

Fredriksson, Per G.; Gupta, Satyendra Kumar

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Irrigation and Culture: Gender Roles and Women's Rights

Per G. Fredriksson* Satyendra Kumar Gupta[‡]

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Abstract

This paper proposes that ancestral use of irrigation reduces contemporary female labor force participation and female property rights. We test this hypothesis using an exogenous measure of irrigation and data from the Afrobarometer, cross-country data, the European Social Survey, the American Community Survey, and the India Demographic and Household Survey.

Our hypothesis receives considerable empirical support. We find negative associations between ancestral irrigation and actual female labor force participation, and attitudes to such participation, in contemporary African and Indian populations, 2nd generation European immigrants, 1.5 and 2nd generation US immigrants, and in cross-country data. Moreover, ancestral irrigation is negatively associated with attitudes to female property rights in Africa and with measures of such rights across countries. Our estimates are robust to a host of control variables and alternative specifications.

We propose multiple potential partial mechanisms. First, in pre-modern societies the men captured technologies complementary to irrigation, raising their relative productivity. Fertility increased. This caused lower female participation in agriculture and subsistence activities, and the women worked closer to home. Next, due to the common pool nature of irrigation water, historically irrigation has involved more frequent warfare. This raised the social status of men and restricted women's movement. These two mechanisms have produced cultural preferences against female participation in the formal labor market. Finally, irrigation produced both autocracy and a culture of collectivism. These are both associated with weaker female property rights.

JEL Codes: J16, J21, N50, O10, P14, Q15, Z13.

Keywords: Irrigation; agriculture; culture; gender; norms; labor force participation; property rights.

* Corresponding author. Department of Economics, University of Louisville, Louisville, KY 40292; Global Labor Organization Fellow, Germany. Email: per.fredriksson@louisville.edu.

[‡] Jindal School of Government and Public Policy, O.P. Jindal Global University Sonapat, Haryana-131001, NCR of Delhi, India. Global Labor Organization Fellow, Germany. E-mail: skgupta@jgu.edu.in.

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1. Introduction

In many parts of the world, labor market participation and the right to own property is not equal for men and women. This has obvious effects on women's incomes, on overall economic growth and welfare, and on the education and welfare of future generations (see, e.g., Duflo, 2012; Jayachandran, 2015). In this paper, we explain these adverse outcomes for women by the ancestral practice of irrigation agriculture, a technique utilized for at least the last five thousand years (Vasey, 1992). We test the hypothesis that having a history of irrigation agriculture is associated with lower contemporary female labor market participation and weaker female property rights. The historical reasons are numerous.

Ancestral irrigation is linked to contemporary female labor force participation in two ways, not previously discussed in the literature. First, Boserup (1970) and Murdock and Provost (1973) argue that men have historically tended to capture new technologies in agriculture such as irrigation. This raised their relative productivity and participation in agriculture.¹ Moreover, increased food production caused women to specialize in cereal processing, cooking, cleaning, gathering of fuel wood and water, care of small animals, and intensive child care due to raised fertility (Murdock and Provost, 1973; Minge-Klevana, 1980; Ember, 1983; Hansen et al., 2015).^{2,3} In irrigated areas women's work gravitated over time away from agricultural field work and toward the homestead, and this division of labor has persisted.

Second, irrigation water is frequently a common pool resource, accessed by different communities with opposing interests. Water consumption by upstream groups sometimes severely affect consumption possibilities downstream, especially during droughts. Similarly, communities sharing lake water are likely to face such a tragedy of the commons problem (Hardin, 1968; Ostrom, 1993). The likelihood of conflict rises in situations of resource scarcity (see, e.g., Acemoglu et al., 2012; Kimbrough et al., 2017). Moreover, because irrigation agriculture historically involved an increase in the productivity of land, it generated a storable surplus in need of defence (Ember, 1982). In addition, at the local level, irrigation activities often occur at night and involved conflicts with neighbors over water (Bastidas, 1999; Bichsel, 2009), which is particularly dangerous for women. In sum, irrigation water has been associated

¹ Such technologies include the Shaduf, the Noria (Egyptian water wheel), the Qanat, the Sakia (Persian water wheel), the Tambour (Archimedes' screw), and Persian water pumping windmills.

² Child care next to canals and ditches involves risks. If instead the offspring was left with caretakers at home, women would need to frequently return home. This appears difficult to combine with irrigation which requires near-constant attention.

³ Sociologists argue that men have historically monopolized membership and leadership of irrigation management organizations deciding on water allocation (Ramamurthy, 1991; Upadhyay, 2003).

with conflicts and warfare, which produced a need for male combatants and greater male status (Chagnon, 1988; Ramos-Toro, 2019). Irrigation caused women to relocate activities toward home production, while the men were more likely to work away from home. This pattern has persisted.

The intensification of agriculture by irrigation facilitated the emergence of private property rights, historically allocated exclusively to men (Engels, 1902). We propose that irrigation agriculture may have weakened female property rights via two channels. First, historical irrigation is associated with a higher probability that a pre-industrial society was ruled by an elite (Bentzen et al., 2017). Resource curse theory suggests that the elite captured the surplus from irrigation. This resulted in lower levels of both historical and contemporary democracy. In turn, Gradstein (2007) argues that autocracy is associated with more insecure property rights. Fish (2002) suggests an association between authoritarianism and outcomes negative to females. We propose that ancestral irrigation is linked to weaker contemporary female property rights via autocracy.⁴

Second, irrigation historically required constant cooperation, which in turn yielded collectivism (Buggle, 2020). Gorodnichenko and Roland (2017) suggest that collectivism is negatively associated with the level of property rights protection (in particular, protection against expropriation risk), and Binder (2019) finds that collectivism is associated with a belief in traditional gender roles. This suggests that collectivism may be a channel between ancestral irrigation and weaker female property rights.

We employ multiple data sets and provide a host of logit, ordered logit, and OLS and estimates. The measure of irrigation is the potential increase in crop yield as a result of irrigation (Bentzen et al., 2017), which has the advantage of being highly exogenous.

First, using Murdock's (1967) *Ethnographic Atlas* we find the irrigation potential for pre-industrial African societies. Using contemporary individual level survey data from the Afrobarometer, we match respondents' ethnicity to the irrigation potential in the corresponding pre-industrial society. We show that respondents with an ancestry associated with greater irrigation potential have more negative attitudes toward female labor force participation and female property rights.

Second, we provide cross-country evidence from up to 165 countries. Adjusted for population movement occurring due to the Columbian Exchange, areas with greater irrigation

⁴ Ross (2008) similarly argues that oil production has resulted in patriarchal laws and political institutions.

potential today have lower female labor force participation rates and weaker female property rights. In contrast, irrigation potential has no such effects on males.

Third, we use individual level data on the gender attitudes of the children of European immigrants (2nd generation immigrants) from four waves of the European Social Survey. Having ancestors from a country with greater irrigation potential is associated with more negative attitudes toward female labor market participation relative to males, and the view that women should favor the family over their own careers. The strongest cultural transmission appears to occur from immigrant fathers to their sons.

Fourth, we analyze individual level American Community Survey data on the children of immigrants to the United States. The sample consists of both 2nd generation and 1.5 generation immigrants (who arrived in the US before age six). Greater ancestral irrigation potential is again negatively associated with female labor force participation.

Fifth, we utilize individual level data from the India Demographic and Household Survey. In rural areas with greater irrigation potential, women are less likely to work outside the home. This is not the case for men.

The estimates provide consistent evidence of associations between ancestral irrigation, lower female labor force participation, and weaker female property rights. These associations show strong cultural persistence across generations. The results are robust to the inclusion of a host of confounders and robustness checks, including traditional plow use (e.g., Boserup, 1970; Alesina et al., 2013).

We provide evidence in favor of the four proposed partial mechanisms which help explain contemporary economic outcomes. First, in pre-industrialized societies, irrigation potential is associated with lower levels of female participation in agriculture, and increased allocation of activities close to home. Second, evidence from pre-industrial societies suggest that the historical incidence of external warfare among pre-industrial societies is a moderate link between irrigation potential and female participation in agriculture. Similarly, we use district level data from rural India on historical land battles during years 610-1962. This analysis suggests that the frequency conflict is a partial channel linking irrigation potential and female participation in the agricultural labor market. Finally, both autocracy and collectivism appear to serve as partial channels connecting irrigation potential to weaker contemporary female property rights.

The paper is organized as follows. Section 2 provides a literature review, and Section 3 outlines the data used. Section 4 reports the empirical results, Section 5 discusses possible mechanisms, and Section 6 provides a brief conclusion. Online Appendix A describes all data

sources, online Appendix B provides descriptive statistics, and online Appendix C reports several supplementary robustness checks.

2. Related literature

Irrigation and the plow use were historically the two techniques used to intensify agricultural production. The literature on the ancestral drivers of gender disparities has largely focused on the plow.⁵ This study instead discusses irrigation agriculture, which in Mesopotamia has a history stretching back more than 5,000 years (Vasey, 1992). Irrigation has often been crucial for human survival in arid areas. Boserup (1970) suggests that technologies complementary to irrigation tended to be captured by men, increasing their productivity and status relative to women. Similarly, Murdock and Provost (1973) argue that the invention and introduction of new processes such as irrigation, which made agriculture more complex, increased male participation in all agricultural operations in pre-industrial societies. Engels (1902) argues that intensification of agricultural production (irrigation being a primary example) resulted in the development of private property rights, all of which were allocated solely to men. The literature also finds that men historically benefited substantially more from the construction and maintenance of irrigation projects, and have taken available leadership roles in water management organizations.⁶

Hansen et al. (2015) find that an earlier agricultural transition is associated with more patriarchal values and persistent gender bias, yielding lower female labor force participation in 2000 AD.⁷ Women specialized in child rearing and the processing of cereals at the homestead while the men worked the fields, viewed as a more productive activity.^{8,9} Burton and White

⁵ See Boserup (1970), Murdock and Provost (1973), Martin and Voorhies (1975), Ember (1983), Burton and White (1984), Hinsch (2003) and Alesina et al. (2013).

⁶ See, e.g., Ramamurthy (1991) and Upadhyay (2003). The individual rights to irrigation water were often based on the amount of labor input provided into canal digging and construction, activities women were restricted from. Buggle (2020) argues that ancestral irrigation is associated with more collectivism and less innovation today.

⁷ Ember (1983) and Iversen and Rosenbluth (2010) argue that gender equality was high in hunter and gatherer societies, because the overall contribution to subsistence was fairly equal.

⁸ Ember (1983) argues that women in preindustrial societies with intensive agriculture (using irrigation or the plow) spent more time processing crops, prepare slow-cooked food, carry more water, collect more firewood, and perform more household chores in larger houses located in more permanent settlements. Women spent more time on child care because intensive agriculturalists had more children than horticulturalists and hunter and gatherers, as they were in greater need of labor. Women tended to contribute to subsistence activities close to home, the tasks were relatively monotonous and interruptible, the work not dangerous; these activities are more compatible with child care (Brown, 1970).

⁹ A low historical agricultural output yield (Hazarika et al., 2019), an earlier agricultural transition (Fredriksson and Gupta, 2018), and ancestral plow use (Alesina et al., 2018) bias contemporary sex ratios. Carranza (2014)

(1984) view the number dry months as a measure of seasonal time pressure and a predictor of female participation in agriculture.¹⁰ Alesina et al. (2013) report a bias against female labor force participation among the contemporary children of European and US immigrants from areas with ancestral plow agriculture. Fernández and Fogli (2009) find that parental source country labor force participation and fertility rates influence 2nd generation immigrants.¹¹ Eder and Halla (2020) show that a pre-industrial focus on animal husbandry was associated with higher illegitimacy ratios in the past, and these societies still approve illegitimacy and birth outside of marriage to a greater degree today. Becker (2019) argues that pastoralism in pre-industrial societies is associated with more restrictions on women's movement and sexuality.

According to Boyd and Richerson (2005), cultural norms, beliefs, and values have persisted because they reduce the cost of information acquisition, including what is considered appropriate roles and actions by the genders. In Akerlof and Kranton (2000), gender identity prescribes the type of work men and women are expected by society to perform. A social norm where males are expected to work outside the home and women are homemakers helps explain why lower female labor market participation is perpetuated. Deviations from this norm, e.g. if a woman is in a “man's job” it decreases her individual utility.¹²

Water has a long association with conflict, for example in pre-industrial societies, the Andes, and the American West.¹³ Ostrom (1993) discusses institutional arrangements that help overcome common problems in irrigation systems. Acemoglu et al. (2012) provide a theory of resource conflicts, and Kimbrough et al. (2017) provide a literature survey. Wittfogel (1957) argues that large-scale irrigation systems necessitated the centralization of power, which yielded autocratic rulers. Bentzen et al. (2017) develop this hypothesis by relying on resource curse theory. Ownership of irrigation infrastructure enabled local elites to monopolize arable land in arid areas, concentrating the wealth from agriculture. Bentzen et al. produce robust evidence that greater irrigation potential is associated with lower levels of democracy in pre-industrial societies and today. This has implications for female property rights. In Gradstein's

shows a connection between soil texture, deep land tillage, and the sex ratio in India. Bhalotra et al. (2019) find that land property rights in India affect male and female child survival rates differently. Guiliano and Nunn (2019) show that traits that have evolved up to the previous generation are more likely to be optimal for the next generation as long as the environment is similar across generations.

¹⁰ Burton and White's descriptive data from the *Ethnographic Atlas* suggest that in areas with no dry month crop tending is 16% male, while in areas with 7-12 dry months 78% of crop tending is done by males.

¹¹ Cultural transmission is discussed by, e.g., Bisin and Verdier (2000), Farré and Vella (2013), Dhar et al. (2018).

¹² Moreover, male co-workers may suffer a loss from women performing the same tasks. Males may reduce their anxiety by taking actions against female co-workers, which reduces everyone's productivity and likely the rate of female labor market participation.

¹³ See, e.g., Dunbar (1948), Bolin (1990), Ember and Ember (1992), Gleick and Heberger (2014).

(2007) model, democracy provides a commitment to maintain property rights and reduce rent seeking. Autocracy is associated with insecure property rights, and in gender unequal societies women are likely to have the weakest rights.

Buggle (2020) argues that historical irrigation practices have affected the cultural dimension of collectivism vs. individualism. Irrigation required constant cooperation by farmers, resulting in collectivism. Relatedly, Ang (2019) find that a legacy of farming of more (less) labor-intensive crops is associated with collectivism (individualism). Gorodnichenko and Roland (2017) find that the collectivism vs. individualism dimension affects property rights. Binder (2019) presents individual level data suggesting that collectivism is associated with a belief in traditional gender roles. To the best of our knowledge, the present study suggests novel associations between ancestral irrigation, female labor force participation, female property rights, and proposes multiple mechanisms explaining these links.

3. Data

This section provides details and sources of the measures of gender inequality and bias used in our data sets: pre-industrial societies, cross-country, the children of European and US immigrants, as well as rural India. The basic irrigation methods we have in mind are based on dam and canal surface water combined with gravity. During history, associated technologies such as the Shaduf, the Noria (Egyptian water wheel), the Qanat, the Sakia (Persian water wheel), the Tambour (Archimedes' screw), and Persian water pumping windmills have been used in irrigation, and increased irrigators productivity.¹⁴ Detailed data sources and definitions for all variables are provided in online Appendix A and descriptive statistics are offered in online Appendix B.

3.1 Irrigation Potential

The irrigation potential data is compiled by Bentzen et al. (2017), based on data from the Food and Agriculture Organization's (FAO) global Agro-Ecological Zones (GAEZ) 2002 database. The globe is divided into $0.083^\circ \times 0.083^\circ$ size grid cells, equivalent to 9×9 km² at the equator. Taking multiple agro-climatic conditions into account, the FAO calculates the combination of (between 1 and 154) individual crops that maximizes nutritional value yield in each grid cell. The soil data comes from circa 1990, and the climatic data from 1961-1990.

¹⁴ See <http://www.irrigationmuseum.org/exhibit2.aspx>.

Irrigation potential measures the theoretically possible (hypothetical) increase in yield if irrigation is introduced in an area where agriculture was previously rain fed. The yield increase naturally differs across areas, providing five different Impact Classes as classified by the FAO. We use as a measure the fraction of arable land where irrigation can potentially increase yields (measured in kilogram per hectare per year) by more than 100 percent, denoted by Impact Class 5 (in Impact Class 1 areas, irrigation does not raise yields), i.e. irrigation potential = (area in Impact Class 5)/(land suitable for agriculture). This yield increase may occur either because the availability of irrigation allows multiple harvests, or because agriculture is infeasible without irrigation. The hypothetical potential increase is independent of the actual technology used and the actual variety of crops grown. Areas unsuitable for agriculture are not part of the measure. Few people would have survived in such areas, and thus their geographical features would have little effect on culture. Irrigation potential is a highly exogenous measure, alleviating concerns about reverse causality. In the robustness analysis, we also present results with areas where irrigation raises output by 50-100%. Figure 1 provides a map of the distribution of irrigation potential across countries. [Figure 1]

To what extent is irrigation potential related to actual irrigation? Irrigation potential has a correlation of 0.31 with actual irrigation in our sample of 649 pre-industrial societies provided by Murdock (1967). This provides some reassurance that irrigation potential is a reasonable proxy for the presence of irrigation in pre-industrial societies.

3.2 The Afrobarometer

The 2016-18 Afrobarometer (round 7) provides individual level survey data from 34 countries. We were able to match the ethnicity of respondents from each of these countries. The minimum number of observations is seven (Swaziland) and the maximum 1888 (Ghana). We utilize the answers to the following two statements, which were not asked in any of the previous rounds. First, “When jobs are scarce, men should have more right to a job than women?”. Second, “Women should have the same rights as men to own and inherit land?”. The possible answers to both these statements are: 1 = Strongly disagree; 2 = disagree; 3 = Neither agree nor disagree; 4 = agree; 5 = strongly agree.

We utilize the respondents’ stated ethnicity in the Afrobarometer to match them with their ancestral irrigation potential, using data on pre-industrial societies from the *Ethnographic Atlas* by Murdock (1967). While the *Atlas* contains information on the centroid of each society, the measurement of the precise location may involve errors. Moreover, information about the land

area covered by these pre-industrial societies is missing. We use a buffer zone of 200 km around the centroid in order to construct the measure of irrigation potential, following Alesina et al. (2013).

The sample size is 43,267. However, the sample size declines because the question about the respondent's ethnic community or the tribe of was either not asked, no response was given (respondent did not see herself as belonging to a tribe, refused, or did not know), or the ethnic group reported in the Afrobarometer could not be matched to ethnicities reported in the *Ethnographic Atlas*. We utilize a concordance table to exactly match the ethnicity of respondents in the Afrobarometer to the ethnicities reported in the *Ethnographic Atlas*. We also use Nunn and Wantchekon's (2011) concordance list to match respondents who report an ethnicity subclass. We were able to match the ethnicity of 20,192 respondents. We use the premodern data on plow use, the presence of large animals, economic complexity, political hierarchy, and agricultural suitability from the *Ethnographic Atlas* as historical control variables. The individual controls are age, age squared, and gender. We also control for the interviewer's characteristics which include age, age squared, gender, and the language used for the interview.

3.3 Cross-country Data

The first dependent variable used in the cross-country analysis is female labor force participation in year 2000 from World Bank (2015). The variable measures the percentage of women aged 15 to 64 in the labor force, and ranges from 0 to 100. The second dependent variable utilized is female property rights, measured as a response to question "Do women enjoy right to private property?" provided by Coppedge et al. (2019). The answers vary from 0 (virtually no women enjoy private property rights of any kind) to 5 (virtually all women enjoy all, almost all, property rights). The ordinal scale is converted to an interval by using Bayesian item response theory modelling techniques (Johnson and Albert, 1999) that address possible scale inconsistencies, coder reliability issues and biases inherent in surveys (see Coppedge et al., 2020).

The measure of irrigation potential is compiled by Bentzen et al. (2017). Contemporary countries with Impact Class 5 irrigation potential have on average 50 percentage points more of their cultivated land irrigated relative to countries with no irrigation potential (Bentzen et al., 2017). Due to the falling cost of novel irrigation techniques in the 20th century, it has become profitable to use irrigation, including as insurance against drought. Using data on actual contemporary irrigation is less useful in our case, as we expect historical irrigation to drive

gender bias and property rights institutions. In the robustness analysis we also include Impact Class 4 areas where irrigation raises output by 50-100%.

We argue that intergenerational cultural transmission is important for the historical effect of irrigation potential on contemporary outcomes. Thus, our cross-country analysis takes post-Columbian Exchange population movements into account, following Putterman and Weil (2010). Implicit in this adjustment is the belief that the effect of irrigation potential is embedded in individuals and their cultural traits, not in geographic areas themselves.

Traditional plow use is the fraction of citizens with ancestors that used the plow in pre-industrial agriculture. We adjust plow use for population movements. The geographic control variables are landlocked, temperature, precipitation, and elevation.

3.4 The European Social Survey

We use data from four waves of the European Social Survey (the relevant questions were not asked in all waves): the second (2004–2005), fourth (2008–2009), fifth (2010–2011), and eighth (2016–2017). Our main sample is comprised of 2nd generation respondents living in 32 European countries, with parents coming from up to 173 countries. The benefit of using a sample of 2nd generation immigrants is that all individuals in a particular country have been exposed to similar national institutions.¹⁵ As indicators of gender views, we utilize the responses to two statements in the survey: “When jobs are scarce, men should have more right to a job than women”; and “Women should be prepared to cut down on paid work for the sake of family”.

The irrigation potential variable reflects either the father’s or the mother’s ancestral home country. We control for traditional plow use, the fraction of citizens with ancestors that used the plow in pre-industrial agriculture in the immigrant parent’s country of origin. Other historic country of origin controls are economic complexity, the presence of large animals, and political hierarchy. The individual controls include age, age squared, and years of education variable.

3.5 The American Community Survey

We use data from the annual American Community Survey for years 2000–2018. The sample contains two categories: 2nd generation female children of immigrants, born in the US with at least one foreign-born parent, and 1.5 generation female immigrants who were born

¹⁵ We also have data on 1st generation immigrants, which yield consistent results (available upon request). We do not have data on 1.5 generation immigrants, as the year of immigration is unknown.

abroad but immigrated to the US before the age of six years. Children born abroad to US citizens are excluded. For 2nd generation immigrants, we use country of origin as the country of birth of the mother or the father. The literature argues that 2nd generation immigrants may self-misidentify their ancestry (see Duncan and Trejo, 2011; Galor et al., 2020). One benefit of using 1.5 generation immigrants is that their ancestry is less uncertain (we know their country of birth) compared to 2nd generation immigrants (where we are forced to use their parents' country of birth). Some misclassifications may have occurred in the data. It is possible that an immigrant came to the US at a young age, but one of parent had immigrated earlier and they answered the survey with the year of this parent's immigration. Moreover, an immigrant may be born to parents (perhaps from different countries) who were simply transient in a third country before arriving in the US (e.g., refugees living in camps, or parents working in a third country before arriving in the US). We assume that the country of birth is the 1.5 generation immigrant's ancestral origin. This is consistent with the assumption that the country of birth equals the country of origin for 1st generation immigrants who arrived in the US as adults, and thus became the parents of the 2nd generation immigrants.

The dependent variable measures whether the female respondent is in the labor force or not. The potential irrigation variable reflects the irrigation potential for the mother's ancestral home country, or the country of birth of the 1.5 generation immigrant herself. We account for a tradition of plow use, absolute latitude, ruggedness, and potential crop yield (post-1500) in the immigrant's ancestral country. The individual controls include age, age squared, years of education, and an indicator variable for being single.

3.6 The India Demographic Household Survey

The 2015-16 National Family Health Survey, India's version of the Demographic Household Survey (DHS), provides information on the demographic, health, and nutritional status of women and men aged 15-49 located in rural areas. The rural sample was selected through a two-stage sample design with villages as the primary sampling units (PSUs) in the first stage (selected with probabilities proportional to size). In the second stage, a complete mapping of households in each PSU was performed, followed by a random selection of 22 households.

We focus on female and male respondents living in rural areas. We are unable to match urban migrants with the irrigation potential in their previous home districts, and they are not included. The survey reports whether the respondent does any work other than domestic work for the own household. Non-domestic work by the respondent included working for a family

member, for someone else, or being self-employed, whether paid in cash, in kind, or unpaid. If the respondent works outside the home, the survey gives the occupation. We have data on 27,920 women residing in rural areas who are in the workforce, 56,937 which are not in the workforce, and 79 women whose status is ‘don’t know’, i.e., a total of 84,936. Complete information (e.g., education level, caste, language, religion, wealth) is available for 78,198 of these women (26,041 in work force, and 52,157 not in the work force). We also have data on 71,019 males, 58,273 of whom are in the workforce. Female and male labor force participation is a dichotomous variable which takes a value of 1 if the respondent is working, 0 otherwise.

Information on respondents’ age, religion, language in which the interview was conducted, education level, state of household is available from DHS. Moreover, the survey data also provide information on temperature, precipitation, latitude, and altitude of the cluster. For each cluster, we calculate the average irrigation potential in a circular area with a 50 km radius surrounding each cluster. The correlation between irrigation potential and the share of arable land actually irrigated in rural India equals 0.62.

4. Empirical Results

4.1. Evidence from Africa

This section presents individual level results on the association between irrigation potential and ancestral African ethnic groups (Murdock, 1967), and contemporary respondents’ attitudes to female labor market participation and female property rights (Afrobarometer, 2016-18). We estimate the following ordered logit regression model:

$$y_{iec} = \alpha + \beta_1 \text{irrigation}_i + X_i^e \Gamma + X_i \Phi + X_i^I \Upsilon + \alpha_c + \alpha_{cr} + \epsilon_{iec} \quad (1)$$

where y_{iec} is the response by individual i with ancestral ethnicity e in country c . irrigation_i is irrigation potential in a 200 km circle around the reported latitude and longitude of the ancestral ethnic society of individual i , X_i^e denotes various historical ethnographic controls (plow use, presence of large animals, economic complexity, political hierarchy, agricultural suitability in the society) in this ancestral ethnic society, X_i is a vector of individual controls (age, age squared, and gender), X_i^I is a vector of interviewer controls (age, age squared, gender, and language used for the interview), α_c is a country characteristics fixed effect (ruggedness, soil quality, distance from coast), α_{cr} a region fixed effect (Eastern Africa, Western Africa,

Southern Africa, and Central Africa), and ϵ_{iec} is a robust standard error term. Standard errors are clustered at the country-ethnic group level.

Columns (1)-(4) in Table 1 report results for the survey question “When jobs are scarce, men should have more right to a job than women?”. Columns (5)-(8) report results for the question “Women should have the same rights as men to own and inherit land?”. Country characteristics and region fixed effects are included in all columns, following Anderson (2018). We sequentially add ethnographic controls, individual controls, and interviewer controls. The ethnographic controls address the possibility that the results reflect differences in historical economic or political development. For example, economic complexity or political hierarchy may conceivably be associated with gender inequality.

The respondents are on average relatively more favorable to equal property rights than to equal participation in the labor market, as suggested by the means. Greater irrigation potential is associated with responses less favorable to women across all columns. The effects appears stronger for female property rights (columns (5)-(8)). [Table 1]

4.2 Cross-country Evidence

While the Afrobarometer provides individual level data for a cross-section of countries, using a sample restricted to a single continent may involve limitations. For example, the average income is relatively low, the reliance on a more limited number of sectors (agriculture, resource extraction), or colonial history may possibly limit the applicability of the results. This section uses a cross-country sample to study the effect of ancestry adjusted irrigation potential on female labor force participation rates and female property rights, respectively. The ancestry adjustment is based on population movements after 1500 AD, following Putterman and Weil (2010). The empirical OLS model equals

$$y_{ir} = \alpha + \beta_1 \text{irrigation}_i + X_i^C \Gamma + X_i^g \Phi + \epsilon_{ir} \quad (2)$$

where y_{ir} is either the female labor force participation in country i in year 2000, or the level of female property rights in country i averaged over years 2000 and 2018. irrigation_i is irrigation potential in country i , X_i^C denotes country specific controls (e.g., region fixed effect and plow use), X_i^g denotes a vector of geographical controls (e.g. landlockedness, average temperature, average precipitation, and average elevation). Regions are Africa, Asia, Europe, North America, Oceania, South America, and Sub-Saharan Africa. Standard errors are clustered at the

region level. We expect β to be negative, i.e., higher irrigation potential is associated with a lower female labor force participation. Figure 2 presents the unconstrained relationship between irrigation potential and female labor force participation. The linear fit shows a negative association between irrigation potential and female labor force participation. [Figure 2]

Table 2 reports the ancestry adjusted cross-country OLS results. Culture may permeate neighboring countries' borders. To address possible concern of spatial autocorrelation between female labor force participation and (ancestry adjusted) irrigation potential, we provide Conley (1999) standard errors in square brackets (cutoff 500 km). The Conley standard errors are similar to the ordinary robust standard errors, indicating that spatial autocorrelation is not a concern. Column (1) reports the unconditional association between irrigation potential and female labor force participation. The estimated irrigation potential coefficient of -26.25 is significant at the 1% level. This is over 51 percent of the sample mean and around 1.66 standard deviations in female labor force participation. To put this in perspective, with a hypothetical 100% irrigation potential, the female labor force participation in Sweden (FLFP = 58.2%; irrigation potential = 0) or Finland (FLFP = 58.3%; irrigation potential = 0) would equal the one in Afghanistan (FLFP = 31.3%; irrigation potential = 0.72) or Algeria (FLFP = 31.3%; irrigation potential = 0.79). Column (2) accounts for ancestry adjusted traditional plow use. Column (3) accounts for several geographical controls. Figure 3 plots the estimated partial effect of irrigation potential on female labor force participation from column (3). To account for unobserved regional heterogeneity, column (4) adds continent fixed effects. The irrigation potential coefficient declines, which indicates regional heterogeneity in female labor force participation. Irrigation potential is negative and significant in columns (1)-(4). [Figure 3]

Figure 4 presents the unconstrained relationship between irrigation potential and female property rights. The linear fit shows a negative association between irrigation potential and female property rights. Columns (5)-(8) in Table 2 study female property rights. Columns (6) adds plow use, and column (7) includes geographical controls. Figure 5 plots the estimate from column (7). Column (8) adds continent fixed effects. Column (8) suggests that moving from zero to full irrigation potential is associated with a 0.87 point decrease in the level of female property rights. This is 75.2% of the sample mean and 81.8% of a standard deviation in female property rights. Table 2 reports the Altonji et al. (2005) statistic for the importance of selection

on unobservables relative to observables, which is at least 2.2 in these specifications.¹⁶ This gives us reasonable confidence that unobserved geographical variation does not drive the results. Tables C1-C3 in the Online Appendix C provides further robustness analysis and discussion.¹⁷ [Table 2] [Figures 4, 5]

4.3 Evidence from European Immigrants

We now turn our attention to the children of European immigrants, i.e. 2nd generation immigrants. This sample has the advantage that all respondents in each country have grown up with similar institutions.¹⁸ One possible concern is selection effects related to parental migration. However, in our case this is likely yield an underestimate of the actual effects. Unmarried men are unlikely to leave their home country due to gender inequality. Married men may leave due to gender inequality affecting their wives. However, in this case they should be less likely to transfer cultural views consistent with gender bias, not more likely. Unmarried female migrants may leave due to gender inequality, but they should be less likely to harbor views negative to women. Tied migration by trailing wives likely implies less influence on the migration decision, and selection effects are consequently again of less concern.

The influence of potential irrigation on the children of immigrants is estimated using both logit and ordered logit regression as follows:

$$y_{i,d,c} = \alpha_d + \alpha_t + \beta \text{irrigation}_c + X_c^c \Gamma + X_i \Phi + \epsilon_{i,d,c} \quad (3)$$

where $y_{i,d,c}$ denotes the gender attitude by respondent i , a child of an immigrant currently residing in destination country d who comes from country c . α_d and α_t are destination-country

¹⁶ A test statistic greater than unity implies that to reduce the estimated coefficient on irrigation potential to zero, unobservables must explain more of the covariance between irrigation potential and the female labor force participation (or female property rights) than the included control variables.

¹⁷ The robustness analysis in Tables C1-C3 addresses omitted variable bias by including the following control variables: years since the Neolithic transition; technology in agriculture (1500AD), GDP per capita (log), years in school, common law, fertility, age dependency ratio, Muslim population, precipitation variation, plow positivity, plow negativity, OPEC dummy, agricultural suitability. Since the plow is included in the measure of technology in agriculture (1500 AD), we drop plow use in columns (2), (7), (10), and (15) of Table C1. We believe the endogeneity of location choice by groups with biased gender views is not likely to be a problem. For example, since hunter and gatherer groups had high gender equality (Iversen and Rosenbluth, 2010), gender inequality is likely to have emerged after the Neolithic transition, not before. Moreover, areas with high irrigation potential (but lacking irrigation infrastructure) were not desirable or feasible areas for agriculture, and groups are thus likely to avoided such areas. In any case, years since the Neolithic transition controls for length of stationary settlement.

¹⁸ Wang (2019) finds divergent gender attitudes among immigrant groups in Britain, but differences decline in the 2nd generation.

and year-of-survey fixed effects. $irrigation_c$ is irrigation potential in the origin country c . X_c^C denotes a vector of country specific characteristics, and X_i denotes a vector of individual specific characteristics. Errors are clustered at the country of origin level.

We use two measures from the European Social Survey (ESS) data, collected biennially for all European countries. First, the survey provides the following statement to the respondents: “When jobs are scarce, men should have more right to a job than women.” This question measures who is viewed as breadwinner, or who has a more important career. The respondents can choose among “agree strongly,” “agree,” “neither agree nor disagree,” “disagree,” and “disagree strongly.” We construct two measures using these responses. The first measure takes values of 1 to 5 for each of these responses; ordered logit is used. The second measure is an indicator equal to 1 for the first two options and 0 for either of the last two options. Respondents who neither agree nor disagree with this statement are excluded from the latter measure. Logit regression results are reported in Table 4, Panels A for female respondents, and Panel B for male respondents. Columns (1)-(4) use the father’s ancestry, while columns (5)-(8) use the mother’s ancestry. Even numbered columns include language fixed effects and a respondent citizenship indicator.

Irrigation potential is positive and significant in three columns in Panel A (female respondents), all of which use the father’s ancestry. Fathers appear to transfer irrigation-related gender attitudes to their daughters, but mothers do not. Citizenship does not appear to matter, i.e. there is little evidence of cultural assimilation. Panel B suggests that irrigation potential in both the father’s and the mother’s country is important for male respondents’ attitudes, although the mother’s ancestry appears less influential (columns (7) and (8) report insignificant results). The significant coefficients on irrigation potential are up to 50% greater in columns (1)-(4), Panel B, using the father’s ancestry.

Panels C and D analyze answers to a second statement from the ESS surveys: “Women should be prepared to cut down on paid work for sake of family”. This statement reflects the degree to which the respondent gives priority to women taking care of the family (children, presumably) at the expense of their income and careers. The possible answers and classifications are analogous to Panels A and B. Panel C reports results for female respondents, and Panel D for male respondents. Panel C suggests that female respondents’ views are influenced somewhat more by their mothers’ ancestry than their fathers’ on this issue, although the difference is not substantial. Specifically, while three out of four coefficients are significant for the mother’s ancestry (columns (6)-(8)), two coefficients are significant for the father’s ancestry (columns (3)-(4)). The coefficient sizes are close to 50% greater in columns (7) and

(8) than in (3) and (4). Citizenship is associated with a strong opposing effect on gender attitudes in three of the relevant columns, suggesting cultural assimilation. Panel D indicates that male respondents are affected relatively more by the irrigation potential in their father's ancestry, with irrigation potential significant in columns (1)-(5) and (7). The coefficient sizes are roughly similar across the significant coefficients, however. Citizenship does not affect male attitudes in Panel D.

The influence of irrigation potential in the parents' ancestral country on gender attitudes thus appears persistent across generations. The strongest cultural transmission appears to occur to 2nd generation male immigrants. This channel is strongest via the fathers, but the mothers also transfer gender views associated with irrigation agriculture. Males' attitudes do not assimilate over time (as measured by citizenship), while females' views of their family commitments appear to moderate over time. [Table 3]

4.4. Evidence from US immigrants

The American Community Survey (ACS) provides responses to questions on labor market outcomes by the female children of US immigrants.¹⁹ ACS includes socioeconomic information on the respondents and their immigrant parents. Our 2000-2018 sample consists of two categories denoted 2nd generation immigrants and 1.5 generation immigrants, respectively. 2nd generation immigrants are born in the US, and at least one parent is foreign born. 1.5 generation immigrants are born abroad, but immigrated to the US before the age of six. Children born abroad to US citizens are excluded. As discussed above for 2nd generation European migrants, we believe that selection issues may be a relatively minor issue in the case of gender inequality.

We estimate the following logit model:

$$y_{i,c} = \alpha_s + \alpha_t + \beta \text{irrigation}_c + X_c^c \Gamma + X_i \Phi + \epsilon_{i,c} \quad (4)$$

where $y_{i,c}$ denotes labor force participation by female respondent i , a female child of an immigrant from origin country c residing in the US at the time of the ACS. Participation in the labor force equals 1, not participating equals 0. α_s and α_t are state-of-residence and year-of-survey fixed effects, respectively. irrigation_c is ancestry adjusted irrigation potential in the

¹⁹ By providing evidence for both European and US immigrants, we provide support for the view that the transmission and persistence of cultural traits in focus occur independently of the host continent's culture and policy environments.

country of origin, X_c^C denotes a vector of country specific characteristics (age, age squared, education level, and marital status), and X_i denotes a vector of individual specific characteristics (age, age squared, marital status, and education fixed effects). Errors are clustered at the state level and ancestral country, i.e. their interaction.

Panel A, Table 4, provides evidence for 1.5 generation immigrants who arrived in the US before age 6, and uses the irrigation potential in their country of birth. Panels B and C present results for 2nd generation immigrants only using irrigation potential in the mother's or father's country of birth, respectively. All columns include geographical controls (absolute latitude, ruggedness, ancestry adjusted plow use, and potential crop yield (post-1500) for the country of origin), and state and year fixed effects. Column (2) adds individual controls (age, age squared, marital status, and education fixed effects), and column (3) includes language fixed effects (language spoken at home). Parents' education fixed effects are included in column (4); this reduces the number of observations sharply, especially for the sample of 1.5 generation immigrants. Race fixed effects are instead included in column (5). In columns (6) and (7) we exclude sample outliers by dropping origin countries with female labor force participation rates in the bottom or top 10% (female labor force participation below 24% and above 70%), respectively. Column (8) includes only source countries with at least 50,000 first generation immigrants, and column (9) drops immigrants from the five largest source countries (China, El Salvador, India, Mexico, and the Philippines). Column (10) restricts the sample to females aged 25-45 only. These individuals are in their prime working age and the most likely to participate in the labor market. Women in this age group are likely to have completed their education but are not close to retirement. If cultural attributes affect labor force participation rates, the effect may be relatively smaller in this group. Finally, column (11) controls for the labor force participation rate in the parent's country of origin, which Fernández and Fogli (2009) find influences immigrants' labor force participation.

Irrigation potential in the country of ancestry is negatively and significantly associated with current female labor force participation in all columns except column (10), Panel B. The mother-to-daughter attitude transmission appears relatively weaker in the sample of 2nd generation 25-45 year old female immigrants. However, the link between fathers and 25-45 year old daughters remains significant. Note also the significant effect for 1.5 generation immigrants. [Table 4]

4.5 Evidence from India

This section presents individual level results using data from rural India. A measure of labor force participation is unavailable. However, we study the likelihood of working on tasks other than being a homemaker. Even with this measurement error we still obtain consistent estimates, albeit with large standard errors.

We estimate the following logit regression model:

$$y_{i,c} = \beta_0 + \beta_1 \text{irrigation}_c + X_i\Phi + X_c^G\Gamma + \delta_s + \epsilon_{i,c} \quad (5)$$

where $y_{i,c}$ is the response by individual i in cluster c . irrigation_c is the irrigation potential in a circular area (radius 50 km) surrounding DHS survey cluster c . X_i denotes a vector of individual specific characteristics (age, age squared, marital status, education level, religion, language, and caste category), X_c^G denotes a vector of geographical controls (average precipitation, average temperature, and average elevation), and $\epsilon_{i,c}$ are the standard errors clustered at the DHS cluster level. We include each respondent's sample weight. This avoids giving more weight to clusters having a greater number of units surveyed, or less weight due to refusal or no response from some respondents. We also include stratification identification information from the survey so that we estimate more homogenous clusters.

Columns (1)-(6) in Table 5 report the association between irrigation potential and the likelihood of a female working. Column (1) presents the unconditional association. Column (2) accounts for individual level controls, in particular age, religion, language, education level, and family wealth category. Column (3) accounts for mean temperature, mean precipitation and elevation, and column (4) for the proximity to water and night-time luminosity (proxy for local income). Water closer to the home raises the probability of a female working, while luminosity has a negative effect. Column (5) accounts for the length of the growing season, which affects the intensity of agricultural work. The length of the growing season has a positive association with the likelihood of females working more in non-domestic activities. Column (6) combines all controls. Irrigation potential is negative and significant at least at the 5% level in columns (1)-(6). Finally, the placebo analysis in column (7) shows that irrigation potential has no effect on the probability of males working. The length of the growing season has a negative correlation with the probability of men working. A shorter growing season is associated with more intensive production, which favors males. Table C4 provides a robustness analysis reporting reduced form estimates using a measure of actual irrigation in India, and an IV probit analysis. [Table 5]

5. Possible Mechanisms

In this section, we discuss possible mechanisms for the effect of irrigation potential on female labor force participation and female property rights, respectively.

5.1. *Female participation on pre-industrial agriculture*

Boserup (1970) argues that males have historically captured technologies complementary to irrigation, which increased their productivity in irrigated agriculture. Women worked with less advanced technology and were relatively less productive. Irrigation activities may also be dangerous (including to accompanying children), and may involve confrontations with neighbors over water allocation. These factors all contribute to male labor specialization in irrigated agriculture. While women still worked in agriculture to some degree, their work gravitated toward the homestead, e.g. specializing in processing cereals and child care, spending their lives mainly indoors or in the courtyard with little contact with non-relatives (Ember, 1983).²⁰

The Standard Cross-Cultural Sample (SCCS), compiled by Murdock and White (1969), has data from 186 separate pre-industrial societies.²¹ The *Ethnographic Atlas* by Murdock (1967) has data on 1,267 pre-industrial societies from around the world. The *Atlas* contains little information about the societies themselves, however. The measure of the female-relative-to-male participation in overall agricultural production takes values from 1 to 5, where relative participation is coded as follows. 1: males exclusively; 2: males predominantly; 3: equally; 4: females predominantly; and 5: females exclusively. The dependent variables. The measure of the relative time and effort spent on subsistence activities by females varies from 1 to 3, where 1: men expend more; 2: men and women expend roughly equal; 3: women expend more.

²⁰ Ember (1983) argues that intensive agriculture raised fertility rates, increasing women's workload and barring them from working outside the home during late pregnancy. Infant and child mortality was high. As primary providers of child care, women may have been hindered from working the fields by the risks involved with having their young offspring close to canals and ditches. While women may leave some young offspring with caretakers at home, they would need to return home during the work day to nurse. This may be difficult to combine with irrigation, which likely required near-constant attention to the flowing water and neighboring farmers' incentive to divert the flow. Leaving large draught animals in the field may also have been infeasible.

²¹ The SCCS provides a representative sample of world cultures "for the earliest period for which satisfactory ethnographic data are available or can be constructed" (Murdock and White, 1969, p. 340). The years of observation are in the 19th or early 20th century. Murdock and White (1969, p. 329) suggest that "cultural independence of each unit in terms of historical origin and cultural diffusion could be considered maximal with respect to the other societies in the sample".

While the SCCS and the *Atlas* contain information on the centroid of each society, the measurement of the precise location may involve errors. Moreover, information about the land area covered by these pre-industrial societies is missing. We use a buffer zone of 200 km around the centroid in order to construct the measure of irrigation potential and control variables (Alesina et al., 2013). The ethnographic controls include suitability of the local environment for agriculture, the presence of large domesticated animals, the proportion of the local environment that is tropical or subtropical, an index of settlement density, and an index of political development.

The mean variable values are provided in the table heading of Table 6. While column (1) uses data from the *Ethnographic Atlas*, the remaining columns use SCCS data. Columns (1)-(4) use female overall participation in agriculture as outcome variable, column (5) studies the overall relative female contribution to subsistence in time and effort, and columns (6)-(8) provide estimates for crop tending, harvesting, and milking, respectively. All columns include fixed effects for the century-of-observance and language, ethnographic controls including plow use, suitability of the local environment for agriculture, the presence of large domesticated animals, the proportion of the local environment that is tropical or subtropical, economic complexity, and political development.

Column (1) irrigation potential has a negative and statistically significant influence on relative female participation in agricultural activities overall. The effect of moving from zero to complete irrigation potential equals -1.45, which is substantial given the 3.04 mean. The effect is stronger in column (2), using SCCS data. Column (3) adds a dummy for whether cereals are the main crops, which Ember (1983) and Hansen et al. (2015) suggest influences female labor force participation. The coefficient on irrigation potential rises further. Column (4) controls for societies with formal class stratification systems, where males may be less likely to participate in agricultural field work. The two added controls are insignificant, while irrigation potential remains significant. Column (5) suggests that the female relative contribution to subsistence activities were lower in societies with greater irrigation potential. This reflects a shift away from agricultural field activities towards greater domestic and child rearing duties. Columns (6)-(7) provide evidence that irrigation is associated with a decline in female participation in some important agricultural activities outside the home, while column (8) suggests the opposite effect occurred to milking which occurs closer to home. Table C5 in online Appendix C provides cross-country OLS evidence that irrigation is associated with

restrictions on women's freedom of movement within a country, using data from Coppedge et al. (2019).

Overall, the results are consistent with women staying closer to the homestead in irrigated areas during the pre-industrial time period. This suggests one possible partial mechanism which links irrigation to lower contemporary female labor force participation rates and related attitudes. The division of labor appears to have persisted through intergenerational cultural transmission. [Table 6]

5.2. Warfare

Irrigation water is frequently a common pool resource. Since water consumption by upstream communities may affect consumption by downstream communities, especially in times of drought, conflicts are likely to occur. Anecdotal evidence includes Iraq and the Andes.²² Irrigation agriculture also led to a storable surplus and relatively more valuable land, providing incentives for raids and external warfare by other groups (e.g., Ember, 1982; Ang and Gupta, 2018). We hypothesize that irrigation societies had a greater incidence of violent external conflict. This yielded a greater demand for men due to greater muscle strength and aggressiveness, improving their social standing (Chagnon, 1988; Ramos-Toro, 2019). Ramos-Toro (2019) provides evidence of a negative relationship between exposure to conflict and contemporary female labor force participation.²³ Warfare may also have been associated with reduced female mobility, and stricter social norms and restrictions on women's labor market participation outside the home.

Table 7 provides some support for this hypothesis. Columns (1)-(3) utilize society level data from the SCCS (Murdock and White, 1969), while columns (4)-(9) use historical district level data from India. The dependent variable in column (1) is a measure of external warfare. We focus on societies with agricultural activities. We recode the Murdock and White (1969) external warfare measure as follows: it takes a value of 1 if external war is 'frequent, occurring at least yearly' or 'common, at least every five years'; it takes a value of zero if 'occasional, at

²² Fernea (1963) describes the constant conflicts over water among Iraqi tribes, which ended only after British occupation. Fernea (1963, p. 79) quotes a report by the British colonizers, *Administration Report of Diwaniyah District, 1918* (Bagdad, 1918), where cereal cultivating neighboring groups had "from time immemorial held a reputation for reckless lawlessness, which they well merited." These groups had never cooperated or agreed on a fair distribution of water, but continually been in conflict. Billman (2002) discusses irrigation and increased tribal conflict in Peru during 1-400 AD, and Bolin (1990) study more recent conflicts in an Andean irrigation system. Chagnon (1988) and Glowacki and Wrangham (2015) report that renowned male warriors had greater status, more wives and offspring, suggesting an influence on gender roles.

²³ Oldenburg (1992) discusses an association between violence and son preference in India.

least every generation' or 'rare or never'. The sample size declines to 54. This renders language and century fixed effects and the inclusion of tropical climate infeasible in this analysis. The results should thus be interpreted with these drawbacks in mind. The logit model in column (1) suggests that irrigation potential is positively associated with external warfare. Columns (2)-(3) present ordered logit regressions. Column (2) is the basic model from Table 1 with female participation in overall agriculture as the outcome variable (but with a smaller sample size). External warfare is negative and significant in column (3), while the irrigation potential point estimate declines modestly (in absolute value) from -2.00 to -1.67. This provides some support for the hypothesis that a history of external warfare is a partial channel between irrigation and female participation in agriculture in pre-industrial societies.

Columns (4)-(9) provide district level evidence from India in support of the proposed warfare mechanism. In rural India, most households working outside the home are engaged in agricultural sector work (Kapsos et al., 2014). We measure female employment outside the home by the ratio of the population of female agricultural workers to the total female population in year 2011. In column (4), war count is a measure of the total number of land battles over years 610-1962 occurring within a distance of 50km from the district, geocoded using Jacques (2007).²⁴ In column (7), the period of observations for war count is instead restricted to 1001-1867AD. Jacques (2007) records relatively few instances of wars before 1001 (data quality may be an issue), and in 1858 the British Crown took over the administration of India from the British East India Company. The wars for accession of the native states ceased after 1857. Columns (4) and (7) present negative binomial regressions, while columns (5), (6), (8), and (9) are generalized linear model regressions. Geographical controls (temperature, precipitation, latitude, area, land quality, and nightlight luminosity) and language fixed effects (largest language group within the district, reflecting cultural variation across districts) are included. One benefit of using data on India is the low interstate migration rate, which maintains long-term cultural differences (Kone et al., 2018).

Column (4) suggests a positive association between a district's irrigation potential and the historical experience with wars. When war count is included in column (6), the (absolute value of the) irrigation potential point estimate declines relative to column (5), from -0.137 to -0.115, while war count is negative and significant. The takeaway from columns (7)-(9) is similar. These findings provide some support for the hypothesis that a history of warfare is a possible

²⁴ Jacques (2007) recodes all conflicts in India for which written evidence is available and which can be verified by at least two independent sources.

partial mechanism linking irrigation and female participation in agriculture in contemporary India. [Table 7]

5.3. *Autocracy*

Next, we provide evidence that historical irrigation may affect contemporary female property rights regimes via an autocracy channel. Underpinned by resource curse theory, Bentzen et al. (2017) argue that historical irrigation agriculture raised the likelihood that a pre-industrial society was ruled by an elite based on the control of a natural resource. This has yielded lower levels of contemporary democracy. Autocracies have weaker property rights (Gradstein, 2007), and Fish (2002) suggests that authoritarianism is associated with negative outcomes for women.²⁵

To study the determination of female property rights, we utilize the standard general measures of democracy, Polity2. The male political majority (in both democracies and autocracies) is likely to determine the extent of female property rights. Table 8 shows that democracy works as channel for the effect of irrigation potential on contemporary female property rights. Column (1) establishes that irrigation potential has a negative effect on democracy, measured by Polity2. In column (2), irrigation potential has a negative effect on female property rights as shown above, but this effect disappears when we include democracy in column (3). This suggests that the effect of irrigation on female property rights works at least partially through the democracy channel. In contrast, while democracy has a positive association with male property rights in column (5), there is no evidence that democracy works as a link between irrigation and male property rights. [Table 8]

Table C6 in the online appendix provides additional evidence that attitudes, actual female political participation rates, and the freedom to discuss politics are negatively associated with irrigation potential. The first column uses a statement from the Afrobarometer as outcome variable, and the remaining three columns use variables from Coppedge et al. (2019).²⁶

5.4. *Individualism vs. Collectivism*

²⁵ A simple correlation using SCCS data (Murdock and White, 1969) from 93 societies provides some moderate support for this mechanism in pre-industrial societies. The correlation between the degree of elite stratification (measured on a five-point scale, with higher values representing more autocracy) and property control for women (women have either “high control” or “low control” over property) equals -0.21 (significance level 0.04).

²⁶ Ember (1983) discusses how in pre-industrial societies female labor specialization caused women to have fewer contacts with the outside society, building fewer relationships and receiving less information about the world. In turn, this hindered their political participation. Moreover, in irrigated areas, men have historically monopolized leadership of water management organizations where water allocation rules were decided and enforced.

This section investigates the cultural dimension of individualism vs. collectivism as a possible potential mechanism. Buggle (2020) finds that irrigation is negatively correlated with individualism, because irrigation required constant collaboration which yielded collectivism. Gorodnichenko and Roland (2017) argue that the degree of individualism influences societies' institutional choices. In particular, they find that individualism has a positive association with the level of protection against expropriation risk, a measure of property rights. Binder (2019) reports that collectivism is correlated with a belief in traditional gender roles.

Table 9 explores whether individualism vs. collectivism may function as a partial channel between irrigation potential and contemporary female property rights. We use Hofstede et al.'s (2010) measure of individualism and Coppedge et al.'s (2019) measure of property rights. Irrigation potential has a negative correlation with individualism in column (1) and with female property rights in column (2). This effect declines moderately (in absolute value) when individualism is entered in column (3), from -1.75 to -1.64. However, a similar pattern occurs for male property rights in columns (4) and (5), from -1.67 to -1.57. It appears that the individualism vs. collectivism dimension of culture may provide a partial link between irrigation potential and property rights for both genders. Thus, we do not find strong evidence that this link is stronger for female than for male property rights. To investigate this further, Table C7 in the online appendix includes both individualism and democracy as potential mechanisms. It appears that both mechanisms work for female property rights, but only democracy constitutes a channel for male property rights. [Table 9]

6. Conclusion

We test the hypothesis that female labor force participation and female property rights are negatively associated with ancestral irrigation agriculture. Ancestral irrigation, actual female labor force participation, and attitudes to such participation, have negative associations in contemporary African and Indian populations, among 2nd generation European and 1.5 and 2nd generation US immigrants, and in cross-country data. Moreover, ancestral irrigation is negatively associated with attitudes to female property rights in Africa and with female property rights across countries. The cultural link between ancestral irrigation and gender-based norms appears persistent.

We propose four partial mechanisms for the effect of irrigation on female labor force participation and female property rights, respectively. First, starting in the pre-industrial era irrigation affected the pattern of gender-based labor specialization, where the men primarily worked the fields and the women worked in and around the homestead. Second, areas with

irrigation were historically more frequently involved in external warfare, due to the common pool nature of irrigation water. Warfare raised the social status of males and tended to confine women to the home. These two partial mechanisms jointly resulted in cultural beliefs that have persisted until today, leading to lower female labor force participation. Finally, ancestral irrigation is partially linked to weaker female property rights via associations with both autocracy and collectivism.

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Table 1: Irrigation potential and evidence from the Afrobarometer

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	“When jobs are scarce, men should have more right to a job than women?”				“Women should have the same rights as men to own and inherit land?”			
Mean	2.69				3.86			
Irrigation potential	0.47** (2.15)	0.47** (2.02)	0.48** (2.07)	0.56** (2.14)	-0.77*** (-2.72)	-0.73** (-2.56)	-0.73*** (-2.58)	-0.80*** (-2.78)
Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ethnographic controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Individual controls	No	No	Yes	Yes	No	No	Yes	Yes
Interviewer control	No	No	No	Yes	No	No	No	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16605	16605	16605	16605	16753	16753	16753	16753

Notes: This table presents ordered logit results. Plow use comes from the *Ethnographic Atlas* (Murdock, 1967). Individual controls are age, age squared, and gender. Interviewer controls are age, age squared, and gender of the interviewer, and language of interview. Ethnographic controls are plow use, presence of large animals, economic complexity, political hierarchy, and agricultural suitability (Murdock, 1967). Standard errors are clustered at country-ethnic group level. Country characteristics are the ruggedness, soil quality, distance from coast. Regions are Eastern Africa, Western Africa, Southern Africa, and Central Africa. All estimates include constant term, not reported for brevity. Survey responses in columns (1) to (8) can take five values: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree. t statistics in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: Irrigation potential, female labor force participation and female property rights

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Female labor force participation				Female property rights			
Mean	50.95				1.16			
Irrigation potential	-26.25*** (-6.65) [-6.22]	-23.37*** (-10.06) [-6.01]	-22.48*** (-5.38) [-4.74]	-20.49*** (-5.81) [-3.61]	-1.26** (-2.59) [-4.11]	-1.45*** (-4.19) [-5.11]	-1.09*** (-5.26) [-3.40]	-0.87*** (-3.86) [-2.25]
Plow use		-12.94*** (-4.73)	-16.42*** (-4.93)	-10.47** (-3.58)		1.01** (2.81)	0.33 (1.15)	0.13 (0.91)
Landlocked			8.28 (1.39)	6.69 (1.18)			-0.39** (-2.79)	-0.35** (-3.19)
Temperature			-0.34* (-2.09)	-0.70*** (-5.98)			-0.06*** (-6.00)	-0.04* (-1.98)
Precipitation			0.01 (0.18)	0.03 (0.69)			0.00 (0.91)	0.00 (0.50)
Elevation			-0.01 (-0.12)	-0.05 (-0.54)			-0.01*** (-7.32)	-0.01** (-3.10)
Region FE	No	No	No	Yes	No	No	No	Yes
R ²	0.19	0.30	0.39	0.46	0.10	0.24	0.40	0.45
Observations	165	165	162	162	159	159	159	159
Altonji et al. test statistic		8.1	5.9	3.6		7.6	6.4	2.2

Notes: This table presents OLS regressions of irrigation potential (ancestry adjusted) on female labor force participation in columns (1) through (4). Columns (5) through (8) presents OLS results for irrigation potential (ancestry adjusted) on property rights for women. Female labor force participation is measured as percentage of females in the workforce in 2000, and ranges from 0 to 100. Property rights for women is measured as a response to the question “Do women enjoy right to property?”, measured on a scale 0 to 5, converted to a zero-mean variable (range -2.79 to 2.69). Plow use is ancestry adjusted. All specifications contain a constant term (unreported). Region fixed effects are for Africa, Asia, Europe, North America, South America, and Oceania. *t* statistics in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. *t* statistics based on Conley (1999) standard errors are in square brackets (cutoff = 500 km). The Altonji et al. (2005) test statistic takes columns (1) and (5) as the restricted model, respectively.

Table 3: Irrigation potential and gender attitudes among 2nd generation European Immigrants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable:	“When jobs are scarce, men should have more right to a job than women” survey response, 2004-2017							
	Father’s country				Mother’s country			
	1-5 scale		Indicator		1-5 scale		Indicator	
Panel A (Female sample)								
Irrigation potential	0.27** (1.98)	0.33** (2.24)	0.23 (1.36)	0.35* (1.86)	0.20 (1.34)	0.23 (1.36)	0.06 (0.28)	0.19 (0.79)
Citizen		-0.11 (-0.57)		-0.09 (-0.44)		-0.09 (-0.40)		-0.19 (-0.57)
Observations	5043	5042	4415	4415	2588	2587	2272	2272
Panel B (Male sample)								
Irrigation potential	0.59*** (3.18)	0.58*** (3.07)	0.56*** (2.79)	0.55** (2.42)	0.38** (2.24)	0.41** (2.04)	0.34 (1.26)	0.35 (1.15)
Citizen		-0.07 (-0.62)		-0.14 (-0.80)		0.04 (0.20)		0.02 (0.07)
Observations	4310	4310	3548	3548	2247	2247	1843	1843
Dependent Variable:	“Women should be prepared to cut down on paid work for the sake of family” survey response, 2004-2017							
Panel C (Female sample)								
Irrigation potential	0.18 (1.20)	0.22 (1.43)	0.29* (1.73)	0.30* (1.79)	0.27 (1.59)	0.30* (1.65)	0.44** (2.15)	0.44** (2.04)
Citizen		-0.31* (-1.74)		-0.60*** (-2.83)		-0.31 (-1.56)		-0.57** (-2.53)
Observations	3734	3733	2979	2978	1895	1894	1518	1517
Panel D (Male sample)								
Irrigation potential	0.54** (2.41)	0.41** (1.99)	0.68** (2.27)	0.51** (1.97)	0.51* (1.92)	0.38 (1.45)	0.64* (1.80)	0.49 (1.41)
Citizen		-0.11		-0.20		0.01		0.13

		(-0.74)		(-0.99)		(0.10)		(0.68)
Observations	3138	3137	2426	2425	1609	1608	1279	1278
Destination country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Language FE	No	Yes	No	Yes	No	Yes	No	Yes
Historic controls of origin	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents logit (columns (3), (4), (7), and (8)) and ordered logit (remaining columns) estimates. An observation is the child of an immigrant, reported in four waves of the European Social Survey (ESS). The four waves include the second (2004–2005), the fourth (2008–2009), the fifth (2010–2011), and the eighth (2016–2017). Irrigation potential is for the country of origin and is ancestry adjusted. All regressions control for 33 European country-of-destination fixed effects, three survey-year fixed effects for four different survey waves, historic country of origin controls (plow use, economic complexity, large animals, and political hierarchy), and individual controls (age, age squared, the number of years of education). Plow use is the fraction of citizens with ancestors that used the plow in pre-industrial agriculture in the country of origin of the children of immigrants (father, mother) and is ancestry adjusted. Standard errors are clustered at the country of origin level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Irrigation potential and labor force participation among 1.5 and 2nd generation female US immigrants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dependent Variable:	In the labor force?										
	Panel A: 1.5 generation immigrants; origin: country of birth										
Irrigation potential	-0.60*** (-7.34)	-0.53*** (-8.19)	-0.24*** (-3.40)	-0.42*** (-2.82)	-0.22*** (-3.11)	-0.40*** (-4.08)	-0.22*** (-3.06)	-0.24*** (-3.03)	-0.13* (-1.94)	-0.36*** (-3.52)	-0.31*** (-3.53)
FLFP - source country											-0.14 (-1.33)
Observations	232494	232494	232467	23495	232467	227664	221367	226458	165295	127526	232467
R ²	0.00	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	Panel B: 2 nd generation immigrants; origin: mother's country of birth										
Irrigation potential	-0.42*** (-3.95)	-0.29** (-2.41)	-0.40*** (-3.88)	-0.31*** (-2.82)	-0.41*** (-3.90)	-0.48*** (-2.86)	-0.40*** (-3.81)	-0.41*** (-3.88)	-0.38*** (-3.52)	-0.21 (-1.30)	-0.45*** (-3.78)
FLFP - source country											-0.10 (-0.76)
Observations	162730	162730	162696	93470	162696	158836	152653	143150	92833	80256	162696
R ²	0.01	0.05	0.06	0.05	0.06	0.06	0.06	0.05	0.07	0.07	0.06
	Panel C: 2 nd generation immigrants; origin: father's country of birth										
Irrigation potential	-0.36*** (-3.38)	-0.24** (-1.97)	-0.27*** (-2.61)	-0.33*** (-3.00)	-0.29*** (-2.81)	-0.60*** (-3.34)	-0.26** (-2.50)	-0.27** (-2.52)	-0.20* (-1.82)	-0.29* (-1.94)	-0.32*** (-2.70)
FLFP - source country											-0.10 (-0.70)
Observations	108394	108394	108359	94595	108359	104354	99881	103342	53212	52734	108359
R ²	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0.05
Geographic Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Language FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parents' Education	No	No	No	Yes	No	No	No	No	No	No	No
Race FE	No	No	No	No	Yes	No	No	No	No	No	No

Sample	Global	Global	Global	Global	Global	Drop low 10% of FLFP	Drop high 10% of FLFP	Number of immig. > 50 K	No immig. from 5 largest sources	Age 25- 45 years	Global
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Notes: This table presents logit estimation results. An observation is the child of an immigrant, reported in 19 waves of the American Community Survey for 2000-2018. The dependent variable is a dummy which equals 1 if the respondent is in the labor force, 0 otherwise. Irrigation potential is for female immigrant's country of origin (details given in the data appendix). Irrigation potential is ancestry adjusted. Geographic controls are absolute latitude, ruggedness, potential crop yield (post-1500) for country of origin, and plow use (ancestry adjusted). Individual controls are age, age squared, marital status, and education fixed effects. Language FE is the language fixed effect for the language spoken at home. Race fixed effect controls are for Black or Caucasian. Parents' education is the education fixed effect for the parents. Standard errors are clustered at ancestry and state level. *t* statistics in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Irrigation potential and work in rural India

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Female working? 0.34				Male working? 0.82
Mean							
Irrigation potential	-0.24*** (-5.45)	-0.12** (-2.20)	-0.12** (-2.03)	-0.19*** (-3.00)	-0.12** (-2.02)	-0.19*** (-3.00)	0.07 (0.92)
Proximity to water				0.08*** (4.18)		0.08*** (4.18)	0.06** (2.40)
Night-time luminosity				-0.03*** (-2.61)		-0.03*** (-2.61)	0.02 (1.29)
Growing season					0.02*** (2.82)	0.01*** (2.73)	-0.01*** (2.63)
Individual controls	No	Yes	Yes	Yes	Yes	Yes	Yes
Geographic controls	No	No	Yes	Yes	Yes	Yes	Yes
Observations	78198	78192	78192	78192	78192	78192	71019

Notes: This table presents logit estimation results. The dependent variable equals 1 if the respondent is working (other than homemaker), 0 otherwise. The data come from the 2015-16 National Family Health Survey (NFHS), the India version of the Demographic Household Survey (DHS). Individual controls are age, age squared, marital status, education level, religion, language, and caste category of the individual. Geographic controls are temperature, rainfall, and elevation. Respondent sample weight and strata identification included in all estimations. All specifications contain constant term, not reported for brevity. *t* statistics in parenthesis. Standard errors are clustered at DHS cluster level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Irrigation potential and female participation in pre-industrial agriculture

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Female participation in overall agriculture				Female time and effort on subsistence activities	Crop tending	Harvesting	Milking
Mean	3.04		2.85		2.06	3.22	3.26	3.05
Irrigation potential	-1.45** (-2.40)	-1.85* (-1.82)	-2.25** (-2.12)	-1.82* (-1.74)	-4.20*** (-2.63)	-2.78** (-2.43)	-2.64** (-2.39)	3.64* (1.66)
Major Crop: Cereal			0.24 (0.45)					
Class stratification				-0.16 (-0.69)				
Century FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Language FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ethnographic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	EA	SCCS	SCCS	SCCS	SCCS	SCCS	SCCS	SCCS
Observations	649	117	116	117	69	116	123	42
Pseudo R^2	0.23	0.40	0.41	0.40	0.52	0.30	0.32	0.31

Notes: This table presents ordered logit regressions of irrigation on relative female participation in various activities. Column (1) uses data from the *Ethnographic Atlas* (Murdock, 1967), the remaining columns use data from the *Standard Cross-Cultural Sample* (Murdock and White, 1969). The dependent variable in columns (1)-(4) and (6)-(8) are relative female labor force participation in overall agricultural activities. It varies from 1 to 5, where 1 – males exclusively; 2 – males predominantly; 3 – equally; 4 – females predominantly; and 5 – females exclusively. The dependent variables in column (5) is relative time and effort spent on subsistence activities by females, which varies from 1 to 3, where 1 - men expend more; 2 - men and women expend roughly equal; 3 - women expend more. All specifications contain constant term, not reported for brevity. Ethnographic controls are plow use, the suitability of the local environment for agriculture, the presence of large domesticated animals, the proportion of the local environment that is tropical or subtropical, economic complexity, and political hierarchy. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Warfare and female participation in agriculture

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	External warfare	Female participation in overall agriculture		War count years 610-1962	Female agricultural workers/total female population		War count years 1001-1857	Female agricultural workers/total female population	
Mean	0.76	3.09	3.09	4.58	15.76		3.81	15.76	
Irrigation potential	4.26** (2.08)	-2.00** (-2.01)	-1.67* (-1.67)	0.032*** (3.67)	-0.137*** (-4.33)	-0.115*** (-3.50)	0.036*** (3.08)	-0.137*** (-4.33)	-0.119*** (-3.65)
Warfare			-0.99* (-1.87)						
War count						-0.101*** (-3.18)			-0.093*** (-2.84)
Ethnic controls	Yes	Yes	Yes	-	-	-	-	-	-
Geographical controls	-	-	-	Yes	Yes	Yes	Yes	Yes	Yes
Language FE	-	-	-	Yes	Yes	Yes	Yes	Yes	Yes
Sample	SCCS	SCCS	SCCS	India	India	India	India	India	India
Estimator	Logit	OL	OL	NB	GLM	GLM	NB	GLM	GLM
Observations	54	54	54	601	601	601	601	601	601

Notes: Column (1) presents a logit regression, and columns (2)-(3) present ordered logit regressions for SCCS societies. Ethnic controls are plow use, presence of large animals, economic complexity, political hierarchy, and agricultural suitability. External warfare takes a value of 1 if external war with other societies is 'frequent, occurring at least yearly' or 'common, at least every five years'; it takes a value of zero if 'occasional, at least every generation' or 'rare or never' (Murdock and White, 1969). The results are sensitive to this classification and do not survive with language and century FE. Columns (4) and (7) present negative binomial regressions. War count is the number of wars occurring in a 50 km buffer area around a district. Column (4) uses years 610-1962; column (7) uses years 1001-1867. Columns (5), (6), (8), and (9) present GLM regressions. Language fixed effect is for the most commonly spoken language in the district. Geographical controls are temperature, precipitation, latitude, area, nightlight luminosity, and land quality for districts. A constant term is included in all models, not reported for brevity. Robust standard t-statistics in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Democracy and property rights

	(1)	(2)	(3)	(4)	(5)
	Democracy	Female property rights		Male property rights	
Mean	2.89	1.12		1.03	
Irrigation potential	-6.87** (-3.02)	-0.97*** (-3.94)	-0.23 (-0.77)	-0.33 (-0.82)	0.50 (0.80)
Democracy			0.11*** (11.00)		0.12*** (10.59)
Region FE	Yes	Yes	Yes	Yes	Yes
Geographical Controls	Yes	Yes	Yes	Yes	Yes
Observations	152	152	152	152	152
R ²	0.50	0.43	0.61	0.27	0.55

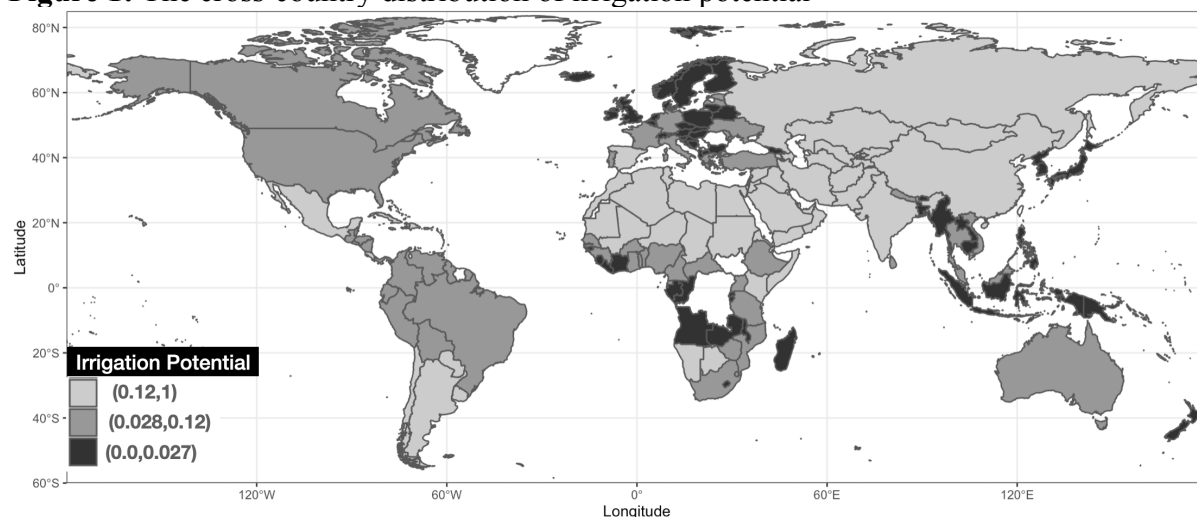
Notes: This table presents OLS regressions. Female property rights is measured as a response to the question “Do women enjoy rights to property?” measured on a scale 0 to 5, converted to a zero-mean variable. An analogous variable is used for male property rights. Geographical controls are plow use, landlockness, temperature, precipitation, elevation. Regions are Asia, Europe, North America, Oceania, South America, and Sub-Sahara Africa. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Individualism and property rights

	(1)	(2)	(3)	(4)	(5)
	Individualism	Female property rights		Male property rights	
Mean	39.76	1.51		1.37	
Irrigation potential	-15.50* (-1.95)	-1.75*** (-4.84)	-1.64*** (-4.46)	-1.67** (-3.27)	-1.57** (-3.18)
Individualism			0.01** (3.41)		0.01** (3.55)
Region FE	Yes	Yes	Yes	Yes	Yes
Geographical Controls	Yes	Yes	Yes	Yes	Yes
Observations	95	95	95	95	95
R ²	0.65	0.73	0.74	0.58	0.60

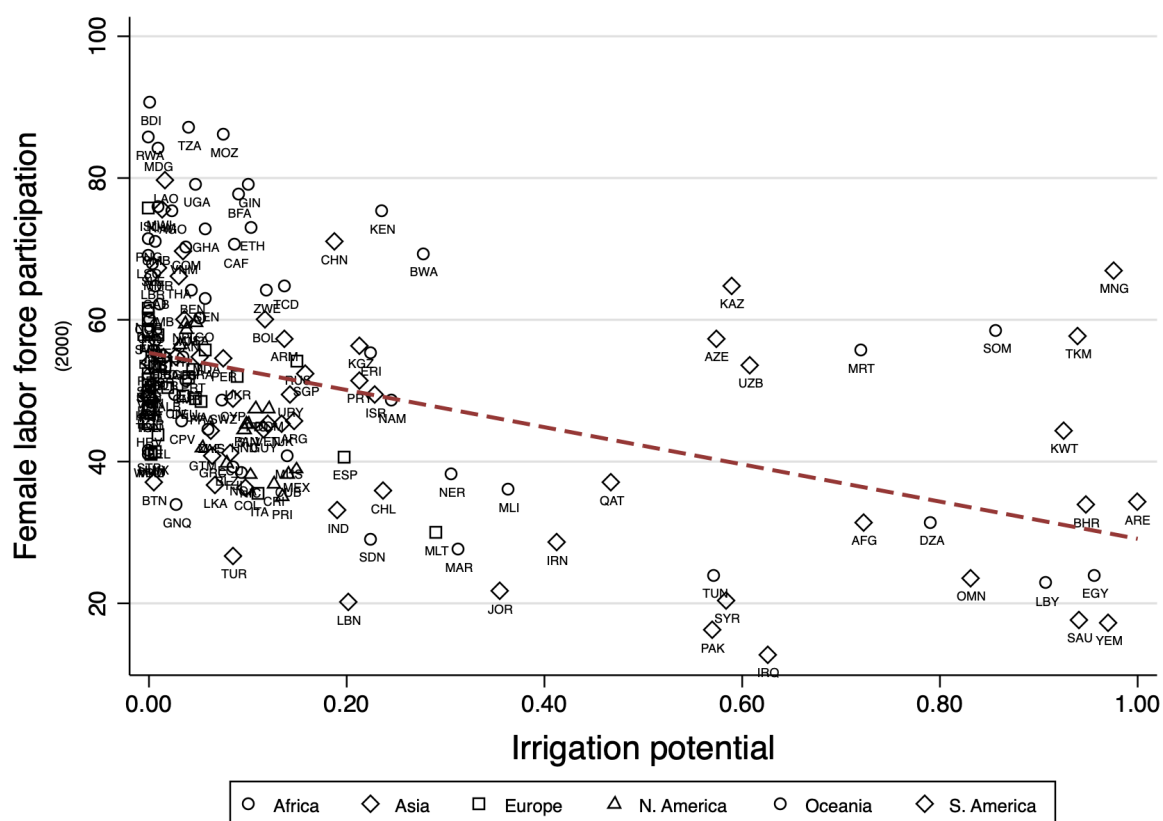
Notes: This table presents OLS regressions. Female property rights is measured as a response to the question “Do women enjoy rights to property?” measured on a scale 0 to 5, converted to a zero-mean variable. An analogous variable is used for male property rights. Geographical controls are plow use, landlockness, temperature, precipitation, elevation. Regions are Asia, Europe, North America, Oceania, South America, and Sub-Sahara Africa. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 1: The cross-country distribution of irrigation potential



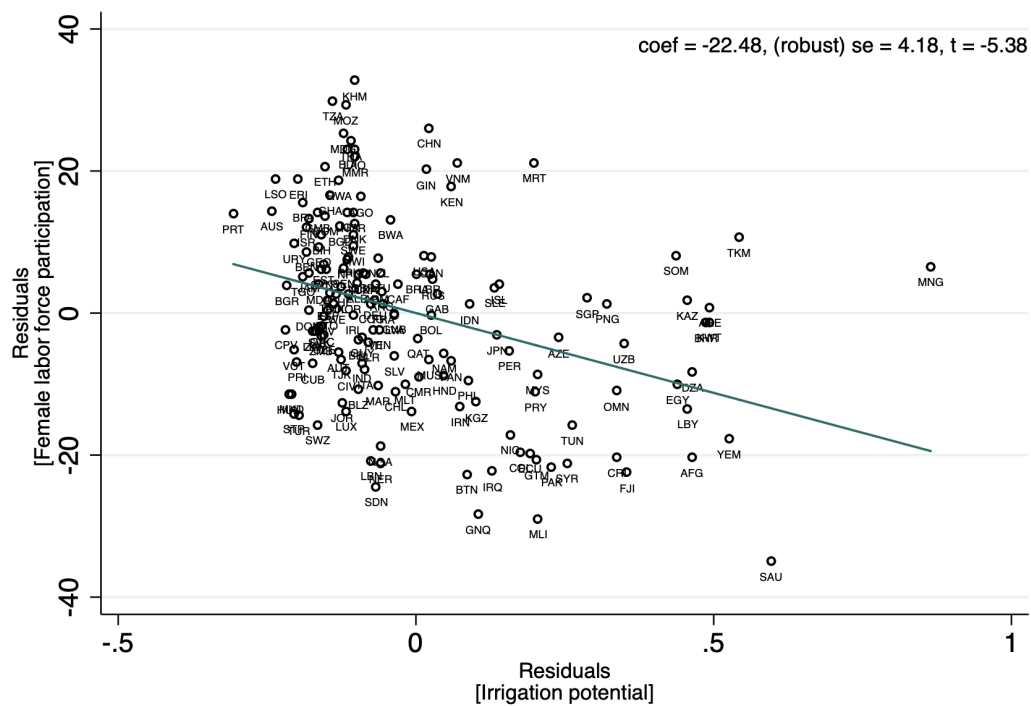
Source: Bentzen et al. (2017).

Figure 2: Female labor force participation and irrigation potential



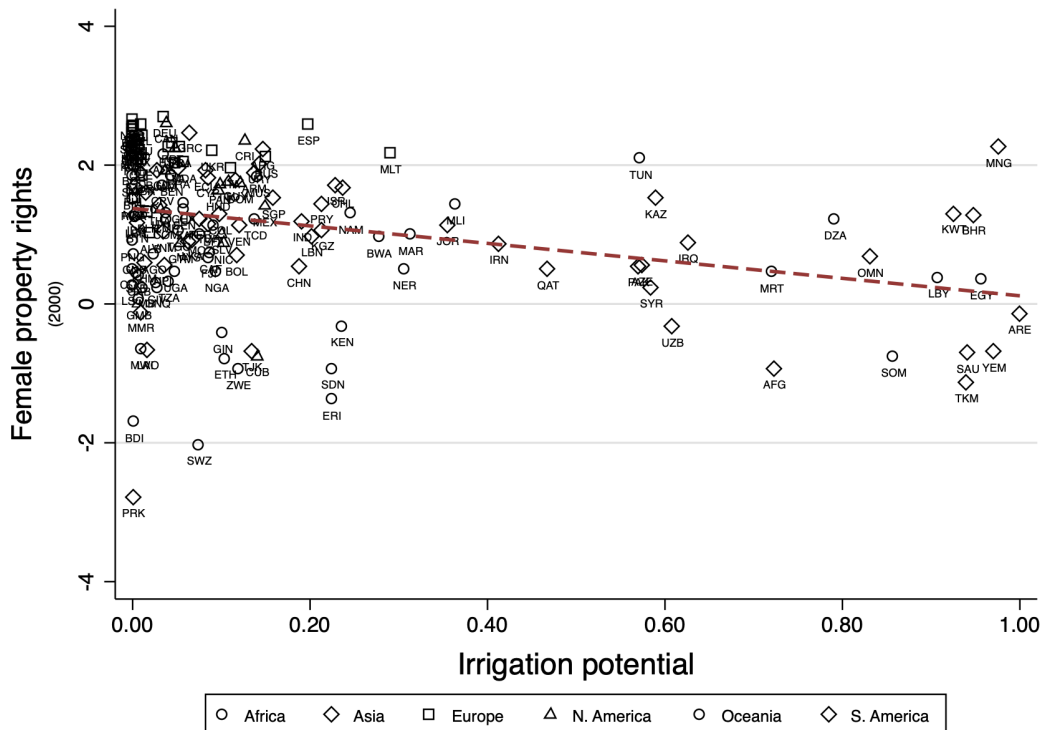
Notes: This figure shows the unconstrained relationship between irrigation potential (ancestry adjusted) and female labor force participation (coefficient = -12.18; t-statistic = -6.53).

Figure 3: Residuals female labor force participation and irrigation potential



Notes: This figure shows the residual plot of the OLS estimate of irrigation potential (ancestry adjusted) on female labor force participation, based on column (3), Table 2.

Figure 4: Female property rights and irrigation potential



Notes: This figure shows the unconstrained relationship between irrigation potential (ancestry adjusted) and female property rights (coefficient = -1.26; t-statistic = -4.15).

coef = -1.09, (robust) se = .21, t = -5.26

Residuals
[Female property rights]

Residuals
[Irrigation potential]

Online Appendix A

Data definitions and sources

Pre-industrial Societies

Female relative participation in agriculture: Traditional female relative to male participation in agriculture. Participation is grouped into five categories: (1) males only; (2) males appreciably more; (3) equal participation (combines two categories: ‘equal participation’ and ‘differentiated but equal participation’); (4) females appreciably more; and (5) females only. Sources: *Ethnographic Atlas* (Murdock, 1967); *Standard Cross-Cultural Sample* (Murdock and White, 1969).

Irrigation potential: Share of arable land where irrigation more than doubles agricultural yield (share of land in Impact Class 5). Source: Bentzen et al. (2017).

Plow use: Indicates whether the plow was used traditionally in pre-industrial agriculture or not. Source: Murdock and White (1969).

Century: Indicates the century in which a society was sampled. Variable v102 in the *Ethnographic Atlas*. Source: Murdock and White (1969).

Language: Indicates a society’s linguistic group. Variable v98 in the *Standard Cross-Cultural Sample*. Source: Murdock (1967).

Presence of large domesticated animals: Indicates the historical presence of large domesticated animals. Variable v40 of the *Ethnographic Atlas*. The original variable groups the type of animal husbandry practiced into seven categories: (1) absence of large domesticated animals; (2) pigs are the only large animals; (3) presence of sheep and/or goats without any larger domesticated animals; (4) presence of equine animals; (5) presence of deer; (6) presence of camels, alpacas or llamas; and (7) presence of bovine animals. We create an indicator variable equal to zero if the society is coded as category (1), and equal to one if the society is coded as category (2)-(7). Source: Murdock and White, (1969).

Economic complexity: Indicates economic development as measured by settlement complexity. Source: Murdock and White (1969)

Tropical climate: The proportion of the local environment that is classified as tropical or subtropical by the GAEZ (2002) database. Source: Murdock and White (1969)

Agricultural suitability: The ethnographic controls that measure the historical geographical environment are constructed as follows. The centroid of each ethnic group as reported in the *Ethnographic Atlas*, and land within 200 km of the centroid, are identified. Using information on global geo-climatic conditions for crop cultivation from the FAO's *Global Agro-Ecological Zones* (GAEZ) v3.0 database, we calculate the fraction of this land that is suitable for the cultivation of barley, wheat, rye, sorghum, foxtail millet, or pearl millet. This measure is used to construct the average suitability of the land historically inhabited by a location's ancestors. Source: Alesina et al. (2013).

Elevation: Average altitude (in meters) of a society. Variable v183 in the SCCS. Source: Murdock (1967).

Temperature: Average daily temperature (degrees Celsius) measured between 1950 and 1959. Source: *Terrestrial Air Temperature and Precipitation: 1900-2006 Gridded Monthly Time Series, Version 1.10*.

Precipitation: The average rainfall each month (in mm) measured between 1950 and 1959. Source: *Terrestrial Air Temperature and Precipitation: 1900-2006 Gridded Monthly Time Series, Version 1.10*.

Elite stratification: Grouped into five categories: (1) "absence among free men"; (2) "wealth distinctions"; (3) "elite stratification"; (4) "hereditary aristocracy"; (5) "complex stratification," where higher values represent a higher level of autocracy. Source: Murdock (1967).

External warfare: Takes a value of 1 if external war is 'frequent, occurring at least yearly' or 'common, at least every five years'; takes a value of zero if 'occasional, at least every generation' or 'rare or never' (recoded variable). Source: Murdock and White (1969).

Afrobarometer Data

"When jobs are scarce, men should have more right to a job than women?" Responses can take values 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree. Source: Afrobarometer round 7 (2016-18).

"Women should have the same rights as men to own and inherit land?" Responses can take values 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree. Source: Afrobarometer round 7 (2016-18).

Statement 1: "Men make better political leaders than women, and should be elected rather than women," versus Statement 2: "women should have the same chance of being elected to political office as men." Responses can take values 1 = agree very strongly with statement 1, 2 = agree with statement 1, 3 = agree with neither, 4 = agree with statement 2, 5 = agree strongly with statement 2. Source: Afrobarometer round 7 (2016-18).

Age: Age of the respondent. Source: Afrobarometer round 7 (2016-18).

Gender: Gender of the respondent. Source: Afrobarometer round 7 (2016-18).

Gender of the interviewer. Source: Afrobarometer round 7 (2016-18).

Language of interview. Source: Afrobarometer round 7 (2016-18).

Religions: Catholics, Protestants, Muslims, and Others. Source: Afrobarometer round 7 (2016-18).

Ethnographic variables for societies (irrigation potential, plow use, presence of large domesticated animals, economic complexity, political hierarchy, and agricultural suitability): See definitions for pre-industrial societies.

Cross-country Data

Female labor force participation: The percentage of women aged 15 to 64 that are in labor force. Source: World Bank (2015).

Male labor force participation: The percentage of men aged 15 to 64 that are in labor force. Source: World Bank (2015).

Female property rights: This variable measures the response to the question: "Do women enjoy the rights to private property?" Private property includes the right to acquire, possess, inherit, and sell private property, including land. Responses: 0: Virtually no women enjoy private property rights of any kind. 1: Some women enjoy some private property rights, but most have none. 2: Many women

enjoy many private property rights, but a smaller proportion enjoys few or none. 3: More than half of women enjoy most private property rights, yet a smaller share of men have much more restricted rights. 4: Most women enjoy most private property rights but a small minority does not. 5: Virtually all women enjoy all, or almost all property rights. The ordinal scale is converted to a continuous interval by a measurement model with mean zero. Source: Coppedge et al. (2019).

Male property rights: Analogous to Female property rights.

Irrigation potential: FAO's global Agro-Ecological Zones (GAEZ) 2002 database classifies Impact Class 1 as areas where additional water beyond natural rainfall does not increase yields. Impact Class 5 is areas where irrigation can more than double yields. Impact Classes 2-4 are intermediate cases. Irrigation potential is a measure of the fraction of land suitable for agriculture in Impact Class 5. The variable ranges from 0 to 1. Source: Bentzen et al. (2019).

Ancestral irrigation: This index measures population-weighted ancestral use of irrigation in agriculture. Source: Buggle (2020).

Plow use: The estimated proportion of citizens with ancestors that used the plow in pre-industrial agriculture. The variable ranges from 0 to 1. Source: Alesina et al. (2013).

Plow positive crops; plow negative crops: Information comes from the FAO's *Global Agro-Ecological Zones* (GAEZ) v3.0 database, available at <http://webarchive.iiasa.ac.at/Research/LUC/GAEZv3.0/>. The database reports the suitability for the cultivation of different crops for grid-cells 5 arc-minutes by 5 arc-minutes (approximately 56 km by 56 km) for the world. The suitability of wheat, barley, and rye (plow positive), and suitability for sorghum, pearl millet, foxtail millet (plow negative) are calculated for each grid-cell. Society- and country-level averages of plow-positive and plow-negative suitability are constructed. Source: Alesina et al. (2013).

Years since Neolithic transition: The number of years elapsed in 2000 AD since the transition to agriculture is estimated to have occurred, in thousands of years. Source: Putterman (2006).

Technology in agriculture (1500AD): Indicates use of technology in the most prominent society in the country in 1500 AD. It measures extensive margin of technology adoption in the country. Source: Comin et al. (2010).

GDP per capita: GDP divided by midyear population, in constant 2005 US dollars. Source: World Bank's (2015) World Development Indicators and Penn World Table v8 by Heston and Aten (2011).

Years in school: The average years of schooling for the population aged 15 or 25 years and above in 2000. Source: Barro and Lee (2013).

Fertility rate: The average number of children per women in 1980. Source: World Bank (2015).

Democracy: Polity2 from the Polity IV project. Values range from -10 to +10, where 10 indicates the highest degree of democracy. Source: Marshall et al. (2015).

Age dependency ratio: The ratio of the sum of the (0-14) and (65+) populations, divided by the (15-64) population in 1980. Source: World Bank (2015).

Children of European Immigrants

Irrigation potential: The irrigation potential in the children's mother's or father's country of origin. Ancestry adjusted to account for population migration during Columbian exchange. For construction of this variable see details for the cross-country variables. Source: Bentzen et al. (2017).

Plow use: The estimated proportion of citizens, in the country of origin of mother or father, with ancestors that used the plow in pre-industrial agriculture. The variable ranges from 0 to 1. Source: Alesina et al. (2013).

Citizen: Indicates whether 2nd generation immigrant is citizen of the country where the interview was conducted, or not. Source: European Social Survey (2004-2017).

Language: First language spoken at home by the immigrant. Source: European Social Survey.

Age: Age of the respondent. Source: European Social Survey (2004-2017).

Years of education: Number of years in school attended by respondent. Source: European Social Survey (2004-2017).

Gender: Gender of respondent. Source: European Social Survey (2004-2017).

Children of US Immigrants

Country of origin: Country of origin for the 2nd generation immigrants is the country of birth of the respondent's mother or father. Country of origin of 1.5th generation of immigrants is the birthplace

of the respondent.

Female labor force participation: A dichotomous variable indicating whether a person participated in the labor force. Source: American Community Survey (2000-2018).

Irrigation potential: The irrigation potential for the country of origin of the respondent. Source: Bentzen et al. (2017)

Latitude: The absolute value of the latitude of a country's centroid. Source: CIA (2015).

Ruggedness: The calculation for ruggedness takes a point on the earth's surface and measures the difference in elevation between this point and each of the eight major directions of the compass (north, northeast, east, southeast, south, southwest, west, and northwest). The index at the central point is given by the square root of the sum of the squared differences in elevation between the central point and the eight adjacent points. Source: Nunn and Puga (2012).

Calorie yield (post-1500): Caloric yield (post-1500) for the country of origin. Source: Galor and Özak (2016).

Plow negative crop: Fraction of area of country suitable for plow-negative crops. Source: Alesina et al. (2013).

Age: Age of the respondent. Source: American Community Survey (2000-2018).

Married: Current marital status of the respondent. Source: American Community Survey (2000-2018).

Education: Measured as 12 categories: no schooling, nursery to grade 4, grade 5-8, grade 9, grade 10, grade 11, grade 12, 1 year of college, 2 years of college, 4 years of college, 5+ years of college. Source: American Community Survey (2000-2018).

Education (father/mother): Measured as 12 categories: no schooling, nursery to grade 4, grade 5-8, grade 9, grade 10, grade 11, grade 12, 1 year of college, 2 years of college, 4 years of college, 5+ years of college. Source: American Community Survey (2000-2018).

India DHS Data

Female working: This indicates whether a woman works in other than domestic work for the own household. Non-domestic work by the respondent included working for a family member, for someone else, or being self-employed, whether paid in cash, in kind, or unpaid. If the respondent works outside the home, the survey gives the occupation. Source: DHS (2015-2016).

Male working: See 'Female working'.

Irrigation potential: See cross-country analysis.

Age: Current age of respondent. Source: DHS (2015-2016).

Marital status: Indicates current marital status. Source: DHS (2015-2016).

Education: This indicates the education of the respondent into the following categories: None, incomplete primary, complete primary, incomplete secondary, complete secondary, higher education. Source: DHS (2015-2016).

Religion: This indicates religion of the respondent. Source: DHS (2015-2016).

Language: Respondent's mother tongue. Source: DHS (2015-2016).

Wealth: Rural wealth index, a composite measure of a household's cumulative living standard. Source: DHS (2015-2016).

Caste/tribe: Indicates the caste/tribe of the respondent. Source: DHS (2015-2016).

Mean temperature: The average annual land surface temperature within the 10 km (rural) buffer surrounding the DHS survey cluster location. Source: Mayala et al. (2018).

Mean rainfall: The average annual rainfall within the 2 km (urban) or 10 km (rural) buffer surrounding the DHS survey cluster location. Source: Mayala et al. (2018).

Elevation: Average altitude of the DHS survey cluster location. Source: Mayala et al. (2018).

Proximity to water: The geodesic distance to either a lake or the coastline (in meters). Source: Mayala et al. (2018).

Nightlights: The average night time luminosity of the area within the 10 km (rural) buffer surrounding the DHS survey cluster location. Source: Mayala et al. (2018).

Growing season length: The length of the growing season in days (reported in one of 16 categories) for the area within the 10 km (rural) buffer surrounding the DHS survey cluster location. Source: Mayala et al. (2018).

Female agriculture workers: Females in a district who reported having worked for the major part of the last six months or more in agricultural activities. Source: Census of India (2011).

India: mechanism study

Female employment outside the home: The ratio of the population of female agricultural workers to the total female population in year 2011. Source: Census of India (2011).

Warfare: The total exposure to land battles over years 610-1962 within a distance of 50km from the district. Source: Jacques (2007).

Land quality: Average probability within a region that a particular grid cell will be cultivated. Source: Ramankutty et al. (2002).

Nightlight luminosity: This is light density from satellite images over a district. Sources: Image and data processing: NOAA's National Geophysical Data Center. DMSP data: US Air Force Weather Agency.

Online Appendix B

Table B1: Summary statistics: pre-industrial societies

	Observations	Mean	SD	Min	Max
Female overall participation in agriculture	117	2.85	1.09	1.0	5.0
Female input into subsistence activity	69	2.06	0.64	1.0	3.0
Irrigation potential	117	0.16	0.32	0.0	1.0
Plow use	117	0.22	0.42	0.0	1.0
Presence of large domesticated animals	117	0.80	0.40	0.0	1.0
Economic complexity	117	5.87	1.75	1.0	8.0
Political hierarchy	117	2.26	1.26	1.0	5.0
Agricultural suitability	117	0.42	0.37	0.0	1.0
Tropical climate	117	0.89	0.30	0.0	1.0
Century	117	9.53	1.37	1.0	10.0
Linguistic group	117	29.97	30.82	2.0	99.0
Land clearance	121	1.48	0.78	1.0	5.0
Soil preparation	117	2.21	1.36	1.0	5.0
Planting	123	2.89	1.31	1.0	5.0
Crop tendering	116	3.22	1.42	1.0	5.0
Harvesting	123	3.26	1.21	1.0	5.0

Source: Standard Cross-Cultural Sample.

Table B2: Summary statistics: Afrobarometer data

	Count	Mean	SD	Min	Max
“When jobs are scarce...”	16486	2.68	1.59	1.0	5.0
“Women should have...”	16638	3.86	1.33	1.0	5.0
“Statement 1: “Men make better...”	16753	3.86	1.56	1.0	5.0
Irrigation potential (%)	16753	0.07	0.14	0.0	1.0
Plow use	16753	0.03	0.18	0.0	1.0
Age	16753	36.42	14.61	18.0	103.0
gender	16753	0.50	0.50	0.0	1.0
Interviewer’s Age	16753	29.64	6.32	20.0	61.0
Interviewer’s sender	16753	0.49	0.50	0.0	1.0
Presence of large animals	16753	0.98	0.15	0.0	1.0
Economic complexity	16753	6.38	1.31	1.0	8.0
Political hierarchy	16753	2.65	0.92	1.0	4.0
Agricultural suitability	16753	0.70	0.34	0.0	1.0

Notes: The observation counts for the control variables equal the dependent variable with highest count. The differences are negligible is using the observation counts for the remaining two dependent variables. Source: Afrobarometer (2016-18).

Table B3: Summary statistics: cross-country data

	Obs	Mean	SD	Min	Max
Female labor force participation	162	50.95	15.78	12.60	90.5
Female property rights	159	1.16	1.06	-2.79	2.69
Irrigation potential (ancestry adjusted)	162	0.17	0.26	0.0	1.0
Plow use (ancestry adjusted)	162	0.61	0.41	0.0	1.0
Years since Neolithic Transition	156	4835	2428	400	10500
Technology adoption in agriculture (1500 AD)	111	0.72	0.31	0	1
GDP per capita, log (year 2000)	162	7.88	1.67	4.92	11.19
Years in school (year 2000)	134	6.95	3.10	0.68	12.64
Fertility rate (year 1980)	160	4.66	2.09	1.44	8.99
Democracy (year 2000)	152	2.89	6.69	-10.0	10.0
Age dependency ratio (year 1980)	160	77.71	18.83	41.52	112.77

Notes: This table presents summary statistics for the cross-country data.

Table B4: Summary Statistics 2nd generation immigrants in Europe

	Father's country			Mother's country				
	Count	Mean	SD	Count	Mean	SD	Min	Max
“When jobs are scarce...” (1-5 scale)	9656	2.32	1.23	5122	2.38	1.26	1.0	5.0
“When jobs are scarce...” (0-1 indicator)	8226	0.24	0.43	4365	0.27	0.44	0.0	1.0
Irrigation potential	9656	0.16	0.24	5122	0.20	0.27	0.0	1.0
Plow use	9656	0.94	0.19	5122	0.94	0.18	0.0	1.0
Economic complexity	9656	6.66	0.98	5122	6.57	1.00	1.5	8.0
Presence of large animals	9656	0.99	0.09	5122	0.99	0.08	0.0	1.0
Political hierarchy	9656	4.15	0.61	5122	4.12	0.59	1.0	5.0
Age	9656	44.3	17.8	5122	44.3	17.7	15.0	92.0
Age ²	9656	2276.4	1693.9	5122	2281.6	1686.1	225.0	8464.0
Gender	9656	1.5	0.5	5122	1.5	0.5	1.0	2.0
Number of years in school	9656	12.8	3.6	5122	12.6	3.7	0.0	40.0
“Women should be...” (1-5 scale)	7097	3.17	1.19	3711	3.23	1.19	1.0	5.0
“When should be...” (0-1 indicator)	5600	0.59	0.49	2961	0.62	0.49	0.0	1.0
Irrigation potential	7097	0.16	0.24	3711	0.20	0.27	0.0	1.0
Plow use	7097	0.94	0.19	3711	0.95	0.18	0.0	1.0
Economic complexity	7097	6.67	0.98	3711	6.59	0.98	1.5	8.0
Presence of large animals	7097	0.99	0.09	3711	0.99	0.08	0.0	1.0
Political hierarchy	7097	4.16	0.59	3711	4.14	0.58	1.0	5.0
Age	7097	43.73	17.84	3711	43.78	17.86	15.0	90.0
Age ²	7097	2230.8	1694.2	3711	2235.9	1695.2	225.0	8100.0
Gender	7097	1.55	0.50	3711	1.55	0.50	1.0	2.0
Number of years in school	7097	12.48	3.64	3711	12.29	3.66	0.0	28.0

Source: European Social Survey (2004–2017).

Table B5: Summary statistics: Female Children of US Immigrants

	1.5 generation			2 nd generation			Min	Max
	count	Mean	SD	count	Mean	SD		
In the labor force?	172121	0.72	0.45	118647	0.79	0.41	0.0	1.0
Irrigation potential	172121	0.08	0.11	118647	0.09	0.11	0.0	1.0
Latitude	172121	28.37	15.08	118647	26.40	13.61	1.0	64.0
Ruggedness	172121	1.47	0.70	118647	1.58	0.69	0.0	6.7
Calorie yield (post-1500)	172121	1392.26	546.98	118647	1356.97	464.02	0.0	2742.8
Plow negative crop	172121	0.41	0.17	118647	0.43	0.16	0.0	0.9
Age	172121	41.99	12.77	118647	32.67	9.45	24.0	75.0
Married	172121	0.57	0.49	118647	0.17	0.37	0.0	1.0
Education	172121	7.65	2.41	118647	7.75	2.20	0.0	11.0
Education (father)	15835	58.55	34.71	79905	60.68	32.38	2.0	116.0
Education (mother)	23452	53.62	32.99	110598	58.24	30.27	2.0	116.0

Source: American Community Survey (2000-2018).

Table B6: Summary statistics: India Demographic and Household Survey

	Observations	Mean	SD	Min	Max
Female in non-domestic work?	78198	0.33	0.47	0.0	1.0
Male in non-domestic work?	71019	0.82	0.38	0.0	1.0
Irrigation potential	78198	0.29	0.38	0	1
Age (years)	78198	29.7	9.8	15.0	49.0
Proximity to water	78198	1.55	1.11	0.0	5.2
Nightlight	78198	0.71	1.39	0.0	31.0
Growing season length	66880	7.60	2.37	1.0	14.0
Other castes	64502	0.18	0.39	0.0	1.0

Source: India Demographic and Household Survey (2015-16).

Online Appendix C

Robustness Analysis: Cross-Country Sample

Female Labor Force Participation

Columns (1) - (6), Panel A, Table C1 provide robustness checks for the cross-country analysis of irrigation potential on female labor force participation, using additional controls. Baseline controls and regional fixed effects are included in all columns, except that columns (2), (6), and (7) drop plow use since technology in agriculture (1500AD) accounts for plow use. Irrigation potential has a consistently negative and significant effect on female labor force participation. In contrast, the placebo analysis in column (7) suggests that irrigation potential has no significant effect on the male labor force participation rate.

Female Property rights

Columns (1) - (6), Panel B, Table C1 provide robustness analysis for the cross-country analysis of irrigation potential on female property rights, using additional controls. Baseline controls and regional fixed effects are included in all columns, except that columns (2), (6), and (7) drop plow use since technology in agriculture (1500AD) accounts for plow use. A common law legal origin dummy is now added, while years in school (which may be less expected to influence female property rights) is dropped. Irrigation potential has a negative and significant effect on female property rights in all columns, but not in the placebo analysis on male property rights in column (7).

Further Robustness Analysis

Table C2 further studies female labor force participation. Baseline controls and regional fixed effects are included in all columns. World Bank (2004) suggests that Muslim societies tend to be associated with lower female labor force participation. A continuous measure for the Muslim population share does not bear this out, while a Muslim majority dummy has a negative association. Annual variation in precipitation, reflecting a need to reduce output fluctuations with irrigation, is insignificant. Next, since one may be concerned that plow use may be endogenous, we divide crops into plow positive which benefit from use of plow, and plow negative which do not benefit (Alesina et al., 2013). These measures represent the fraction of arable land that is suitable for plow positive and plow negative crops, respectively. Plow positive crops have a negative influence on female labor force participation, while plow negative crops have no significant effect. An OPEC dummy is negative, which supports Ross

(2009) who argues that oil is associated with gender bias. We alternatively measure irrigation potential by including both Irrigation Classes 4 and 5. The last column utilizes a measure of ancestral irrigation from Buggle (2020). Irrigation potential remains negative and statistically significant in all models. In unreported results, we drop the 25 % largest countries by area, as measurement errors in irrigation potential are likely greater in large countries. We also drop OECD countries. Our results remain intact in both cases, and the irrigation potential coefficient size rises. Agricultural suitability includes information on precipitation, frequency of wet days, mean temperature, and multiple additional local conditions (Alesina et al., 2013). It may partially overlap with irrigation potential, which likely explains the insignificant result.

Table C3 further studies female property rights using the same controls and measures as Table C2. Irrigation potential has a negative and significant effect in all columns, except with agricultural suitability. This may be because irrigation potential and agricultural suitability are likely to partially overlap. In unreported results, the irrigation potential coefficient remains robust when we drop the 25% largest countries, or the group of OECD countries.

Table C1: Irrigation, female and male labor force participation and property rights

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Female labor force participation						Male labor force participation
Panel A							
Mean	51.05	51.05	50.29	51.03	51.03	49.79	75.37
Irrigation potential	-15.81*** (-7.38)	-32.42*** (-6.22)	-21.32** (-3.17)	-18.33** (-2.80)	-18.89*** (-4.50)	-18.35* (-2.43)	-5.72 (-1.73)
Years since Neolithic Transition	-2.22*** (-4.72)					-2.59** (-2.57)	-1.31 (-1.50)
Technology in agriculture (1500 AD)		-1.35 (-0.16)				-4.81 (-0.81)	6.68 (1.48)
GDP per capita, log			-1.37 (-1.00)			-4.35 (-1.56)	0.09 (0.14)
Years in school			11.93 (0.16)			71.83 (0.38)	-78.55 (-1.91)
Fertility				-0.91 (-0.67)		-1.44 (-0.52)	1.28 (0.82)
Age dependency ratio					-0.18*** (-4.42)	0.05 (0.19)	0.01 (0.18)
Observations	156	111	130	160	160	96	96
Altonji et al. test statistics	1.51	5.25	4.32	2.31	2.57	2.32	1.02
R ²	0.53	0.49	0.52	0.46	0.47	0.61	0.58
Panel B							
Dependent Variable:	Female Property Rights						Male Property Rights
Mean	1.18	1.25	1.20	1.18	1.18	1.29	1.17
Irrigation potential	-0.72*** (-6.51)	-1.01** (-2.74)	-1.09*** (-6.24)	-0.67** (-3.00)	-0.97*** (-4.53)	-0.39** (-2.53)	-0.44 (-0.96)

Years since Neolithic Transition	8.39 (0.12)					-16.68 (-0.22)	-44.66 (-0.46)
Technology in agriculture (1500 AD)		-0.27* (-2.11)				-0.14 (-1.03)	-0.21 (-0.66)
GDP per capita, log			0.17*** (5.32)			0.12 (1.65)	0.15 (1.93)
Years in school							
Common law			-0.24 (-1.35)			-0.19 (-1.69)	0.09 (0.68)
Fertility				-0.17*** (-4.31)		-0.08 (-0.70)	0.17 (1.17)
Age dependency ratio					-0.01*** (-4.73)	-0.00 (-0.24)	-0.01 (-1.77)
Observations	154	110	153	158	158	105	105
Altonji et al. test statistics	1.33	4.04	6.41	1.24	3.34	0.51	0.86
R ²	0.47	0.54	0.54	0.54	0.53	0.60	0.40
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table presents coefficients for OLS regression of irrigation potential (ancestry adjusted) on female labor force participation (columns (1)-(6)), male labor force participation (column (7)) in panel A, female property rights (columns (1)-(6)), and male property rights (column (7)) in Panel B. Female (male) labor force participation is measured as percentage of females (males) in the workforce in 2000, which ranges from 0 to 100. Property rights for female (male) is measured as a response to the question “Do women enjoy right to property?” measured on a scale 0 to 5, converted to mean at zero (range -2.79 to 2.69). Irrigation potential is ancestry adjusted. All specifications contain a constant (not reported). Baseline controls are plow use (ancestry adjusted), landlockedness, elevation, temperature, and precipitation in columns (1), (3), (4) and (5). Columns (2), (6), and (7) drop plow use since technology in agriculture (1500AD) already accounts for plow use. Regional fixed effects include Africa, Asia, Europe, North America, South America, and Oceania. *t* statistics in parenthesis. *, **, and *** indicates 10%, 5%, and 1% statistical significance.

Table C2: Irrigation potential and female labor force participation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Female labor force participation							
Mean	51.05	50.95	50.95	50.89	50.95	50.95	50.95	51.18
Irrigation potential	-13.09*	-15.29**	-20.36***	-18.66***	-19.19***	-17.31***		
	(-1.96)	(-3.39)	(-4.82)	(-3.79)	(-5.28)	(-3.97)		
Muslim population	-13.02							
	(-1.46)							
Muslim population >50%		-7.91*						
		(-2.08)						
Precipitation variation			0.00					
			(0.08)					
Plow positive crops				-15.60**				
				(-3.36)				
Plow negative crops				6.86				
				(1.14)				
OPEC dummy					-4.28**			
					(-2.81)			
Agricultural suitability						3.91		
						(1.13)		
Irrigation potential (IC 4+5)							-23.50***	
							(-6.65)	
Irrigation								-19.55***
								(-5.05)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	161	162	162	159	162	162	162	152
Altonji et al. test statistics	0.99	1.40	3.46	2.49	2.72	1.94	8.55	2.92
Adj. R^2	0.44	0.43	0.41	0.44	0.41	0.41	0.42	0.49

Notes: OLS estimation of irrigation potential on female labor force participation, measured as percentage of females in the workforce in 2000, which ranges from 0 to 100. Irrigation potential and plow use are ancestry adjusted. All specifications contain a constant (reported). Baseline controls are plow use (ancestry adjusted), landlockedness, elevation, temperature, and precipitation. Plow use is not included in column (4). The irrigation measure in column (8) comes from Buggle (2020). Regional fixed effects include Africa, Asia, Europe, North America, South America, and Oceania. t statistics in parenthesis. *, **, and *** indicates 10%, 5%, and 1% statistical significance.

Table C3: Irrigation potential and female property rights

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Female property rights								
Mean	1.16	1.16	1.16	1.15	1.18	1.16	1.16	1.16	1.13
Irrigation potential	-0.67** (-2.77)	-0.73** (-2.67)	-0.93** (-3.50)	-0.86** (-2.71)	-0.69** (-2.66)	-0.85*** (-3.79)	-0.36 (-1.52)		
Muslim population	-0.35* (-2.24)								
Muslim population >50%		-0.21 (-1.37)							
Precipitation variation			-0.00 (-0.57)						
Plow positive crops				0.21 (0.52)					
Plow negative crops				0.02 (0.05)					
Year of universal suffrage					-0.00 (-1.60)				
OPEC dummy						-0.06 (-0.98)			
Agricultural suitability							0.63*** (5.00)		
Irrigation potential (IC 4+5)								-0.82** (-3.40)	
Irrigation									-0.79*** (-5.01)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographical Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	161	162	162	159	159	162	162	162	151
Altonji et al test statistics	1.14	1.38	2.82	2.15	1.21	2.07	0.4	1.86	1.68
Adj. R^2	0.44	0.43	0.41	0.44	0.40	0.41	0.41	0.42	0.46

Notes: The table presents OLS regressions of irrigation potential on female property rights. The outcome variable ranges from 0 to 5, converted to mean 0. Irrigation potential and plow use are ancestry adjusted. All the specifications contain constant term (not reported). Baseline controls are plow use (ancestry adjusted), landlockedness, elevation, temperature, and precipitation. Plow use is not included in column (4). The irrigation measure in column (9) comes from Buggle (2020). Regional fixed effects are for Africa, Asia, Europe, North America, South America, and Oceania. t statistics in parenthesis. *, **, and *** indicate 10%, 5%, and 1% statistical significance.

Robustness Analysis: India Sample

Table C4, Panel A reports reduced form estimates using a measure of actual irrigation in India, while Panels B and C provide IV probit analysis. The variable used in the second stage is actual irrigation, measured as the share of the area within a 10 km buffer surrounding the DHS survey cluster that is irrigated. This measure can be viewed as exogenous to individual households. The design of large irrigation projects (e.g., canal irrigation) routes are decided by government agencies in consultation with the district administration, likely factoring in some political influence of local leaders. An individual household is unlikely to wield any influence on such decisions. The instrument is irrigation potential in a circular area (50 km radius) around the DHS cluster.²⁷

The first stage results reported in Panel C indicate that irrigation potential is a strong instrument for actual irrigation at the DHS cluster level. Panel B suggest that actual irrigation has a negative association with the likelihood that a female is working in rural India. Note that the point estimates for actual irrigation increase in all columns after being instrumented by irrigation potential. This indicates that measurement errors in the actual irrigation variable and endogeneity bias are corrected. However, this result can also be due to violation of the exclusion restrictions. We use Conley et al.'s (2012) exogeneity test to investigate the validity of the instrumental variable. First, we estimate the value of γ required to run plausibly exogenous estimations. We find that the point estimate of actual irrigation in Panel A lies within the lower and upper bound of the 95% confidence interval, suggesting that potential irrigation is a plausibly exogenous instrument for actual irrigation. The Anderson and Rubin test and the Wald test for weak instrument indicate that potential irrigation is a valid and relevant instrument for actual irrigation.

²⁷ A 10km radius is too small for the irrigation potential measure, as most cells would have no data. The analysis assumes that irrigation potential does not change sharply within 50km.

Table C4: Female work in rural India: IV probit analysis

	(1)	(2)	(3)
Panel A: Reduced form			
Dependent variable:	Female working?		
Actual irrigation	-0.15*** (-26.36)	-0.09*** (-14.66)	-0.10*** (-14.68)
Panel B: Second stage			
Dependent variable:	Female working?		
Actual irrigation	-0.37*** (-14.61)	-0.13*** (-3.49)	-0.18*** (-3.92)
Panel C: First stage			
Dependent variable:	Actual irrigation		
Irrigation potential (%)	0.48*** (198.81)	0.43*** (146.17)	0.38*** (123.59)
Individual controls	No	Yes	Yes
Geographical controls	No	No	Yes
Observations	74661	74661	74661
Tests for weak instrument:			
Anderson and Rubin Chi ² [<i>p</i> -value]	212.2 (0.000)	12.2 (0.000)	15.4 (0.000)
Wald test Chi ² [<i>p</i> -value]	213.4 (0.000)	12.2 (0.000)	15.4 (0.000)
Conley et al. (2012) exogeneity test			
γ	0.01	0.03	0.02
Lower bound	-0.169	-0.210	-0.189
Upper bound	-0.113	-0.051	-0.061

Notes: Panel A in this table reports a [logit](#) analysis using actual irrigation as measure. Panels B and C present an IV probit analysis. The dependent variable equals 1 if the respondent is working (other than homemaker), 0 otherwise. Actual irrigation is instrumented by irrigation potential. Individual controls are age, age squared, marital status, education, religion, language, and caste. Geographical controls are temperature, rainfall, and elevation. *t* statistics in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table C5: Irrigation potential and female freedom of movement

Dependent variable:	Female freedom of movement
Mean	0.95
Irrigation potential	-1.36*** (-7.51)
Baseline controls	Yes
Region FE	Yes
Observations	159
R^2	0.46

Notes: This table presents an OLS regression result for irrigation potential and women's freedom of movement. The outcome variable uses the 2001-2019 average (Coppedge et al., 2019). Baseline controls are plow use (ancestry adjusted), landlocked, temperature, precipitation, and elevation. t statistics in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table C6: Irrigation potential and gender inequality in political participation and freedom

	(1)	(2)	(3)	(4)
Dependent variable:	Statement 1: “Men make better political leaders than women, and should be elected rather than women,” versus Statement 2: “women should have the same chance of being elected to political office as men.”	% enfranchised Females	Female political participation index	Female freedom of discussion
Mean	3.86	93.1	0.80	0.93
Irrigation potential	-0.62** (-2.11)	-31.32** (-3.71)	-0.35*** (-5.03)	-0.96** (-3.23)
Country FE	Yes	-	-	-
Ethnographic controls	Yes	-	-	-
Individual controls	Yes	-	-	-
Interviewer control	Yes	-	-	-
Baseline controls	-	Yes	Yes	Yes
Region FE	-	Yes	Yes	Yes
Observations	16872	159	159	159
R^2	-	0.26	0.48	0.43

Notes: Column (1) presents an ordered logit regression result. Individual controls are age, age squared, and gender. Interviewer controls are age, age squared, and gender of the interviewer, and language of interview (Afrobarometer, 2016-18). Ethnographic controls are presence of large animals, economic complexity, political hierarchy, and agricultural suitability (Murdock, 1967). Standard errors are clustered at country-ethnic group level. Country FE are the ruggedness, soil quality, distance from coast, and region FE. Regions are Eastern Africa, Western Africa, Southern Africa, and Central Africa. Constant term included, not reported. Survey responses in column (1) can take five values: 1 = agree very strongly with statement 1, 2 = agree with statement 1, 3 = agree with neither, 4 = agree with statement 2, 5 = agree strongly with statement 2. Columns (2)-(4) present OLS regression results. Irrigation potential is ancestry adjusted. The outcome variable in column (2) measures the approximate percentage of de facto (as opposed to de jure) enfranchised female adults older than the minimal voting age, column (3) uses a female political participation index, and column (4) studies whether females are free to openly discuss political issues in private homes and in public spaces. Outcome variables come from Coppedge et al. (2019). All outcome variables use the 2001-2019 average. Baseline controls are plow use (ancestry adjusted), landlocked, temperature, precipitation, and elevation. t statistics in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table C7: Individualism, democracy, and property rights

	(1)	(2)	(3)	(4)	(5)	(6)
	Individualism	Democracy	Female property rights		Male property rights	
Mean	39.31	5.16	1.49	1.49	1.36	1.36
Irrigation potential	-16.82*	-16.56**	-1.75***	-1.07*	-1.69**	-0.93
	(-2.24)	(-2.66)	(-4.39)	(-2.08)	(-3.08)	(-1.09)
Individualism				0.005*		0.004
				(2.10)		(1.79)
Democracy				0.04*		0.04**
				(2.07)		(2.55)
Region FE	Yes	2.59	0.26	0.09	-0.19	-0.36
		(0.73)	(0.73)	(0.30)	(-0.42)	(-0.89)
Geographical Controls	Yes	-1.11	-0.20	-0.19	-0.07	-0.04
		(-0.83)	(-0.77)	(-0.85)	(-0.42)	(-0.25)
Observations	90	90	90	90	90	90
R^2	0.64	0.71	0.73	0.76	0.58	0.63

Notes: This table presents OLS regressions. Property rights for women is measured as a response to the question “Do women enjoy right to property?” measured on a scale 0 to 5, converted to a zero-mean variable. An analogous variable is used for male property rights. Geographical controls are landlockness, temperature, precipitation, elevation. Regions are Asia, Europe, North America, Oceania, South America, and Sub-Sahara Africa. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.