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From open to closed societies: Inequality, migration, and women's rights

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ABSTRACT

We study six centuries of institutional change in the governance of the commons across over three hundred Italian communities. Wealthier communities, facing migration pressure due to unequal resource endowments, restricted access to common property resources by excluding women from membership, thereby limiting migration through marriage. Using archival data and an agent-based model, we show that this endogenous closure spread via a domino effect and persisted until a centralized Napoleonic reform reinstated egalitarian access. The findings highlight how migration, inequality, and gendered institutions interact in polycentric systems, offering broader insights for the political economy of property rights on land and institutional reform in developing contexts.

1. Introduction

A puzzling institutional transformation occurred in the early modern period across communities in Northern Italy: over the course of several centuries, women's rights to community membership and access to common property resources were systematically eroded (Alfani, 2015; Casari and Lisciandra, 2016). A stark example comes from a 1573 decree from the Fiemme valley: *"Our Community has consensually convened that henceforth female members of our Community shall neither have nor inherit membership rights."*[1] Before this edict, women had equal membership rights, including access to communal resources. This system was only reversed more than two centuries later in 1807 under Napoleonic rule, which restored egalitarian membership across the region. What explains the exclusion of women from accessing the community resources? Why and how was openness later reinstated? We argue that the answers lie in the economic and demographic pressures that shaped the institutions governing access to the commons.

This paper traces and explains a process of endogenous institutional closure and its later reversal, spanning over six centuries (1200–1800) across hundreds of self-governing communities in Trentino, a region of Italy. Using detailed archival records of local institutions, we document a gradual decline in egalitarian membership rules, particularly those involving the inheritance of property rights over common resources by women. While women retained rights over private assets, they increasingly lost rights to the commons.[2] The empirical evidence is both institutional and quantitative. We argue that this exclusion was not driven by rising cultural bias or religious norms, but rather emerged as a strategic response to economic inequalities and migration pressures.

Our analysis identifies a causal chain: when the population increased, the inequality in common property endowments across communities led to migration from poorer to wealthier communities. These wealthier communities sought to protect their valuable commons by narrowing the definition of community membership, and more specifically by excluding women, thus reducing migration via marriage. This transformation sparked a decentralized, self-reinforcing process: as some communities adopted restrictive rules, others followed to prevent themselves from becoming migrant destinations, creating a domino effect of institutional closure. This path-dependent process locked communities into a patrilineal and closed system.

The closure lasted until a centralized intervention under Napoleon reinstated egalitarian rules and re-opened all communities, a change that could not have occurred through bottom-up, decentralized action alone. These dynamics illustrate how institutional openness or closure results from both endogenous adaptations and exogenous shocks, and how polycentric organizations evolve differently from monocentric ones.

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[1] Le consuetudini, Libro II, del civìl, Cap. 117 in Sartori-Montecroce (1891). A map of the Fiemme Valley is in Appendix B (Figure B1).

[2] For an analysis of private property inheritance in Northern Italy during the period 1242–1436, see Botticini and Siow (2003).

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To pin-down how these mechanisms operate, we develop a computational model of multiple interconnected communities deciding on membership rules under varying levels of resource inequality and migratory pressure. The model highlights the strategic nature of institutional closure and the emergence of network externalities in polycentric organizations. We put forward four model predictions and provide four empirical patterns observed in archival data. We report that the model predictions align closely with the historical evidence. The empirical strategy relies on identifying what factors could explain the transition of a community from egalitarian to a patrilineal membership. The panel dataset includes between 285 and 361 villages, depending on the specification. We use an instrumental variable approach relying on geographic and terrain characteristics applied both in a static and in a dynamic way.

This study contributes to several strands of literature. First, it advances research on long-run institutional change (Greif and Laitin, 2004; Acemoglu and Robinson, 2012) by offering a micro-level, historical analysis of how economic incentives and migration shaped institutions over centuries. In contrast to works that treat gender bias as exogenous or cultural, we show how gender-discriminatory institutions can emerge endogenously from economic pressures. Second, our approach shifts from the conventional monocentric perspective to a polycentric framework (Ostrom, 2010), emphasizing how decentralized choices interact across communities and create unintended systemic outcomes. Finally, we contribute to the literature on the governance of common property resources (Baland and Platteau, 1996) by highlighting the intergenerational transmission of community membership as a key mechanism shaping exclusion, inequality, and institutional persistence—an area largely overlooked in development economics.

One element that sets this study apart from most other studies about long-run institutional change is the presence of detailed empirical evidence about the transition process. Typically, the above studies show econometrically that an event from the distant past had an influence on a present-day outcome (Bisin and Federico, 2021). A contribution of the present paper is to cover the time interval between the two distant events by showing the underlying dynamics and providing a theoretical explanation about the transition process. What emerges is the central role of common property resource governance in shaping economic, social, and demographic trends as well as the distinct characteristics of endogenous and centralized institutional changes.

2. Governing the commons in a polycentric framework

The geographical focus of our investigation is Trentino, a region nestled within the rugged terrains of the Italian Alps, home to over 300 distinct communities, each typically composed of a few hundred inhabitants. The main source of wealth in the local economy was agriculture, and in particular crops, livestock, and timber. It is important to note that only about 8 percent of the territory was arable land. Because of its higher altitudes or steeper slope, most of the territory was devoted to forest, meadows, pasture or wasteland. Vineyards were particularly valuable but could grow only in few areas and below about 750 m of altitude above the sea level. Crops included grains, lentils, and turnips, while fruit trees were present but uncommon.

In terms of property rights structure, common property resources were extensive, valuable, and essential for the villagers' survival. According to our estimate, they accounted for 58.5 percent of the land surface and roughly 25 percent of the land value. Usually, common property was extensive in forests, meadows, and pastures, while private property predominated in houses, fruit gardens, orchards, vineyards, arable land, and meadows closer to the village. Forests offered firewood and timber for building and crafting. Communal meadows and pastures offered grazing land in the summer and hay to feed cattle during the winter. The output from the common property land was an essential input for raising livestock, building tools and houses, and providing warmth during the winter. Hence, there was a strong complementarity between privately and commonly owned land, and a limited degree of substitutability. As documented by Netting (1981) in a similar setting in Switzerland, the persistence of collective property over forests and pastures can be explained by transaction costs in property rights, increasing returns to scale, and risk management.

Trentino was structured as a Principality from 1027 to 1803. The prince allowed each community considerable autonomy to define property rights and to shape local institutions. Similar types of self-governing institutions were present all over pre-modern Europe to manage water resources, forest, pastures, and fisheries (Ostrom, 1990). They are still widespread today in low-income countries, although they often do not rely on written rules (Baland and Platteau, 1996). Our main data sources about institutions were hundreds of community charters (*Carte di Regola*). These charters were official deeds designed to define and enforce property rights over collective land. For instance, they detailed who could access common pastures and when, how forests were zoned for harvesting, and the regulations for livestock grazing. In addition, they outlined the governance structure of the community in terms of offices, monitoring and sanctioning activities, and enforcement procedures. They also codified membership rules, but the formalization of pre-existing informal rules in writing usually occurred when they became controversial or needed to be replaced with new provisions. It was the community itself that wrote and voted on the charter, more precisely the assembly of the community members, which comprised one representative for each family—usually the *pater familias* but sometimes also the widow. A notary drafted the charter on behalf of community members, and, finally, the document was promulgated by the prince. Typically, a charter was updated over the centuries by adding new chapters or replacing the entire document. Any institutional change involved a formal process initiated by discussion and a vote of the community assembly. Participation in the assembly was often compulsory, and decisions typically required a two-thirds majority or more.

Who could access the commons? Those who were members (*vicini*). People from neighboring villages were treated the same as strangers (*forestieri*). Hence, from an economic and legal standpoint, these resources were not open access but rather common property. Even long-term residents born in the village had no right to access the commons. How was access to the commons related to marriage? One way to gain access to the commons was to marry a member of the community. This was because access to the commons extended to the entire household: if one household member was a community member, everyone in the household was entitled to use the commons. However, most benefits allocated to households were unrelated to the number of persons living under the same roof. For instance, every year firewood lots were randomly distributed among households, regardless of their size. Importantly, total benefits remained the same regardless of whether both the wife and husband were members or only one of them.[3]

To study the governance of the commons in a polycentric organization, it is essential to focus on membership rights within the community.[4] In many respects, membership rights resemble modern citizenship rights. Each community, akin to a country, could set its own rules for acquiring membership (citizenship) rights, and members (citizens) were entitled to both economic benefits and political rights within their community (country).[5] In our historical case, commons were not open

[3] A similar governance system could be found in other areas of Northern Italy, such as Cadore (Bonan and Lorenzini, 2021), and Switzerland (Netting, 1981; Kissling-Näf et al., 2002; Lorenzetti and Merzario, 2005).

[4] Unlike the approach adopted in this study, community governance is most often analyzed as a mechanism to mitigate or prevent the 'tragedy of the commons' (Baland and Platteau, 1996; Agrawal, 2005; De Moor, 2009).

[5] The distinction between residence and membership is analogous to the distinction between residence and citizenship. Individuals who had acquired residence but not membership were denied access to the community's commons unless they married a member of that community.

access: community members held exclusive rights to exploit them collectively and to shape governance rules. More specifically, benefits from the local commons were restricted to those who held membership and resided in the community. Both conditions were necessary. For example, if a member moved out of the community, they would no longer be eligible for community benefits. Upon relocation, a member could not sell their membership but would simply forfeit it. Membership was typically acquired through inheritance from the original families of the village. In some cases, membership could also be purchased directly from the community, never from individual members, and was subject to approval by a supermajority of the existing members.[6]

The governance of Trentino prior to 1807 reflected Elinor Ostrom's concept of a polycentric governance, with decision-making distributed across the region, communities, and individuals (Ostrom, 1990, 2010). Communities could independently design rules on property rights and resource access, with strategic interaction between them. Individuals lived in a community but were free to marry members of other communities and relocate within the region (Fig. 1). This decentralized system, documented in charters dating from 1202 to 1796, abruptly ended in 1807 after Napoleon's conquest of Northern Italy. Napoleon replaced it with a monocentric organization, centralizing authority, suppressing local autonomy, and shifting resource control to the political center. The charter system and other *Ancien Régime* institutions were dismantled and replaced by a modern centralized state, characterized by procedural uniformity, citizen equality, and the principle of egalitarian universal succession.[7]

3. The dynamics of institutional change

This section outlines the possible triggers of institutional change and the main channels through which it propagated. In a polycentric setting, a key consideration is the potential for network spillovers, where the institutional decision of one community affects the welfare of others. To illustrate the triggers of institutional change, consider a simple game of two communities, two strategies, and individuals who may relocate to another community through migration by marriage (Table 1). Let us assume two communities, A and B, with different levels of per-capita common property resources. This inequality is a critical driver of migration: if we remove this assumption, both the argument and the model lose their validity. Recall that access to a community's common property resources is based on membership rights, which are inherited from parents.

Each community can choose between an *egalitarian* or a *unilineal* membership system. In an egalitarian system, men and women alike can inherit community membership and transmit it to their offspring. A unilineal system, by contrast, may be either patrilineal—where only men have this right, as in our historical case—or matrilineal, where only women have it.[8] In the strategic choice of a membership system within a community, as illustrated in Table 1, three key elements must be considered: insurance against shocks (s), aversion to inequality (g), immigration cost (m).

Shock insurance ($s > 0$). Throughout history, regions have been repeatedly ravaged by a variety of natural disasters, including fires, landslides, floods, famines, and infectious diseases (Alfani and Murphy, 2017). Since these exogenous shocks may affect communities asymmetrically, the ability to relocate to other communities can serve as a form of protection.[9] For instance, if community B switches from an egalitarian to a patrilineal, men from community A become more vulnerable to shocks, as they can no longer acquire membership through marriage in community B. This reasoning holds regardless of whether community A adopts an egalitarian or unilineal system. The argument also applies when the roles of communities A and B are reversed. In short, the parameter s represents a negative externality arising from a unilineal choice made by the other community.

Aversion to inequality ($g > 0$). We assume that transitioning to a unilineal membership imposed a social cost on the adopting community. For example, consider the shift to patrilineal membership. Such a system typically reduced women's bargaining power, both in selecting a life partner and within their future household. Additionally, when daughters relocated for marriage, parents often lost their assistance in old age (Cassar and Rigdon, 2021). In Trentino, several factors indicate a reluctance to fully adopt highly unequal membership systems. The transition from an egalitarian to a patrilineal membership system was often gradual rather than abrupt. Between 1525 and 1630, several communities shifted to a soft-patrilineal system, where one or all daughters could inherit membership in the absence of male-line offspring, before eventually transitioning to a strict patrilineal system (Casari and Lisciandra, 2016). In contrast, in the neighboring German-speaking area of Süd Tirol, a primogeniture membership system was widely adopted, creating strong incentives to limit community size. However, in Trentino, this system played only a very marginal role and did not lead to the adoption of similarly restrictive systems. Hence, we hypothesize that parents' desire to ensure equitable economic conditions and bargaining power for their children when selecting a spouse is reflected in the model, implying a positive value for the parameter g.[10]

Immigration cost ($m > 0$). In line with Tiebout's framework, individuals could exploit inequalities in the per-capita endowment of common property resources by 'voting with their feet' through marriage decisions. The addition of a new member accessing the commons reduces the benefits of each insider. The parameter m captures this decline in payoffs for insiders of wealthier communities due to net immigration, as well as the corresponding increase in payoffs for insiders of poor communities. Consider the unilineal system—specifically the patrilineal system—as an example. Patrilineal membership protects the share of common resources for community insiders by ensuring that immigration and emigration remain balanced. The community's population remains constant because when a man marries an outsider, a woman from the community will eventually relocate. Under a patrilineal system, women invariably choose to reside in their husbands' communities, as only men have access to the commons.

To illustrate Table 1, we initially focus on the s and g payoff parameters, excluding any migratory impact on the game ($m = 0$). In this case, the game has a unique equilibrium in which both communities adopt an egalitarian membership system. This equilibrium outcome is also socially optimal. Introducing migration into the model changes the dynamics: if the payoff consequences (m) of migratory pressure on the

[6] A very similar configuration of membership is currently found in some places in Switzerland, where the local community still votes on whether to admit an outsider as a new citizen (Hainmueller and Hangartner, 2013).

[7] See O'Grady and Tagliapietra (2017) for evidence on how the loss of communal resource institutions in Northern Italian Alpine communities affected biological welfare.

[8] Both regimes are partible in the sense that inheritance is never restricted to a single child. Alternative inheritance options will be discussed in subsequent sections.

[9] Mitigating economic risks and implementing strategies to enable consumption smoothing have been fundamental in traditional societies (e.g., Rosenzweig and Stark, 1989; Zuijderduijn and De Moor, 2013).

[10] Consider the political economy of institutional change in Trentino. The community assembly, responsible for voting on institutional arrangements, was predominantly composed of married men. While a patrilineal system would have made single men more desirable as potential partners, the voters themselves were already married. It is likely that their concerns extended to the welfare of all their children, the future security of their partner as a widow, and the assistance they would receive in old age. For families with only daughters, a patrilineal system would compel parents to ensure their daughters married within the community to retain access to the commons. Such disparities in accessing common resources could have been viewed unfavorably by the community. We are grateful to David Ciepley for his suggestions on this point.

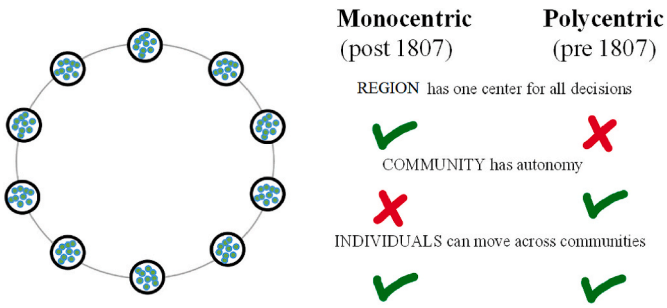

Fig. 1. Governance systems.

Table 1
Strategic selection of membership systems.

		Community B (poor)	
		Egalitarian	Unilineal
Community A (rich)	*Egalitarian*	10-m, 10+m	10-m-s, 10+m-g
	Unilineal	10-g, 10-s	10-s-g, 10-s-g

rich community (B) are sufficiently large, the equilibrium shifts. Specifically, when $m > g$, the game admits a unique equilibrium with an egalitarian poor community and a unilineal rich community—an outcome that is not socially optimal.[11] Now, consider the same game under the condition $m < g$, which could represent a setting characterized by low population density, an abundance of resources (e.g., forests, meadows, and pasture), and limited mobility. In this scenario, the game retains a unique equilibrium where both communities adopt egalitarian systems, and the equilibrium remains socially optimal. In summary, this game-theoretical framework suggests that institutional change emerges as a balance between the preference for equality and the need for protection from migratory pressures.

How does institutional change propagate? Consider a region with more than two communities governed by a polycentric organization (Fig. 2). If all communities are initially egalitarian but inequalities are sufficient to generate migratory pressure ($m > g$), some communities may transition from egalitarian to unilineal membership. Moreover, this shift can trigger a domino effect, propagating institutional change across the region.

One can predict where institutional change is likely to occur first. Individuals from poor communities will generally seek spouses in the nearest wealthy communities and migrate there.[12] The rich community shaded in Fig. 2A is the first to transition to a unilineal system. Following this closure, migratory flows from poor communities will shift toward new targets (Fig. 2B), increasing pressure on other wealthy communities to change their membership system. In Fig. 2C, three additional communities have adopted unilineal systems, leaving only one attractive destination for those still seeking to migrate. The remaining wealthy community with an egalitarian membership will then face unprecedented migratory pressure.[13] Notably, some communities remain egalitarian because they are unattractive in terms of per-capita collective wealth.

To contextualize this theoretical narrative within the historical setting, we refer to a letter dated 1583 from the governor of a local community to the Prince of Trento, requesting approval for a proposed institutional change.[14] The letter explicitly links the community's transition to patrilineal membership with concerns about immigration. It notes that, under the existing egalitarian membership system, many men from outside the community were seeking to marry local women. This qualitative evidence reinforces the formal model in two key ways. First, the community had a substantial endowment of common forests, which generated considerable revenues from timber exports to the Republic of Venice and the sale of harmonic wood used for making musical instruments, including, later, Stradivari violins (Allen, 2012). Second, the letter was written during a period when Trentino had experienced a century-long trend of communities gradually shifting from egalitarian to patrilineal membership. By this time, fewer communities remained attractive for migration through marriage, creating unprecedented migratory pressure and triggering a domino effect of institutional change.

Society offered various opportunities to establish marital connections across villages. Many individuals from poorer families traveled daily or seasonally outside their village in search of employment: young men often worked as agricultural laborers, while young women served as family helpers or nannies. Sundays were traditionally reserved for family visits to relatives in nearby villages, while markets in the valley centers provided additional opportunities for social interaction. More broadly, the number of travelers, pilgrims, and merchants from outside the region steadily increased from the 15th century onward. There is no evidence that arranged marriages were practiced in the area. However, a strict norm required Catholics to marry within their denomination. At the same time, formal Church rules, as codified in the *Corpus Iuris Canonici*, strictly prohibited marriage between close relatives—a requirement reinforced by the Fourth Lateran Council in 1215. This rule pushed people in small villages—of which there were many—to seek spouses outside their immediate communities (Donahue, 1993). In most cases, the nearest village was only a few miles away, and many others reached within a day's travel. As we will see, the formal model assumes, for simplicity, that prospective migrants could easily switch destinations. In practice, however, as long as social connections existed with at least two reachable villages, individuals could exert greater effort to

[11] For illustrative purposes, migration is modeled as a zero-sum game. In reality, migration can either increase or decrease the total surplus produced by a society. In economic models, migrants are often regarded as a resource that enhances productivity (Peri, 2012). However, in the context of Trentino commons, immigration that enlarged community population and increased diversity may have had negative effects (Casari and Tagliapietra, 2018).

[12] If two wealthy communities are equidistant, migrants will prefer the one experiencing less migratory pressure. If the pressure is equal, migration will be evenly distributed between the two.

[13] Migration alters the per-capita endowment of common resources in both poor and wealthy communities. Over time, this dynamic may also reduce migratory flows between origin and destination communities.

[14] Latin Section, C.12, fols. 69 and 72, State Archive of Trento.

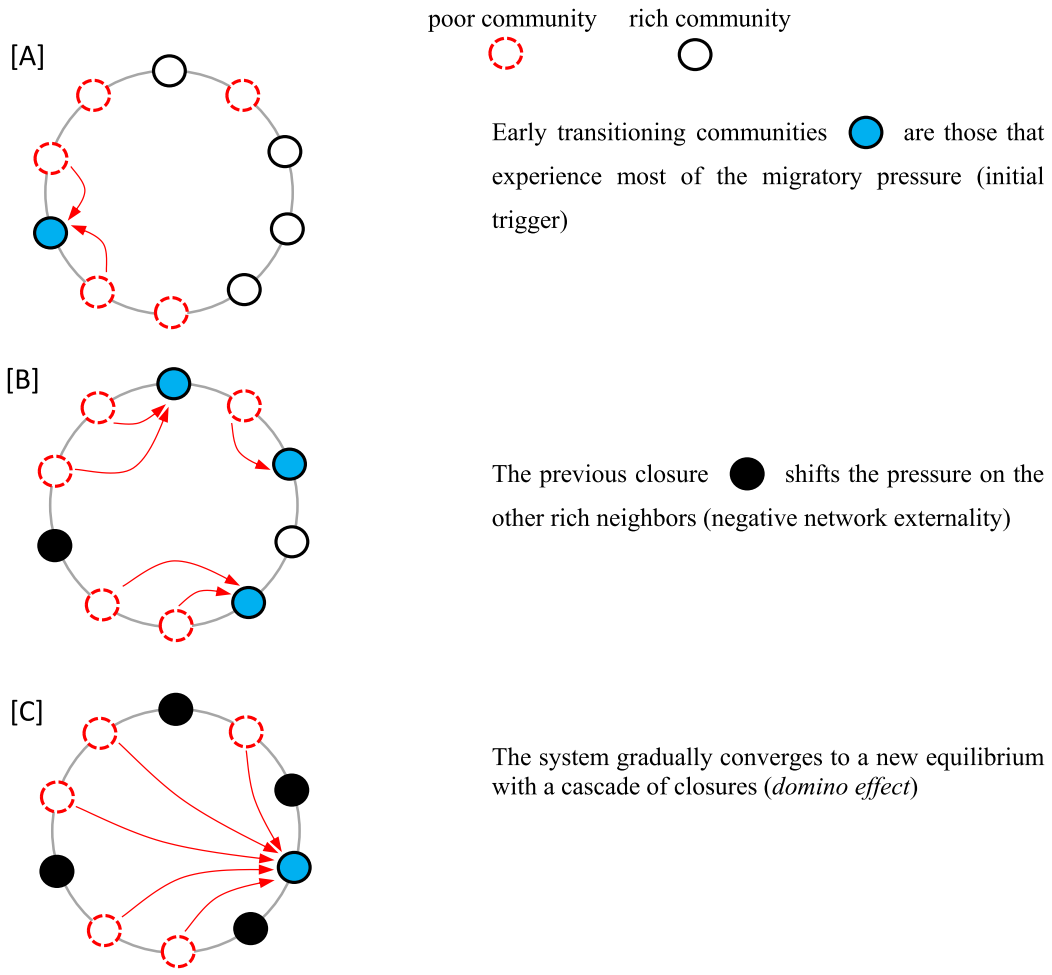

Fig. 2. Illustration of the propagation of institutional change and the domino effect.
Notes: Only rich communities attempt to protect their interests from immigration. Relocation costs are assumed to increase with distance.
Source: Authors' elaboration.

secure a partner in the village with the best endowment of common property resources. Thus, the model provides a reasonable approximation of migration through marriage.

To recap, network externalities generate two key effects on the propagation of institutional change. First, they accelerate and expand institutional change through a domino effect, without which some communities may have retained their original institutions. An implication that we will later test is that if a community in the district adopts unilineal membership, the likelihood that other communities in the district—which had so far remained egalitarian—adopt unilineal membership will increase. Second, once institutional change is implemented, reverting to the previous arrangement becomes increasingly prohibitive. This is particularly true as other communities maintain barriers to migration through marriage, redirecting migratory flows toward the other attractive communities that remain open. This process exhibits hysteresis, creating a lock-in effect: after institutional change stabilizes, unilineal communities find themselves trapped in a state of closure that is difficult to reverse. A unilateral shift back to openness would lead to unsustainable levels of immigration.

4. A computational model of institutional change

To support the intuition about the dynamics of institutional change, here we present an agent-based computational model. While the model in Section 3 treats communities as the primary decision makers, the computational model provides a micro-foundation by incorporating explicit individual choices, such as whom to marry and where to reside as a couple. Rather than aiming to precisely replicate field data, the computational model serves the same purpose as a theoretical model: it is a tool for illustrating the mechanisms and principles that drive migration, inequality, and institutional change.

Individuals interact both within and between communities. The model consists of K communities, each with an equal initial population ($n_k = n$), diverse endowments of commons (W_k), and initially adopting egalitarian membership systems ($k = 1, \ldots, K$). The model proceeds in a sequence of rounds, during which each community independently selects its membership system—egalitarian or unilineal. The model configuration is based on both micro- and macro-level assumptions.

In terms of micro-level assumptions, individuals are characterized by two traits: personal attractiveness (a) and private economic assets (p). Personal attractiveness reflects a combination of physical features and personality traits, while private economic assets (p) include wealth, such as private land and houses, and can be sold. Thus, unlike the per-capita endowment of common resources, which is a fixed asset, private economic assets are mobile.[15] In each simulation, communities are assigned random locations in a two-dimensional Euclidean space, and relocation

[15] If the total amount of private land and houses in a community is fixed, prices will adjust to meet demand. The computational model does not incorporate this aspect. In small communities, land prices may decrease in those experiencing net emigration and increase in those experiencing net immigration.

costs are defined based on the squared distance between communities. As a result, individuals prefer not to relocate at all (endogamous marriage), and when they do, they prefer moving to nearby communities over more distant ones.

Individual i can choose whom to marry, and newly formed couples can decide where to reside, whether to remain in their own community or relocate to their partner's community. These choices are unrestricted and made simultaneously. Couples are matched using the Gale and Shapley (1962) algorithm, maximizing a utility function based on the partner's attractiveness (a_j), private assets (p_j), the per-capita endowment of common resources in the couple's destination community (w_k), and relocation costs based on the distance between designated community and their current community ($d_{k,l}$). After marriage, each couple has two children—a boy and a girl—whose individual traits (a_j and p_j) depend on their parents' traits, with an additional random component. The children's private assets and membership rights are determined by the specific legal inheritance regime governing these forms of property (see Appendix A for further details).

The main macro-level assumptions are that the stock of commons (W_k) in each community and the aggregate population level of the region remain constant.[16] However, the population (n_k) of individual communities can change due to migration, causing the per-capita common endowment (w_k) to vary over time. Additionally, the membership system of individual communities can switch probabilistically. Specifically, if w_k falls considerably below its initial level, the community is more likely to transition to a unilineal membership system. Conversely, if w_k remains roughly equal to or exceeds its initial level, the community tends to adopt or maintain an egalitarian membership system.[17] To reflect the assumption of aversion to inequality ($g > 0$), the model incorporates a built-in bias favoring egalitarian membership.

5. Model predictions and empirical patterns

In this section, we present four testable predictions derived from our computational model. Each prediction is followed by an empirical statement based on historical evidence that documents whether and when each village adopted a charter (including the year[s] of adoption or revision) and provides information on membership rules, indicating whether (and when) a community adopted an inheritance rule prior to 1801.[18]

5.1. Shift toward patrilineal membership

Prediction 1. *Under polycentric governance, an all-egalitarian membership system is inherently unstable. The shift toward a unilineal system occurs gradually and reaches a plateau in the long run.*

When communities have the autonomy to change their local institutions, there is a tendency to adopt unilineal membership. After 150 rounds, on average 32.9 percent of the communities are predicted to switch from egalitarian to unilineal membership. Fig. 3 illustrates the cumulative number of institutional changes over time when the system begins with an all-egalitarian structure. The predicted pattern has an initial latency period, then a sharp increase in institutional change, followed by a slowdown, and an eventually cease. Contrary to expectations of widespread transitions toward unilineal membership, Prediction 1 suggests that only a minority of communities will make this shift. As individuals migrate, the average Gini coefficient of per-capita collective wealth (w_k) will decrease from 0.15 in the first round to 0.03 in the final round.

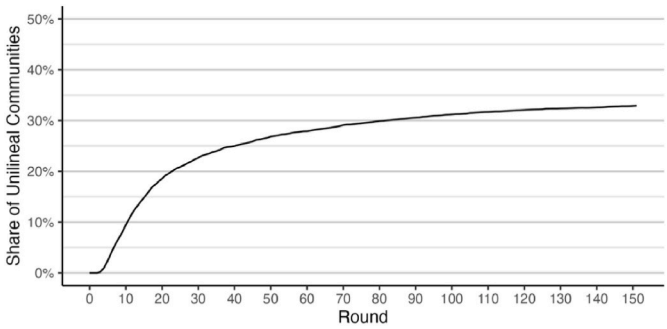

Fig. 3. Predicted trend of institutional change across communities.
Notes: Cumulative number of communities. An observation in a round is the average of 1000 runs.
Source: computational model.

This unexpected pattern is definitely shaped by dynamic feedback loops. The closure of one community redirects migratory flows to the remaining open communities deemed most attractive. However, as the shift toward unilineal membership progresses, the marginal benefits of further transitions diminish, reducing the incentive for additional communities to adopt this change. Our computational model effectively captures these feedback mechanisms in a region comprising K communities—not just two, as in Section 3—allowing us to identify when the system stabilizes at a general equilibrium outcome.

Prediction 1 contrasts with the outcome under a monocentric organization, where institutional change is impossible because communities cannot modify their membership systems. In a fully unilineal monocentric system, population and inequality in per-capita collective wealth remain stable due to balanced migration flows. Conversely, in an egalitarian monocentric system, migration from poorer to wealthier communities leads to population divergence over time and reduces inequality. Unlike the dynamic feedback loops and gradual transitions observed in the polycentric organization (Fig. 3), a monocentric organization lacks the flexibility needed to generate such patterns of institutional change.

Empirical pattern 1. *Several egalitarian communities experienced a shift toward a patrilineal membership system. In the aggregate, the timing of institutional change follows an S-shaped dynamic.*

The earliest charter in Trentino dates back to 1202, and the most recent to 1796. By the end of this period, approximately 78.2 percent of the villages (283) had adopted at least one charter with encoded content, covering 83.9 percent of the land. An additional 21 villages had charters, but the content details are unavailable. This information has been matched to information in the 1897 cadastral register, which comprises 362 geographical units corresponding to the current Province of Trento, Italy.

Among the 286 villages that either adopted at least one charter by 1801 with encoded the content, or for which membership system information was retrieved from additional documentation, only a minority (97villages, approximately 33.9 percent) has a record of patrilineal membership that formalizes the transition to, or the adoption of, a patrilineal membership system.

At the beginning of the period, around the year 1200, the membership system in Trentino villages was predominantly egalitarian, based on the available evidence (Casari and Lisciandra, 2016). By the end of

[16] The introduction of endogenous population growth does not affect the fundamental mechanism described below.

[17] Predictions remain qualitatively consistent when using a model with a deterministic threshold for institutional transition. However, we opted for a probabilistic instead of a fixed threshold, as there is no strong theoretical basis to justify a specific threshold value for per-capita collective wealth. Using an interval provides a more robust modeling choice.

[18] These data incorporate both published and unpublished sources. They update and expand upon the original data compiled by Casari (2007) and, subsequently, by Casari and Lisciandra (2016), through the inclusion of newly collected documents.

the period, in 1801, 86 villages had adopted a strict-patrilineal membership system, while 11 had soft-patrilineal system.[19] Although most villages transitioned directly from an informal egalitarian system to a strict patrilineal system, in several cases, this transition occurred in stages. Initially, a village would adopt a soft-patrilineal system, allowing families with only daughters and no sons to transmit membership to one or more daughters—but not all of them—before eventually shifting to a strict-patrilineal system. Overall, the region experienced a clear departure from the egalitarian membership system.[20]

The timeline of institutional change roughly follows an S-shaped curve (Fig. 4). The earliest recorded event of formalizing patrilineal membership dates to 1265, followed by a slow beginning until 1482, an acceleration in the 16th century, and a long tail extending up to the Napoleonic conquest. The latest event occurred in 1794, indicating that institutional changes spanned 529 years. Predictions in Fig. 3 and empirical evidence in Fig. 4 differ somewhat during the early and final phases. Specifically, the empirical pace of institutional change over six centuries is relatively slow in the early phase (1200–1470) and relatively fast in the final phase (1671–1800), particularly between 1750 and 1800, compared to the predicted patterns.

These discrepancies likely stem from demographic dynamics, as the model assumes a constant regional population, whereas historical data indicate fluctuations. During the early phase, the demographic collapse caused by the 1348 plague slowed institutional change. Population levels in Italy took more than a century to recover to the pre-plague level (Bellettini, 1987), although recovery in Trentino may have been quicker.[21] The final phase, by contrast, was characterized by sustained population growth, which likely reduced the per-capita endowment of resources. As discussed in Empirical Pattern 3 below, we document an empirical link between population pressure and the faster pace of institutional change in this period.[22]

Fig. 4 also reveals a disconnection between the timing of charter adoption and the formalization of patrilineal membership, suggesting that these two institutional innovations may have originated from distinct factors. This pattern is in line with our explanation of institutional change. For example, while the first charter dates to 1202, it does not reference membership systems. More broadly, formalization of patrilineal membership typically occurred years after the adoption of the first charter, in 85.6 percent of cases. In approximately half of these cases, the shift to patrilineal membership coincided with a general revision of the charter. In the remaining instances, it was implemented either through specific chapters added to an existing charter or via separate legal documents.[23] By the time of the Peasant war (1525), which marks roughly the midpoint of the period, most villages had adopted a charter. However, villages that had introduced patrilineal membership regulations accounted for less than 3.5 percent of the regional territory.

5.2. Inequality as a driver for institutional change

Prediction 2. *With polycentric governance, inequality systematically influences institutional change: the poorest community always remains egalitarian, while the richest community almost always transitions to a unilineal system.* Moreover, spatially central communities are more likely to switch to a unilineal system.

In the computational model, the initial distribution of collective wealth (w_k) among the 7 communities in the region is randomly assigned. The model predicts a strong correlation between a community's rank in terms of per-capita collective wealth and the frequency of institutional change (Table 2). While the poorest communities never transition to a unilineal system, the richest community does so in about 95 percent of simulations. Overall, institutional change typically affects a minority of communities and, rather infrequently extends to more than 4 out of 7 communities.

In the simulations, communities located more centrally are more attractive for migration due to their lower average relocation costs. Because relocating to these communities imposes less cost on a greater fraction of agents, they are more likely to be chosen by newly forming couples. As a result, central communities receive more incoming migrants, leading to a decrease in endowment per capita in the egalitarian system. This migratory pull accelerates the adoption of a unilineal system in drives surrounding communities toward institutional change as well (Figure A4 in Appendix A).

Empirical pattern 2. *The commons were unequally distributed, and communities with a higher per-capita value of commons were more likely to adopt patrilineal membership systems.*

Commons represented not only a valuable asset for communities but were also distributed unevenly. Due to orographic differences, the endowment of common property varied considerably among villages. A Gini coefficient calculated for per-capita value of collective land in a subsample of 32 villages in 1780 is 0.61, statistically significantly higher than the Gini index for the combined values of private and collective land, which is 0.27. This disparity highlights the unequal distribution of commons and underscores its role as a potential driver for geographical mobility, as access to the commons was more desirable in certain communities than in others.

The available historical data suggest that communities with a higher per-capita value of commons were more likely to adopt patrilineal

[19] Only one village, Ivan-Fracena, formally codified egalitarian membership in 1794. Ivan-Fracena was a small, isolated community. In the dataset, we do not consider this case as an institutional change but a simple restatement of the existing membership system. First, its first mention of membership happened during the late stages of the polycentric governance period in Trentino. Second, the source of the membership information was a document of admission of a new member to the community.

[20] This pattern aligns with scattered evidence documented in other regions of Italy. Similar restrictions on women's access to membership also emerged in other parts of Northern Italy during the same period (see Zanderigo-Rosolo, 2013; Alfani, 2015).

[21] Cole and Wolf (1974) provide population estimates for Trentino of 83,373 in 1312 and 125,059 in 1427.

[22] Institutional factors could also explain some patterns observed in the codification of patrilineal membership.First, an alternative explanation for the surge in institutional modifications during the 18th century may lie in the central government's efforts to assert greater authority by limiting local self-determination. This pressure may have prompted communities to rewrite charters in resistance to this top-down intervention. Second, the three earliest codification events took place in 1265 (Pieve Tesino), 1289 (Pradibondo), and 1413 (Zuclo), and involved a special type of community known as a vicinia. Although the computational model does not account for the vicinia type, theoretical arguments from Section 3 suggest that these communities would likely be among the first to adopt patrilineal membership. The reason lies in the unique structure of the vicinia, which was a form of common property distinct from the village's common property. While memberships in different communities were mutually exclusive, some individuals could legally hold dual memberships—one in the community and one in the vicinia—and combine their benefits. Given the preference for endogamic marriages, a vicinia with an egalitarian membership system faced a considerable risk of attracting new members through marriage, thereby diluting the benefits of existing members.

[23] This coding approach suggests that the formalization date of the patrilineal membership system was not primarily influenced by the transaction costs associated with amendments. In the remaining cases, the formalization of the patrilineal membership system coincided with the adoption of the first charter in 6.2 percent of cases, or even preceded it in 8.2 percent of cases.

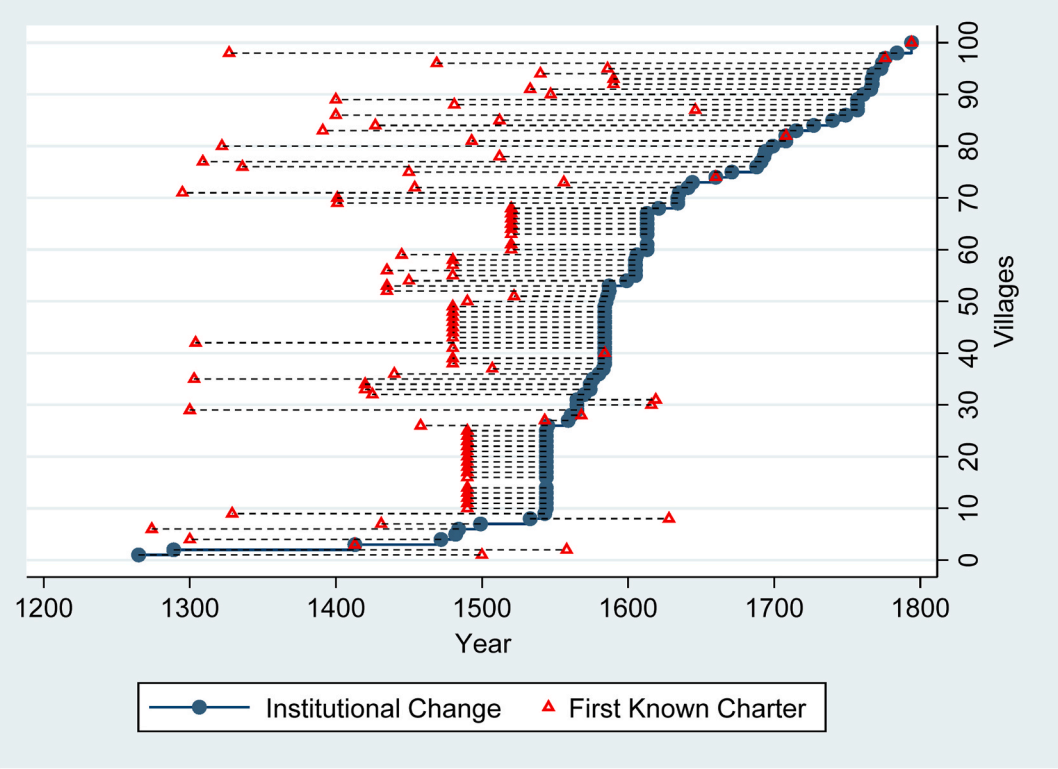

Fig. 4. Observed trend of institutional change (cumulative number of first adoptions).
Notes: A dot represents the year in which a village first changed its membership system, while a triangle indicates the year of the village's first charter adoption. Dashed lines denote the time span between the adoption of the first known charter in a village and its subsequent institutional change, or vice versa. A community regulated by a charter may comprise one or more villages, where a village corresponds to the geographic unit listed in the 1897 cadastral register, which references the current Province of Trento, Italy.
Source: Authors' own historical records.

Table 2
Predicted institutional changes correlate with communities' wealth.

Community rank in terms of collective wealth (w_k) before the first generation	1st (Richest)	2nd	3rd	4th	5th	6th	7th (Poorest)
Percentage of communities transitioning from egalitarian to unilineal membership	95.0	75.3	44.3	13.1	2.6	0.2	0

Notes: Simulation with K = 7. Percentages based on 1000 simulation runs, reflecting the frequency predicted by the last generation. Communities are ranked from 1 to 7 in order of decreasing initial per-capita collective wealth.
Source: computational model.

membership systems (Table 3).[24] An instrumental variable probit regression was performed, using as the dependent variable a dummy indicating whether a community transitioned from egalitarian to patrilineal membership by 1801 (1 = transition, 0 = no transition). The objective is to identify the empirical link between per-capita value of commons, measured in terms of land values, and an institutional change. In addition to the per-capita value of commons, the regression includes other explanatory variables: two proxies for remoteness—walking time to larger reference centers and village altitude above sea level—and valley fixed effects.[25] In a mountainous landscape, remoteness implies isolation, reducing opportunities for interaction with other communities.

This estimation may, however, be subject to reverse causality, as the adoption of patrilineal institutions might have resulted in higher wealth, rather than wealth driving the adoption of these institutions. For example, communities undergoing membership system changes may have exhibited distinct population dynamics compared to those without such changes, potentially influencing institutional evolution.

To address endogeneity concerns, we employ an instrumental variable probit analysis, using the geographic characteristics of village *i* as exogenous sources of variation. Specifically, we use the *Terrain Ruggedness Index* (TRI), which measures terrain irregularity or

[24] Information on collective land ownership percentages by land type is sourced from the 1780 cadastral registers. The value of commons is calculated based on its surface area and per-hectare value, with surface area derived from the 1897 cadastral data and per-hectare value based on the 1780 tax records. The per capita value of commons is obtained by dividing the total value of commons by the 1810 village population.

[25] Walking time is coded based on the location of each village relative to 17 major towns, identified as government administrative headquarters in 1810. Walking times are calculated using the Google Maps Direction Matrix API in walking mode, which assumes a standard walking speed of approximately 5 km/h on flat terrain and accounts for actual terrain elevation changes along the route. The API provides times in seconds, which are converted into decimal hours. It should be noted that these calculations are based on modern pedestrian infrastructure and may not fully reflect historical paths.

Table 3
Static analysis of observed institutional change by the year 1801.

Dep. variable: *1 = Institutional change by the year 1801, 0 = Otherwise*	(1) Instr. Var: FPI, TRI	(2) Instr. Var: FPI, TRI	(3) Instr. Var: FPI, TRI, FPI range, TRI range	(4) Instr. Var: FPI, TRI, FPI range, TRI range	(5) Instr. Var: FPI, TRI, FPI range, TRI range	(6) Instr. Var: FPI, TRI, FPI range, TRI range
Per-capita value of commons	0.1189***	−0.0818	0.1163***	−0.0283	0.1042***	−0.0178
	(0.0299)	(0.0721)	(0.0239)	(0.0652)	(0.0215)	(0.0597)
Altitude (km)	−0.380***	−0.8870***	−0.370***	−0.7120***	−0.2376**	−0.5336***
	(0.1331)	(0.2424)	(0.1229)	(0.2137)	(0.1075)	(0.1959)
Walking time to local center	−0.0195	−0.0105	−0.0198	−0.0138	−0.0290*	−0.0230
	(0.0182)	(0.0189)	(0.0181)	(0.0191)	(0.0155)	(0.0165)
Per capita value of commons × Altitude		0.2334***		0.1647**		0.1412**
		(0.0822)		(0.0742)		(0.0694)
First-stage F-statistic	16.39	9.93	16.60	9.19	25.16	13.48
Wald test of exogeneity (Prob>$\chi2$)	p = 0.0222	p = 0.0615	p = 0.0005	p = 0.0336	p = 0.0005	p = 0.0425
Hansen J statistic	$\chi^2(1) = 1.10$	$\chi^2(2) = 1.04$	$\chi^2(3) = 1.16$	$\chi^2(6) = 5.90$	$\chi^2(3) = 2.97$	$\chi^2(6) = 11.63$
	p = 0.295	p = 0.593	p = 0.762	p = 0.434	p = 0.396	p = 0.071
Number of obs. (villages)	285	285	285	285	361	361

Notes: TRI=Terrain Ruggedness Index, FPI=Photosynthesis Potential Index. Average marginal effects estimated using instrumental variable probit (*ivprobit* in Stata) with MLE and robust standard errors. To control for geographical fixed effects, 11 area dummies are included among the regressors but are not reported. Trento, the capital town, is excluded from the analysis. See Table B1 in the Appendix for the corresponding summary statistics and Table B2 for the first-stage regression results. For an earlier analysis using a less comprehensive dataset and a different empirical framework, see Casari and Lisciandra (2016). Figures in parentheses represent standard errors. Significance levels are denoted as follows: * for 10 %, ** for 5 %, and *** for 1 %.
Source: Authors' own historical records.

"roughness," and the *Photosynthesis Potential Index* (FPI), a composite indicator of photosynthetic potential based on solar exposure, slope, and vegetation index.[26] The TRI captures the physical challenges associated with land use and accessibility, while the FPI captures the potential agricultural yield of the terrain. Both TRI and FPI serve as proxies for land productivity and suitability, shaping whether land is allocated for commons or private use.

These instrumental variables satisfy the exclusion restriction for several reasons. First, these geographic characteristics were formed by geological processes over millennia, making them pre-determined and independent of human decision-making. Second, they affected institutional choices especially through their impact on land property rights between common and individual ownership: in historical Trentino, areas with high FPI or low TRI were more suitable for cultivation and typically privatized, while areas with low FPI or high TRI were less suitable and designated as commons—a relationship empirically supported by statistically significant correlations between our instruments and the common-to-private surface ratio ($r = -0.316$, $p < 0.01$ for FPI; $r = 0.568$, $p < 0.01$ for TRI). Third, the variability of TRI and FPI within a community captures environmental heterogeneity and its wealth potential, as diverse micro-environments support complementary economic activities such as forestry, grazing, and crop cultivation. This environmental diversity likely fostered economic resilience and enhanced productivity by creating synergies between private and common land use, such as manure from grazing supporting agriculture and forests providing essential resources (Casari, 2007; Casari and Lisciandra, 2016). To account for this, we included the range of TRI and FPI values as additional instruments, as larger ranges indicate conditions favorable to simultaneous utilization of private and collective resources. In fact, the correlation between per-capita value of commons and TRI range variable is statistically significant ($r = 0.435$, $p < 0.01$), as well as the correlation with the FPI range variable ($r = 0.415$, $p < 0.01$).

We also address potential violations of the exclusion restriction by considering alternative channels through which geography might directly influence institutional choices. First, a rugged terrain could create cultural isolation affecting institutional change independently of resource considerations, so we explicitly control for altitude and walking time to reference centers to account for isolation effects. Second, terrain variations might have provided natural defense capabilities shaping community structure, which we address through district/valley fixed effects that absorb shared security concerns. Third, one might worry that terrain generated cropping systems with distinct gender divisions of labor directly influencing inheritance norms; however, our instruments exploit exogenous geo-physical variation that shifts the relative payoff of keeping land in common rather than private use. Conditional on altitude, market access, and district fixed effects—which absorb any region-wide agricultural regime—the instruments can affect the transition from egalitarian to patrilineal membership only through their impact on commons wealth. While complete excludability cannot be definitively proven, these controls narrow the pathways through which our instruments can affect outcomes, strengthening the case for conditional excludability.

Table 3 presents six different specifications of our instrumental variable probit analysis, progressively expanding both the set of instruments and the sample size. Specifications 1 and 2 utilize the baseline instruments—TRI and FPI—using a sample of 285 communities. Specification 1 estimates the direct effect of per-capita value of commons, while specification 2 introduces an interaction term between per-capita value of commons and altitude to examine how the effect of wealth varies with geographic isolation. Specifications 3 and 4 expand the set of instruments to include measures of within-village land use variability, such as TRI range and FPI range. For robustness, specifications 5 and 6 extend the analysis to a larger sample of 361 communities, including those lacking documentary evidence, such as charters or other relevant

[26] TRI quantifies elevation variation between adjacent cells within a digital elevation grid. For a given 5 × 5 m cell, TRI is calculated as $TRI = \text{sqrt}[(\Sigma(x_i - x_0)^2)/8]$, where x_0 represents the elevation of the central cell, and x_i represents the elevation of each neighboring cell *i*. Low-TRI areas are suitable to crop cultivation, while high-TRI areas are better suited for grazing, summer pastures, and forestry. FPI is defined as FPI = Solar Exposure*(1-(Slope/90°)) × NDGI. *Solar Exposure* reflects the amount of solar radiation received, *Slope* represents the terrain's inclination in degrees, normalized by dividing by 90°, and *NDGI* (Normalized Difference Greenness Index) indicates vegetation density and health. Villages with higher FPI values typically feature well-sunlit terrain with gentle slopes, making them favorable for cultivating crops such as grains and vegetables. Conversely, villages with lower FPI values likely supported forests, pastures, and grazing activities. *Data Sources*: Portale Geocartografico Trentino (www.territorio.provincia.tn.it) and the TINITALY project at INGV (https://tinitaly.pi.ingv.it/), accessed on 30 June 2024.

documents. For these additional communities, we conservatively assume that no institutional change occurred, given that meaningful modifications to membership systems were typically well-documented. This approach enables us to assess whether the findings are robust in a more comprehensive sample, while maintaining the expanded set of instruments.

The estimates reveal that higher per capita value of commons increases the likelihood of patrilineal institutions in a statistically significant way, with marginal effects of 10.4–11.9 percentage points (columns 1, 3, 5). This relationship is robust and economically meaningful, highlighting wealth's role in institutional change. While altitude generally reduces the likelihood of institutional change (coefficients ranging from −0.238 to −0.887), the positive interaction terms between per-capita value of commons and altitude (ranging from 0.141 to 0.233) indicate that wealth differentials were pivotal in driving institutional modifications in highland areas. Highland communities were typically more resistant to institutional change due to their isolation, which naturally limited migratory pressures. However, in wealthier highland communities, valuable commons such as high-altitude pastures and productive forests provided the resources necessary to attract migrants despite the higher costs and harsher conditions of settlement. In contrast, poorer highland communities, lacking these resources, struggled to sustain their populations and faced little incentive to adopt patrilineal systems.[27]

The diagnostic checks corroborate our identification strategy. First-stage F-statistics span 9.19–25.16, all above the Stock–Yogo 15 percent-size critical value of 8.96, and—except for one borderline case—above the Staiger–Stock rule-of-thumb of 10, confirming that the geographic variables are strong predictors of commons wealth. Wald tests of exogeneity reject or very nearly reject the null in every specification, underscoring the need for an IV correction. Over-identification tests are equally reassuring: Hansen J p-values lie between 0.29 and 0.76 in four specifications and stay above 0.07 even in the most saturated model, so we cannot reject joint orthogonality. These patterns remain unchanged when the instrument set is expanded and the sample grows from 285 to 361 communes, giving us consistent evidence that the instruments satisfy relevance and (conditional) excludability assumptions.

Fragmentary evidence on marriage patterns, collected from a small sample of communities, offers additional insights consistent with the resource-protection hypothesis.[28] Communities that had adopted patrilineal membership exhibited higher endogamy rates compared to those with egalitarian systems (66.6 vs. 56.5 percent, two-tailed t-test, n = 83, p = 0.145), with this difference becoming statistically significant in communities with high endowment of commons per-capita (79.8 vs. 63.5 percent two-tailed t-test, n = 42, p = 0.062).

The results are particularly prominent in high-altitude communities with valuable commons, where patrilineal inheritance dramatically changed marriage patterns. In particular, it sharply reduced foreign-husband and local-wife marriages—by almost 50 percentage points (OLS with robust standard errors, p = 0.005; Table B4, column 4 in Appendix B)—thereby increasing the share of unions within the community. This result is confirmed when examining marriages between local husbands and outside wives: communities with patrilineal membership showed statistically significantly lower rates of such marriages compared to communities with egalitarian systems (5.6 vs. 11.6 percent, two-tailed t-test, n = 69, p = 0.049).[29] To sum up, these empirical patterns exhibit the strongest effects in those communities where they would be most economically relevant: those with valuable commons, particularly in highland areas where resources were most critical for survival.

5.3. Network externalities

Prediction 3. *Under polycentric governance, the transition to a unilineal system unfolds through a domino effect. Once this process is set in motion, communities are likely to experience a lock-in effect, effectively keeping them within a closed system.*

With additional simulations we further quantify network externalities: the *domino effect*, which accelerates the propagation of institutional change across communities, and the *lock-in effect*, which entrenches communities in a unilineal system. To evaluate these effects, we compare trajectories of institutional change under alternative scenarios. In the baseline scenario, all communities are free to switch to a unilineal system if they choose. In contrast, in the scenario without domino effects, only a single community is allowed to switch, while the other communities are fixed in an egalitarian system. We repeated this process for communities of all wealth ranks and show that the frequency of institutional change is lower in the absence of the domino effect as expected. Graphically, the domino effect corresponds to the gap between the solid and dashed lines in Fig. 5. The dashed line represents a hypothetical scenario designed to sterilize one of the network externalities, where each simulation is repeated K times, giving each community the opportunity to transition autonomously in the absence of migratory pressure stemming from other communities becoming unilineal. The dashed line aggregates the results of these K simulations of such counterfactual scenario. The domino effect increases the share of unilineal communities in the final round by 3.5 percentage points, which corresponds to an increase of 11.9 percent in the frequency of institutional change.

The lock-in effect describes the difficulty for a community to unilaterally revert to an egalitarian membership system within a region because of the migratory pressure due to all other communities adhering to a unilineal system. To identify the lock-in effect, consider a scenario where one community begins with egalitarian membership while the remaining communities start with unilineal memberships and are fixed at their initial status by design. Again, we repeat the simulation for each wealth rank and record the institutional change. Hence, to construct the dotted line, each simulation is repeated K times, subjecting each community at a time to high migratory pressure because of the closure of all other destinations. The lock-in scenario shows a more rapid transition

[27] The wealth differential between rich and poor mountain communities was generally more pronounced than in the plains, where agricultural opportunities were more homogeneous. This pattern is supported by the data: communities above the median altitude display significantly higher dispersion in per-capita value of commons (sd = 2.12) compared to lowland communities (sd = 1.17). A formal test of variance equality strongly rejects the null hypothesis of equal variances (p < 0.001).

[28] The marriage dataset covers 83 communities with observations primarily from 1735 to 1796 (some extending back to 1566), with 1–11 observations per community across different time intervals. The data sources are parochial registers and have been compiled from Casari and Lisciandra (2016) and Casari et al. (2019). We measure three key metrics: marriages between foreign husbands and local wives, marriages between local husbands and foreign wives, and endogamy rates. The sample includes communities that had adopted patrilineal membership (31.3 percent) and those that maintained egalitarian systems (68.7 percent). All communities with patrilineal systems had adopted this change before 1735. Therefore, our analysis focuses on comparing marriage patterns of egalitarian vs. patrilineal communities. Appendix B reports the empirical analyses with the regressions in Table B3, Table B4, and Table B5.

[29] These findings on marriage patterns align with additional evidence reported in Casari et al. (2019), which shows that communities with patrilineal membership exhibited significantly higher levels of endogamy and consanguinity than those with egalitarian membership. The focus of Casari et al. (2019) is on the Napoleonic conquest at the turn of the 19th century and the institutional shock of imposing egalitarian membership on all communities, which provides further confirmation of the impact of membership systems on marriage strategies.

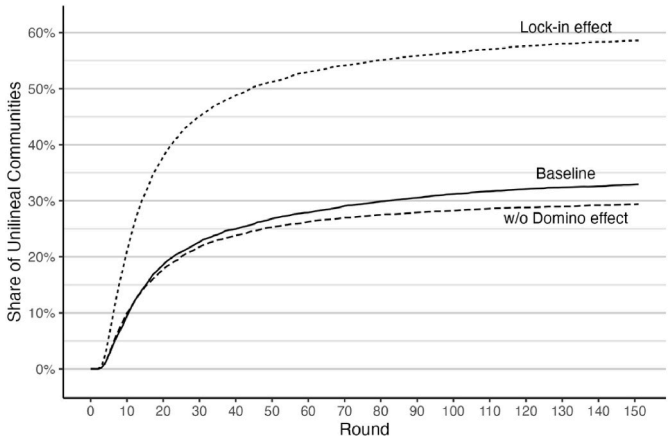

Fig. 5. Predicted trajectories of institutional change.
Notes: Each observation in a round is the average of 1000 simulation runs. The Baseline curve depicts the predicted trajectory of institutional change. The *Lock-in effect* line, shown as dotted, captures the high pressure for institutional change faced by an egalitarian community when all other communities have adopted unilineal membership. The *w/o Domino effect* line, shown as dashed, reflects the reduced pressure for institutional change in an egalitarian community in the absence of network effects.
Source: computational model.

toward unilineal membership than the Baseline, with institutional change in the last round about 25.7 percentage points higher than in the Baseline. Graphically, the lock-in effect corresponds to the distance between the solid and dotted line in Fig. 5.

As highlighted in the literature, a lock-in often arises from increasing returns to scale (North, 1990; Arthur, 1994), which in this model is reflected through growing negative network externalities. Specifically, a region of communities with unilineal membership and decentralized decision-making are locked-in, as reverting unilaterally to an egalitarian system will entail substantial costs.

Empirical pattern 3. *Patrilineal membership systems spread through spatial contagion and then persisted. An exogenous shock eventually reinstated the egalitarian membership system.*

We illustrate the spatial patterns of institutional change propagation with a map of the region (Fig. 6). The six-century period can be divided into four intervals. In the early phase (1200–1470), the formalization of the membership system occurred in only three villages and was achieved not through village charters but via special documents.[30] These regulations applied to a limited portion of the village territory, with the commons benefiting only a sub-group of the community. As a result, intermarriage within the community was highly likely. In the subsequent century (1470–1570), institutional changes were concentrated within a relatively small and contiguous area, excluding the early special cases. During the next century (1571–1670), institutional changes spread more broadly, evolving in clusters. The geographical contiguity of these changes becomes particularly evident. This pattern of geographically contiguous institutional change is further reinforced in the final stage, spanning the years 1670–1800.

To complement the visual patterns in Fig. 6, Table 4 presents an empirical analysis of the dynamics of institutional change, examining whether and when villages transitioned to new membership systems. While Table 3 provides a snapshot of institutional arrangements as of 1801, the analysis in Table 4 is dynamic, tracking the evolution of changes over the period 1200–1800. The dependent variable is coded as zero until an institutional change occurs, after which it becomes one, and the community is removed from subsequent intervals. This approach estimates the likelihood of an institutional change occurring at a specific point in time, conditional on the absence of change up to that point.[31]

To estimate contagion, it is essential to define a metric for the proximity between communities. In this study, we measure the empirical magnitude of contagion using a spatial weights matrix based on walking times (in hours) between communities. These walking times accounts for the terrain elevation changes and walking routes along the paths. This metric offers a close representation of the historical accessibility of communities.[32]

The empirical model is specified as follows:

$$\mathrm{P}(\mathrm{event}_{it}=1)=\Phi\Big(\beta_0+\beta_1\mathrm{spatial\_contagion}_{it}+\beta_2\mathrm{pc\_value\_of\_commons}_{it}+G_i'\beta_3+V_t'\gamma+\varepsilon_{it}\Big)$$

We estimate the specification as a probit discrete-time duration model, which is the standard approach for interval-censored events.[33] This model estimates the probability of institutional change occurring in village i at time t. Φ is the cumulative distribution function of the standard normal distribution. The spatial contagion term captures the cumulative influence of prior adopters in nearby villages, weighted by walking times.[34] The per-capita value of commons is the same variable used in Table 3, adjusted by the estimated village population at time t.[35] The term G_i accounts for time-invariant geographical characteristics, such as altitude and walking time to reference centers. Finally, V_t bundles time-varying common shocks: an aspatial tree-ring index that proxies Alpine-wide climatic conditions, plus period-specific indicators for regional population trends and major historical events. The inclusion of this basin-wide climate control ensures that the strong and statistically significant effect of spatial contagion we observe cannot be attributed to coincident weather shocks affecting all communities simultaneously.[36]

We then estimate several variants of this baseline specification to

[30] As already discussed in footnote 21, Pieve Tesino in 1265, Pradibondo in 1289, and Zuclo in 1413 were *vicinie*, subgroups of community members with exclusive access to specific portions of land. These documents were atypical in several ways. Notably, none of them received the approval of the Prince Bishop of Trent, which was required for charters.

[31] Both Tables 3 and 4 aim to identify the determinants of institutional change, specifically communities' decisions to adopt a restrictive inheritance regulation. While the analysis in Table 3 is static, focusing on the situation at a specific point in time, the analysis in Table 4 is dynamic, examining institutional change over six centuries.

[32] Refer to footnote 24 above for additional details on the estimation of walking times.

[33] We re-estimated all columns with a complementary-log-log link—the canonical hazard-model parametrization. Coefficients retain sign, magnitude and significance, confirming that our results are robust to a proportional-hazards interpretation. We will gladly share the output upon request.

[34] The operational definition of the spatial_contagion variable is as follows. For each community i and five-year period t, $\mathrm{spatial\_contagion}_{it} = \sum_{j\neq i} w_{ij} 1\left[\mathrm{first\_adoption}_j < t\right]$, where w_{ij} are row-standardised inverse walking-time weights. Hence *spatial_contagion* is the cumulative proportion of previously adopting neighbors, weighted by historical accessibility.

[35] The village population at time t is estimated by scaling the 1810 population based on the population ratio of Centre-North Italy between time t and 1800.

[36] This tree ring measure relies on historical data of Norway spruce (*Picea abies*) ring width from 1200 to 1800, collected at an elevation of 1250 m in the Lauenen region of the Swiss Alps (46.42°N, 7.32°E) and nearby locations. The measure represents the average among 37 yearly samples. It provides a time-varying control for environmental conditions that may have influenced communities' resource management decisions. Because the series assigns the same value to every community within each five-year period, it filters out region-wide climatic shocks rather than local weather. *Source*: Schweingruber, F.H. (2002-05-29): NOAA/WDS Paleoclimatology - Schweingruber - Lauenen + div. Stao CH - PCAB - ITRDB SWIT177. NOAA National Centers for Environmental Information. https://doi.org/10.25921/6rdm-eq19. Accessed December 2024.

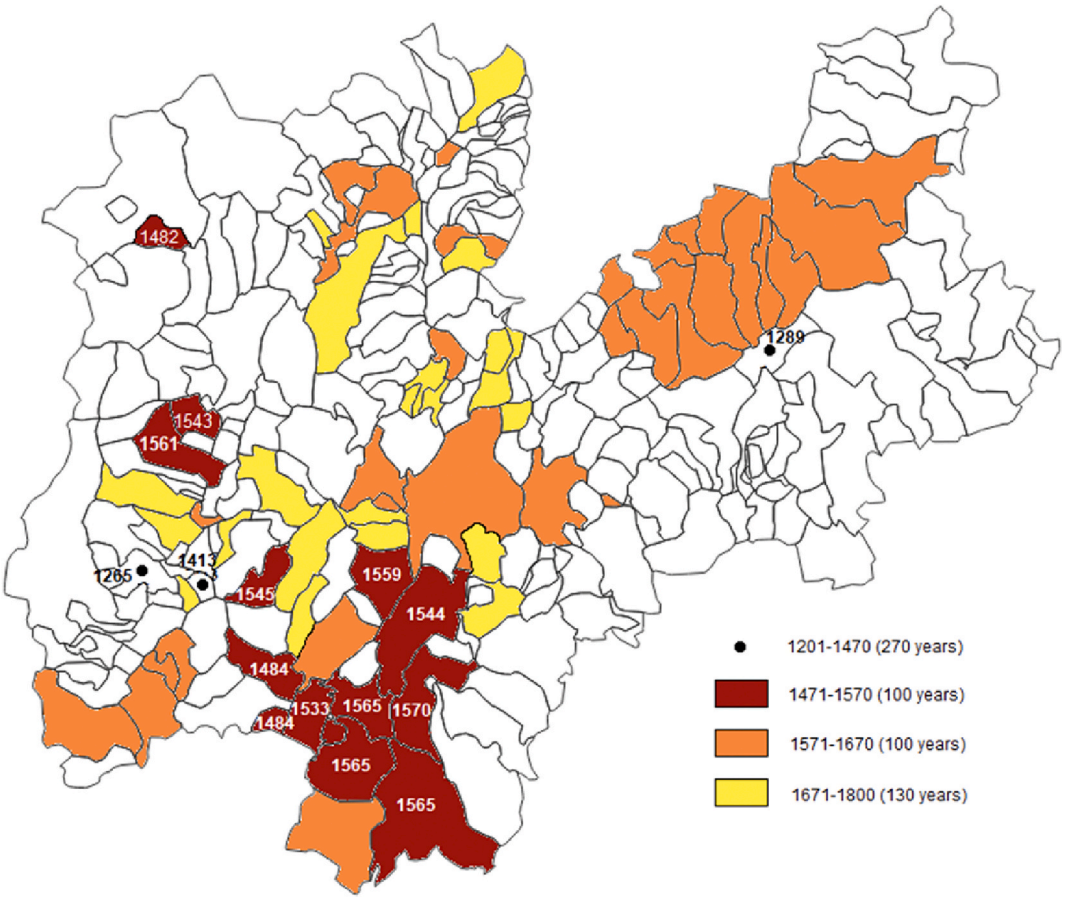

Fig. 6. Observed spatial diffusion of patrilineal membership in Trentino.
Notes: The data points from 1265, 1289, and 1413 refer not to entire villages but to specific portions of village territories.
Source: Authors' own historical records.

explore different dimensions of the adoption process: the non-linearity in spatial diffusion via the inclusion of a quadratic term (column 3), the interaction between economic and spatial factors through the interaction of spatial contagion and commons wealth (column 4), and the interaction between economic and geographical factors by allowing the effect of commons wealth to vary with altitude (column 5).

The results provide strong evidence for spatial diffusion effects in the adoption of patrilineal institutions. In the baseline specification, the coefficient on spatial contagion is positive and statistically significant (2.074, $p < 0.01$), indicating that a community's probability of institutional change substantially increases with the share of neighboring communities that previously adopted restrictive membership systems. When time-varying controls for demographic and environmental factors—such as the tree ring index, population trends, and other common socio-economic shocks—the spatial contagion effect remains positive and statistically significant (1.257, $p < 0.01$), though with a reduced coefficient. This reduction suggests that some spatial correlation reflects shared characteristics between neighboring communities. However, the robust significance of the contagion effect indicates that institutional diffusion is not driven by common climate alone and operates independently of other socio-economic factors.

In column 3, the combined effect of the positive and statistically significant coefficient on spatial contagion (3.921, $p < 0.01$) and the negative and statistically significant quadratic term (−9.091, $p < 0.01$) highlight diminishing returns. This indicates that while the influence of neighboring communities initially drives institutional change, the marginal impact of additional adopting neighbors diminishes as more neighbors transition to patrilineal membership.

In column 4, the direct effect of spatial contagion becomes statistically insignificant (0.351), but the positive and statistically significant interaction term between spatial contagion and per-capita value of commons (0.456, $p < 0.05$) suggests that diffusion primarily operated through the level of collective resources. Communities with greater commons wealth were more likely to be influenced by their neighbors' institutional changes, as they sought to protect their valuable resources.

In column 5 the positive and statistically significant interaction term between commons wealth and altitude (0.199, $p < 0.05$) reveals that wealth played a more critical role in driving institutional changes at higher altitudes. This result is consistent with Table 3, indicating that while isolation generally reduced migratory pressures and increased resistance to change, wealthier highland communities, endowed with valuable commons such as high-altitude pastures and forests, were better positioned to attract migrants than poor isolated communities, despite high settlement costs.

Finally, although the coefficient on the per-capita value of commons does not exhibit strong statistical significance across all specifications, its consistent positive sign indicates that the wealth of commons played an important role in driving institutional change. This finding aligns with the results reported in Table 3 and supports the theoretical expectation that wealthier communities had stronger incentives to adopt patrilineal systems to protect their resources.

One could debate whether the channel of propagation for institutional change was imitation or structural need. The imitation channel views institutional change as an innovation, with geographical proximity facilitating the transmission of information about this innovation. However, communities are likely to imitate an innovation only if it enhances welfare, yet this particular institutional change might have reduced payoffs. Unlike technological innovations, this legal innovation

Table 4
Dynamic analysis of observed institutional change in the period 1200-1800.

Dep.Variable: 1 = Institutional change between t and t+5 years, 0 = Otherwise	Baseline	With Controls	Non-linear Contagion	Contagion × Commons	Commons × Altitude
Spatial contagion	2.074***	1.257***	3.921***	0.351	1.278***
	(0.321)	(0.417)	(1.312)	(0.594)	(0.411)
Per-capita value of commons	0.034	0.037*	0.040*	−0.015	−0.125*
	(0.021)	(0.022)	(0.021)	(0.035)	(0.069)
Walking time to local center	−0.007	−0.010	−0.020	−0.013	0.003
	(0.030)	(0.032)	(0.033)	(0.032)	(0.032)
Altitude (km)	−0.111	−0.138	−0.149	−0.115	−0.615**
	(0.176)	(0.184)	(0.184)	(0.187)	(0.259)
Tree ring index (mm)		1.120***	0.997***	1.104***	1.133***
		(0.290)	(0.297)	(0.292)	(0.290)
Population trend (binary)		0.437***	0.404***	0.422***	0.437***
		(0.144)	(0.146)	(0.144)	(0.143)
Italian crisis (binary)		0.589***	0.494***	0.567***	0.589***
		(0.117)	(0.124)	(0.118)	(0.118)
Peasant war (binary)		−0.504	−0.439	−0.490	−0.518
		(0.324)	(0.328)	(0.325)	(0.325)
Council of Trento (binary)		0.479***	0.468***	0.492***	0.472***
		(0.112)	(0.113)	(0.113)	(0.112)
Spatial contagion2			−9.091**		
			(4.419)		
Spatial contagion × Commons				0.456**	
				(0.208)	
Commons × Altitude					0.199**
					(0.078)
Num.Obs.	30589	30589	30589	30589	30589
Num. Villages	285	285	285	285	285
AIC	1259.3	1186.9	1183.8	1183.8	1182.3
BIC	1384.3	1353.4	1358.7	1358.7	1357.2
Log.Lik.	−614.664	−573.437	−570.905	−570.923	−570.129

Notes: Probit discrete-time duration model estimated using MLE with robust standard errors. Communities exit the sample after experiencing the event (single-spell model). Spatial contagion is based on walking times between communities. Tree ring index represents a five-year average of yearly tree ring widths. To control for geographical fixed effects, 11 area dummies are included among the regressors but are not reported. Trento, the capital town, is excluded from the analysis. See Table B1 in the Appendix for the corresponding summary statistics. For an earlier analysis using a less comprehensive dataset and a different empirical framework, see Casari and Lisciandra (2016). Figures in parentheses represent standard errors. Significance levels are denoted as follows: * for 10 %, ** for 5 %, and *** for 1 %. Significance levels: * for 10 %, ** for 5 %, and *** for 1 %.
Source: Authors' own historical records.

was simple to understand, even in the absence of direct exposure from neighboring villages. Furthermore, the imitation channel fails to explain why only a minority of communities adopted this innovation instead of the vast majority (Empirical Pattern 1). It also fails to clarify why resource-poor communities refrained from adopting it (Empirical Pattern 2) or why a central authority would revoke a supposedly welfare-enhancing system (Empirical Pattern 3).

Instead, we argue for a structural need channel. Historical records from Trentino communities reveal that written rules were not comprehensive frameworks governing relationship between peasants and resources but rather ad hoc responses to specific, contingent issues. Early charters were brief and often required amendments to address practical disputes (Casari, 2007). This indicates that changes in formal institutions were plausibly reactive rather than anticipatory.[37] As shown in Table 4, changes in membership regulations by neighboring communities redirected migratory pressure. In response, affected communities may have restricted membership to limit immigration through marriage—an action they might not have otherwise considered. Thus, the spillover effects of a neighbor's decision could have shifted the cost-benefit balance, prompting institutional changes driven by necessity rather than imitation.

As a final remark, the institutional change shows clear signs of lock-in effects. Once a community adopted a patrilineal membership system, it consistently upheld this decision over time; even the restrictions imposed on women's membership rights showed no evidence of regression (as illustrated in Empirical Pattern 1). Only an exogenous shock was capable of breaking the institutional lock-in and reinstating property rights for women. Between 1805 and 1807, following the Napoleonic conquest, the central government abolished all ancient feudal institutions, replacing the polycentric organization with a monocentric one. This new system standardized rules across all territories in Northern Italy under the French legal framework. The changes that replaced the charters introduced two notable differences (Casari et al., 2019). First, discrimination against women in accessing common land was eliminated, and membership rights became egalitarian across all communities. Second, the former decentralized decision-making system was replaced by a centralized government that prohibited local variations in the membership system. Consequently, communities lost their prerogative independently establish and modify membership rules. The motivations behind this reform were likely both ideological and practical. It aligned with the broader package of institutional innovations inspired by the French Revolution, yet the reform persisted in Trentino even after the departure of the French administration.

5.4. *Inheritance of private assets*

Prediction 4. *Inheritance regimes for private assets are irrelevant to aggregate migration across communities; migration patterns are instead driven by membership systems.*

To assess the role in institutional change of the inheritance regime on private assets independently from membership systems, we simulated

[37] This interpretation is further supported by the extremely slow speed of observed changes in membership rules in Trentino.

the effects of two distinct inheritance regimes for private assets while holding membership constant. In the egalitarian inheritance regime, a child inherits an equal share of both parents' assets, regardless of gender. In the unilineal inheritance regime, only sons (daughters) inherit assets, while daughters (sons) receive none. Fig. 7 compares population dynamics across these two regimes under polycentric governance and shows no discernible differences in aggregate outcomes. Population, migration flows, and institutional transitions remain largely unaffected by the choice of inheritance regime on private assets. These results suggest that the membership system, rather than the inheritance regime for private assets, plays the dominant role in shaping migratory behavior and institutional change.

Empirical pattern 4. *Inheritance regimes on private assets followed a different path of institutional change compared to membership systems.*

The academic literature often conflates the inheritance of community membership with the inheritance of private assets. For instance, the Murdock, (1967) fails to distinguish between the two. However, these regimes are conceptually and legally distinct, and they historically followed different institutional trajectories in Trentino. While membership systems transitioned from egalitarian to patrilineal, inheritance regimes for private assets remained predominantly egalitarian. Historical evidence highlights this divergence.[38]

First, the persistence of egalitarian inheritance for private property can be traced back to Roman law, which embraced egalitarian principles. These principles in the *Novellae* 118 and 127.1 of Justinian's late Roman Empire and later reinforced by Canon law, as codified in the *Decretum Gratiani* (1150). This legal tradition, based on bilateral descent, influenced many European regions, including Trentino.

Second, the 1425 Statute of Trento codified a broadly egalitarian inheritance regime for private assets, applying uniformly across the Bishopric of Trento unless superseded by specific local charters. However, this last occurrence never took place. Women in Trentino typically received dowries and, in some cases, additional private property such as land or buildings. In contrast, regulations concerning the inheritance of common land and membership were absent, reflecting a decentralized decision-making approach. This pattern was evident in Trentino and mirrored in other European regions (e.g., Wegge, 2021).

Third, this dichotomy is further illustrated by the charter of the Fiemme community. As noted in the introduction, inheritance regimes for private and collective properties were identical prior to 1583.[39] After 1583, they diverged: private assets continued to follow an egalitarian regime, while common land shifted to a patrilineal system.

6. Conclusions

What makes a society open or close to migration? This study has modeled the interactions between inequality, gender discrimination, and migration using a general equilibrium framework that captures the salient features of a historical setting found in a European region. Our setting comprises multiple communities, each locally regulating its common resources. A key innovation of this study is moving away from the traditional perspective of a single, isolated community managing its commons and studying instead a network of interlinked communities.

To address migration driven by inequalities, communities often restrict property rights by transforming resources from open access to common property. However, this transformation may prove insufficient as migration can occur through marriage. Our focus on membership rules—specifically the choice between egalitarian and unilineal systems—reveals that while egalitarian membership is desirable, it is inherently unstable. Communities with abundant common resources attract substantial immigration, which erodes insiders' income. In response, insiders in wealthier communities advocate for stricter anti-immigration rules, triggering institutional transformations and generating negative network externalities for other communities.

The broader implications of our findings extend to contemporary issues of migration. Just as egalitarian institutions face instability when outsiders can share in the commons' benefits, affluent nations implement protectionist immigration policies to preserve access to non-transferable benefits such as public services and economic opportunities. These policies create global ripple effects as changes in one nation influence migration patterns, diverting flows to more receptive countries.[40] The general point about institutional change is that a monocentric perspective—which views the community as a largely self-contained entity with a singular decision-making center—fails to adequately account for these historical patterns. Instead, the explanation becomes clearer when each community is considered part of a network of interconnected communities, each wielding considerable decision-making authority over its own institutions. Any configuration aligning with the Tiebout model shares common elements with a polycentric organization.[41]

This perspective enables a unified interpretation for both the gradual closure of communities and their rapid re-opening with regard to the historical situation in Trentino, Italy. The present study spans six centuries and illustrates the long-run dynamics in the institutional evolution of community membership, which bears striking similarities to the crafting of modern citizenship systems. By employing a computational model, we uncovered the mechanisms observed underlying these processes, connecting historical evidence with theoretical insights. To conclude, we highlight three lessons from our study.

First, institutions characterized by gender bias may arise from economic incentives that destabilize egalitarian systems. Once established, such institutions can persist over long periods, even when egalitarian principles are socially preferred. Besides reporting the empirical evidence, this study also elucidates the theoretical mechanisms underpinning this process.[42]

Second, our analysis examines institutional change within a polycentric framework (Ostrom, 2010). The majority of existing studies tend to analyze institutions and the effects of exogenous shocks from a monocentric perspective (Bisin and Federico, 2021). In contrast, we adopt a polycentric viewpoint, where changes arise not only from central decision-making but also through network externalities (Arthur, 1994), leading to domino effects and institutional lock-ins. This perspective blurs the lines between endogenous and exogenous causes: a change factor may be considered endogenous at the system level, yet it might be perceived as exogenous at the single unit level. To elucidate this point, consider the case of a country that initially chooses to adopt a particular gauge standard for its railway tracks. If we take the example of an island nation, this decision can induce persistence owing to the high switching costs. This standard could be subject to modification only if internal dynamics necessitate it. Conversely, in the case of a country sharing extensive borders with other countries, network externalities

[38] For more details, see Appendix A in Casari et al. (2019).

[39] Sartori-Montecroce (1891), *Le consuetudini di Fiemme - Libro II del civil*, 1613 charter, Ch. 114, p. 278.

[40] Historical and modern examples, such as 19th-century migration (Timmer and Williamson, 1998; Bertoli and Fernández-Huertas Moraga, 2013; Giordani and Ruta, 2013) and the 2004 EU expansion (Boeri and Brücker, 2005), demonstrate how restrictive policies in one country can impact others globally, creating a domino effect in migration and resource allocation.

[41] While most modern states operate under a monocentric framework, numerous examples of polycentric governance exist, including the European Union, the United States, and the Swiss Confederation.

[42] What triggered the erosion of women's rights was an external pressure coming from population growth and endowment inequalities across communities. It was not the effect of an increased cultural bias against women but rather, a response that reflected a latent discrimination against women. Eroding men's rights would have proved equally effective in coping with such external pressure.

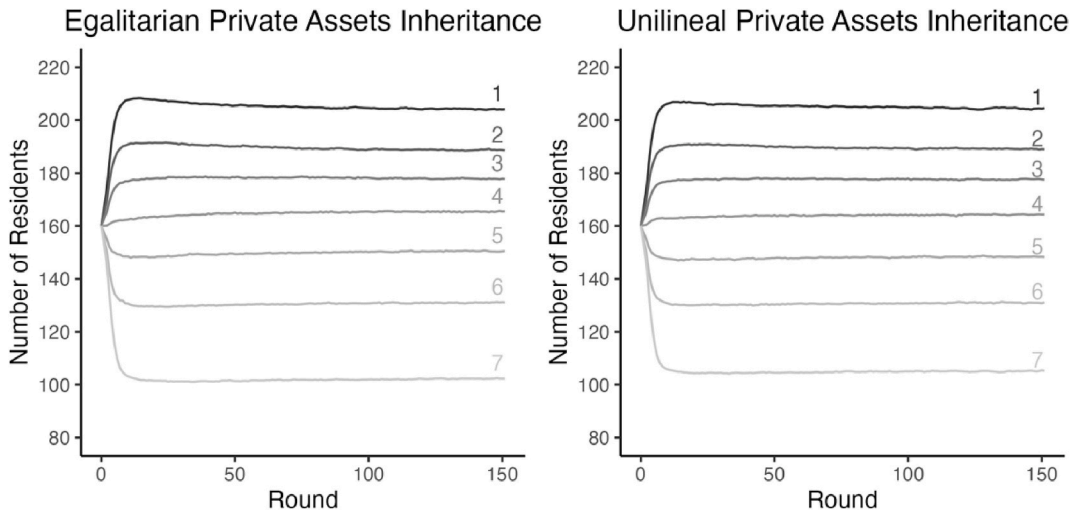

Fig. 7. Predicted effect of Inheritance Regimes for Private Assets under Polycentric Governance.
Notes: Simulation with $K = 7$ and an initial population of $n = 160$ in each community. All communities start with an all-egalitarian membership system. Communities are ranked by initial per-capita value of commons, with 1 indicating the highest wealth. Each observation in a round represents the average of 1000 independent runs.
Source: Computational model.

may drive change in spite of the initial internal considerations and the associated switching costs. Viewing institutional changes through the lens of a polycentric perspective recasts the understanding of the political economy of such changes and places them within a wider context.

Third, the intergenerational transmission of common property resources is critical for understanding inequality, migratory trends, and marriage patterns within a society. Despite its importance, this topic has been essentially unexplored in the economic literature (for an exception see Valsecchi, 2014), which has instead focused almost exclusively on private assets (e.g., BenYishay et al., 2017; Wegge, 2021). Our research underscores the pivotal role of inheritance systems over common property resources in contrast with the low relevance of inheritance regimes over private property. We advocate for a shift in academic and policy attention—particularly in low-income nations—toward studying common property resources in order to improve our understanding of economic, social, and demographic trends.

CRediT authorship contribution statement

Marco Casari: Conceptualization, Methodology, Visualization, Formal analysis, Data curation, Writing – original draft. **Maurizio Lisciandra:** Conceptualization, Methodology, Visualization, Formal analysis, Data curation, Writing – original draft. **Ali Seyhun Saral:** Visualization, Software, Formal analysis, Data curation.

Disclaimer

During the preparation of this work M.Casari and M.Lisciandra used AI in order to improve the writing style of the manuscript. After using these services, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Structure of the Computational Model

We consider a simulated region comprising K communities. Each community can adopt either an *egalitarian* or a *unilineal* membership system. In an egalitarian system, both men and women can inherit community membership and transmit it to their offspring, thus granting all members of the couple access to the community's commons. By contrast, in a unilineal system—patrilineal (as in our historical case) or matrilineal—only individuals of one sex have the right to inherit and transmit membership; couples in which neither spouse is a member therefore do not gain access to the commons. If all communities begin with egalitarian membership—a plausible representation of the historical context at the start of the thirteenth century—then, over time, each community may switch its membership rule in response to changes in its per-capita endowment of the commons.

To formalize the model, let each of the K communities have an initial population $n_k = n$ and a distinct endowment of common resources W_k, implying that the initial per-capita endowment is $w_k = W_k/n_k$. The population in each community may evolve due to marriage migration, but the total regional population remains stationary.[43] The model incorporates both micro- and macro-level assumptions, which we detail below.

[43] Introducing endogenous population growth does not alter the basic mechanism that we will now describe.

Micro Assumptions

At the individual level, we consider two traits: personal attractiveness (a_i) and private economic assets (p_i). Personal attractiveness encompasses physical and personality characteristics, while private economic assets include privately owned wealth, such as land or houses, which can be sold.[44] Both traits range between 0 and 1. In the first generation of each simulation, a_i and p_i for every individual i are drawn from a Beta distribution, *Beta* (α,β) with $\alpha = \beta = 5$. This yields an expected initial value of 0.5 for both traits.

Each individual can marry a partner from any community in the region. If two individuals come from different communities, the newly formed couple must decide where to reside (i.e., in the husband's or the wife's community). To model the cost of relocation, we assign each community a random location within a two-dimensional Euclidean circle of radius 2. The relocation cost is proportional to the squared Euclidean distance between the two communities. As a result, couples tend to prefer residing in the community that minimizes relocation costs, favoring shorter-distance moves, while remaining in one's own community incurs no cost.

We use a two-sided matching procedure with no search costs based on the deferred acceptance algorithm (Gale and Shapley, 1962), where individuals simultaneously choose partners. An individual i evaluates a potential partner j and a prospective community of residence k by balancing four elements[45]

$$U_i = a_j + \sqrt{p_j} + \sqrt{2w_k} - 0.1\, d_{ik}^2$$

where a_j is the partner's attractiveness, p_j is the partner's private assets, w_k is the per-capita endowment of the chosen community, and d_{ik} is the distance between agent's current community and the location of the designated community. Marginal utility decreases in the private and common assets, which we approximate by taking square roots. The algorithm processes proposals from a single side of the marriage market until all individuals are matched in couples.

When a couple has children, traits are transmitted in a noisy manner. Each couple has exactly two children, a son and a daughter, who replace the parents in the next generation, such that population remains stationary at the regional level. For personal attractiveness, 80 percent of the child's attractiveness is the average of the parents', with the remaining 20 percent drawn randomly from the same Beta distribution used initially. For private assets, 80 percent are inherited according to the legal inheritance regime in force for private property, again with 20 percent randomly assigned from the Beta distribution. This process ensures some persistence in individual traits while introducing variation in each new generation.

Macro Assumptions

The region consists of $K = 7$ communities, each initially populated by $n_k = n = 160$ individuals (80 men and 80 women), giving a total of 1120 individuals. At the start of each independent simulation, W_k—the constant endowment of common resources—is generated by multiplying n (the initial community population) by ω_k, where $\omega_k \sim Beta(\alpha,\beta)$ with $\alpha = \beta = 5$. Thus:

$$W_k = n\omega_k, \text{for } k = 1, \ldots, K, \omega_k \in [0, 1].$$

This construction normalizes the expected W_k around 80 (i.e., $160 \times [\alpha/(\alpha+\beta)]$) and yields an initial per-capita endowment w_k with an expected value of 0.5. Although W_k is fixed for each community, w_k can change over time as community populations fluctuate through marriages.

In a polycentric organization, each community can switch from one system to another after each round of marriages. This switch is modeled probabilistically and depends on the ratio $w_{k\ (current)}/w_{k\ (initial)}$. When a community's per-capita endowment declines substantially from its initial level (e.g., below 0.33), it switches to unilineal membership with certainty. For moderate declines, the probability of adopting unilineal membership decreases linearly until it reaches zero at a ratio of 0.93. A community keeps its current system with certainty if the ratio is between 0.93 and 0.98. Once the ratio exceeds 0.98, the probability of switching toward egalitarian membership becomes positive, rising linearly until the community switches with certainty at a ratio of 1.58. Figure A1 illustrates these transition rules. Because there is an aversion to inequality (in line with Section 3), the parametrization is biased toward egalitarian membership: if $w_{k\ (current)} = w_{k\ (initial)}$, there is already a positive probability of remaining or transitioning to an egalitarian system.[46]

[44] If the amount of private land and houses in a community is fixed, prices will adjust to meet demand. The computational model does not account for this aspect. Given the small size of communities, prices of land may decrease in communities of net emigration and increase in communities of net immigration.

[45] Notice that w_k is multiplied by 2 because the share of collective wealth that partners can enjoy is family (couple) based, such that if both partners are members or one of them is a member, then the share is the same. Also notice that in the case of an exogamic marriage $b_i = 0$.

[46] Predictions do not qualitatively differ when using a model with a deterministic threshold for institutional transition. We preferred a probabilistic rule to a simple threshold because we do not have a strong theory that justifies the choice of a specific value for the threshold in terms of per-capita collective wealth, hence having an interval is a more robust model choice.

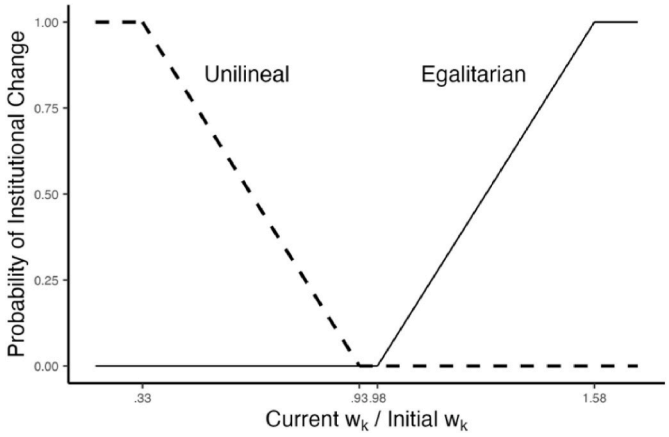

Fig. A1. Rule for deciding institutional change in the simulation.

Flow of the Simulation

Time is discrete and unfolds in generations. Each generation comprises all 1120 individuals in the region. Within one generation, the entire population eventually marries, reproduces, and is then replaced in the next generation by offspring. To introduce randomness into partner matching, a generation is subdivided into ten rounds (cohorts). In each round, 1/10 of the men (56) and 1/10 of the women (56) are randomly selected to form couples through the matching process described above. By the end of ten rounds, all individuals in the generation have formed couples.

After each round of matching, the population of each community and thus its per-capita endowment w_k are updated. Because the commons are divided among member families, as the number of couples with membership in a community changes, so does the available w_k.

Once every individual in the generation has married (i.e., after ten rounds), each couple has exactly two children—a son and a daughter—who inherit personal attractiveness and private assets according to the rule above. The parents then die, and the children become adults in the next generation.

We run each scenario for 15 generations.[47] Figure A2 illustrates an example of matching patterns across cohorts and generations. The results reported in the paper are averages over 1000 independent runs, each drawing initial endowments W_k and individual traits (a_i, p_i) from the specified Beta distributions. The model is implemented in Python, and the source code is available upon request.

[47] The findings demonstrate stability even when the analysis is extended to encompass 45 generations.

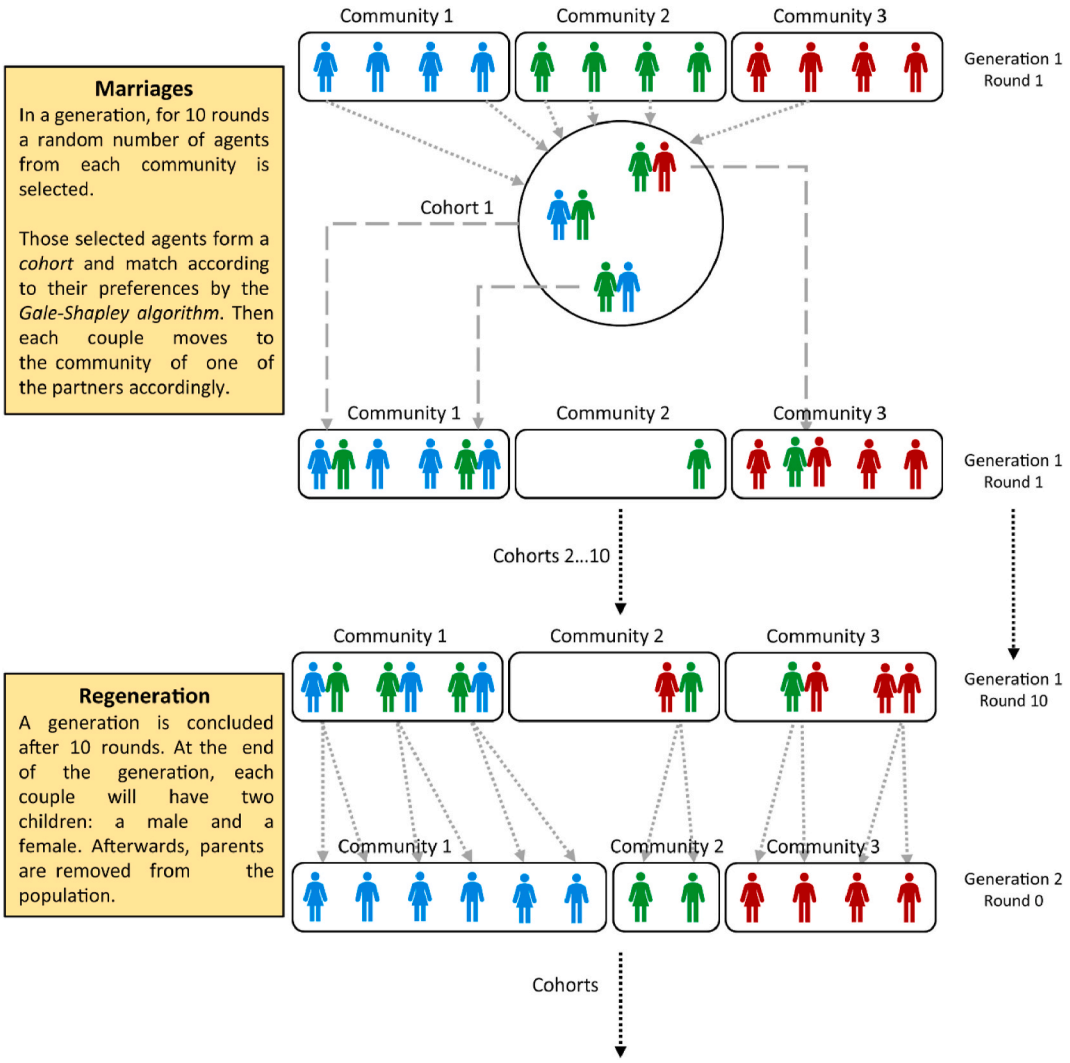

Fig. A2. Example of matching patterns across cohorts and generations in the simulation.

Simulation results

In order to understand the spatial effects for our institutional change, we used two simple metrics to calculate centrality of each community. *Average Pairwise Distance* (APD) is the mean Euclidean distance from a given community to every other community, capturing its overall spatial remoteness:

$$\mathrm{APD_k} = \frac{1}{\mathrm{K\text{-}1}} \sum \mathrm{d_{kl}}, \text{ for all } l, k \neq l$$

and *Nearest Neighbor Distance (NND)* which is shortest distance from a community to its closest neighboring community, reflecting its immediate spatial isolation,

$$\mathrm{NND_k} = \min \{\mathrm{d_{kl}}\}, \text{ for all } l, k \neq l$$

where d_{kl} is the Euclidian distance between communities k and l. Figure A3 shows an example of how communities could be randomly located in space. An application of APD is in Figure A4.

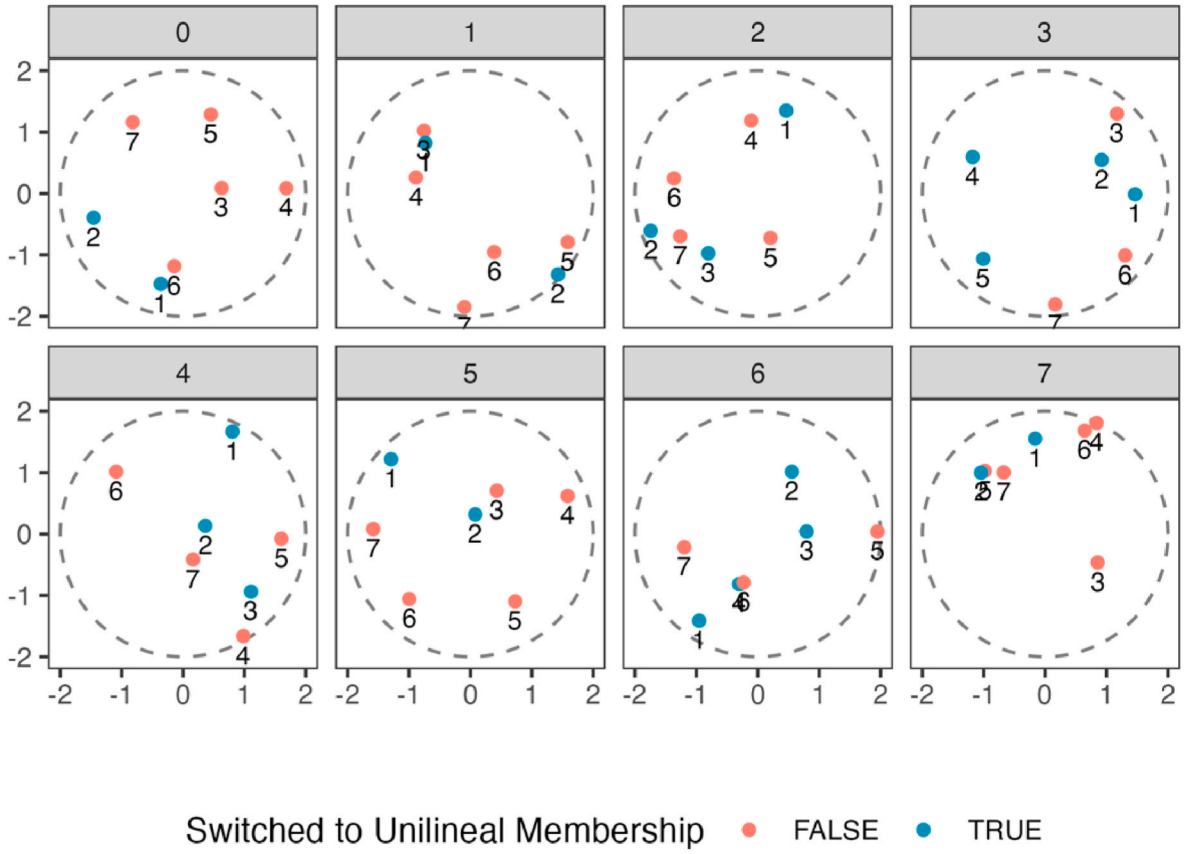

Fig. A3. Examples of communities with their spatial dimensions in the simulation.
Notes: An example of the spatial setup used in the simulations. Communities are randomly assigned a location within a circle of radius 2. Each panel corresponds to a random iteration (8 out of 1000), and the color of each dot indicates whether the community switched to a unilineal membership system (blue) or remained egalitarian (red) by the end of 150 rounds. Numbers indicate the wealth rank of each community.

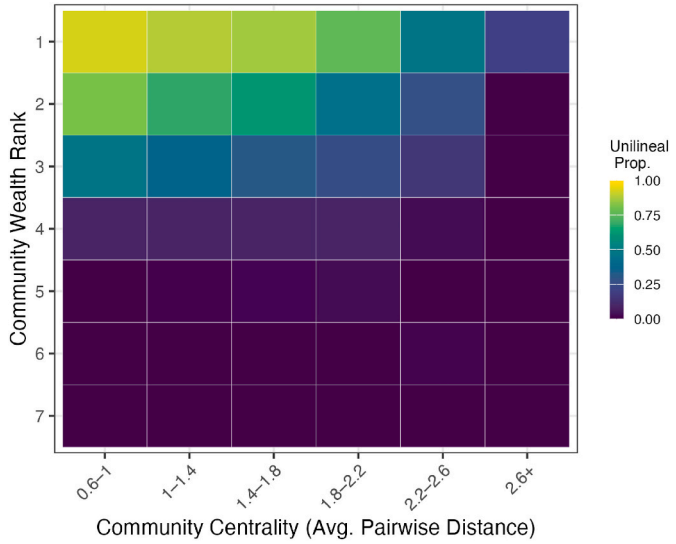

Fig. A4. Predicted share of Unilineal communities by wealth and spatial centrality
Notes: Simulation with $K = 7$ and an initial population of $n = 160$ in each community. All communities start with an all-egalitarian membership system. Communities are ranked by initial per-capita value of commons, with 1 indicating the highest wealth. Each observation in a round represents the average of 1000 independent runs. *Source:* Computational model.

Table A1
Institutional Change and Spatial Centrality

Dependent Variable: Unilineal (1/0)		
	(1) APD	(2) NND
(Intercept)	−0.54 (0.02)***	−0.66(0.02)***
Community Endowment	0.01(0.00)***	0.01(0.00)***
Avg. Pairwise Distance	−0.11(0.01)***	
Nearest Neighbor Distance		−0.08(0.01)***
Num. Obs./adj. R^2	7000/0.46	7000/0.46

Notes: This table presents the results of logistic regression models predicting the likelihood that a community adopts a unilineal institutional system (dependent variable = 1) after 150 rounds. Model 1 includes average pairwise distance as a measure of spatial remoteness, while Model 2 substitutes nearest neighbor distance. Standard errors are reported in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table A1 shows that models, community endowment is positively associated with the likelihood of adopting unilineal system, while greater spatial distance—whether measured by average pairwise or nearest neighbor distance—reduces this likelihood. Figure A4 complements this finding by showing that unilineal institutions are most common in communities that are more spatially central. As average pairwise distance increases (moving from left to right), the proportion of unilineal communities declines across those communities that show institutional change, highlighting the effect of spatial remoteness on institutional change.

Appendix B. Additional Tables and Figures

Table B1
Summary statistics for the dataset used in Tables 3 and 4.

	Mean	SD	Min	Max	Obs.
Institutional change (1 = yes, 0 = no)	0.337	0.473	0	1	285
Per-capita value of commons (carantani)	2.470	1.964	0.085	19.46	285
Village population in 1810 (inhabitants)	638.9	724.4	52	7069	285
Altitude (km)	0.677	0.290	0.073	1.579	285
Walking time to local center (decimal hours)	2.126	1.496	0	8.088	285
FPI	0.081	0.019	0.046	0.141	285
TRI	7.335	3.025	0.910	20.17	285
FPI range	0.971	0.375	0.134	1.410	285
TRI range	1104	1720	18.02	6653	285
Tree ring index (mm – 5-year average)	0.826	0.252	0.140	1.250	34,200

Notes: This table reports summary statistics for 285 communities plus a single time-only variable (last row). *Institutional change* is a binary indicator for shifts in the membership system (1 = yes, 0 = no). *Per-capita value of commons* is measured in carantani (historical currency unit), *Village population in 1810* in total inhabitants, *Altitude* in kilometers (km), and *Walking time to local center* in decimal hours. *FPI* stands for Photosynthesis Potential Index, *TRI* stands for Terrain Ruggedness Index; *FPI range* and *TRI range* capture the respective within-community ranges of those indices. The *Tree ring index* (in millimeters, five-year average) does not vary across communities but spans the years 1200–1800 (34,200 observations). Key historical events—such as the Peasant War (1525–1535), the Council of Trento (1545–1565), and the Italian Crisis (1600–1650)—enter the duration model as separate time dummy variables and are therefore not listed in the summary statistics.

Table B2
First-stage regression results relative to regression in Table 3.

	(1) Baseline	(2) w/Interact	(3) Baseline	(4) w/Interact	(5) Baseline	(6) w/Interact
Instruments:						
FPI	−19.203*** (6.384)	4.834 (17.635)	−26.343*** (6.227)	−1.656 (19.293)	−22.467*** (5.319)	8.438 (15.583)
TRI	0.123*** (0.040)	0.298*** (0.084)	0.020 (0.046)	0.252** (0.110)	0.035 (0.038)	0.196** (0.084)
FPI range			1.237*** (0.300)	0.514 (0.825)	1.217*** (0.262)	0.371 (0.679)
TRI range (× 10,000)			1.730** (0.720)	0.270 (2.020)	2.170*** (0.610)	1.930 (1.610)
FPI × Altitude		−34.661 (22.329)		−33.043 (23.855)		−40.930** (19.416)
TRI × Altitude		−0.240** (0.101)		−0.303** (0.127)		−0.216** (0.104)
FPI range × Altitude				0.974 (1.210)		1.188 (0.989)
TRI range × Altitude (× 10,000)				1.920 (2.430)		0.340 (1.930)
Controls:						
Altitude	2.415*** (0.482)	6.980*** (2.169)	1.895*** (0.470)	5.415** (2.165)	1.474*** (0.395)	5.047*** (1.863)
Walking time	0.120 (0.077)	0.085 (0.077)	0.071 (0.074)	0.048 (0.075)	0.059 (0.061)	0.038 (0.062)
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	285	285	285	285	361	361
F-statistic	16.39	9.93	16.60	9.19	25.16	13.48
R-squared	0.401	0.415	0.462	0.475	0.436	0.446

Notes: TRI=Terrain Ruggedness Index, FPI=Photosynthesis Potential Index. The heterogeneity measures TRI range and TRI range × Altitude are rescaled by 10,000 for readability. Robust standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. District fixed effects included but not reported.

Table B3
Marriage-migration analysis for observed endogamic marriages.

	(1) Full sample
Patrilineal membership (=1)	+16.66
Per-capita commons value	+4.33
Patrilineal × Commons value	−2.64
Controls	✓
Num. Obs./adj. R^2	83/0.33

Notes: Dependent variable: Endogamy rate. Values are time-weighted averages for each community, where communities with observations over multiple time periods are weighted proportionally to the length of each period to ensure proper representation in the analysis. Robust (HC1) standard errors clustered by district; *p < 0.10, **p < 0.05, ***p < 0.01. Controls include altitude (km), walking time to nearest reference center (decimal hours), and district fixed effects. The altitude-split specifications for endogamy turn out to be perfectly collinear with district dummies in this sample; therefore, we report only the pooled estimate.

Table B4
Migration through marriage – wife-centered analyses.

	(1) Full sample	(2) + geo controls†	(3) Low altitude‡	(4) High altitude‡
Patrilineal membership (=1)	+2.61	+19.45	+27.95	−48.67***
Per-capita commons value	+1.42	+0.17	−2.96	+0.12
Patrilineal × per-capita commons value	−2.99	+0.53	−2.88	+6.13
Controls	✓	✓ (+ alt × chg, walk × chg)	✓	✓
Num. Obs./adj. R^2	69/0.26	69/0.31	42/0.38	27/0.74

Notes: Dependent variable: Percentage of marriages between foreign husbands and local wives. Values are time-weighted averages for each community, where communities with observations over multiple time periods are weighted proportionally to the length of each period to ensure proper representation in the analysis. Robust (HC1) standard errors clustered by district; *p < 0.10, **p < 0.05, ***p < 0.01. Controls include altitude (km), walking time to nearest reference center (decimal hours), and district fixed effects. † Column 2 adds interaction terms between patrilineal membership and both altitude and walking time to examine whether the effect of patrilineal rules varies with geographic isolation. ‡ Columns 3 and 4 split the sample at the median altitude (0.79 km above sea level) to compare effects in lowland versus highland communities.

Table B5
Migration through marriage – husband-centered analyses.

	(1) Full sample	(2) + geo controls†	(3) Low altitude‡	(4) High altitude‡
Patrilineal membership (=1)	−8.26*	+1.39	−9.50	−59.03***
Per-capita commons value	−2.74	−3.52**	−2.17	−9.31**
Patrilineal × per-capita commons value	+0.81	+3.43	+3.25*	+12.75**
Controls	✓	✓ (+ alt × chg, walk × chg)	✓	✓
Num. Obs./adj. R^2	69/0.57	69/0.60	42/0.70	27/0.76

Notes: Dependent variable: Percentage of marriages between local husbands and foreign wives. Values are time-weighted averages for each community, where communities with observations over multiple time periods are weighted proportionally to the length of each period to ensure proper representation in the analysis. Robust (HC1) standard errors clustered by district; *p < 0.10, **p < 0.05, ***p < 0.01. Controls include altitude (km), walking time to nearest reference center (decimal hours), and district fixed effects. † Column 2 adds interaction terms between patrilineal membership and both altitude and walking time to examine whether the effect of patrilineal rules varies with geographic isolation. ‡ Columns 3 and 4 split the sample at the median altitude (0.79 km above sea level) to compare effects in lowland versus highland communities.

Fig. B1. A map of the Fiemme Valley
Source: Carta escursionistica di Val di Fiemme, Lagorai, Latemar, Detail, 1:25.000 by Tabacco, Italy.

Data availability

Data will be made available on request.

References

Acemoglu, D., Robinson, J., 2012. Why Nations Fail: the Origins of Power, Prosperity and Poverty. Crown, New York.

Alfani, G., 2015. Closing a network: a tale of not-so-common lands (Nonantola, sixteenth to eighteenth centuries). In: Fertig, G. (Ed.), Social Networks, Political Institutions, and Rural Societies, pp. 153–182. Brepols.

Alfani, G., Murphy, T.E., 2017. Plague and lethal epidemics in the pre-industrial world. J. Econ. Hist. 77 (1), 314–343.

Agrawal, A., 2005. Environmentality: Technologies of Government and the Making of Subjects. Duke University Press.

Allen, A.S., 2012. 'Fatto di Fiemme': stradivari and the Musical Trees of the Paneveggio. In: Auricchio, L., Cook, E.H., Pacini, G. (Eds.), Arboreal Values: Trees and Forests in Europe, North America, and the Caribbean. Voltaire Foundation, Oxford, pp. 1660–1830.

Arthur, W.B., 1994. Increasing Returns and Path Dependence in the Economy. University of Michigan Press, Ann Arbor.

Baland, J.M., Platteau, J.P., 1996. Halting Degradation of Natural Resources: Is there a Role for Rural Communities? Claredon Press, Oxford.

Bellettini, A., 1987. La Popolazione Italiana: Un Profilo Storico. Einaudi, Torino.

BenYishay, A., Grosjean, P., Vecci, J., 2017. The fish is the friend of matriliny: reef density and matrilineal inheritance. J. Dev. Econ. 127, 234–249.

Bertoli, S., Fernández-Huertas Moraga, J., 2013. Multilateral resistance to migration. J. Dev. Econ. 102, 79–100.

Bisin, A., Federico, G., 2021. Merger or acquisition? Introduction to the handbook of historical economics. In: Bisin, A., Federico, G. (Eds.), The Handbook of Historical Economics. Academic Press, Boston.

Boeri, T., Brücker, H., 2005. Why are European so tough on migrants? Econ. Policy 20 (44), 629–703.

Bonan, G., Lorenzini, C., 2021. Common forest, private timber: managing the commons in the Italian alps. J. Interdiscip. Hist. 52 (1), 1–26.

Botticini, M., Siow, A., 2003. Why Dowries? The American Economic Review 93 (4), 1385–1398.

Casari, M., 2007. Emergence of Endogenous Legal Institutions: property rights and community governance in the Italian Alps. J. Econ. Hist. 67 (1), 191–226.

Casari, M., Lisciandra, M., 2016. Gender discrimination in property rights: six centuries of Commons governance in the alps. J. Econ. Hist. 76 (2), 559–594.

Casari, M., Lisciandra, M., Tagliapietra, C., 2019. Property rights, marriage and fertility in the Italian alps: 1790-1820. Explor. Econ. Hist. 71, 72–92.

Casari, M., Tagliapietra, C., 2018. Group size in social-ecological systems. Proceedings of the National Academy of Sciences USA 115 (11), 2728–2733.

Cassar, A., Rigdon, M., 2021. Option to cooperate increases women's competitiveness and closes the gender gap. Evol. Hum. Behav. 42 (6), 556–572.

Cole, J.W., Wolf, E.R., 1974. The Hidden Frontier: Ecology and Ethnicity in an Alpine Valley. Academic Press, New York & London.

De Moor, T., 2009. Avoiding tragedies: a Flemish common and its commoners under the pressure of social and economic change during the eighteenth century. Econ. Hist. Rev. 62 (1), 1–22.

Donahue Jr., C., 1993. Law, Marriage, and Society in the Later Middle Ages: Arguments About Marriage in Five Courts. Cambridge University Press, Cambridge.

Gale, D., Shapley, L., 1962. College admissions and the stability of marriage. Am. Math. Mon. 69 (1), 9–15.

Giordani, P.E., Ruta, M., 2013. Coordination failures in immigration policy. J. Int. Econ. 89 (1), 55–67.

Greif, A., Laitin, D.D., 2004. A theory of endogenous institutional change. Am. Polit. Sci. Rev. 98 (4), 633–652.

Hainmueller, J., Hangartner, D., 2013. Who gets a Swiss passport? A natural experiment in immigrant discrimination. Am. Polit. Sci. Rev. 107 (1), 159–187.

Kissling-Näf, I., Volken, T., Bisang, K., 2002. Common property and natural resources in the Alps: the decay of management structures? For. Pol. Econ. 4 (2), 135–147.

Lorenzetti, L., Merzario, R., 2005. Il Fuoco Acceso. Famiglie E Migrazioni Alpine Nell'Italia D'Età Moderna. Roma, Donzelli Editore.

Murdock, G.P., 1967. Quantifiable Data for Anthropology: Ethnographic Atlas. University of Pittsburgh Press, Pittsburgh.

Netting, McC., 1981. Balancing on an Alp: Ecological Change and Continuity in a Swiss Mountain Community. Cambridge University Press, Cambridge.
North, D.C., 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge.
O'Grady, T., Tagliapietra, C., 2017. Biological welfare and the commons: a natural experiment in the Alps, 1765–1845. Econ. Hum. Biol. 27 (A), 137–153.
Ostrom, E., 1990. Governing the Commons: the Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge.
Ostrom, E., 2010. Beyond markets and states: polycentric governance of complex economic systems. Am. Econ. Rev. 100 (3), 641–672.
Peri, G., 2012. The effect of immigration on productivity: evidence from U.S. states. Rev. Econ. Stat. 94 (1), 348–358.
Rosenzweig, M.R., Stark, O., 1989. Consumption smoothing, migration, and marriage: evidence from rural India. J. Polit. Econ. 97 (4), 905–926.
Sartori-Montecroce, T., 1891. Die Thal- Und Gerichtsgemeinde Fleims Und Ihr Statutarrecht. Wagner, Innsbruck.
Timmer, A.S., Williamson, J.G., 1998. Immigration policy prior to the 1930s: labor markets, policy interactions, and globalization backlash. Popul. Dev. Rev. 24 (4), 739–771.
Valsecchi, M., 2014. Land property rights and international migration: evidence from Mexico. J. Dev. Econ. 110, 276–290.
Wegge, S.A., 2021. Inheritance institutions and landholding inequality in nineteenth-century Germany: evidence from hesse-cassel villages and towns. J. Econ. Hist. 81 (3), 909–942.
Zanderigo-Rosolo, G., 2013. I Laudi Delle Regole Di Candide, Lorenzago E San Vito in Cadore. Istituto Bellunese di Ricerche Sociali e Culturali, Belluno.
Zuijderduijn, J., De Moor, T., 2013. Spending, saving, or investing? Risk management in sixteenth-century Dutch households. Econ. Hist. Rev. 66 (1), 38–56.