Endogenous Kinship Institutions.*

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Abstract

Kinship structures the patterns of human relationships within the family, whereby matrilineal succession is believed to weaken both the males' authority and their incentives to cooperate. To evaluate this conjecture, we study a society equally split in males and females interested in maximizing the return on their joint investment by selecting property rights shaping their ex post bargaining power. The investment return is determined by both a couple-specific technological parameter and the product of the parties' non-contractible time allocations in farming and home production. Being—on average—farming the most productive activity, society achieves the first best by fully protecting either side when they are better at farming and by favoring the party with the lowest farming productivity otherwise. While in the first case couples specialize in farming, in the second one, more productive couples focus on farming and less productive ones diversify. Ultimately, society embraces matrilineal succession when females are less productive than males and patriliny otherwise. Crucially, this prediction is consistent, across identification strategies, with a novel regional data set of the kinship institutions and farming productivity observed over the 600-1550 CE period in the Ghana, Mali and Songhai empires. Notably, temperature drops, which increased the yield of plow-positive crops and in turn, the male farming productivity, induced reforms towards matrilineal succession. The latter are negatively related to the proxy for matrilineal inheritance of real property devised by the Ethnographic Atlas.
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"*Men are from Earth, women are from Earth. Deal with it.*" George Carlin.

1 Introduction

Kinship institutions determine the patterns of human relationships and the social obligations of individuals towards their group of relatives (Radcliffe-Brown, 1950). While matrilineal kinship systems prescribe that children are part of their mother's kin group and inheritance is restricted to the children of the female group members, patriliny foresees that individuals are part of their father's kinship group and inheritance is passed on to children of male group members (Schulz et al., 2019; Enke, 2019; Schulz, 2022). Because authority is dispersed between the partners' kin groups, matrilineal succession should then decrease the authority of husbands over wives weakening, at the same time, their incentives to cooperate within the household (Radcliffe-Brown, 1950; Gluckman, 1963; Douglas, 1969; Schlegel, 1972). Although a growing empirical literature has tried to confirm these conjectures (Alesina et al., 2013; Moscona et al., 2020; Bahrami-Rad et al, 2022; Lowes, 2024; Tene, 2026), the lack of a formal theoretical framework makes the credibility of these tests limited. To tackle this issue and shed more light on the determinants and impact of kinship institutions, we construct an incomplete contracting model of their design and we test its main prediction on a novel regional data set on the rich history of reforms of the succession rule and environmental shocks to the farming productivity observed over the 600-1550 CE period in the West African kingdoms of Ghana, Mali and Songhai (McKissack and McKissack, 1994).

While, indeed, the seventh and eighth century cooling raised the productivity of plow-positive crops and in turn, males' effort and were associated to the adoption of matrilineal succession, the beginning of the second millennium medieval warming was characterized by a shift towards patriliny (Davidson, 1998; Hill, 2009). Similarly, the twelfth and thirteenth century Little Ice Age was marked by a comeback of matrilineal inheritance, whereas the fourteenth, fifteenth and sixteenth century were characterized by both a new heating up and a novel spread of patrilineal succession (Conrad. 2005; Reece, 2006; Hill, 2009).

To elucidate the rational incentives behind these epochal events and provide a general model of the selection of kinship institutions, we study a society designing gender-based property rights to maximize the welfare of a population of offspring equally split into males and females, who are, then, paired in couples (Guerriero, 2016; 2023). Within each couple, each partner's non-contractible choice of the time to devote to either farming or home production produces both a self-investment in each activity, whose value is shaped by a gender-specific farming productivity parameter and constitutes the agent's default payoff, and a cross-investment, whose value rises in a couple-specific technological parameter as well as the product of the parties' time allocations in each activity and determines the possible gains from trade. The latter are distributed according to each party's ex post bargaining power, which in turn, is fully determined by the property rights on its input, e.g., human capital or physical assets (Guerriero and Pignataro, 2024).[1] Given this technology and the—average—superiority of farming, society designs property rights to push parties to specialize in farming when socially optimal and in the activity in which they are most productive otherwise. To elaborate, society attains the first best by fully protecting either side when they are both better at farming and by favoring the party with the lowest farming productivity otherwise. While specialization in farming prevails in the first case, in the second one more productive couples pick farming and less productive ones diversify. Under the assumption that society breaks any indifference between property institutions in favor of the less efficient party to discourage inefficient outside options and/or incidental inequity, matrilineal succession—i.e., a female ex post bargaining power equal to one—will prevail over patriliny when females are less productive. Finally, females' property rights become inefficiently weak in a political economy allowing their exclusion from the institutional design.

We evaluate the model implications by analyzing the unbalanced panel of the 1234 cell-epochs in which the Ghana, Mali and Songhai empires can be divided and that we observe at the 0.5 degree spatial resolution for possibly each half-century between 600 and 1550 CE and a total of 5411 cell-epochs. Compared to similar databases on pre-industrial societies and notably the sample of ethnicity described by the Murdock's (1981) Atlas, our sample is uniquely fitted to test our theory for three crucial reasons. First, and different from these cross-sectional databases, it displays a very large panel variation on units demarcated by well-defined, narrow, and stable boundaries and entertaining in activities sufficiently simple

[1] We label a female with "she," a male with "he" and a generic party with "it."

to credibly link exogenous ecological shocks to institutions. Second, it is characterized by epochal episodes of climate change included the medieval warm period and the Little Ice Age. Finally, our historical laboratory is unaffected by the obfuscating impact of the European colonization (Boranbay and Guerriero, 2019; Benati and Guerriero, 2026).

Lacking credible data on past land suitability (Benati and Guerriero, 2025), we capture situation in which females are more productive than males with a dummy equal to one if the most productive plow-negative crop among those observed over the sample—i.e., either millet or sorghum—would have produced over the previous half-century—on average—more kcal per ha than the most productive plow-positive crop, i.e., barley. To obtain the expected energy from each crop, we combine simulated historical temperature data with the coefficients describing the inverted U-shaped link between the natural logarithm of the energy produced by the specific crop and the temperature in the unbalanced panel of 131 countries spanning the 1986-2012 period and studied by Agnolucci et al. (2020). Ultimately, our indicator for female farming productivity advantage over males equals one if a sufficiently high rise in temperature made less appealing—from a fitness point of view—plow-positive crops and in turn, male cooperation (Alesina et al., 2013). Turning to kinship institutions, we build on the extant historical literature on the evolution of inheritance rights over our sample (McKissack and McKissack, 1994; Davidson, 1998; Conrad, 2005; Reece, 2006), and we construct a dummy for the adoption of matrilineal—rather than patrilineal—succession of personal and real property over the 40 years around each of the sample half-century observations.

Conditional on cell-epoch and empire fixed effects and the direct—and possibly non-linear—impact of climate factors, temperature drops, which raised the productivity of plow-positive crops and in turn, the males' effort, induced reforms towards matrilineal succession.

While these basic estimates are consistent with the model predictions, they may be capturing reverse causality, unobserved heterogeneity and/or measurement error. We evaluate these issues in turn. First, we notice that reverse causality is not an issue since our measures of female farming productivity advantage are independent from human decisions. Second, our conclusions are the same if we control for other key determinants of property rights such as the diffusion of Islam (Huntington, 1996), severity of external and internal conflicts (Acemoglu and Robinson, 2000; Besley and Persson, 2009) and inclusiveness of the political process (Guerriero, 2016; 2023), which, as foreseen by our model, should positively related to matrilineal succession. To put this conclusion in perspective, we calculate that to attribute the entire estimates to selection effects, selection on unobservables would have to be on average more than nineteen times greater than selection on observables. More important, our results are robust to switching to a panel difference-in-differences design, in which we compare cells experiencing climate shocks shaping the female farming productivity advantage that are more severe, to cells experiencing less severe shocks, before and after these ecological fluctuations. Finally, we obtain qualitatively similar estimates when we employ a continuous measure of the female farming productivity advantage defined as the average natural logarithm of the expected kcal per ha produced by the most productive plow-negative crop less that delivered by the most productive plow-positive crop.

One last criticism to our empirical test concerns its external validity. To evaluate this issue, we build on the Murdock's (1981) Atlas dummies for matrilineal inheritance of immovable and movable property and we document their negative correlation with our continuous measure of the female farming productivity advantage, conditional on climate factors averaged over the half-century preceding the observation by the Atlas of each ethnicity.

Ultimately, we contribute to the literature on endogenous kinship institutions in three crucial ways. First, we construct the first model of the selection of kinship institutions and notably, the relative protection of female and male property rights on their scarce inputs (Enke, 2019). Second, we test the main implications of our theoretical model by reconstructing the institutional evolution of the most important pre-colonial states in Africa established after the disintegration of Ancient Egypt (Davidson, 1998). Finally, by documenting a significant negative correlation between our measure of matrilineal succession and the indicator for matrilineal inheritance of real property developed by Murdock (1981), we underline the limited reliability of his Atlas, which is based on ethnographic surveys rather than the most credible review of the historical literature (Rijpma and Carmichael, 2016).

The paper proceeds as follows. In section 2, we discuss stylized facts on the evolution of the Ghana, Mali and Songhai empires consonant with our general model of kinship institutions, which we illustrate in section 3 and whose testable predictions we detail in section 4. Next, we describe in section 5 our test and we conclude in section 6. We report figure and tables in the appendix and a description of each variable coding in the Internet appendix.

2 Kinship in the Ghana, Mali and Songhai Empires

Ghana empire (300-1240 CE).—The empires of medieval west Africa plunged their roots in the Tichitt tradition of the proto-Mandé peoples—i.e., present-day Soninke, which flourished in the Sahelian floodplains starting from 300 CE thanks to the unprecedented mix of the improved climate and the diffusion of iron-using among farmers (McIntosh, 2008). To illustrate, these households started to organize irrigation infrastructures aimed at domesticating cold-resistant crops necessitating plow use by males, within farming compounds in which men and women shared the farming workload [McKissack and McKissack 1994, p. 34-35; MacDonald, 2015]. The need of incentivizing intra-household cooperation shaped kinship institutions [Linares-Matás 2022, p. 168-170], and it is not surprising that these agro-pastoralist chiefdoms generally embraced matrilineal succession in its avuncular version [McKissack and McKissack 1994, p. 7 and 30].[2] The subsequent introduction of the camel placed the Soninke at the crossroads of the routes connecting the northern salt-mining centers of Taghaza to the southern gold-bearing areas of Wangara and Bouré (see figure 1), favoring the rise of a confederation of middlemen states in varying relationships with the core and forming the Ghana empire (McKissack and McKissack, 1994; McIntosh, 2008).

Starting from the seventh century foundation of the Kumbi Saleh capital (Es'andah, 1976), the royal family acquired undisputed authority on the affiliated polities and relied on local elites to administer justice, impose levies and provide public goods [Davidson 1998; McKissack and Fredrick 1994, p. 30-32]. At the end of tenth century zenith, the empire was even able to force the rich commercial center of Awdaghust to accept its rule, while maintaining the Islamic property law brought during the ninth century by the Berber traders [McDougall 1985, p. 7]. Ghana's great wealth, however, also attracted competitors bent on loosening its hold and notably, the Almoravids, who succeeded during the tenth century in imposing their external political control, converting the population to Islam and inducing a gradual shift towards patriliny (Page, 2005; Reece, 2006). As figure 2 suggests, this last

[2] Under such a version of matrilineal succession, inheritance and lineage are traced via the female line, specifically from a mother's brother—i.e., the avunculus—to his sister's son, i.e., his nephew (Barnard, 2010).

discontinuity was accompanied by the Medieval warm period diffusion of plow-negative crops like millet and sorghum [McKissack and McKissack 1994, p. 35]. Taking advantage of the political instability, Sundiata, ruler of the Kangaba state, conquered in 1240 the remnants of the Ghana empire founding the Mali empire (Conrad, 2005).

Mali empire (1240-1500 CE).—The core elite of the rising reign belonged to the Malinke ethnicity, the largest subgroup of the Mandé peoples, which soon imposed matrilineal succession on all subjugated populations, including the Tuareg, Dogon, Senufo, Fula, Bozo, Somono and Songhay peoples (see figure 1). This expansion coincided with the beginning of the Little Ice Age (see figure 2). The Mali's monarchs, known as the Mansas, ruled such a vast empire via appointed governors, known as farbas (Reece 2006), and, even if increasingly attracted by the Islamic doctrine, continued to safeguard the Tichitt cultural traditions until the end of Mali's Golden Age (Conrad, 2005; Hill, 2009). To elaborate, albeit Mansa Musa, Mali's most famous king, was remembered for bringing back from his 1325 CE fabulous pilgrimage to Mecca scientists and legal scholars who established Muslim courts of law in Timbuktu, Jenne, and Gao [Reece 2006, p. 18], patriliny diffused in the rest of the empire only by ca. 1400, when Northern Africa started to experience improved climate conditions (see figure 2). Meanwhile, the Songhai people, once under Mali's suzerainty, rose in strength and eventually seized key cities such as Gao and Timbuktu (Reece, 2006). As centralized control waned, peripheral provinces began to assert independence, and by the late fifteenth century, only the capital Niani remained under imperial authority (Conrad, 2005).

Songhai empire (1500-1591 CE).—The rise of the Songhai empire can be traced to the reign of Sunni Ali Beeri, who ruled between 1464 and 1492. The Sonni dynasty conquered a vast territory, which was then organized in five provinces governed by appointed officials, and imposed both the Sharia and patrilineal succession (Davidson, 1998). The ensuing Askia Dynasty, instead, struggled to maintain political stability and the 1591 Moroccan invasion caused the irreversible crisis of the Western African reigns (Conrad, 2005).

3 Theory

Technology.—Consider a society interested in regulating the economic activities of a population of offspring of mass two, equally divided in randomly paired females F and males M.

While agent F can invest a non-contractible share of time $\alpha \in [0,1]$ in a farming activity and the remainder in home production, agent M can invest a non-contractible share of time $\beta \in [0,1]$ in the farming activity and the remainder in home production.

Within pairs that are unwilling to cooperate, an agent F selecting α produces levels of farming and home production equal to, respectively, $\varphi\alpha$ and $1-\alpha$ and a party M picking β obtains levels of farming and home production equal to, respectively, $\mu\beta$ and $1-\beta$. Hence, $\varphi > 0$ and $\mu > 0$ gauge agent F's and party M's productivity in farming vis-a-vis home production, whose productivity is normalized to one. The relative size of the two parameters is shaped by environmental conditions, such as the climate shocks that we analyze in our empirical exercise. To focus on the most empirically relevant case of subsistence farming (Davidson, 1998), we impose the following restriction on the productivity parameters:

Assumption 1: $\varphi + \mu > 2$.

In words, we adopt the view that on average the two parties are more productive in farming than in home production. While, moreover, each agent's outside option is zero (Guerriero and Pignataro, 2024), its default payoff is d_i, with $i \in \{F, M\}$, $d_F = \varphi\alpha + 1 - \alpha$ and $d_M = \mu\beta + 1 - \beta$. These last two payoffs are, respectively, agent F's and party M's next-best alternative to joint production (Grossman and Hart, 1986; Whinston, 2003).

Within pairs that are willing to cooperate, instead, choices α and β deliver levels of farming and home production equal to, respectively, $\varphi\alpha + \mu\beta + \lambda\alpha\beta$ and $1 - \alpha + 1 - \beta + \lambda(1-\alpha)(1-\beta)$, with λ uniformly distributed over $\left[0, \overline{\lambda}\right]$, $\lambda_m \equiv \overline{\lambda}/2$ and $\overline{\lambda} > 1$. As a consequence, the parameter λ picks the degree of complementarity between the inputs of the two agents within a match, which we agnostically assume to equally affect farming and home production. Relaxing this assumption comes at the cost of a more cumbersome algebra.

Payoffs.—Within a possibly cooperative match, the parties first invest and then, bargain over trade, i.e., they decide whether to accept the default payoffs or use their assets for joint production. In the second case, the agents split production in such a way that party F receives her default payoff plus a share γ of the gains from trade—i.e., project value net of the default payoffs—and agent M pockets the rest. Parties F and M's ex post bargaining payoffs are $\pi_F(\gamma) \equiv d_F + \gamma\left[\varphi\alpha + \mu\beta + \lambda\alpha\beta + 1 - \alpha + 1 - \beta + \lambda(1-\alpha)(1-\beta) - d_F - d_M\right] = \varphi\alpha + 1 - \alpha + \gamma\lambda(2\alpha\beta + 1 - \alpha - \beta)$ and $\pi_M(\gamma) \equiv \mu\beta + 1 - \beta + (1-\gamma)\lambda(2\alpha\beta + 1 - \alpha - \beta)$.

Interpretation.—The parameter γ captures the strength of agent F's property rights on her ability, human capital and assets in both farming and home production relative to the strength of the property rights on the inputs available to party M. To elaborate, γ is larger the stronger are the remedies in agent F's hands, i.e., strength of matrilineal inheritance, the more efficient is their enforcement and the longer is their prescription period. Symmetrically, it is smaller the more intense is the legal protection of party M's inputs. In general, the investment interaction that we study can be envisioned as any endeavor requiring cooperation between F and M—e.g., individuals, firms and organizations—and such that agent F's renegotiation power is determined by the socially devised γ (Guerriero and Pignataro, 2024).

Timing of events.—The sequence of the institutional and economic decisions is as follows.

In t_0, society selects the protection of party F's property rights γ.

In t_1, and within a pair, agents decide whether they prefer to accept the outside option.

In t_2, and within a pair, parties that did not settle for the outside option at time t_1 select simultaneously and noncooperatively an allocation of their time.

In t_3, and after having invested, agents bargain over trade, i.e., pick either d_i or π_i.

Discussion.—In evaluating the soundness of our setup, several remarks should be headed.

First, our conclusions will remain qualitatively similar should the farming and home production functions be Cobb-Douglas (Guerriero and Pignataro, 2024).

Second, albeit we maintain that all land is private, communal land is a key asset in pre-industrial societies and is systematically shaped by kinship institutions whereby women in matrilineal groups have more secure access to these areas (Meinzen-Dick and Zavale, 2025). Our sample was not different being communal land assigned by rulers following the same kinship institutions of the population [McKissack and McKissack 1994, p. 34, 55 and 56], and accordingly our analysis immediately extends to a world in which property rights shape the returns of the two groups on both private and communal land.

Third, our baseline assumption is that farming productivity is shaped by shocks, like changes in temperature, affecting the two groups in opposite ways. A more general view, however, is that the very same discontinuities could also indirectly affect productivity in such a way that φ and μ would then capture their combined effects. The role of climate is a case in point. Not only does a sufficiently large rise in temperature make female more productive than males in farming (see section 5), but it also discourages fertility while intensifying internal conflicts (Burke et al., 2015; Conte Keivabu et al., 2024). Ultimately, these alternative channels merely widen the applicability of our setup, which also extends to the case in which the available time is residually determined by the parties' involvement in gender-specific activities such as child-bearing and war-waging.

Fourth, our results survive when investments are discrete (Müller and Schmitz, 2016).

Fifth, since modulating property rights only shapes within match decisions, our analysis is the same for any continuous probability density function of λ (Guerriero, 2016; 2023).

Sixth, the randomness of λ can be seen as an unforeseen shock to already matched pairs.

Seventh, the division of the gains from trade will still be determined by γ should we envision that the parties can contract on a different ex post bargaining parameter ζ at time t_1 but can also obtain at time t_3 that γ is enforced by filing suit. Then, one party will always prefer ex post γ over $\zeta \neq \gamma$ and thus, ζ will be picked in the shadow of the law to equal γ.[3]

Finally, our results will stand should a group dominate institutional design (section 3.2).

3.1 Equilibrium

Regularities.—We focus on SPE in pure strategies. Any such an equilibrium prescribes a property rights level γ^* and, for each project, possibly multiple α^* and β^* time allocations. Three characteristics of a SPE immediately follow from our assumptions. First, the parties will never pick the zero outside option since it does not improve over the positive default payoffs. Second, because of the multiplicative returns from cooperation, the two parties weakly prefer the ex post bargaining payoff to the outside option. Finally, because of the complementarity in the agents' time allocation choices and the opposite impacts of γ^* on their ex post bargaining payoffs, society will design property rights in order to have the two parties specialize in possibly different activities and thus, maximize social welfare. To see this, notice that the social welfare $W(\alpha, \beta) \equiv \varphi\alpha + 1 - \alpha + \mu\beta + 1 - \beta + \lambda(2\alpha\beta + 1 - \alpha - \beta)$ is such that $W(1,1) > W(0,0)$ being $\varphi + \mu > 2$, $\frac{\partial W}{\partial \alpha} \geq 0 \leftrightarrow \lambda \geq \frac{1-\varphi}{2\beta-1}$ and $\frac{\partial W}{\partial \beta} \geq 0 \leftrightarrow \lambda \geq \frac{1-\mu}{2\alpha-1}$. Hence,

[3] The parameter γ can also be seen as the share of courts favoring party F and determined by the strength of agent F's property rights (Guerriero, 2023). This view squares with the idea that courts arbitrarily evaluate the evidence when the state of the world is hard to verify and thus, the latter can be manipulated at adjudication (Gennaioli, 2013). More generally, our setup entails that the legal order can enforce property rights without, however, allowing contract completeness (see Guerriero and Pignataro, [2024]).

society will design property rights to avoid the $\alpha^* = \beta^* = 0$ pair because always dominated by the $\alpha^* = \beta^* = 1$ equilibrium and, as detailed in the appendix, it will not select $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$ since for these choices the social welfare is strictly increasing with α^* and β^* for either $\varphi > \mu \geq 1$ or $\mu \geq \varphi \geq 1$ (a), rising with α^* and falling with β^* for $\varphi \geq 1 > \mu$ (b) and decreasing with α^* and increasing with β^* for $\mu \geq 1 > \varphi$ (c). Ultimately, society will only consider as alternative to the time allocations $\alpha^* = \beta^* = 1$ the pair $\alpha^* = 1$ and $\beta^* = 0$ under scenario (b) and the equilibrium $\alpha^* = 0$ and $\beta^* = 1$ under scenario (c).

3.1.1 Selecting Investment

To illustrate, given λ and γ^*, parties F and M select $\alpha \in [0,1]$ and $\beta \in [0,1]$ to maximize

$$\varphi\alpha + 1 - \alpha + \gamma\lambda\left(2\alpha\beta + 1 - \alpha - \beta\right) + \delta_1\alpha - \delta_2\left(\alpha - 1\right), \tag{1}$$

$$\mu\beta + 1 - \beta + \left(1 - \gamma\right)\lambda\left(2\alpha\beta + 1 - \alpha - \beta\right) + \delta_3\beta - \delta_4\left(\beta - 1\right), \tag{2}$$

subject to the usual dual feasibility and complementary slackness conditions. While δ_1 and δ_3 are, respectively, the Karush-Kuhn-Tucker multipliers of the constraints $-\alpha \leq 0$ and $-\beta \leq 0$, δ_2 and δ_4 refer to the constraints $\alpha \leq 1$ and $\beta \leq 1$, respectively.

The necessary—and sufficient—first order conditions are, respectively:

$$\varphi - 1 + \gamma^*\lambda\left(2\beta^* - 1\right) + \delta_1 - \delta_2 = 0, \tag{3}$$

$$\mu - 1 + \left(1 - \gamma^*\right)\lambda\left(2\alpha^* - 1\right) + \delta_3 - \delta_4 = 0. \tag{4}$$

3.1.2 Selecting Property Rights

Society attains the first best by fully protecting either side when their incentives are aligned (a) and by fully protecting the agent with the lowest farming productivity otherwise, i.e., by picking $\gamma^* = 0$ under scenario (b) and $\gamma^* = 1$ under scenario (c). In the (b) and (c) cases, both parties cooperate in farming for large λ and the agent more productive in home production switches to this activity for small values of λ, i.e., for $\lambda \leq 1 - \mu$ under scenario (b) and for $\lambda \leq 1 - \varphi$ under scenario (c). This institutional design discourages deviations to suboptimal time allocations in which the parties are not specialized (see the appendix).

Ultimately, under scenario (a), society equalize γ^* to either zero or one and obtains $\alpha^* = \beta^* = 1$ and $W = \varphi + \mu + \lambda_m$. Under scenario (b), instead, society picks $\gamma^* = 0$ and induces the choices $\alpha^* = \beta^* = 1$ for $\lambda > 1 - \mu$ and $\alpha^* = 1$ and $\beta^* = 0$ otherwise, obtaining a social welfare of $(\varphi + 1)\frac{1-\mu}{\bar{\lambda}} + (\varphi + \mu)\frac{\bar{\lambda}-1+\mu}{\bar{\lambda}} + \lambda_m$. Similarly, under scenario (c), society selects $\gamma^* = 1$ and brings about the choices $\alpha^* = \beta^* = 1$ for $\lambda > 1 - \varphi$ and $\alpha^* = 0$ and $\beta^* = 1$ otherwise, obtaining a social welfare of $(1 + \mu)\frac{1-\varphi}{\bar{\lambda}} + (\varphi + \mu)\frac{\bar{\lambda}-1+\varphi}{\bar{\lambda}} + \lambda_m$.

To turn these model implications into a testable prediction, we assume that:

Assumption 2: *Whenever indifferent between any two levels of protection of party F's property rights, society will select the one safeguarding the most the less efficient party.*

Two are the key justification to this tie-breaking rule. First, by adopting it, society can discourage the less efficient party from embracing outside options that are individually favorable but socially inefficient (Guerriero and Pignataro, 2024). To see the point, consider without loss of generality the $\mu > \varphi > 1$ scenario and envision a positive outside option ϵ with $\mu > \epsilon > \varphi$. Then, $\gamma^* = 0$ deters any cooperation being $\pi_F(0) = \varphi < \epsilon$, whereas matrilineal succession induces farming production for every $\pi_F(1) \geq \epsilon \leftrightarrow \lambda \geq \epsilon - \varphi$ and thus, it is strictly optimal. Second, the tie-breaking rule minimizes any social loss from incidental inequality by reducing the difference between the two parties' ex post bargaining payoffs (Fehr and Schmidt, 1999). Building again on the $\mu > \varphi > 1$ scenario, such a gender pay gap falls from $\mu + \lambda - \varphi$ to $\varphi + \lambda - \mu$ when society switches from $\gamma^* = 0$ to $\gamma^* = 1$.

The following proposition summarizes our analysis (see figure 3):

Proposition 1: *Under assumptions 1 and 2, party F's property rights γ^* weaken with her farming productivity φ, being zero if she is more productive than party M—i.e., for either $\varphi > \mu \geq 1$ or $\varphi \geq 1 > \mu$—and one otherwise, i.e., for either $\mu \geq \varphi \geq 1$ or $\mu \geq 1 > \varphi$.*

3.2 The Political Economy of Kinship Institutions

Thus far, we have examined the choice of the design of gender-based property rights under the assumption that the two groups have equal political power. Reality, however, might be quite different. To evaluate this issue, we follow Guerriero (2016, 2023) and Guerriero and Pignataro (2024), and we consider a situation in which a partisan legislator can exclude from the social welfare maximization the payoffs of either of the two parties and notably agent F.

Starting with scenario (a), political economy distortions will induce a fall of γ^* from 1 to 0 without, however, affecting the efficiency of the equilibrium, which would still induce the first best. Similarly, γ^* will remain equal to zero under scenario (b) leaving the equilibrium socially efficient. Finally, under scenario (c), the protection of party F's property rights will end up be inefficiently weak. Proposition 2 summarizes the analysis of this section:

Proposition 2: *Under assumptions 1 and 2, the strength of party F's property rights inefficiently weakens when party M can exclude from the institutional design the other party.*

4 Empirical Implications

The model implications can be restated as testable predictions as follows:

Testable Predictions: *Matrilineal succession is more likely when females are less productive than males and the more inclusive the political process is.*

5 Evidence

Our sample is constituted by the unbalanced panel of 860 cells of 0.5 degree spatial resolution in which the Ghana, Mali and Songhai empires can be divided over the 600-1450 CE period (see figure 1). As clarified below, this is the granularity of the climate variables that we use to define the female farming productivity advantage. Using these units to identify the cross-sections in our sample would be appropriate only if the comparison among cells part of a single empire and those spanning multiple empires is appropriate. Given, however, the epochal changes that have determined the fall and rise of empires over our historical case, we assign a new identifier to a cell becoming part of a new empire. This choice leaves us with an unbalanced panel of 1234 cell-epochs possibly observed for each half-century between 600 and 1550 CE for a total of 5411 cell-epochs. Crucially, sample selection does not seem to be an issue since the estimates of an Heckman model, run on a sample encompassing the aforementioned 860 cells and spanning each half-century between 600 and 1450 CE period, suggest that the residuals of regression and selection equations are unrelated at the 34% statistical level (results available upon request). To identify selection, we exploit the fact that cells disappearing from the sample mainly lied in the south-western corner of figure 1 and thus, the sampling probability is negatively related to each cell's latitude and longitude.

Regarding the temporal span of our sample, two are the key constraints that have guided our choice. First, the institutional evolution of the period preceding the foundation of the Kumbi Saleh capital is still ill-understood (McKissack and McKissack, 1994; Reece, 2006; Hill, 2009). Second, the 1591 Moroccan invasion induced an irreversible crisis of the Western African reigns, which, in turn, has significantly reduced the available written sources and makes significantly less credible and informative their historical analyses (Conrad 2005).

5.1 Measurement

5.1.1 Female Farming Productivity Advantage

To capture the female farming productivity advantage over males, we start from the distinction made by the literature on the economics of kinship between plow-positive crops, like barley, teff, rye, wet rice and wheat, and plow-negative crops, such as maize, millet, sorghum, and roots (Alesina et al., 2013). While the latter respond less intensely to plow use—and in turn, males' effort—since they require small tracts of land to be prepared in a short period of time, soils that are thin, sloped, and/or rocky, and higher temperature, the latter are less responsive to plow use since they require diametrically different environments (Pryor, 1985; Agnolucci et al., 2020). Since recent evidence based on a vast paleobotanical literature suggests that the available land suitability data cannot capture the historical soil capacity to retain and supply nutrients and water (Benati and Guerriero, 2025),[4] we capture situation in which females are more productive than males with a dummy equal to one if the most productive plow-negative crop among those observed over the sample—i.e., either millet or sorghum (Conrad, 2005; Logan et al., 2024)—would have produced over the previous half-century more kcal per ha than the most productive plow-positive crop—i.e., barley, i.e., *Female* (see table 1 for the definition and sources of each variable).

[4]These indicators are produced by the GAEZ project on the basis of post-1981 agro-climatic factors—i.e., radiation and temperature—and possibly, present-day agro-edaphic conditions, such as the terrain management systems and the soil salinity (Fischer et al., 2021). Since the latter can reflect past human intervention, the extant literature has focused on the land suitability indexes based only on agro-climatic conditions under low-input farming, which should be then independent from human decisions. Yet, this approach is correct only if historical climatic conditions can be proxied by present-day ones, which is unreasonable in our sample since the post-1960 global warming has altered the productivity ranking of our cells by improving the climate of those further away from the equator while worsening those nearer to it (Benati and Guerriero, 2025).

To obtain the natural logarithm of the crop-specific expected energy, we calculate the sum of the natural logarithm of the energy content of each crop in kcal per unit of yield reported by FAO and natural logarithm of the yields of the specific crop in kg per ha predicted by combining simulated historical temperature data with the coefficients from an inverted U-shaped relationship between yields and temperature estimated on present-day data (see figure 4).[5] To illustrate, this last link is obtained from country fixed effects OLS models regressing the natural logarithm of each crop yields in kg per ha on the annual precipitation in mm, the temperature in degree Celsius and its square and run on the unbalanced panel of 131 countries spanning the 1986-2012 period and studied by Agnolucci et al. (2020). Rainfall is always insignificant in the these regressions (results available upon request). For what instead concerns the coeval temperature data, we directly collect this information from Armstrong et al. (2019), who, in turn, combine discrete equations for fluid motion with grid-specific information on land, soil and plant characteristics to simulate the interactions among atmosphere, ice and land surface for each month between 60,000 and 0 BP—i.e., 1950—and the northern hemisphere at a 0.5 degree spatial resolution. Since plow-negative crops requires higher temperatures, *Female* equals one when a sufficiently strong warming made less appealing plow-positive crops and in turn, male cooperation.[6] As figure 2 suggests, female farming productivity first increased as Western Africa entered in the medieval warm period, then felt with the Little Ice Age and finally increased again at the end of the sample.

Four observations validate our measurement strategy. First, actual and predicted yields are strongly correlated in the Agnolucci et al.'s (2020) sample (results available upon request). Second, the Armstrong et al.'s (2019) data are more widely available but strongly related to alternative proxy data (Benati and Guerriero, 2025). Third, the Armstrong et al.'s (2019) data are strongly correlated with the available cereal yields data in comparable pre-industrial samples (Benati and Guerriero, 2025). Finally, our conclusions are similar when we switch to a continuous measure of the female farming productivity advantage defined as the average—over the previous 50 years—natural logarithm of the expected kcal per ha produced by the most productive plow-negative crop less the average natural logarithm of the expected kcal

[5]The energy content of each crop is available from https://www.fao.org/4/x9892e/X9892e05.htm

[6]*Female* equals zero when barley is the most productive crop because the average temperature is below 27.86 degree Celsius, and one otherwise. In the second case, sorghum is always superior to millet.

per ha delivered by the most productive plow-positive crop (see section 5.4), i.e., *Female-C*.

To account for the—possibly non-linear—direct effect of climate conditions,[7] we always control for the temperature in degrees Celsius—i.e., *Temperature*, monthly precipitation in mm—i.e., *Precipitation*, square of both variables—i.e., *Temperature*^{2} and *Precipitation*^{2}, standard deviation of the temperature in degrees Celsius—i.e., *Temperature-SD*—and standard deviation of the monthly precipitation in mm, i.e., *Precipitation-SD*, all calculated over the previous half-century and again based on the Armstrong et al.'s (2019) data.

5.1.2 Kinship Institutions

Turning to the kinship institutions, we build on the extant historical literature on the evolution of inheritance rights over our sample (see the Internet appendix), and we construct a dummy for the adoption of matrilineal—rather than patrilineal—succession of personal and real property over the 40 years around each observation, i.e., *Matrilineal*. As the parameter γ^* in our model, *Matrilineal* captures the strength of the females' property rights on their ability, human capital and assets in farming and home production relative to the strength of the males' property rights on their own inputs. To elaborate, the index will turn on when matrilineal inheritance is widely diffused in the population, its enforcement is more stringent and its prescription is longer (Guerriero, 2016; 2023). As figure 2 clarifies, matrilineal succession was dominant until the Ghana empire started to disintegrate because of the Almoravids' political and military pressure. Next, it was reinstated during the first phase of the Mali empire to completely disappear in its final phase and during the Songhai empire.

Crucially, we can document a significant—at 1 %—negative partial correlation between our measure of matrilineal succession and the indicator for matrilineal inheritance of real property developed by the Murdock's (1981) Ethnographic Atlas, conditional on *Female*, *Temperature*, *Precipitation*, *Temperature*^{2}, *Precipitation*^{2}, *Temperature-SD* and *Precipitation-SD*. This evidence underlines the limited reliability of the Atlas itself, which is based on ethnographic surveys rather than the most credible review of the archaeological, anthropological and historical literature that we embrace (Rijpma and Carmichael, 2016).

[7] While both factors have an inverted U-shaped link with matriliny, the impact of climate volatility is negative.

5.2 Estimating Equation

A glance at figure 2 reveals that the model predictions square with our data. While, indeed, the improvement in the climatic conditions between the beginning of the second millennium low and the medieval warming induced a passage from matrilineal succession to patrilinial succession, the twelfth and thirteenth century Little Ice Age was marked by a comeback of matrilineal inheritance. Similarly, the warming up of the fourteenth, fifteenth and sixteenth century was accompanied by a novel spread of patriliny. Although anecdotal evidence is informative, empirical evidence is more convincing. We run by OLS the models

$$Y_{c,t} = \alpha_c + \gamma' \mathbf{X}_{c,t} + \delta' \mathbf{Z}_{c,t} + \varepsilon_{c,t}, \tag{5}$$

where $Y_{c,t}$ labels *Matrilineal* and α_c encapsulates cell-epoch fixed effects controlling for time-independent determinants of $Y_{c,t}$, i.e., environmental traits, such as the land suitability for horticulture and pasture (Aberle, 1961; Holden and Mace, 2003), and predetermined shocks like the out of Africa exodus of modern humans and the agricultural revolution (Olsson and Paik, 2016).[8] $\mathbf{X}_{c,t}$ includes, instead, either *Female* or *Female-C* along with *Temperature*, *Precipitation*, *Temperature*^{2}, *Precipitation*^{2}, *Temperature-SD* and *Precipitation-SD* as well as empire fixed effects.[9] This last indicator picks macro-shocks such as unobserved dynastic characteristics (McKissack and McKissack, 1994; Reece, 2006).[10] Finally, $\mathbf{Z}_{c,t}$ possibly incorporates the extra control variables discussed in section 5.4.

To tackle within-cell correlation possibly driven by institutional persistence, we rely on errors clustered at the cell-epoch level. In the Internet appendix moreover, we document that our conclusions are similar when we model the spatial dependence in $\varepsilon_{c,t}$ possibly driven by regional climatic patterns by relying on Conley's (1999) standard errors with Bartlett kernel. To elaborate, we consider as thresholds beyond which the correlation between error terms is assumed to be zero one, two or three times the approximate distance between the centroid

[8]While Olsson and Paik (2016) claim that an early Neolithic transition to agriculture favors patriarchal cultural values, Aberle (1961) and Holden and Mace (2003) advance the idea that matriliny is correlated with, respectively, the productivity of horticulture and cattle herding.

[9]Since kinship institutions ares not very persistent in our sample (see figure 2), our empirical results do not suffer the drawbacks typical of staggered difference-in-differences estimates (Baker et al., 2022).

[10]Given the limited between variation, we do not include in the specifications half-century fixed effects.

of each cell and its closest neighboring cell, i.e., 60, 120 and 180 km.

5.3 Basic Empirical Results

The basic estimates are consistent with the anecdotal evidence discussed in section 2 and the main model prediction (column (1) of table 2). To illustrate, our measure of matrilineal succession is negatively and significantly—at 5%—related to *Female*, conditional on cell-epoch and empire fixed effects as well as the direct—and possibly non-linear effect—of climate factors, and the implied effect is sizable whereby a climate shock making female more productive in farming entailed a more than 12% rise in the expected value of *Matrilineal* over its 0.5 mean. That being said, these estimates may be capturing reverse causality, may be driven by omitted variables and/or might be attenuated by measurement errors.

5.4 Gaining More Insights About Causality

In the following, we assess these three crucial endogeneity issues in turn.

5.4.1 Evaluating the Impact of Reverse Causality

The independence of the proxies for the female farming productivity advantage from human decisions excludes reverse causation from institutions to environmental conditions.

5.4.2 Evaluating the Impact of Unobserved Heterogeneity

We pursue a three-step strategy to evaluate the role of unobserved heterogeneity.

Controlling for Observables.—To begin with, we assess the impact of considering the other key determinants of kinship institutions identified by the extant literature.

To begin with, we incorporate in the vector $\mathbf{Z}_{c,t}$ a dummy for the adoption of Islam by the majority of the population over the half-century preceding each observation, i.e., *Islam*. This dummy picks the impact on the prevailing kinship institutions of the Almoravids' pressure to adopt Islamic property institutions at the end of the Ghana empire and the Mansas' willingness to embrace the Sharia law during the Mali empire (Reece, 2006; Hill, 2009).

Second, we consider a long economic tradition suggesting that producing common interest goods, such as fighting external wars, is conducive to forceful private rights (Besley and Persson, 2009), and we construct a dummy switching on when the province to which the cell belonged partook in an external conflict over the previous half-century, i.e., *External-*

Conflicts. A growing body of research suggests, instead, that inter-groups conflicts might impede the protection of private property (Acemoglu and Robinson, 2000). Hence, we consider a dummy equal to one if the province to which the cell belonged experienced an uprising over the previous half-century, i.e., *Internal-Conflicts*. We base *External-Conflicts* and *Internal-Conflicts* on the available secondary sources on warfare (see the Internet appendix).

Finally, we test the second model prediction that matrilineal succession is more likely the more inclusive the political process is by considering a dummy for the existence of a council of nobles sharing the decision-making power with the ruler, i.e., *Political-Institutions*.[11]

Columns (2) to (5) of table 2 confirm that the message of our analysis remains unchanged when we consider possibly together the aforementioned control variables.[12] To elaborate, the coefficient on *Matrilineal* remains negative and becomes statistically significant at 1% conditional on all observables. As expected, both conflicts and the diffusion of Islam discouraged the spread of matrilineal succession, whereas more inclusive political institutions favored it.

Bias from unobservables.—Despite our attempts to control for observable factors, the estimates presented so far may still be biased by unobservable factors. To evaluate this issue, we calculate the index proposed by Bellows and Miguel (2009) to measure how much stronger selection on unobservables, relative to selection on observables, must be to explain away the entire estimated effects. To see how the index is calculated, consider a regression with a restricted set of controls and one with a full set of controls. Next, denote the estimate of the coefficient attached to the variable of interest from the first regression λ^R, where R stands for "restricted," and that from the second regression λ^F, where F stands for "full." Then, the index is the absolute value of $\lambda^F/(\lambda^R - \lambda^F)$. Intuitively, the lower the absolute value of $(\lambda^R - \lambda^F)$ is, the less the estimate of the coefficient attached to the variable of interest is affected by selection on observables, and the stronger selection on unobservables needs to be to explain away the entire effect. Similarly, the higher the absolute value of λ^F is, the greater is the effect that needs to be explained away by selection on unobservables.

We consider the specifications without controls listed in column (1) of table 2 as the restricted regression and those in columns (2) to (5) of the same table as the full regressions,

[11] The post-Mansa Musa Kangaba was the only province directly controlled by the ruler (Davidson, 1998).

[12] Another factor that might have shaped *Matrilineal* is the incidence of slavery (Lowes and Nunn, 2024). Yet, no slave shipment has embarked from our sample according to the trans-Atlantic slave trade database.

respectively. Two are the crucial observations (see table 3). First, no index is lower than one. Second, the average (median) of these indexes is 19.6 (20). Hence, to attribute the entire estimates to selection effects, selection on unobservable factors would have to be on average more than nineteen times greater than selection on all observables, which seems unlikely.

Panel difference-in-differences.—We re-estimate equation (2) via a panel difference-in-differences design, measuring, moreover, the female farming productivity advantage with *Female-C* and including in $\mathbf{Z}_{p,t}$ the first lag of this proxy to explicitly test for the existence of pre-trends (see column (6) of table 2). Two are the key remarks. First, the message of our analysis remains unchanged. Second, the p-value of a t-test that the coefficient on the lagged variable is zero implies that the parallel trend assumption is verified.

5.4.3 Evaluating the Impact of Measurement Error

Turning to the impact of measurement errors, our results are qualitatively similar when we switch to our continuous measure of female farming productivity advantage. To elaborate, a rise in *Female-C* is associated with a significant—at 10% or better—fall in the expected value of the adoption of matrilineal succession (see columns (6) and (7) of table 2).

5.4.4 Discussion

The estimates discussed in this subsection make it difficult to envision that our results are driven by mechanisms different from those we model and thus, we take them as consistent with causality running from the ecological shocks shaping *Female* to kinship institutions.

5.5 External Validity

One last criticism to our test concerns its external validity. To evaluate this issue, we study the correlation between the dummies for matrilineal inheritance of, respectively, immovable and movable property developed by the Murdock (1981) and *Female-C*, conditional on *Temperature*, *Precipitation*, *Temperature*^{2}, *Precipitation*^{2}, *Temperature-SD* and *Precipitation-SD* (see figure 5). In both cases, we obtain our continuous measure of female farming productivity advantage and our proxies for climate factors by averaging climate data over the half-century preceding the observation by the Ethnographic Atlas of each ethnicity. As figure 5 suggests, matrilineal succession was embraced by ethnicities that had experienced just before the European colonization temperatures sufficiently low to sufficiently increase the yield of plow-positive crops and in turn, the male farming productivity.

6 Conclusions

We have developed and tested a unifying theory of how contract incompleteness induces societies to design kinship institutions in order to favor less productive groups and thus, achieve innovation and resilience (Benati et al., 2022; Guerriero and Pignataro, 2024). Crucially, our model sheds light on the evolution of some of the most important pre-colonial states in Africa, and our test qualifies the correlations reported by the empirical literature on the determinants and impact of kinship systems (Alesina et al., 2013; Moscona et al., 2020; Bahrami-Rad et al, 2022; Lowes, 2024; Tene, 2026). Together, these two contributions deliver, in turn, two crucial policy ramifications. First, patriarchy and in general, male domination can be explained by both political economy distortions in the design of kinship institutions and efficiency reasons. While in the former case institutional reforms are welcome, in the latter case they might well distort investment incentives. Second, our analysis suggests that it is desirable to properly combine sound historical reconstructions to robust theoretical models to inform credible empirical studies of kinship systems and thus, avoid the deterministic conjectures of some of the related literature (Benati and Guerriero, 2025).

Appendix

Proof of Proposition 1

The necessary—and sufficient—first order conditions of party F and M are, respectively, $\varphi - 1 + \gamma^* \lambda (2\beta^* - 1) + \delta_1 - \delta_2 = 0$ and $\mu - 1 + (1 - \gamma^*) \lambda (2\alpha^* - 1) + \delta_3 - \delta_4 = 0$. As a consequence, there are nine relevant cases for each parameter ranking.

$\varphi > \mu \geq 1$.—First, $\alpha^* = 0$ and $\beta^* = 0$ if the FOCs $\lambda > \frac{\varphi-1}{\gamma^*}$ and $\lambda > \frac{\mu-1}{1-\gamma^*}$ hold. By selecting either $\gamma^* = 0$ or $\gamma^* = 1$, society can make, respectively, either the first or the second inequality fail. Second, $\alpha^* \in (0,1)$ and $\beta^* = 0$ if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{\varphi-1}{\gamma^*} < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ prevail. Yet, the second inequality never holds. Third, $\alpha^* = 0$ and $\beta^* \in (0,1)$ if the FOCs $\lambda < \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{\mu-1}{1-\gamma^*} < \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{\mu-1}{1-\gamma^*}$ are true. Nevertheless, the first inequality is always false. Fourth, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$, if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*(1-2\beta^*)}$ and $\lambda = \frac{\mu-1}{(1-\gamma^*)(1-2\alpha^*)}$ hold. At these levels of λ, the social welfare is always increasing with both parties' time allocation choices since $\frac{\varphi-1}{\gamma^*(1-2\beta^*)} > \frac{\varphi-1}{(1-2\beta^*)}$ and $\frac{\mu-1}{(1-\gamma^*)(1-2\alpha^*)} > \frac{\mu-1}{(1-2\alpha^*)}$ and thus, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$ cannot be an equilibrium. Fifth, $\alpha^* = 1$ and $\beta^* = 0$, if the FOCs $\lambda < \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{1-\gamma^*}$ are verified. Yet, the second inequality is never true. Sixth, $\alpha^* = 0$ and $\beta^* = 1$, when the FOCs $\lambda < \frac{1-\varphi}{\gamma^*}$ and $\lambda < \frac{\mu-1}{1-\gamma^*}$ hold. Yet, the first inequality is false. Seventh, $\alpha^* = 1$ and $\beta^* \in (0,1)$, if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{1-\mu}{1-\gamma^*} > \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{1-\mu}{1-\gamma^*}$ are verified. The second equality cannot hold. Eight, $\alpha^* \in (0,1)$ and $\beta^* = 1$, if the FOCs $\lambda = \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{1-\varphi}{\gamma^*} > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ are verified. Yet, the first equality is impossible. Finally, $\alpha^* = 1$ and $\beta^* = 1$ if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{1-\gamma^*}$ hold. Both inequalities are always true. Ultimately, society attains the first best by fixing γ^* equal to either 0 or 1 and inducing time allocation choices $\alpha^* = \beta^* = 1$.

$\mu \geq \varphi \geq 1$.—First, $\alpha^* = 0$ and $\beta^* = 0$ if the FOCs $\lambda > \frac{\varphi-1}{\gamma^*}$ and $\lambda > \frac{\mu-1}{1-\gamma^*}$ hold. By selecting either $\gamma^* = 0$ or $\gamma^* = 1$, society can make, respectively, either the first or the second inequality fail. Second, $\alpha^* \in (0,1)$ and $\beta^* = 0$ if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{\varphi-1}{\gamma^*} < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ prevail. The second inequality is always false. Third, $\alpha^* = 0$ and $\beta^* \in (0,1)$ if the FOCs $\lambda < \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{\mu-1}{1-\gamma^*} < \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{\mu-1}{1-\gamma^*}$ are true. The first inequality can never be true. Fourth, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$, if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*(1-2\beta^*)}$ and $\lambda = \frac{\mu-1}{(1-\gamma^*)(1-2\alpha^*)}$ hold. At these levels of λ, the social welfare is always increasing with both parties' time allocation choices and therefore, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$ cannot be an equilibrium. Fifth, $\alpha^* = 1$ and $\beta^* = 0$, if the FOCs $\lambda < \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{1-\gamma^*}$ are verified. The second inequality cannot hold. Sixth, $\alpha^* = 0$ and $\beta^* = 1$, when the FOCs $\lambda < \frac{1-\varphi}{\gamma^*}$ and $\lambda < \frac{\mu-1}{1-\gamma^*}$ hold. The first inequality can never be true. Seventh, $\alpha^* = 1$ and $\beta^* \in (0,1)$, if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{1-\mu}{1-\gamma^*} > \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{1-\mu}{1-\gamma^*}$ are verified. The second equality is false. Eight, $\alpha^* \in (0,1)$ and $\beta^* = 1$, if the FOCs $\lambda = \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{1-\varphi}{\gamma^*} > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ are verified. The first equality cannot be true. Finally, $\alpha^* = 1$ and $\beta^* = 1$ if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{1-\gamma^*}$ hold. Both inequalities are always true. Ultimately, society attains the first best by equalizing the strength of the F's party's property rights equal to either 0 or 1 and inducing $\alpha^* = \beta^* = 1$.

$\varphi \geq 1 > \mu$.—First, $\alpha^* = 0$ and $\beta^* = 0$ if the FOCs $\lambda > \frac{\varphi-1}{\gamma^*}$ and $\lambda > \frac{\mu-1}{1-\gamma^*}$ hold. By selecting $\gamma^* = 0$, society can make the first inequality fail. Second, $\alpha^* \in (0,1)$ and $\beta^* = 0$ if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{\varphi-1}{\gamma^*} < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ prevail. The second inequality does not hold for γ^* approaching zero. Third, $\alpha^* = 0$ and $\beta^* \in (0,1)$ if the FOCs $\lambda < \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{\mu-1}{1-\gamma^*} < \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{\mu-1}{1-\gamma^*}$ are true. Yet, the second equality is impossible. Fourth, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$, if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*(1-2\beta^*)}$ and $\lambda = \frac{\mu-1}{(1-\gamma^*)(1-2\alpha^*)}$ hold. At these levels of λ, the social welfare is increasing with α^* and decreasing with β^* and thus, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$ cannot be an equilibrium. Fifth, $\alpha^* = 1$ and $\beta^* = 0$, if the FOCs $\lambda < \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{1-\gamma^*}$ are verified. These inequalities are verified for a small γ^* and $\lambda \leq 1-\mu$. Sixth, $\alpha^* = 0$ and $\beta^* = 1$, if the FOCs $\lambda < \frac{1-\varphi}{\gamma^*}$ and $\lambda < \frac{\mu-1}{1-\gamma^*}$ hold. Yet, both inequalities are false. Seventh, $\alpha^* = 1$ and $\beta^* \in (0,1)$, if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{1-\mu}{1-\gamma^*} > \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{1-\mu}{1-\gamma^*}$ are verified. The first inequality fails for γ^* approaching zero and β^* small. Eight, $\alpha^* \in (0,1)$ and $\beta^* = 1$, if the FOCs $\lambda = \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{1-\varphi}{\gamma^*} > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ are verified. Yet, the first equality is impossible. Finally, $\alpha^* = 1$ and $\beta^* = 1$ if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{1-\gamma^*}$ hold. The first inequality is true, whereas the second holds for γ^* small. Ultimately, society attains the first best by setting $\gamma^* = 0$ and inducing $\alpha^* = \beta^* = 1$ for $\lambda > 1-\mu$ and $\alpha^* = 1$ and $\beta^* = 0$ otherwise.

$\mu \geq 1 > \varphi$.—First, $\alpha^* = 0$ and $\beta^* = 0$ if the FOCs $\lambda > \frac{\varphi-1}{\gamma^*}$ and $\lambda > \frac{\mu-1}{1-\gamma^*}$ hold. By selecting $\gamma^* = 1$, society can make the second inequality fail. Second, $\alpha^* \in (0,1)$ and $\beta^* = 0$ if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{\varphi-1}{\gamma^*} < \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ prevail. The first equality is false. Third, $\alpha^* = 0$ and $\beta^* \in (0,1)$ if the FOCs $\lambda < \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{\mu-1}{1-\gamma^*} < \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{\mu-1}{1-\gamma^*}$ are true. The first inequality fails for γ^* approaching one. Fourth, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$, if the FOCs $\lambda = \frac{\varphi-1}{\gamma^*(1-2\beta^*)}$ and $\lambda = \frac{\mu-1}{(1-\gamma^*)(1-2\alpha^*)}$ hold. At these levels of λ, the social welfare is decreasing with α^* and increasing with β^* and thus, $\alpha^* \in (0,1)$ and $\beta^* \in (0,1)$ cannot be an equilibrium. Fifth, $\alpha^* = 1$ and $\beta^* = 0$, if the FOCs $\lambda < \frac{\varphi-1}{\gamma^*}$ and $\lambda < \frac{1-\mu}{1-\gamma^*}$ are verified. Both inequalities are false. Sixth, $\alpha^* = 0$ and $\beta^* = 1$, when the FOCs $\lambda < \frac{1-\varphi}{\gamma^*}$ and $\lambda < \frac{\mu-1}{1-\gamma^*}$ hold, which is the case for γ^* reaching one and $\lambda \leq 1-\varphi$. Seventh, $\alpha^* = 1$ and $\beta^* \in (0,1)$, if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*(2\beta^*-1)} \leftrightarrow \frac{1-\mu}{1-\gamma^*} > \frac{1-\varphi}{\gamma^*(2\beta^*-1)}$ and $\lambda = \frac{1-\mu}{1-\gamma^*}$ are verified. The second equality is false. Eight, $\alpha^* \in (0,1)$ and $\beta^* = 1$, if the FOCs $\lambda = \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)} \leftrightarrow \frac{1-\varphi}{\gamma^*} > \frac{1-\mu}{(1-\gamma^*)(2\alpha^*-1)}$ hold. The second inequality fails for sufficiently large γ^* and small α^*. Finally, $\alpha^* = 1$ and $\beta^* = 1$ if the FOCs $\lambda > \frac{1-\varphi}{\gamma^*}$ and $\lambda > \frac{1-\mu}{1-\gamma^*}$ hold. Both inequalities hold for γ^* sufficiently large. Ultimately, society attains the first best by picking $\gamma^* = 1$ and inducing $\alpha^* = \beta^* = 1$ for $\lambda > 1-\varphi$ and $\alpha^* = 0$ and $\beta^* = 1$ otherwise. $\square$

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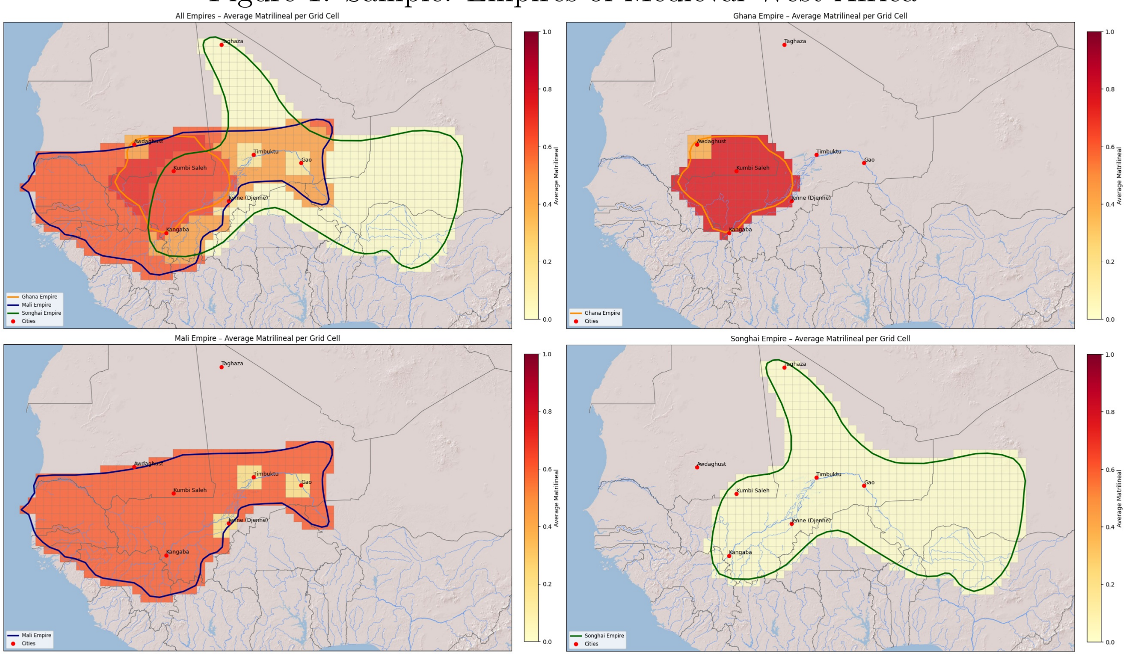
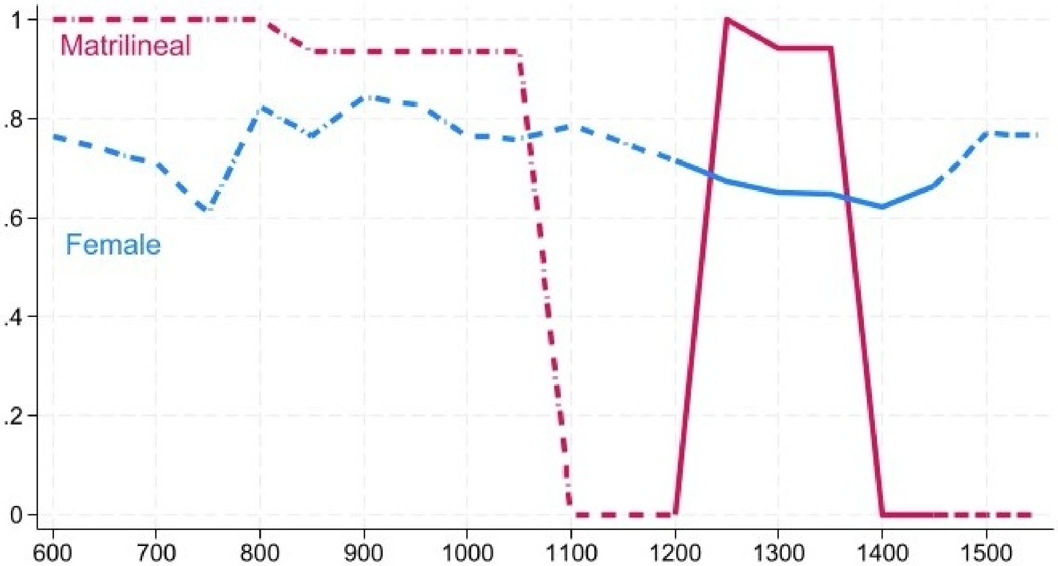
Figures and Tables

Figure 1: Sample: Empires of Medieval West Africa



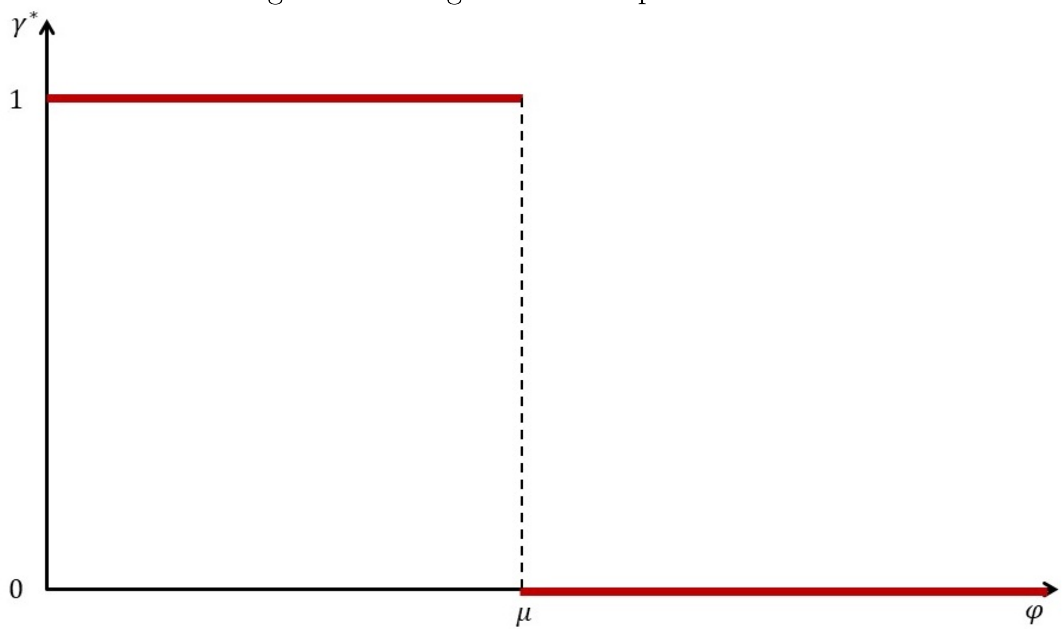
Note: 1. The 860 cells in which the empires can be divided report the average of *Matrilineal* over the 600-1550 CE period in the case of upper-left graph (see table 1 for definition and sources of each variable). The upper-right, lower-left and lower-right graphs focus on the Ghana, Mali and Songhai empires, respectively. The boundaries of each empire come from page 10 of LaGamma (2020).

Figure 2: Matrilineal Succession and Female Farming Productivity Advantage



Note: 1. The graph illustrates the link between our indicator for matrilineal succession—i.e., *Matrilineal*—and our proxy for females' productivity advantage, i.e., *Female*—over the Ghana, Mali and Songhai empires. The data relative to these three periods are depicted through, respectively, dash-dot, solid and dash traits. Table 1 reports the definition and sources of each variable.

Figure 3: Endogenous Kinship Institutions



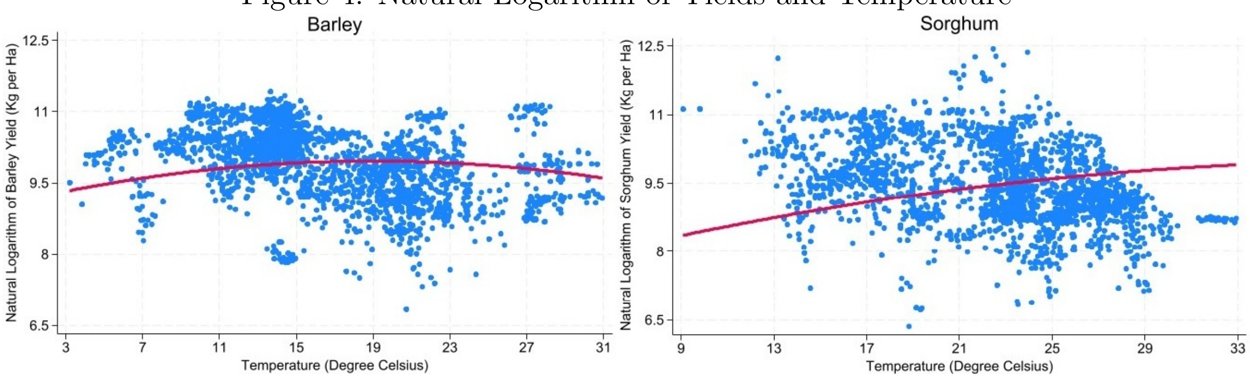
Note: 1. The graph depicts the link between the strength of the protection of the female party's property rights γ^* and the size of her farming productivity φ relative to the male farming productivity μ.

Table 1: Summary of Variables

	Variable	Definition and Sources	Statistics
Kinship:	*Matrilineal*:	Dummy for the adoption of matrilineal succession over the 40 years around each date. Sources: see the Internet appendix.	0.500 (0.500)
Farming return:	*Female*:	Dummy for most productive plow-negative crop yielding more expected kcal per ha than those yielded by the most productive plow-positive crop. Source: Armstrong et al. (2019).	0.715 (0.451)
	Female-C:	Difference between average—over the previous 50 years—natural logarithm of the expected kcal per ha produced by the most productive plow-negative crop less that delivered by the most productive plow-positive crop. Sources: Armstrong et al. (2019).	0.043 (0.113)
	Temperature:	Temperature in degrees Celsius averaged over the previous 50 years. Source: Armstrong et al. (2019).	28.333 (1.326)
	Precipitation:	Monthly precipitation in mm averaged over the previous 50 years. Source: Armstrong et al. (2019).	50.151 (35.165)
	Temperature-SD:	Standard deviation of temperature in degrees Celsius over the previous 50 years. Source: Armstrong et al. (2019).	3.387 (1.021)
	Precipitation-SD:	Standard deviation of monthly precipitation in mm over the previous 50 years. Source: Armstrong et al. (2019).	67.132 (37.066)
Control variables:	*Islam*:	Dummy for Islam adoption over the previous 50 years. Sources: see the Internet appendix.	0.775 (0.417)
	External-Conflicts:	Dummy for external conflicts over the previous 50 years. Sources: see the Internet appendix.	0.384 (0.486)
	Internal-Conflicts:	Dummy for uprisings and/or rebellions over the previous 50 years. Sources: see the Internet appendix.	0.345 (0.475)
	Political-Institutions:	Dummy for the existence of a council of nobles sharing the decision-making power with the ruler over the previous 50 years. Sources: see the Internet appendix.	0.995 (0.070)

Note: 1. The last column reports the mean value and, in parentheses, the standard deviation of each variable. Both are computed building on the sample used in tables 2 and 3.

Figure 4: Natural Logarithm of Yields and Temperature



Note: 1. While the left graph depicts the inverted U-shaped relationship between the natural logarithm of the barley yields in kg per ha and the temperature in degree Celsius obtained for the 88 countries studied over the 1986-2012 period by Agnolucci et al. (2020) conditioning on the annual precipitation in mm and country fixed effects, the right graph displays the inverted U-shaped relationship between the natural logarithm of the sorghum yields in kg per ha and the temperature in degree Celsius obtained for the 99 countries analyzed over the 1986-2012 period by Agnolucci et al. (2020) conditioning on the annual precipitation in mm and country fixed effects. The number of observations is 2179 in the former case and 2450 in the second one. Table 1 details definitions and sources of each of the employed variables.

Table 2: Endogenous Kinship

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	The dependent variable is *Matrilineal*						
Female	- 0.063 (0.031)**	- 0.061 (0.031)**	- 0.056 (0.015)***	- 0.061 (0.031)**	- 0.057 (0.015)***		
Female-C						- 0.044 (0.025)*	- 0.493 (0.130)***
Islam		- 0.602 (0.012)***			- 0.335 (0.014)***	- 0.009 (0.085)	- 0.334 (0.014)***
External-Conflicts			- 0.258 (0.022)***		- 0.032 (0.037)	- 0.509 (0.079)***	- 0.032 (0.037)
Internal-Conflicts			- 0.629 (0.019)***		- 0.777 (0.030)***	- 0.234 (0.060)***	- 0.777 (0.030)***
Political-Institutions				0.478 (0.015)***	0.117 (0.011)***	0.002 (0.003)	0.118 (0.012)***
Estimation	OLS	OLS	OLS	OLS	OLS	Difference-in-difference	OLS
Within R^2	0.20	0.32	0.80	0.20	0.83		0.83
No pre-trends (P-value)						0.44	
Number of observations	5411	5411	5411	5411	5411	5411	5411

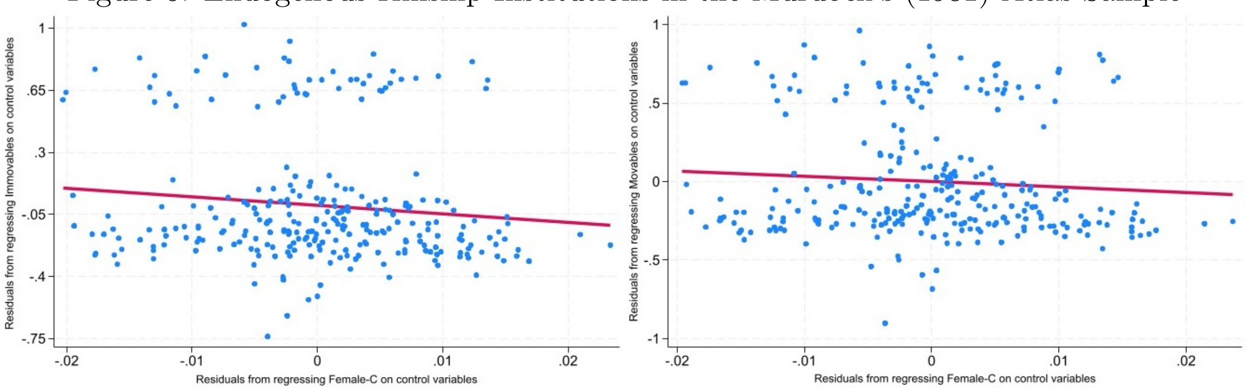
Notes: 1. Robust standard errors standard errors clustered at the cell-epoch level in parentheses. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include cell-epoch and empire fixed effects, *Temperature*, *Precipitation*, *Temperature*^{2}, *Precipitation*^{2}, *Temperature-SD* and *Precipitation-SD*.
3. The p-value for insignificant pre-trends refers to the p-value from a t-test that the coefficient on *Female-C* lagged one period is zero.

Table 3: Using Selection on Observables to Assess the Bias from Unobservables

	(1)	(2)	(3)	(4)
	The dependent variable is *Matrilineal*			
The index is calculated for				
Female	30.5	8	30.5	9.5

Note: 1. The restricted set of controls includes those employed in the specifications reported in column (1) of table 2, whereas the "full set" of covariates gathers those used in the specifications listed in columns (2) to (5) of the same table, respectively. The sample size is always 5411.

Figure 5: Endogenous Kinship Institutions in the Murdock's (1981) Atlas Sample



Note: 1. The left (right) graph depicts the correlations between the Murdock's (1981) Atlas dummy for matrilineal inheritance of immovable (movable) property—i.e., *Immovables* (*Movables*)—and *Female-C*, conditional on *Temperature*, *Precipitation*, *Temperature*^{2}, *Precipitation*^{2}, *Temperature-SD* and *Precipitation-SD*, and it is obtained for the 275 (293) ethnicities for which both the dependent and the independent variables are available. The coefficient on *Female-C* equals - 4.778 (- 3.404) and is significant at 1% (insignificant). Table 1 details the definition and sources of each variable except *Immovables* and *Movables*.

APPENDIX (FOR ONLINE PUBLICATION)

I Supplementary Tables

Table I: Allowing for Spatial Correlation

	(1)	(2)	(3)	(4)	(5)	(6)
	The dependent variable is *Matrilineal*					
Female	- 0.063 (0.032)**	- 0.063 (0.037)*	- 0.063 (0.043)	- 0.057 (0.015)***	- 0.057 (0.017)***	- 0.057 (0.020)***
Estimation	Cell-epoch and empire fixed effects OLS					
Centered R^2	0.48	0.48	0.48	0.89	0.89	0.89
Number of Observations	5411	5411	5411	5411	5411	5411

Notes: 1. Conley's (1999) standard errors with Bartlett kernel and distance beyond which the correlation between error terms is assumed to be zero of 60 (120) km in columns (1) and (4) ((2) and (5)) and 180 km otherwise. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include cell-epoch and empire fixed effects as well as *Temperature*, *Precipitation*, *Temperature*^{2}, *Precipitation*^{2}, *Temperature-SD* and *Precipitation-SD*.
3. The specifications in columns (4) to (6) also include *Islam*, *External-Conflicts*, *Internal-Conflicts* and *Political-Institutions*.

II Coding Dependent and Control Variables

The Regional Structure of the Medieval Western Empires

Ghana Empire (600-1200 CE).—Two are the key regions in which the Ghana empire was divided. The first one revolved around the capital Kumbi Saleh and the other one around Awdaghust (Conrad, 2005). By 1203, the leader of the Susso people, Saman Guru Kante, had taken control of Kumbi Saleh, ending the Ghana empire and opening the way to the creation of the Mali empire by the Sundiata Keita's conquest (Conrad, 2005).

Mali Empire (1250-1450 CE).—The major regions of the Mali empire gravitated towards the cities of Gao, Jenne, Kangaba, Taghaza, Timbuktu and Wangara. While Kangaba was the original capital of the Mali empire, was directly controlled by the Mansa and was replaced by Niani [Davidson, 1998; McKissack and McKissack 1994, p. 53], Timbuktu became a major Islamic center as confirmed by the construction of the Djinguereber mosque (Conrad, 2005). During its expansion, the empire annexed Gao, Jenne, Taghaza and Wangara, which eventually gained independence with the rise of the Songhai (Conrad, 2005).

Songhai Empire (1500-1550 CE).—The main areas of the Songhai Empire revolved around the cities of Gao, Jenne, Taghaza and Timbuktu. While Gao became one of the two administrative capitals under Askia Muhammad (Lang, 2017), Timbuktu emerged as the center of Islamic scholarship and the other administrative capital and Jenne flourished as a major trade and learning hub (Davidson, 1998; Reece, 2006; Long, 2018). All three cities were captured and plundered by Moroccan forces in 1591 (Conrad, 2005; Long, 2018).

Property Rights

Ghana Empire (600-1200 CE).—Ghana was a matrilineal society whereby private property inheritance was traced from a mother's brother to his sister's son and royal succession was passed through the King's sister's line [McKissack and McKissack 1994, p. 7]. Notable examples of this last institution were Diabe Cisse, who succedded to the first ruler of Ghana, and Tunka Menin, who took the seat of his maternal uncle, King Basi, in the eleventh century [Al-Bakri, 1057; McKissack and McKissack 1994, p. 31]. The only exception was the commercial city of Awdaghust that, before becoming part of the empire at the end of the tenth century, followed the Islamic principle imported during the ninth century by the Berber traders [McDougall 1985, p. 7]. After 1050, the Almoravids' influence eased the diffusion of Islam and the consequent adoption of patrilineal inheritance.

Mali Empire (1250-1450 CE).—The Malinke, culturally linked to the Soninke of Ghana, represented the core ethnic group of the Mali empire and initially followed matrilineal succession [Conrad 2005, p. 36]. To elaborate, the shift from matrilineal to patrilineal inheritance was a gradual process balancing the diffusion of Islam with the persistence of the traditional Mande customs. Even if increasingly attracted by the Islamic doctrine, the Mali's monarchs, known as the Mansas, continued to safeguard the Tichitt cultural traditions until the end of Mali's Golden Age (Conrad, 2005; Hill, 2009). To elaborate, albeit Mansa Musa, Mali's most famous king, was remembered for bringing back new from his 1325 CE fabulous pilgrimage to Mecca scientists and legal scholars who established Muslim courts of law in Gao, Jenne, and Timbuktu [Reece 2006, p. 18], patriliny diffused in the rest of the empire only by ca. 1400 (Davidson, 1998). To confirm this dynamics, Musa's designation as "Moses, Son of Kongo," which is a direct reference to his mother, suggests that during his rule maternal lineage continued to possess sociopolitical significance for legitimacy [McKissack and McKissack 1994, p. 56]. Following Musa's rule, rulers blended Islam with local traditions as the population selectively appropriated Islamic practices (Hill, 2009). The inheritance line remained fluid, marked by a lot of speculation and confusion around the bloodline of certain

Mansas (McKissack and McKissack, 1994). By the beginning of the fifteenth century, both Islamic beliefs and patriliny had definitively prevailed (Davidson, 1998).

Songhai Empire (1500-1550 CE).—Islam was the dominant religion in the Songhai Empire since the 1009 CE King Kossoi conversion (Conrad 2005). Hence, over all the Songhai empire's trajectory, patrilineal succession prevailed as the dominant inheritance rule.

Constructing the variable *Matrilineal*.—We assign to *Matrilineal* a value of: 1. one between 600 and 850 CE and zero over the 900-1200 CE period for the Awdaghust area; 2. one between 600 and 1050 CE and zero over the 1100-1200 CE period for the rest of the Ghana empire; 3. one in 1250 CE and zero over the 1300-1450 CE period for Gao, Jenne, and Timbuktu; 4. one between 1250 and 1350 CE and zero over the 1400-1450 CE period for the rest of the Mali empire; 5. zero over the 1500-1550 CE period for the Songhai empire.

Diffusion of Islam

Ghana Empire (600-1200 CE).—Even if Islam reached Awdaghust by 700 CE, the rest of the empire continued to embrace traditional beliefs [McKissack and McKissack 1994, p. 120]. The penetration of the new religion, however, became more forceful with the eleventh century introduction of the Maliki School of Sharia law, which reorganized the empire's criminal and property law as well as market regulation (Davidson, 1998).

Mali Empire (1250-1450 CE).—Although the core elite of the rising realm belonged to the Malinke ethnicity, Islam began spreading under Mansa Barmandana, who did not enforce conversion and saw some people convert while others retained traditional beliefs (McKissack and McKissack, 1994; Davidson, 1998. Islamic beliefs became increasingly more diffuse under Mansa Musa, who promoted the foundation of mosques, Islamic law courts, and Islamic schools and libraries across the empire [Reece 2006, p. 18; McKissack and McKissack 1994, p. 46]. Despite the increasing influence of Islam, many communities retained their traditional beliefs and resisted for a long time religious and cultural conversion. To elaborate, while Gao, Jenne, Kangaba, and Timbuktu were the first to embrace the new cult, Wangara initially rejected it and even threatened to halt gold production if forced to convert (McKissack and McKissack, 1994). Similarly, Taghaza, a remote salt-mining outpost where enslaved labor was common, accepted Islam much later [Bovill 1968, p. 160; Davidson, 1998].

Songhai Empire (1500-1550 CE).—The diffusion of Islam within the Songhai Empire started already with the 1009 CE conversion of King Kossoi [Reece 2006, p. 21]. Over the 1493–1528 CE reign of Askia Muhammad, this cultural shift was formalized through a series of reforms like the imposition of the Sharia as the only source of law, the encouragement by the state of the pilgrimage to Mecca, and the establishment of over 180 Quranic schools [Reece 2006, p. 25]. Finally, institutions, such as the *Sankore*, attracted a vibrant community of jurists and poets, reviving the intellectual legacy of the Mali empire [Conrad 2005, p. 102].

Constructing the variable *Islam*.—Ultimately, we assign to *Islam* a value of: 1. zero between 600 and 700 CE and one over the entire 750-1200 CE period for the Awdaghust area; 2. zero between 600 and 1000 CE and one over the entire 1050-1200 CE period for the rest of the Ghana empire; 3. one for the entire Mali empire except for Taghaza and Wangara for the 1250 half-century; 4. one for the entire Songhai empire.

External Conflicts

Ghana Empire (600-1200 CE).—While Awdaghust was constantly threatened by the Ghana empire, various northern tribes, and the Almoravids [Bovill 1968, p. 71], the Soninke people maintained a complex relationship with the Berbers, characterized by armed peace—between 800 and 1000 CE—and intermittent conflicts, occasionally resolved through marital alliances [McKissack and McKissack 1994, p. 10-11]. From the mid of the eleventh century, the empire was subject to the external pressures of the Almoravids, Susso and Malinke.

Mali Empire (1250-1450 CE).—Starting from the beginning of the fifteenth century, the empire, except the capital Timbuktu, coped with a series of external pressures brought by Tuareg tribes first and the Songhai population later on (Long 2018).

Songhai Empire (1500-1550 CE).—The collapse of the Songhai Empire was triggered by the 1591 Moroccan invasion, led by Sultan Mulay Ahmad al-Mansur (Reece, 2006; Long, 2018). A major factor in triggering this conflict was the control of the valuable salt mines of Taghaza (Davidson, 1998; Reece, 2006). The invaders captured and plundered Gao, Jenne and Timbuktu, forcing the collapse of the empire [Conrad 2005, p. 64; Lang, 2018].

Constructing the variable *External-Conflicts*.—Ultimately, we assign to *External-Conflicts* a value of: 1. one over the entire 600-1200 CE period for the Awdaghust area; 2.

zero between 800 and 1000 CE and one over the 600-750 and 1050-1200 periods for the rest of the Ghana empire; 3. one over the 1400-1450 CE period and zero between 1250 and 1350 CE for all the regions part of the Mali empire except for Timbuktu to which we assign zero over the entire 1250-1450 CE span; 4. zero for the entire Songhai empire.

Internal Conflicts

Ghana Empire (600-1200 CE).—In response to Dyabe Cisse becoming king, Khine raised an army, which forced Diabe to flee (McKissack and McKissack, 1994). These conflicts did not touch in 1200 CE Awdaghust since, at the time, it was just an oasis (Conrad, 2005).

Mali Empire (1250-1450 CE).—After the 1387 CE death of Mansa Musa II, a power struggle ignited internal conflicts leading to the empire's decline [Conrad 2005, p. 46].

Songhai Empire (1500-1550 CE).—At the end of the Askia Muhammad's reign, the Askia Dynasty took control of the empire (Conrad, 2005). Notable rulers were Musa (1528–1531 CE), Muhammad Bunkan (1531–1537 CE), Ismail (1537–1539 CE), Ishaq I (1539–1549 CE), and Askia Dawud (1549–1582 CE). The period following this last reign was marked by a series of internal dynastic conflicts, economic crises, as well as a steady decline in the degree of administrative cohesion (Davidson, 1998).

Constructing the variable *Internal-Conflicts*.—The latter equals: 1. one between 1100 and 1150 CE and zero over the 600-1050 CE and 1200 CE periods for the Awdaghust area; 2. one between 600 and 750 CE and between 1100 and 1200 CE and zero over the 800-1050 CE period for the rest of the Ghana empire; 3. one between 1400 and 1450 CE and zero over the 1250-1350 CE period for the Mali empire; 4. zero for the Songhai empire.

Political Institutions

Ghana Empire (600-1200 CE).—Despite formally kings held economic, military and religious leadership (Davidson, 1998), in practice, their decision were guided by councils of regional governors—i.e., *fados*, who maintained administrative and economic autonomy in exchange for tributes and regardless of the ruling dynasty (McKissack and McKissack, 1994).

Mali Empire (1250-1450 CE).—The Mali Empire was organized into provinces administered by appointed governors known as *farbas*, each responsible for the decision-making on matters like farming, fishing, justice and tax collection [Reece 2006, p. 17]. These governors were often selected from local descent lines, allowing the Mansas to govern a vast and diverse empire through a network of regionally embedded leaders (Davidson, 1998). To support the balance between centralized and regional powers, Mansa Musa established Islamic courts while preserving traditional ones and thus, creating a dual legal system (Davidson, 1998). When, however, Sundiata moved the capital to Niani, the former capital Kangaba felt under the direct control of the emperor [McKissack and McKissack 1994, p. 45-52].

Songhai Empire (1500-1550 CE).—Sonni Ali consolidated Songhai's control by appointing loyal governors in newly conquered provinces to enforce order and secure the steady flow of tribute [Reece 2006, p. 23]. The strategic balance between center and periphery was further strengthened by Askia Muhammad, who reorganized the empire into five major administrative regions divided in provinces and administered by a governor supervising appointed officials responsible of economic and military affairs [Reece 2006, p. 26].

Constructing the variable *Political-Institutions*.—We assign to *Political-Institutions* a value of one except for Kangaba that takes value zero between 1350 and 1450 CE.

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