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ORIGINAL PAPER

Ancestral ecological endowments and missing women

Gautam Hazarika[1] · Chandan Kumar Jha[2] · Sudipta Sarangi[3]

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Abstract

This paper examines the relationship between ecological endowments in antiquity and contemporary female to male sex ratios in the population. It is found that there are proportionately more missing women in countries whose ancestral ecological endowments were poorer. This relationship is shown to be strong even after ancestral plough use, the timing of the Neolithic Transition, and many other potentially confounding factors are controlled for. Similar results are also obtained using district-level data from India.

Keywords Gender inequality · Historical factors · Resource scarcity · Culture

JEL codes D1 · J1 · Z1

1 Introduction

This study infers that there was greater gender inequality in well-being in pre-history in regions less endowed with ecological resources and hypothesizes that the underlying

Responsible editor: Alessandro Cigno

✉ Gautam Hazarika
gautam.hazarika@utrgv.edu

Chandan Kumar Jha
jhack@lemoyne.edu

Sudipta Sarangi
ssarangi@vt.edu

[1] Department of Economics and Finance, The University of Texas Rio Grande Valley, One West University Blvd, Brownsville, TX 78520, USA

[2] Madden School of Business, Le Moyne College, Syracuse, NY 13214, USA

[3] Department of Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA

behaviours, relating to greater gender inequality in command of resources, have been culturally transmitted to the present as norms. First, it employs the deductive methods of archaeologists to infer that the division of resources between the sexes in pre-history was more unfavourable to women in regions less endowed with ecological resources. Second, it hypothesizes that this ancient gender inequality has been culturally transmitted to the present, so that there is more gender inequality in well-being in regions whose peoples' ancestors experienced greater resource stress. It tests this hypothesis to find that, current economic conditions held constant, there is indeed more gender inequality in well-being in countries whose ancestral ecological endowments were poorer and that this pattern also holds, sub-nationally, across the districts of India. Third, it explores plausible mechanisms of cultural transmission from past resource scarcity to present gender inequality.

There is growing interest in the origins and persistence of cultural factors in comparative economic development. For example, Galor and Ozak (2016) maintain that time preference, considered a cultural trait by social psychologists such as Hofstede (1991), has origins in the historical productivity of ancestral land; Alesina et al. (2013) hold that rates of women's participation in economic and public life are closely related to their agrarian ancestors' use of the plough; and Guiso et al. (2016) contend that there is a greater sense of self-empowerment in Italian cities that were self-governing in the Middle Ages. This study, of a connection between ancestral resource scarcity and cultural norms of gender inequality, aims to contribute to this literature.

Whereas the relation between household poverty and intra-household gender inequality in less developed countries has been well researched (Duflo 2012; Jayachandran 2015), the possibility of a connection between *ancestral* or *past* poverty and *present* gender inequality *in the aggregate* has not been entertained. Thus, this study potentially widens our understanding of the causes of gender inequality.

Two recent studies, by Alesina et al. (2013) and Hansen et al. (2015), investigate the role of historical factors in modern gender inequality. Both argue that conditions in the past influence gender inequality at present by having had an effect upon culture. The focus of both is gender difference in societal roles rather than in well-being. Both maintain that cultural norms prescribing a domestic role for women may be traced to an ancient gendered division of labour, whereby women made their contributions from home. Alesina et al. (2013) follow Boserup (1970) in arguing that the adoption of the plough by early agrarian societies was instrumental in this division of labour for at least three reasons. First, the use of the plough calls for more upper body strength than women typically possess, both because it is a heavy implement and since control of the large draft animals that draw it is strenuous. Second, since small children in the vicinity of its operation are endangered by it, and ploughing is not an activity conducive to frequent and unanticipated interruption, the plough may not be handled by persons whose other responsibility is childcare. Third, since the plough can sever the roots of weeds, its use may obviate the need for weeding, a task that mostly fell to women and children. That the adoption of the plough was a factor in the evolution of cultural norms prescribing domesticity in women is supported by the authors' finding that female labour force participation at present, female ownership of businesses and female representation in parliament is lower in countries in which a larger proportion of the

population traces its ancestry to ethnic groups who employed the plough.[1] In contrast, Hansen et al. (2015) hold that a gendered division of labour, by which women were turned to the domestic sphere, was a product of agriculture itself, whether by, or without, the means of the plough.[2] They argue that even agriculture unaided by the plough placed a premium upon male brawn. They note, for example, that Chinese grave goods from an era preceding the adoption of the plough are yet indicative of a gendered division of labour and that it is already observable in the branch of the Kalahari's !Kung tribe recently settled to primitive agriculture absent the plough. The authors observe that women's contribution to the caloric intake of their communities is generally very high in modern hunter–gatherer societies, whereas agriculture, particularly the cultivation of cereals, concentrates food production in the hands of men, with women playing a greater role in the home-bound processing of crops. It is not surprising, therefore, that women in the !Kung tribe's branch that continues hunting and gathering enjoy more autonomy and wield greater influence than their agrarian sisters. That patriarchal cultural norms may be traced to man's transformation from hunter–gatherer to farmer is supported by the authors' finding that gender roles are more unequal in countries with longer histories of agriculture.

This study is different from the others, hence capable of contributing to this literature, in the following ways. Whereas the focus of Alesina et al. (2013) and Hansen et al. (2015) is modern gender inequality in societal roles, this study's concern is modern gender inequality in well-being. Second, to the ancestral adoption of the plough and the duration of experience of agriculture, it adds ancestral ecological resource scarcity as a factor in modern gender inequality.

The remainder of the paper is organized as follows. Section 2 motivates the study's thesis of a connection between ancestral resource scarcity and modern gender inequality in well-being. Section 3 describes the empirical strategy and data utilized in the analyses and presents the ensuing empirical results. Section 4 explores plausible mechanisms of a connection between ancestral resource stress and modern gender inequality in well-being. Section 5 concludes the study.

2 From past resource scarcity to present gender inequality

Hayden (1992) discusses archaeology's approaches to deducing gender inequality in pre-history. These are as follows: comparative ethnography, skeletal and mortuary studies, the study of early texts, the study of art and mythology, physiological studies and comparative zoology. Of these, at least three, namely, comparative ethnography, skeletal and mortuary studies and comparative zoology, yield a form of circumstantial evidence of a connection between resource scarcity and gender inequality in pre-history.

2.1 Comparative ethnography

Archaeologists use comparative ethnographical studies of gender relations in contemporary hunter–gatherer and horticultural societies to make inferences about gender

[1] Relatedly, Grogan (2018) finds that a preference for sons is more pronounced among ethnicities likelier to employ the plough.
[2] Engels (1902) too made just such an argument.

inequality in pre-history. It is notable, then, that a study of 33 modern hunter–gatherer societies by Hayden et al. (1986) finds that the lack of subsistence resources is liable to diminish women's status in the domestic and political spheres.[3] Further, in many less developed countries in which large sections of the population continue to subsist upon agriculture in a manner little changed since antiquity, resources to girls and women are disproportionately curtailed in times of want. For example, Behrman (1988) learns that rural Indian households' favouring of boys in the allocation of nutrition is greatest during the lean agricultural season, Alderman and Gertler (1997) find that rural Pakistani households' demand for the health care of unwell children is more income elastic in the instance of ill girls, and Rose (1999) discovers that the adverse effect of a deficit of rainfall upon children's survival to school age in rural India is more acute in the case of girls.

2.2 Skeletal and mortuary studies

Skeletal and mortuary studies can uncover pre-historic gender differences in nutrition, diets, longevity and physical stress. It is notable that anthropologists have exhumed evidence of differential effects of changes in the resource environment upon men's and women's nutrition in pre-history. Human skeletal remains indicate that pre-historic human sexual dimorphism of height in parts of the world increased during periods of declining nutrition, that is, women became shorter relative to men when average human height fell, whereas this gap decreased during periods of improved nutrition (Cohen and Bennett 1993). Geary (2015) has argued that height in human males may be a sex-selected trait, that is, one involved in competition for mates or mate choice. Such traits, such as the bright plumage of certain male birds, are exaggerated since their purpose is the signalling of health, fitness and genetic endowment. It follows that when health and fitness are compromised by an adverse environment, sex-selected traits sharply advertise this decline. Hence, human male height may be more sensitive to environmental conditions than female height. It follows that a widening gap between the two during periods of resource stress may have been at the hand of man.[4]

2.3 Comparative zoology

Comparative zoology considers the gender behaviour of other primate species, particularly those genetically most similar to humans, and extrapolates from this to human gender relations in pre-history. The two non-human primate species genetically most similar to humans are the chimpanzee (*Pan troglodytes*) and the bonobo (*Pan paniscus*). Chimpanzee society is characterized by severe gender inequality. Female

[3] By these authors, hunter–gatherers suffering resource stress are under pressure to control their numbers, and fertility control is facilitated by the subjugation of women of child-bearing age. This conclusion is borne out in the authors' observation that strictures upon women are significantly loosened upon their reaching menopause.

[4] Since infant mortality is higher in boys than girls, perhaps an adverse environment led to selection, whereby surviving male infants were more robust than average, growing up to be taller than average, and this, not human intervention, led to a widening of the average height difference between the genders. However, since male growth processes are more sensitive to environmental conditions, selection from the greater mortality of boys under adverse conditions may not in itself have led to rise in average adult male height if these conditions persisted to adulthood.

chimpanzees are almost always dominated by males and there is much male violence against them. Gender relations in bonobo society are markedly different. Female bonobos dominate males and there is no significant male violence against them. This striking difference between these similar species of ape has been attributed to the following twin factors. First, unlike female chimpanzees, bonobo females tend to band together into powerful coalitions capable of thwarting males. Second, unlike male chimpanzees, bonobo males tend not to form strong coalitions with other males. Some primatologists (e.g. Wrangham 1986) argue that the historical resource environments of these species lie behind these factors. Wild bonobos are only to be found in a resource abundant region south of the Congo River in the Democratic Republic of the Congo, and it is likely that this is where they evolved. On the other hand, the common chimpanzee is indigenous to regions less endowed with food resources, in which the gorilla, a competitor, too resides. Hence, female chimpanzees, fearing competition for limited food, prefer to forage alone, and this solitude is an impediment to their forging close bonds with other females. Male chimpanzees, in contrast, commonly ally with some males against other males to better vie for control over limited food resources. A mix of coalitions of males and relatively solitary females makes for unequal gender relations. In contrast, since theirs is a resource abundant environment, bonobo females are not averse to feeding together, and this affords them opportunities to forge alliances, whereas bonobo males have less incentive to form strategic coalitions to control resources since these are abundant.

In sum, archaeology's methods of comparative ethnography, skeletal and mortuary studies, and comparative zoology suggest that there was greater gender inequality in well-being in antiquity in regions less endowed with ecological resources. Next, it is hypothesized that this gender inequality has been culturally transmitted to the present by the handing down of resource-driven norms. This reasoning is no different from Boserup's (1970). Boserup's observations of rural life in the developing world led her to note that regions home to plough agriculture show a predominantly male family labour force, because a large proportion of women in the cultivator families are completely exempted from work in the fields. The land is prepared for sowing by men using draught animals, and this thorough land preparation leaves little need for weeding the crop, which is usually the women's task. Therefore, women contribute mainly to harvest work and to the care of domestic animals. Because village women work less in agriculture, a considerable proportion of them are completely freed from farm work. Sometimes, such women perform only domestic duties, living in seclusion within their own homes and appearing in the village street only under the protection of the veil, a phenomenon associated with plough culture, and seemingly unknown in regions of shifting cultivation where women do most of the agricultural toil (Boserup 1970, pp. 13–14). She inferred that this was true as well in antiquity and that the domestic role of women in societies employing the plough eventually led to cultural beliefs that women's proper place was the home. Thus, of Hayden's (1992) six archaeological methods of deducing gender relations in pre-history, Boserup utilized the one method of comparative ethnography, and she held that the ancient modes of behaviour arising from the use of the plough gradually became enshrined in culture. By comparison, this study employs three of Hayden's methods, comparative ethnography, skeletal and mortuary studies and comparative zoology, to infer that there was more gender inequality in well-being in antiquity in regions with poorer ecological

endowments, and it too hypothesizes that the associated behaviours have been culturally transmitted to the present.

3 Empirical strategy, data and findings

3.1 Cross-country

The cross-country empirical analyses rely on regression equations whose dependent variable measures present gender inequality in well-being nationally and primary independent variable gauges nations' ancestral ecological endowments. While there exist various measures of national gender inequality, this study utilizes the female to male sex ratio in the population since it is widely accepted as a key gauge of gender inequality in well-being and is easily computable at the sub-national level. As regards ancestral ecological endowments, these are taken to be agricultural resources since the Neolithic Revolution, man's transformation from hunter–gatherer to settled agriculturist, was, with rare exception, universal and ancient. These resources are measured in terms of the agricultural outputs they were capable of supporting as gauged by historical potential caloric yields per hectare. Extensive empirical analyses uncover a positive relation, across countries and sub-nationally, between current female to male sex ratios and ancestral potential caloric yields.

3.1.1 Measuring gender inequality

The female to male sex ratio, defined as the number of females per 1000 males in the population, has been widely considered a key indicator of gender inequality in well-being at least since Sen (1990) famously wrote of the demographic deficit of more than a hundred million women worldwide. Sen concluded that 'these numbers tell us, quietly, a terrible story of inequality and neglect leading to the excess mortality of females' (Sen 1990). Indeed, skewed sex ratios have been found to be due largely to excess female mortality caused by gender inequality in the intra-household allocation of resources, of health care in particular, though sex-selective abortions are to blame as well in some countries (e.g. Klasen and Wink 2003).[5] The female to male sex ratio is an attractive measure of gender inequality in well-being for a second reason. Economic anthropological studies now routinely supplement their cross-country analyses with sub-national ones. That a trend holds across countries is not enough; it must be shown to hold sub-nationally as well. Whereas alternative metrics of gender inequality in well-being, such as the life expectancy sex ratio, are typically reported only at the national level, census data with which to calculate the female to male sex ratio at the sub-national level are largely on hand.

[5] Given our hypothesis that ancestral resource scarcity led to cultural norms of gender inequality in command of resources, the female to male sex ratio in the population better suits our purpose than children's sex-ratios because skewedness in the former has been a consequence primarily of lifetime deprivation, whereas recent skewedness in the latter, at least in the Asian nations in which it is most pronounced, is driven by sex-selective abortion. Further, Andersen and Ray (2010) note that even in China, a significant proportion of missing females are adults, and that adults constitute the majority of missing females in India.

There is one concern, however. Since a number of nations, mainly in the Middle East, attract large numbers of male migrant workers, their female to male sex ratios are depressed below native levels. This is addressed as follows. First, national male and female populations at mid-year are obtained from the United Nations Population Division. Next, the numbers of male and female immigrants at mid-year in each country and the analogous numbers of male and female emigrants are calculated from data on male and female migrants by origin and destination supplied by the United Nations Population Division. Finally, a nation's 'true' female (male) population is calculated as the national female (male) population is less than the number of female (male) immigrants plus the number of female (male) emigrants. These true populations are, then, used to calculate nations' native female to male sex ratios. Unsurprisingly, the native female to male sex ratio is found to be significantly correlated with other measures of gender inequality such as the life expectancy sex ratio and the United Nations Development Program's (UNDP) Gender Inequality Index and Gender Development Index.

3.1.2 Measuring ancestral ecological endowments

A measure of ancestral ecological endowment may be constructed from data supplied by the Global Ecological Zones (GAEZ) project of the United Nations Food and Agricultural Organization (FAO). The GAEZ project reports agro-climatic potential crop yield data for 5 arc-minute by 5 arc-minute (about 10 km by 10 km) grid cells. These potential yields, kilograms per hectare, are based solely upon temperature, radiation and moisture, that is, the climate alone. While there has been soil degradation since ancient times, often at the hand of man, the world's climate has been fairly stable for at least the past one to two millennia (Jones and Mann 2004). This permits extrapolation of these potential crop yield data to the past. Further, the data are differentiated according to whether crops are rain-fed or irrigated, and whether the level of inputs is low, medium or high. In order to better extrapolate to the past, when agricultural technology was primitive, this study shall consider potential crop yields based only on rain-fed and low-input conditions. Next, crops shall be limited to those grown prior to 1500 AD, since the agricultural landscape was greatly altered by the Columbian Exchange of crops between the New and Old Worlds. Indeed, Galor and Ozak (2016) adopt just such a strategy to calculate the maximum annual potential caloric output per hectare by grid cell.[6] The authors then aggregate grid cells to the level of modern nations to compute national pre-1500 AD average annual potential caloric yields per hectare under rain-fed and low-input conditions. Before these historical caloric yields are taken to measure ancestral ecological endowments, a difficulty must be surmounted. Its historical caloric yields may not accurately measure a nation's *ancestral* ecological endowment since large numbers of its citizens, particularly if it is a New World nation, may trace their ancestry to other nations. This difficulty may be addressed by the calculation of a nation's ancestral ecological endowment as the weighted sum of the historical caloric yields of all the nations to which its citizens

[6] Conversion from crop to caloric yield utilizes the US Department of Agriculture's Nutrient Database for Standard Reference.

can trace their ancestry, the weights being the elements of Putterman and Weil's (2010) migration matrix.[7]

In sum, nations' average annual caloric yields per hectare based on the agro-climatic yields of pre-Columbian crops under rain-fed and low-input conditions, migration-weighted, are taken to measure ancestral ecological endowments. Since the analyses shall control for regions' current resource environments as described by, for example, national per capita income, the effects of migration-weighted pre-1500 AD agro-ecology may all the more plausibly be attributed to the past.

What of the Malthusian argument that there was ultimately no spatial variation in resource scarcity on account of more rapid population growth in better endowed regions? After all, scarcity is really a matter of per capita resource endowment. However, could it not be argued that humans in poorly endowed regions lived at subsistence levels for longer than humans in better endowed regions, the driving down to subsistence levels being a gradual process? Therefore, might not cultures in poorly endowed regions be more marked by resource scarcity? In sum, if the ancient world was ultimately in Malthusian equilibrium, then the above measure of ancestral ecological resource endowment may be interpreted as a proxy of the length of exposure to culture-forming scarcity.

3.1.3 Empirical specification

The regression equation,

$$\text{current female to male sex ratio}_{i,} = a_1 + a_2\ (\text{ancestral ecological endowment}_i) + \boldsymbol{X_i}'\ \boldsymbol{a_3} + e_i, \quad (1)$$

is estimated, wherein the subscript i alludes to country i, the dependent variable is the female to male sex ratio in 2013 adjusted for immigration and emigration, country i's ancestral ecological endowment is measured by its migration-weighted annual caloric yield per hectare of pre-Columbian crops under rain-fed and low-input conditions, the regressors $\boldsymbol{X_i}$ consist of a variety of controls and e_i represents the regression error.

3.1.4 Estimates

Table 1 reports the means and standard deviations of the variables employed in the cross-country analyses. The female to male sex ratio in 2013 adjusted for immigration and emigration has a mean value of 1022.99 females per 1000 males, which is approximately that in the East African nation of Burundi. The lowest and highest female to male sex ratios in the sample of 130 nations upon which Eq. (1) is estimated pertain, respectively, to Jordan and Romania. Figure 1 presents a world choropleth map of female to male sex ratios in 2013. Relatedly, Fig. 2 presents an analogous map of the distribution of the key regressor, ancestral potential caloric yields per hectare in millions of kilocalories.

[7] The element (i,j) of this matrix is the fraction of country i's population in the year 2000 whose ancestors were living in country j in 1500.

Table 1 Summary statistics: cross-country analyses

Variable	Source	Mean	SE
Dependent variables			
Female to male sex ratio (females per 1000 males) in 2013 corrected for migration	UN Population Division (adapted)	1022.992	4.475
Ratio of female-to-male life expectancy at birth	The World Bank (adapted)	1.072	0.039
UNDP Gender Development Index ($N = 118$)	UN Development Programme	0.931	0.073
UNDP Gender Inequality Index ($N = 123$)	UN Development Programme	0.375	0.197
Female labour force participation rate in 2013 ages 15+ years	The World Bank	54.691	1.331
Key regressor (measure of historical scarcity)			
Average potential millions of kilocalories/hectare/year based on pre-Columbian crops under rain-fed & low input conditions—migration weighted	Galor and Ozak (2016)	7.057	0.194
Baseline regressors			
ln (nominal per capita income in 2012—USD)	The World Bank (adapted)	8.461	0.133
Square of ln (nominal per capita income in 2012)	The World Bank (adapted)	73.683	2.301
Agriculture's share of GDP in 2012	The World Factbook—CIA	14.495	1.232
Absolute latitude	The World Factbook—CIA	27.633	1.550
% of national area in the geographical tropics	Gallup et al. (1999)	47.451	4.212
Average monthly precipitation in mm	The World Bank	90.253	5.140
Distance in '000 km to nearest coastline or sea-navigable river	Gallup et al. (1999)	0.365	0.042
Region = Asia	Constructed	0.246	0.038
Region = Europe	Constructed	0.246	0.038
Region = North America	Constructed	0.100	0.026
Region = Oceania	Constructed	0.023	0.013
Region = South America	Constructed	0.085	0.025
Region = sub-Saharan Africa	Constructed	0.269	0.039
Ancestral plough use and experience of agriculture			
Fraction of population with ancestors who used the plough	Alesina et al. (2013)	0.543	0.041
Years in '000 since Neolithic Transition—migration weighted	Hansen et al. (2015)	5.209	0.175
Democracy and institutions			
Polity2 index of democracy in 2012 (− 20 to + 20, increasing in the level of democracy)	Center for Systemic Peace	4.854	0.504
State Antiquity Index (increasing in state antiquity)	Bockstette et al. (2002)	0.455	0.021
Origins of national legal system = Britain	La Porta et al. (2008)	0.269	0.039
Origins of national legal system = France	La Porta et al. (2008)	0.569	0.044
Origins of national legal system = Germany	La Porta et al. (2008)	0.131	0.030
Origins of national legal system = Scandinavia	La Porta et al. (2008)	0.031	0.015

Table 1 (continued)

Variable	Source	Mean	SE
Indicator of experience of communism		0.308	0.041
Religious composition			
% of Catholics in the population	McCleary and Barro (2006)	29.482	2.954
% of Protestants in the population	McCleary and Barro (2006)	11.451	1.520
% of Muslims in the population	McCleary and Barro (2006)	21.724	2.913
% of Hindus in the population	McCleary and Barro (2006)	2.003	0.888
N		130	

Since this study aims to estimate the effect of nations' ancestral economic circumstances upon women's current relative well-being, it is important that it controls for current economic circumstances. Hence, the model's baseline regressors include the log of nominal per capita income in 2012 as well as agriculture's share of GDP that year. Also included are region dummy variables and a number of geographical controls. Historical controls, descriptors of institutions, as well as national religious composition later augment these baseline regressors.

Table 2 presents estimates of the coefficients of various versions of Eq. (1). The estimates in column (3) pertain to the equation's baseline specification. It appears there is a highly statistically significant positive relationship, even controlling for nations' present economic circumstances, between women's current relative well-being, as gauged by the female to male sex ratio, and nations' ancestral ecological endowments.

Table 2, column 4, presents estimates of the coefficients of the baseline version of Eq. (1) expanded to accommodate a host of controls. The theses of Alesina et al. (2013)

Fig. 1 Choropleth map of the female to male sex ratio in 2013

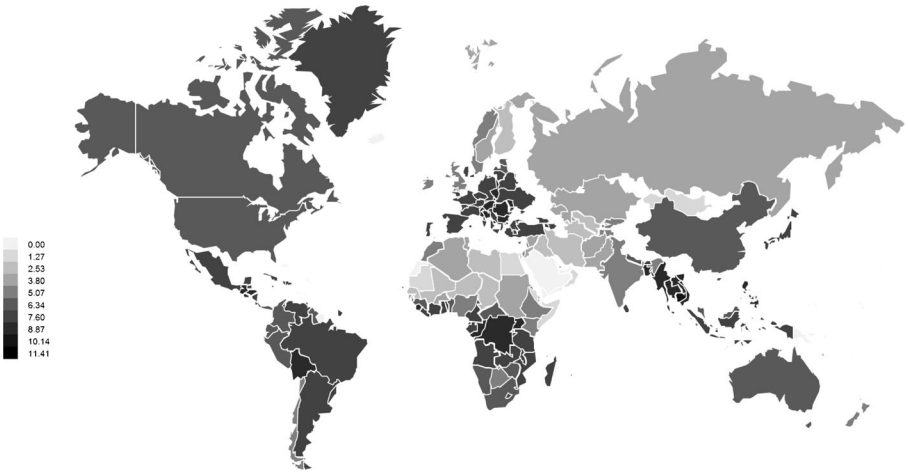

Fig. 2 Choropleth map of ancestral potential caloric yields per hectare

and Hansen et al. (2015) that, respectively, farmers' adoption of the plough, and the Neolithic Revolution, led to cultural norms advocating gender inequality in societal role and are brought into the analysis since gender inequality in roles may have made for gender inequality in intra-household bargaining power, hence well-being. Whereas these estimates indicate greater gender inequality in well-being in countries with longer histories of agriculture,[8] they do not point to the plough being a significant correlate of gender inequality in well-being as measured by the female to male sex ratio.

While this paper has hypothesized that past poverty is *culturally* linked to present gender inequality, it is possible that historical poverty inhibited the development of beneficial institutions capable of checking gender discrimination,[9] so that it is instead the nature of institutions that makes for a connection between the past and the present. Hence, the baseline version of Eq. (1) is also expanded to account for international differences in institutions. Levels of democracy are gauged by the Center for Systemic Peace's Polity2 Index for the year 2012, a 21-point scale ranging from − 10 (hereditary monarchy) to + 10 (consolidated democracy). Nations' historical sophistication of political organization is measured by Putterman's and Bockstette's State Antiquity Index (Bockstette et al. 2002). The index takes low values for nations within which the level of government has been mostly tribal and higher values for nations within which political organization has been more sophisticated since antiquity. The analysis also controls for the origins of nations' legal systems (La Porta et al. 2008), and nations' experience of communism since gender equality was a communist ideal. It is found that there is more gender inequality in older states, and in those whose legal systems originated in Scandinavia, and less gender inequality in states whose legal systems originated in France.

Next, national religious composition is taken into account, religion being a vital influence upon culture. However, religion, itself is an aspect of culture, too is

[8] Fredriksson and Gupta (2018) too find that sex ratios are more skewed against females in countries with longer histories of agriculture.

[9] Note, however, that the advent of sophisticated political organization, conducive to the founding of beneficial institutions, may have had little to do with agricultural productivity (Mayshar et al. 2017).

Table 2 Ancestral ecological endowments and the current female to male sex ratio

Variable	OLS coefficient estimates			
	(1)	(2)	(3) Baseline	(4) Full
Constant	966.733***	635.541***	540.084***	780.047***
	(11.234)	(123.246)	(146.307)	(170.804)
Average potential millions of kcal/hectare/year based on pre-Columbian crops under rainfed & low input conditions—migration weighted	7.972***	8.389***	6.928***	5.761***
	(1.631)	(1.697)	(1.841)	(2.204)
ln (nominal per capita income in 2012—USD)		57.285**	84.410***	55.929*
		(26.158)	(31.706)	(32.597)
Square of ln (nominal per capita income in 2012)		−3.191**	−4.795**	−2.478
		(1.558)	(1.848)	(1.886)
Agriculture's share of GDP in 2012		−0.017	−0.172	0.543
		(0.346)	(0.361)	(0.393)
Absolute latitude		2.071***	1.483*	−0.212
		(0.648)	(0.805)	(1.025)
% of national area in the geographical tropics		0.546***	0.313	0.040
		(0.191)	(0.223)	(0.246)
Average monthly precipitation in mm		−0.042	0.025	−0.225**
		(0.090)	(0.104)	(0.101)
Distance in '000 km to nearest coastline or sea-navigable river		−1.086	2.592	−7.355
		(10.645)	(10.995)	(10.851)
Region dummies			Yes	Yes
Ancestral plough use and experience of agriculture				
Fraction of population with ancestors who used the plough				−2.538
				(11.996)
Years in '000 since Neolithic Transition—migration weighted				−14.406***
				(4.513)
Democracy and institutions				
Polity2 index of democracy in 2012				0.332
				(0.937)
State Antiquity Index				−64.361***
				(20.266)
Origins of national legal system = France				19.470*
				(11.322)
Origins of national legal system = Germany				9.825
				(16.916)
Origins of national legal system = Scandinavia				−53.928*
				(29.741)
Indicator of experience of communism				6.993
				(12.820)
Religious composition				
% of Catholics in the population				−0.259

Table 2 (continued)

Variable	OLS coefficient estimates			
	(1)	(2)	(3) Baseline	(4) Full
				(0.241)
% of Protestants in the population				0.084
				(0.414)
% of Muslims in the population				− 0.077
				(0.246)
% of Hindus in the population				0.411
				(0.479)
Adjusted R^2	0.11	0.23	0.24	0.33
N	130	130	130	130

Dependent variable = national female to male sex ratio in 2013 corrected for migration. Robust standard errors in parentheses

*Significant at 10%; **significant at 5%; ***significant at 1%

potentially shaped by the historical resource environment, so that its inclusion in the analysis may constitute 'over-controlling'. Perhaps this is why religious composition is not a significant correlate of gender inequality.

Table 3 reports estimates, analogous to the baseline estimates in Table 2, pertaining to alternative measure of gender inequality in well-being. The three alternative measures considered are the female-to-male ratio of life expectancy at birth, the UNDP Gender Development Index and the UNDP Gender Inequality Index. The Gender Development Index is a composite measure of gender gaps in three areas of human development: health as measured by life expectancy at birth, education as measured by the expected years of schooling of children and the mean years of schooling of adults and command over resources as measured by estimated earned income. It is the ratio of the UNDP's Human Development Index for females to that for males. Higher values indicate greater gender equality. The Gender Inequality Index summarizes women's disadvantages in the areas of reproductive health, empowerment, and the labour market. Their hardships in the area of reproductive health are described by the maternal mortality ratio (MMR), equivalent to the number of maternal deaths per 100,000 live births, and the adolescent fertility rate (AFR), computed as the number of births per 1000 15 to 19-year-old women. Women's and men's shares of seats in parliament, and the proportions of adult women and men with secondary or higher education, gauge the levels of empowerment of the genders, and women's and men's labour force participation rates measure the genders' standing in the labour market. Lower values indicate greater gender equality. The reported estimates are strongly supportive of a connection between ancestral resource endowments and modern gender inequality in well-being.

In sum, this study's cross-country analyses point to a statistically significant positive relationship, ceteris paribus, between women's current relative well-being and nations' ancestral ecological endowments, consistent with the hypothesis that past economic scarcity had a hand in the shaping of gender norms inimical to women that persist to this day.

Table 3 Robustness: alternate measures of gender inequality

	Life expectancy sex ratio	UNDP gender development index	U N D P gender inequality index
Constant	0.622***	0.422**	0.357
	(0.102)	(0.201)	(0.276)
Average potential millions of kcal/ha/year based on pre-Columbian crops under rain-fed & low input conditions—migration weighted	0.004*** (0.001)	0.009*** (0.003)	− 0.016*** *(0.004)*
ln (nominal per capita income in 2012—USD)	0.093***	0.077*	0.101*
	(0.021)	(0.040)	(0.054)
Square of ln (nominal per capita income in 2012)	− 0.006***	− 0.004**	− 0.010***
	(0.001)	(0.002)	(0.003)
Agriculture's share of GDP in 2012	− 0.0004	− 0.002***	0.0003
	(0.0003)	(0.001)	(0.001)
Absolute latitude	0.001*	0.002**	− 0.001
	(0.001)	(0.001)	(0.001)
% of national area in the geographical tropics	0.0003	0.0001	0.0003
	(0.0002)	(0.0003)	(0.0004)
Average monthly precipitation in mm	0.0000002	0.0003**	0.00004
	(0.00006)	(0.0001)	(0.0002)
Distance in '000 km to nearest coastline or sea-navigable river	0.031*** (0.007)	0.035*** (0.010)	− 0.020 (0.022)
Region dummies	Yes	Yes	Yes
Adjusted R^2	0.54	0.68	0.87
N	130	118	123

Robust standard errors in parentheses

*Significant at 10%; **significant at 5%; ***significant at 1%

3.2 Sub-national

It is found that a positive relationship between women's current relative well-being and ancestral ecological endowments also hold at the sub-national level. The sub-national regions considered are the districts of India, akin to counties in the USA, at the time of the 2001 Census of India. India is well suited to the analysis for three reasons. First, it is an ecologically diverse sub-continent. Second, Indians are relatively geographically immobile (Anderson 2011).[10] This is advantageous in the absence of a Putterman and Weil (2010) style migration matrix for Indian districts. Third, there has largely been no coercive governmental programme to limit fertility of the kind seen in China, whose one-child policy has played an important part in skewing its female to male sex ratio.

[10] Anderson (2011) observes that, by the 1991 and 2001 censuses, 24 to 29% of the population of India consists of migrants, with 60% of these moving within the same district and 25% moving within the same state.

India's sex ratio is notoriously skewed, nonetheless. It was 933 females per 1000 males in 2001. If we consider, as did Sen (1990), that the sex ratio ought to have been about 1020 as in economically comparable Sub-Saharan Africa, there was a deficit of 1020 less 933, or 87, females per thousand males. According to the 2001 Census of India, males numbered 532,223.09. Hence, a Sen-style estimate of the number of missing females in India in 2001 is 87 times 532,223.09 or 46.3 million.

District level sex ratios are obtained from the 2001 Census of India. As in the above cross-country analyses, an Indian district's ancestral ecological endowment is measured by its pre-1500 AD average annual potential caloric yield per hectare under rain-fed and low-input conditions. The requisite agro-climatic potential yields by grid cell of Asian pre-Columbian crops are obtained from the FAO's GAEZ project. These are used to calculate the maximum annual potential caloric output per hectare by grid cell. Districts' pre-1500 AD average annual potential caloric yields per hectare under rain-fed and low-input conditions are calculated by aggregating grid cells to the level of districts.

So that the effects of ecology upon gender inequality might confidently be attributed to the past, the analysis is careful to control for districts' current resource environments. Since per capita income is not reported at the district level, it is substituted by median per capita expenditure, data obtained from the 55th (1999–2000) round of the National Sample Survey. A recent study (Carranza 2014) discovers that the agricultural practice of deep tillage, possible only in loamy soils, reduces the demand for labour in Indian agriculture, so shrinks the employment opportunities of women, lowers their economic value, and, as a result, lowers the local rural child sex ratio. Therefore, the analysis controls for district soil composition.[11] Finally, districts' religious and ethnic compositions are also brought into the analysis.

In sum, the estimated regression equation is

$$\text{current female to male sex ratio}_i = b_1 + b_2\ (\text{ancestral ecological endowment}_i) + \boldsymbol{Z_i}\ \boldsymbol{b_3} + u_i, \tag{2}$$

wherein the subscript i alludes to district i, the regressors $\boldsymbol{Z_i}$ consist of the aforesaid controls as well as state dummy variables and u_i denotes the regression error term. Table 4 presents the sample means and standard deviations of all the employed variables, and Table 5 reports OLS estimates of the coefficients b above. By these estimates, district sex ratios statistically significantly increase in historical caloric yields. By contrast, sex ratios appear significantly more skewed in districts economically better-off at present. This is in keeping with Duflo's (2012) observation that sex ratios at birth remain skewed in prosperous Taiwan and South Korea and that sex ratios are becoming more skewed in India's most prosperous states,[12] and it lends credence to the argument that cultures of gender inequality were moulded in the past. In sum, it appears there is less gender inequality in well-being in Indian districts historically better endowed with ecological resources.

[11] Obtainable from *Soils of India* published by the National Bureau of Soil Survey and Land Use Planning, Indian Council of Agricultural Research

[12] One of these is (East) Punjab, called the 'wheat bowl of India', but its high agricultural productivity is driven by modern irrigation given its annual rainfall of but 649 mm.

Table 4 Summary statistics: sub-national analyses of Indian districts

Variable	Source	Mean	SE
Dependent variables			
District female to male sex ratio	2001 Census of India	937.453	2.523
District female workforce participation rate	2001 Census of India	29.109	0.489
Key regressor (measure of historical scarcity)			
Average potential millions of kilocalories/hectare/year based on pre-Columbian crops under rain-fed & low input conditions	UN Food and Agricultural Organization's GAEZ project (adapted)	6.203	0.092
Other regressors			
ln (district median real per capital monthly expenditure in 1999–2000 - INR)	55th round of the National Sample Survey (adapted)	6.089	0.011
Square of ln (district median real per capital monthly expenditure)		37.137	0.133
% District population that is Muslim	2001 Census of India	9.906	0.658
% District population that is Sikh	2001 Census of India	2.573	0.533
% District population that is Jain	2001 Census of India	0.121	0.015
% District population belonging to scheduled castes	2001 Census of India	0.160	0.004
% District population belonging to scheduled tribes	2001 Census of India	0.179	0.012
% of district land area made up of clayey soils less than that made up of loamy soils	*Soils of India*, 1991, National Bureau of Soil Survey and Land Use Planning, Indian Council of Agricultural Research (adapted)	−44.491	2.243
District average annual rainfall in mm	Daily District-wise Normals of Meteorological Parameters, Indian Meteorological Department (adapted)	1352.853	38.380
N		561	

4 Ancestral ecological endowments and modern gender inequality: a mechanism

By the extensive analyses above, cross-national and sub-national, women today are relatively worse-off in regions whose peoples' ancestors suffered greater, or, if Malthus be heeded, more prolonged, resource stress. This intriguing finding naturally begs explanation. This paper has inferred that women received a smaller share of household resources in antiquity in regions less endowed with ecological resources and has hypothesized that the underlying behaviours have been culturally transmitted to the present as norms. What, however, were these behaviours? This section aims not to be definitive but to discuss the possibilities.

There are, broadly, two. First, perhaps ancestral ecological resource scarcity led to cultural norms that have lowered women's bargaining power over intra-household resource allocations. Second, perhaps ancestral ecological resource scarcity led directly, that is, unmediated by a lowering of women's bargaining power, to an unequal sharing

Table 5 Ancestral ecological endowments and the female to male sex ratio in the districts of India

Variable	OLS coeff. ests.
Constant	2972.171***
	(1048.886)
Average potential millions of kcal/hectare/year based on pre-Columbian crops under rain-fed & low input conditions	*11.060***
	(1.978)
ln (district median real per capital monthly expenditure in 1999–2000—INR)	− 654.863*
	(350.720)
Square of ln (district median real per capital monthly expenditure)	50.675*
	(29.175)
% District population that is Muslim	− 0.281**
	(0.142)
% District population that is Sikh	− 0.400
	(0.338)
% District population that is Jain	− 3.802
	(3.633)
% District population belonging to scheduled castes	− 91.031***
	(33.067)
% District population belonging to scheduled tribes	− 13.848
	(14.071)
% of district land area made up of clayey soils less than that made up of loamy soils	− 0.026
	(0.045)
District average annual rainfall in mm	0.007*
	(0.004)
State dummy variables	Yes
Adjusted R^2	0.59
N	561

Dependent variable = district female to male sex ratio by the 2001 Census of India. Robust standard errors in parentheses

*Significant at 10%, **significant at 5%, ***significant at 1%

of resources between the genders in antiquity, and it is this mode of unequal sharing that became a cultural norm.

Since a woman's bargaining power depends upon her 'threat utility' (e.g. Manser and Brown 1980), which has been demonstrated to be a function of her economic potential (e.g. Aizer 2010), ancestral ecological conditions might affect modern gender outcomes if they shaped cultural norms governing gender roles, women's economic potential being low when their prescribed role is domestic. Consider a simple model of farm life in antiquity wherein a man and his wife allocated their labour between household domestic and agricultural production. The man may have had an absolute advantage in agricultural work given its strenuousness. An interior optimal allocation of their labour would have required each individual's marginal product of labour in agriculture to equal her marginal product of labour in domestic work. However, poor

ecological endowments may have so lowered the woman's marginal product of labour in agriculture that her specialization in domestic work was the optimal corner solution to the problem of the allocation of the couple's labour.

Recent research by Becker (2017) suggests an alternative connection between poor ecological endowments and women's specialization in domestic work. Perhaps poor agricultural endowments led to greater reliance on herding, dominated by males for the reason that animals, susceptible to theft, needed to be protected. Becker finds that a legacy of herding is associated with son preference, the lower bargaining power of wives and the most invasive forms of female circumcision.

Over time, women's specialization in domestic work in ecologically ill-endowed regions may have led to cultural norms prescribing a domestic role for women in society, a confinement that lowers their economic potential, hence bargaining power. By the estimates in column 1 of Table 6, however, there is little evidence of a relationship between ancestral ecological endowments and current female labour force participation. Neither are the estimates in column 1 of Table 7 supportive of such a relationship sub-nationally. Hence, if ancestral ecological resource scarcity shaped cultural norms that lower women's bargaining power, these appear unrelated to women's work. Besides, by the estimates in column 2 of Table 6 and column 2 of Table 7, the positive relationship between the female to male sex ratio and ancestral ecological endowments is robust to controlling for work by women, which indicates

Table 6 Ancestral ecological endowments and modern gender inequality in well-being across countries exploration of mechanism

Variable	OLS coeff. ests.	
	(1)	(2)
	National female labor force participation rate in 2013	National female to male sex ratio in 2013 corrected for migration
Constant	180.942***	723.596***
	(39.230)	(180.227)
Average potential millions of kcal/hectare/year based on pre-Columbian crops under rainfed & low input conditions—migration weighted	0.553	5.592**
	(0.535)	(2.236)
Female labour force participation rate in 2013 ages 15+ years		0.305
		(0.378)
Baseline regressors	Yes	Yes
Ancestral plough use and experience of agriculture	Yes	Yes
Democracy and institutions	Yes	Yes
Religious composition	Yes	Yes
Adjusted R^2	0.65	0.32
N	130	130

Robust standard errors in parentheses

*Significant at 10%; **significant at 5%; ***significant at 1%

that ancestral resource scarcity's effect upon women's current relative well-being is independent of gender roles.

Might a lowering of women's bargaining power be related to the greater potential for violent conflict in less endowed regions? It is possible there was more inter-group warring over resources in such regions,[13] and the resulting premium on male brawn lowered women's bargaining power. On the other hand, perhaps poor ecological

Table 7 Ancestral ecological endowments and modern gender inequality in well-being across Indian district exploration of mechanism

Variable	OLS coeff. ests.	
	(1) District female workforce participation rate	(2) District female to male sex ratio
Constant	597.599***	1950.955*
	(176.756)	(1027.707)
Average potential millions of kcal/hectare/year based on pre-Columbian crops under rain-fed & low input conditions	− 0.440	11.812***
	(0.352)	(1.961)
District female workforce participation rate by the 2001 Census		1.709***
		(0.229)
ln (district median real per capital monthly expenditure in 1999–2000—INR)	− 178.327***	− 350.125
	(57.836)	(344.067)
Square of ln (district median real per capital monthly expenditure)	13.906***	26.912
	(4.723)	(28.673)
% District population that is Muslim	− 0.161***	− 0.006
	(0.035)	(0.134)
% District population that is Sikh	− 0.124	− 0.189
	(0.084)	(0.291)
% District population that is Jain	0.795	− 5.160
	(0.780)	(3.591)
% District population belonging to scheduled castes	− 7.898	− 77.534**
	(7.250)	(30.256)
% District population belonging to scheduled tribes	12.809***	− 35.737***
	(2.404)	(13.486)
% of district land area made up of clayey soils less than that made up of loamy soils	0.003	− 0.032
	(0.009)	(0.043)
District average annual rainfall in mm	0.0001	0.006*
	(0.0005)	(0.004)
State dummy variables	Yes	Yes
Adjusted R^2	0.59	0.64
N	561	561

Robust standard errors in parentheses

*Significant at 10%; **significant at 5%; ***significant at 1%

endowments led directly, that is, not via effects upon women's bargaining power, to an unequal sharing of household resources between men and women in antiquity, and it is this unequal sharing that eventually became a cultural norm. Assume Nash bargaining determined the division of household resources between man and wife in antiquity. Hence, a household in effect maximized

$$\mu.U\left(c_f\right) + (1-\mu).U(c_m)$$

with respect to c_f and c_m, subject to the budget constraint $c_f + c_m = c$, where the function U is each household member's utility function; c_m and c_f denote, respectively, the man's and his wife's consumption; c is household total food production; and μ is the Pareto weight representing the wife's bargaining power. It is plausible her bargaining power was positively related to the extent of her participation in agricultural production. For ease of exposition, assume that the utility function has the tractable exponential form $U(x) = 1 - e^{-\alpha x}$, $\alpha > 0$. Substituting the constraint into the objective function yields

$$\mu\cdot(1-e^{-\alpha c_f}) + (1-\mu)\cdot\left(1-e^{-\alpha\left(c-c_f\right)}\right),$$

to be maximized with respect to c_f. The first-order condition for a maximum is

$$\mu\cdot\alpha\cdot e^{-\alpha c_f} - (1-\mu)\cdot\alpha\cdot e^{-\alpha c}\cdot e^{\alpha c_f} = 0,$$

which may be rewritten as

$$\mu\cdot\alpha\cdot e^{-\alpha c_f} = (1-\mu)\cdot\alpha\cdot e^{-\alpha c}\cdot e^{\alpha c_f}.$$

Multiplying both sides by $e^{-\alpha c_f}$ yields

$$\mu\cdot\alpha\cdot e^{-2\alpha c_f} = (1-\mu)\cdot\alpha\cdot e^{-\alpha c}.$$

Taking the natural logs of both sides transforms this into

$$\ln\mu + \ln\alpha - 2\alpha c_f = \ln(1-\mu) + \ln\alpha - \alpha c.$$

A little manipulation yields

$$\frac{c_f}{c} = \frac{1}{2} + \frac{\ln\left(\frac{\mu}{1-\mu}\right)}{2\alpha c}.$$

In other words, the wife's share of household food production is a function both of μ, her bargaining power, and c, household food production. Letting s_f denote $\frac{c_f}{c}$, it is readily shown that

$$\frac{ds_f}{d\mu} = \frac{1}{2\alpha c}\cdot\frac{1}{\mu(1-\mu)} > 0,$$

that is, that the wife's share of household resources was positively related to her bargaining power, and that

$$\frac{ds_f}{dc} = \frac{-\ln\left(\frac{\mu}{1-\mu}\right)}{2\alpha c^2} > 0 \text{ if } \mu < \frac{1}{2},$$

that is, her share decreased as household resources shrank if her bargaining power were less than her husband's. Since the strenuous nature of agricultural work concentrated food production in men's hands (Hansen et al. 2015), a woman's bargaining power in agricultural antiquity was likely less than her husband's. The latter derivative thus suggests that women's share of household food production was lower on average in regions less endowed with ecological resources. Importantly, it was so not because poor ecological endowments lowered women's bargaining power. It might be reasoned that since the scarcity born of poor ecological endowments was persistent, local geography being persistent, the resulting gender inequality in the division of resources was also persistent, so much so that this manner of division eventually became a cultural norm.[14] Just as Boserup (1970) held that an ancient gendered division of labour gradually became a cultural norm, perhaps an ancient gendered division of household resources eventually became a cultural norm.[15]

5 Conclusion

This study explores a connection between ancestral ecological endowments and modern gender inequality in well-being. Gender inequality is gauged by the female to male sex ratio, widely believed to be determined largely by discrimination in the intra-household allocation of resources. It is commonly considered a key measure of women's relative well-being and has the advantage of being suited to both cross-national and sub-national analyses. The national female to male sex ratio is found to be significantly correlated with the national life expectancy sex ratio, the UNDP Gender Development Index and the UNDP Gender Inequality Index.

The study's measure of nations' ancestral ecological endowments is a plausible one for the following reasons. It is based on crop yields modelled to depend solely upon the climate, believed largely unchanged for at least the past one to two millennia. Only considered are crop yields based on the rain-fed and low-input conditions of antiquity. Crops are limited to those grown prior to 1500 AD, and nations' historical caloric yields per hectare are migration weighted to account for the ancestry of the peoples of today's nations. Further, so that the effects of this migration-weighted historical caloric

[14] Cigno et al. (2017) describe a societal or family norm as prescribed behaviour whose amendment is not in the interest of future generations. It is unclear that norms of gender inequality fit this description. For example, while it may have been optimal for women in antiquity to specialize in household work in societies employing the plough, it cannot be said that this specialization remains advantageous.

[15] Norms governing the inter-gender sharing of household resources might be reconciled with present-day intra-household bargaining if they were viewed as altering the genders' respective utility functions in such a way that bargaining results in greater resource allocations to males. After all, there is evidence of women absorbing patriarchal ideologies to perpetuate gender inequality (Sultana 2010).

yield might confidently be attributed to the past, the analyses are always careful to control for nations' current economic circumstances as measured by per capita income.

Current economic circumstances held constant, gender inequality in well-being is found to be more pronounced, that is, the female to male sex ratio lower, in regions whose peoples' ancestors experienced greater resource stress. This connection holds cross-nationally, as well as sub-nationally, across the districts of India. It is consistent with the hypothesis that ecological resource scarcity led to gender inequality in the intra-household allocation of resources in the past and that the associated behaviours have been culturally transmitted to the present as norms. Hence, even if a region deprived of ecological resources, such as the oil-producing Middle East, was to come upon prosperity in the modern era, its women might continue to suffer discrimination in resource allocations whose final outcome is a shortening of female life spans and a skewing of the female to male sex ratio.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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