratio (IER) for the two empires are substantially different, supporting our general interpretation and discussion (95% highest density intervals 62.2–69.4% for the Roman Empire and 70.9–100.0% for the Han Empire).

### Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

### Data availability

All data and replication files used in the analyses have been deposited in the OpenICPSR data repository<sup>83</sup> for purposes of reproducing or extending the analyses (<https://doi.org/10.3886/E220181V1>).

### Code availability

All code used in the analyses has been deposited in the OpenICPSR data repository<sup>83</sup> for purposes of reproducing or extending the analyses (<https://doi.org/10.3886/E220181V1>).

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### Author contributions

G.A., M.B. and W.S. contributed equally to the work and were involved in all tasks.

### Competing interests

The authors declare no competing interests.

### Additional information

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