Institutional Change in Property Rights: Model and Evidence of a Centuries-Long Dynamic [1]

Marco Casari
University of Bologna and IZA

Maurizio Lisciandra
University of Messina

September 30, 2020

DO NOT DISTRIBUTE WITHOUT AUTHORS' PERMISSION

Abstract

Drawing on a long-term institutional transition, we provide a model that describes the progressive closure of more affluent societies to immigration in order to protect the wealth of insiders. This closure took the institutional form of patrilineal property rights. We show how this institutional change can emerge locally, spread by contagion, and generate a situation where societies are locked into a gender-biased society. Only a centralized top-down intervention could restore gender equality in property rights. This pattern is presented through a model and exemplified through the historical situation of communities in the Italian Alps, where inheritance institutions over common property resources evolved over the course of six centuries (1200-1800). Through a computational model and historical data, we uncover the mechanisms for this shift and show the gradual transition from an egalitarian to a patrilineal institutional regime.

Keywords: land rights; commons; gender; path dependency; lock-in.

JEL: J16; N53; Q20.

[1] We thank Brian Arthur for the suggestion to use a computational model and for the very useful feedback on how to build the model. This project was developed while Casari has spent his sabbatical year at the Center of Advanced Study in Behavioral Sciences at Stanford University, which has provided a stimulating environment for cross-disciplinary research. M.Casari, Department of Economics, University of Bologna, Piazza Scaravilli 2, 40126 Bologna, Italy. E-mail: marco.casari@unibo.it. Corresponding author. M.Lisciandra, Department of Economics, University of Messina, Piazza Pugliatti 1, 98122 Messina, Italy. E-mail: mlisciandra@unime.it.

1. Introduction

We argue that societies tend to close to the outside world when their economic resources are under threat. Picture a world comprising multiple societies that are all open to immigration. On the opposite end, consider a world where nobody accepts migrants. We present a historical situation with a decentralized, gradual transition from an open to a closed world and a later centralized, wholesale switch back to an open world. Based on empirical evidence, we argue that there are strategic reasons behind this asymmetry in transitions: the defensive closure -- one community at a time -- progressively creates a situation where everyone is locked into a closed world; and, only a top-down intervention can restore an open world.

We draw on the empirical evidence from Casari and Lisciandra (2016), which illustrates the endogenous and progressive closure of small communities in the Italian Alps during the Modern Age. The migratory pressure on richer communities generated a reaction to dissuade strangers from moving in. In these communities, women progressively lost their rights to access the commons: those women who married a man from another community lost their rights to exploit the commons and to transmit by inheritance any rights over them.

To gain insights into this phenomenon, we build a model based on the observed historical patterns. The model considers the interactions among many communities who managed their own local commons. The underlying forces that shaped the institutional change may be at work more generally also when considering issues of citizenship rules and migration across nations where a citizen enjoys benefits from the social and economic capital of her nation. Many of these benefits are tied to living in a specific location. When moving, benefits are lost without any compensation. Think about law and order, welfare state in terms of primary schools or basic health care, access to a lucrative job market, public goods like clean air or public parks, etc. By migrating, a citizen loses these benefits in the nation of origin. The migrant citizen cannot transfer her citizenship rights to others, either. Nor, she can sell the above benefits that she no longer consumes after moving. She will access these benefits in the nation of destination by some degree, depending on the access rules. In generalizing this model, the key aspect to assess is to which extent these benefits are rival in consumption. Clean air is obviously not rival, but health care under a fixed budget can be.

The model is computational, and the reason is that it embeds algorithmic routines that are difficult to model analytically. We use a matching algorithm to pair men and women, the Gale-Shapley algorithm (Gale and Shapley, 1962), which is notoriously problematic to write up in equations. When modelling a sequence of generations, individual traits are transmitted from parents to children. This aspect is also difficult to capture in a closed form analytical model. The computational model serves the same purpose of an analytical model. It is not meant to be a simulation exercise that exactly reproduces the field data but rather a tool to demonstrate the mechanisms and principles that could drive the institutional change in the historical situation.

One strength of this paper is the availability of a detailed historical documentation about the institutional transition as well as a dynamic theoretical explanation. In Economics there exists a vast empirical literature on the impact of distant past events on current outcomes (Tabellini, 2010, Alesina et al., 2013, Guiso et al., 2016). Oftentimes, the evidence rests on the comparison of two points in

time, in isolation. Usually, the transition process that leads from the past to the current outcomes remains undocumented. As a consequence, any theoretical explanations cannot be tested using the evidence about the transition, as it can be done instead here.

The paper proceeds as follow. Section 2 puts forward the historical evidence, Section 3 presents the main historical patterns of the institutional change, Section 4 describes the computational model, Section 5 presents the results from the model, Section 6 discusses the results and the limitations of this study.

2. The historical and institutional setting

This section provides some background information about Trentino, the region under study, along with a presentation of the main institutions regulating the region. In this region, during the Middle and Modern Age, a decentralized, endogenous institutional change took place. In the thirteenth century, women enjoyed equal rights on collective resources, but by the end of the eighteenth century, inheritance rights on common property resources (CPRs) became patrilineal.

The Trentino region is situated in the Italian Alps at the border with South Tyrol. The region is mountainous with the presence of about 366 villages, usually with few hundred inhabitants. The administrative center, Trento, was a small town (11,989 inhabitants in 1810). About 28% of the villages were more than 50 km from the capital town through a rugged landscape. About 73% of them were situated at an elevation above mt. 500 a.s.l.. The weather exhibits marked variations across different seasons and altitudes, although usually displays cold temperatures. The arable land was limited to only 8% of the surface (Cadastre 1897) due to the high altitude (70% of the land is above mt. 750) and the steepness of the land. Typical produces were grapes and grains, which were mostly cultivated in private lands, while forests, meadows, and pasture were under the community property. Forests provided the essential source of energy, such as firewood, timber for building and crafting, litter for animals. Common properties were extensive and quite valuable for the peasants. Our data suggest that common property resources accounted for about 58.5% of all land in terms of surface and about 25% in terms of value (Casari and Lisciandra, 2016).[2] Most of it was grazing land, pasture and especially forest. The private property consisted mainly of houses, gardens and arable land, and showed seasonal complementarities with collective land: during summertime, cattle grazed in the high mountain pastures while during wintertime, they were kept in private stalls and fed with the hay collected from collective lands. In sum, commons were vital for the villagers' survival of this Alpine region.

The common property endowment differed widely across villages, mainly due to the high variability of the orographic characteristic throughout the region. The inequality in per-capita collective wealth across villages in a subsample of villages for which data is available is rather high (Gini index=0.61), actually higher than the inequality in the distribution of private and collective wealth combined across villages (Gini index=0.27).

[2] These estimates are based on a sample of 32 villages from the 1780 (Theresian) cadastral register.

Starting from the thirteenth century, many communities of the region formalized local charters to define and enforce property rights on collective forest and pasture. The first document found in the archives dates 1202 and the last one 1796, with added chapters stretching as far as 1801. By the end of the period, about 82% of the villages had adopted a charter. The governance regime of the commons through this charter system fits the classification of self-governance institutions of Elinor Ostrom (Ostrom, 1990). The system abruptly ended shortly after 1796, when Napoleon seized the region. Its definitive removal took place in 1807.

The local charters were official deeds that codified informal rules formerly regulating the management of common resources and mainly aiming at limiting their exploitation only to the community members (*vicini*). Membership could only be acquired by inheritance.[3] Simple residence, or being born in the community by non-members, did not entail the right for membership. The presence of a member in a family unit entailed the access of the whole family to the community resources. The share of common resources was on a family basis, regardless of the numerosity and the number of members living under the same roof. In general, members moving to other communities lost their membership permanently.

The evidence of institutional change comes from a database created by Casari and Lisciandra (2016), which is based on the coding of more than 500 historical documents for the years 1202-1801.[4] With few exceptions, these documents are of a "Carte di Regola" type, which are charters engrossed by a notary on behalf of community members and promulgated by the Prince of Trento for the local governance of their common property resources. The charters were not documents embodying a systematic set of rules governing the relationship between peasants and economic resources, but rather an instrument addressing contingent issues. Over time, the enactment of a new charter could be followed by several modifications once a controversy were to occur.[5] Therefore, charters or their modifications with additional chapters encoded inheritance rules once previous informal rules became dysfunctional and needed to be superseded by formal and commonly recognized rules. Hence, the information about the type of inheritance system on the commons was extracted from those documents, if and when present. Specifically, we can acknowledge that a set of communities substituted over time the informal egalitarian inheritance system with a more functional patrilineal inheritance system.

3. Historical patterns of institutional change

The focus of the current analysis is the dynamics of this institutional change. By expanding on the evidence reported in Casari and Lisciandra (2016), we put forward five main patterns about the inheritance system emerging in this Alpine region, which will be used as a benchmark for the computational model. We also outline the triggers that set off the institutional change.

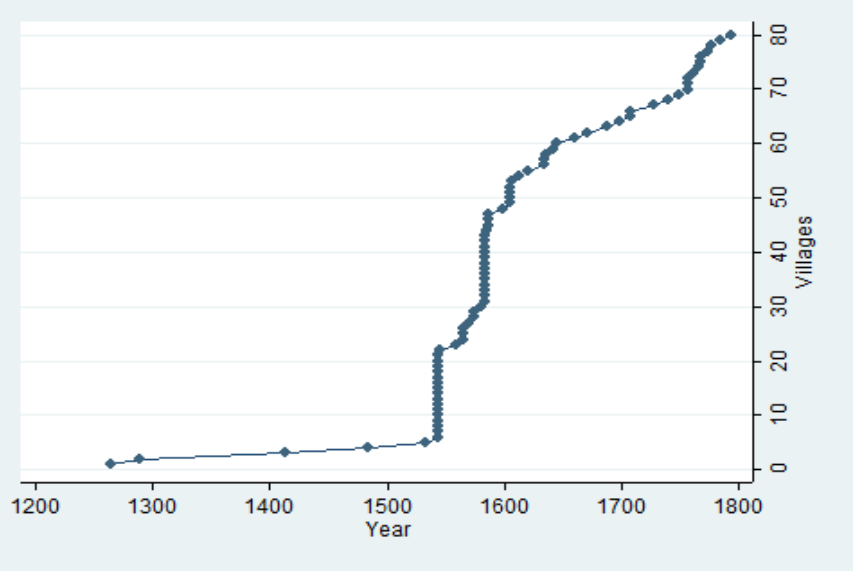
[3] In some instances, membership could be bought from the community (not the single member) subject to the approval of the members by supermajority votes.

[4] Specifically, the database provided 878 entries subdivided as follows: 480 charters, 339 relevant additional chapters that are posterior to a charter's promulgation, 59 other legal documents.

[5] For a study about the emergence of these charters as a way to formally govern the commons, see Casari (2007).

Historical pattern 1: Institutional changes were unidirectional. The available evidence indicates that, in the Medieval period, the inheritance system on the commons of Trentino villages was egalitarian (Casari and Lisciandra, 2016). The formalization of inheritance systems in written documents occurred in 80 villages. Some villages changed over time the inheritance system defined in their first formalization. In all recorded changes, there was a shift towards more gender-biased inheritance systems. In several cases, this transition occurred in multiple steps as villages temporarily adopted a soft-patrilineal system where families with only daughters and no sons could transmit membership to one or more daughters. At the end of the XVI century, 11 villages transitioned from an egalitarian inheritance system to a soft-patrilineal system and, over time, the same villages along with other 8 villages transitioned from a soft-patrilineal system to a patrilineal system. The vast majority of villages (57) transitioned from an informal egalitarian system to a patrilineal system. At the end of the period, 75 villages had a patrilineal system, three had a soft-patrilineal system, two had the Erbhof system, which is a variant of a primogeniture system inherited by the German tradition, and none had an egalitarian system. Thus, the evolution of inheritance rules was essentially unidirectional, going from equal membership rights for men and women toward increasing gender discrimination.[6]

Figure 1. Cumulative number of villages formalizing the inheritance system on the commons.



Notes: a dot represents the year when a village first formalized its inheritance system on the commons. For a similar graph where each village is weighted by its total land surface, see Figure A1 in Appendix.

Historical pattern 2: Slow diffusion. The process of formalizing inheritance regulations on the commons unfolded over at least 529 years. The first formal mention of the inheritance system in a document dates to the 1265, and the last one dates to 1794. To properly frame this process, we should first consider the social, economic, and demographic disruption brought by the 1348 plague. Population in Italy took more than a century to recover to the pre-plague level (Bellettini, 1987), although in Trentino recovery may have been quicker (Cole and Wolf, 1974 reports for Trentino a

[6] In contrast, the evidence does not show a shift toward a patrilineal system for the inheritance system on private land (Casari and Lisciandra, 2016).

population estimate of 83,373 in the year 1312 and 125,059 in 1427). Even when counting only from the restart of the diffusion process in 1484, when a major community adopted a patrilineal inheritance, we are considering a period of 310 years. The pattern of diffusion over time roughly followed an S-shaped curve with a slow beginning in the first three centuries, an acceleration in the XVI century, and then a long tail until 1800 (Figure 1).

Historical pattern 3: No mention of inheritance in most communities. By the year of the Peasant war (1525), the share of Trentino territory who had formally introduced inheritance regulations over their commons amounted to about 2.5% of the regional surface. Formalized inheritance regulations became more widespread later in time, but even in the end of the period in the year 1800, it covered only 25% of the region. A similar pattern emerges when counting villages instead of land surface. The wide majority of communities did not formally regulate inheritance on the commons. Out of 366 villages in Trentino, by the end of the period under scrutiny, only 21.9% did. To put this phenomenon into context, consider that by 1800 most villages had a charter (290), but only 27.6% mentioned inheritance rules. Charters were legal documents with a low level of complexity and dealt with issues in an unsystematic way, usually encoding only problematic aspects, especially those that had generated controversies in the past.

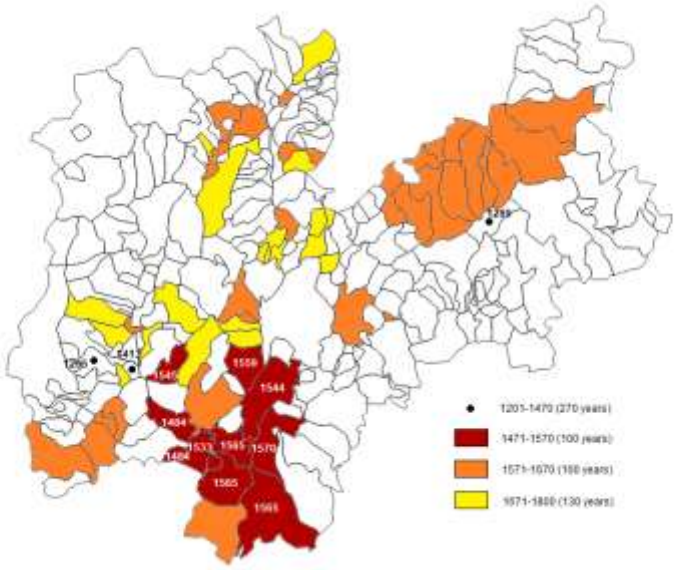
Notice that in most cases (87.5%) the formalization of inheritance regulations on the commons occurred years after a village adopted its first charter. Of these cases, a half were included in later versions of charters, and another half was stated either in specific chapters added to an existing charter or in other legal documents. In the remaining instances, formalization of the inheritance system was concomitant with the adoption of the first charter in 7.5% of cases, or even before in 5% of cases. This evidence suggests that inheritance rules had a specific driver, which was distinct from the need of a general regulation of the commons. Charters were essentially tooled to promote coordination and cooperation among community members (Casari, 2007). Moreover, it suggests that the date of formalization was not primarily affected by the transaction costs associated with the change.

Historical pattern 4: Diffusion by local contagion. Geographical distance played a role in the diffusion of institutional change. If we set aside the earliest movers, the initial wave of institutional changes was clustered in a relatively small and contiguous area (Figure 2): for about a century (1470-1570) we have no record of changes outside this area. The first three villages to formalize the inheritance system on the commons made use of special documents, which disciplined only a portion of the village territory, rather than codifying the inheritance within the village charter. The beneficiaries were small groups and were in many ways atypical.[7] In the following century (1571-1670), institutional change spread more, both locally and in more distant communities. The final geographical pattern shows wide areas without any formalization of the inheritance system as well as clusters of contiguous communities with formal regulations, where the latter only rarely are isolated.

[7] Pieve Tesino in 1265 and Pradibondo in 1289 were *vicinie*, i.e., subgroups of community members who had exclusive access to a specific portion of land. Zuclo in 1413 is a forest regulation document for a specific mountain area. None of these documents had on them the approval of the Prince Bishop of Trent, which was instead required for charters.

Casari and Lisciandra (2016) performed an econometric analysis of local contagion. By considering the seventeen districts of Trentino, they report that the fraction of district villages that already had inheritance regulations on the commons by a given year affected the likelihood of a community to adopt inheritance regulations in the following five years with a highly significant probability (Table 5 in Casari and Lisciandra, 2016). In contrast, the diffusion of charters did not exhibit any statistically significant local contagion (Casari, 2007).

Figure 2. Geographical diffusion of institutional change in Trentino



Notes: the 1265, 1289, and 1413 datapoint refer to a portion of a village territory.

Historical pattern 5: Egalitarian inheritance was restored through a centralized intervention. In Trentino, the Napoleon invasion of 1796 brought the charters experience to an abrupt end. Within few years, the central government removed all ancient regime institutions. The suppression of charters took place in the years 1805-7. The new regime that replaced the charters' system regime exhibited two major differences. First, women discrimination in accessing the commons was abolished and inheritance on the commons became de facto egalitarian for all communities. Second, the previous decentralized decision system was replaced by a centralized government that did not allow local variations in inheritance rules. Thus, the right of each community to locally establish and discretionarily change inheritance rules on collective resources was suppressed.

We conjecture that there were two main triggers that set off the institutional change: population growth and an increase in geographical mobility of people (Figure 3). Beginning around the year 1430, we observe in the Center-North of Italy a long period of population growth (Malanima, 2003), which coincides with the dramatic surge in institutional change observed in Trentino (Figure 4). The correlation between institutional change and population dynamics emerges also from the empirical evidence provided in Casari and Lisciandra (2016).

Figure 3. Triggers of institutional change

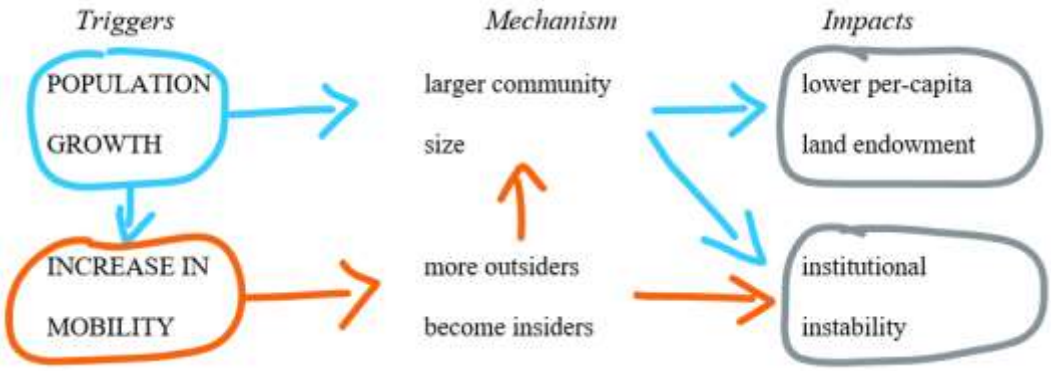
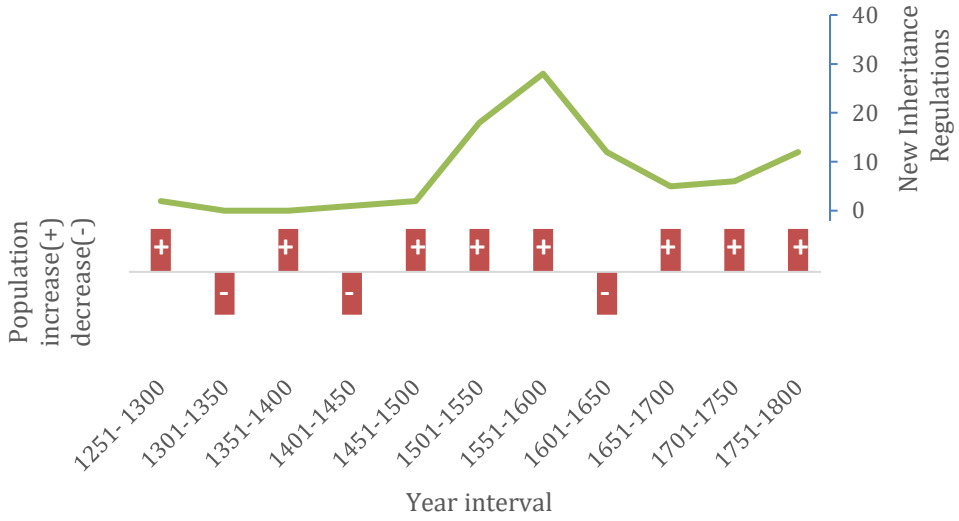


Figure 4. Population variations and institutional change



Sources: Malanima (2003) on population data and our elaborations on inheritance regulations data. *Notes*: Estimates of the population in the Centre-North of Italy (Piemonte, Lombardia, Veneto, Trentino-Alto Adige, Friuli, Istria, Liguria, Emilia-Romagna, Toscana, Umbria, Marche).

The available historical evidence suggests starting in the mid-13th century and for the whole 14th century a substantial increase in the volume of exchanges of goods and services and well as people between the Trentino area and the surrounding regions (Varanini, 2004). We take this as indirect evidence of an increase also of internal migration. As another local historian wrote: "The demographic increase and the intensification of immigration by outsiders, …, in the XVI century induced the introduction of a more rigorous exclusion criteria" (Sartori Montecroce, 1891). In the following century the region became an international crossroad with the Council of Trent, who took place in the years 1545-1563 to counterbalance the Reform movement.

As we will formalize in Section 4, the endogenous growth of the population will increase the average size of a community. Given that the endowment of common land in each community was given, the per-capita amount necessarily will decline. As a consequence, for an insider, the marginal value of the common land rised. Likewise, the increase in mobility boosted the chances of an outsider of marrying an insider. The impact of such instances was twofold. On the one hand, it increased the community size in addition to the endogenous population growth. On the other hand, it also introduced heterogeneity within the group of insiders. Although, this could have been welcomed as it diversified the gene pool in small communities, it likely generated frictions in the collective decision making process that characterized the management of the commons (Casari et al., 2019, Casari and Tagliapietra, 2018).[8]

The two triggers were intertwined in a variety of ways. For instance, a larger population likely brought about an increase in internal mobility; the immigration increased community size; and when a community passed a threshold in terms of size, it could also have had a negative impact on institutional stability (Casari and Tagliapietra, 2018).

4. Computational Model

Consider the following model. A district comprises K communities and every community k=1, ... , K has an endowment W_k of commons. Each community independently sets the rules for the governance of their commons. Access to the commons of the community is based on the membership right, which is inherited from parents. Each community can choose its inheritance system on the commons to be either egalitarian or patrilineal. In an egalitarian system, both men and women can inherit community membership, transmit it to all their offspring, and establish their own families with full rights to access the collective resources. In a patrilineal system, only men have these rights.[9] Residency and membership are distinct. Individuals from other communities that acquire residency in another community have no access to the commons of the incoming community unless they marry a member of that community.

Within this simple framework, we set up a computational model that traces the evolution of a district over time in terms of population, wealth, and governance of the commons (i.e., the inheritance system on the commons). Time is structured in generations. For the first generation, communities have the same population (n=110) but different endowments of commons W_k. The initial endowment of commons is a random draw from a uniform distribution with $W_k \sim U[0,220]$ and remains constant over time.

[8] This situation is epitomized by the 1583 Charter of the Val di Fiemme community that complained about outsiders marrying local women who are blamed for "damaging" the common resources. "*...questa osservanza era molto dannosa et preiudiciale ad essa Communità, perché molte figliuole si maritavano in persone forestiere, quali si accasavano nella valle et facevano gran rovina nelli beni communi et spetialmente alli boschi.*" (Le consuetudini, Libro II, del civìl, Cap. 117).

[9] The right to access as well as the share of collective wealth is family based, regardless of the numerosity of the family and the number of members living under the same roof.

The population of each community is balanced by gender. Everyone in a generation marries and each couple will have exactly two children, one son and one daughter. Hence, the population of a district remains stationary in level and remains gender balanced, although the population size of specific communities can vary because of migrations. Generations do not overlap as each couple is replaced in the next generation by exactly one boy and one girl. Couples are formed through a matching process within a generation that is broken down into rounds, where in each round only a cohort of the overall population participates to matching. In the first generation, each cohort comprises 10 individuals from each community for a total of 70 individuals matching (about 9% of the population, half men and half women). Therefore, the matching process by cohort requires overall 11 rounds to allow the whole population in a generation to match. In the following generations, each cohort comprises as before 70 individuals, although the number of individuals coming from a specific community may vary depending on its overall population. It could be helpful to see a cohort as representing a five-year age group of the population, where individuals are assumed to have a lifespan of 55 years.

We set the number of generations equal to nine. Counting eleven rounds for each of the nine generations, time in the model amounts to a grand total of 99 rounds. After every round, the model updates the community population and the per-capita level of collective wealth, w_k. Given that the commons endowment is fixed for a community, w_k obviously declines as more people have access to the commons. Moreover, after every round, institutional change can take place, as the community may switch the inheritance system on the commons. After every eleven rounds (i.e., one generation), the renewal occurs and a new generation of individuals with new traits substitutes the old one.

The traits of an individual are two. One is his or her level of personal attractiveness (a) -- either physical, moral, or private wealth -- and the other one is the relocation cost (c), which is the cost to move away from the current community of residence. In the model, personal attractiveness is quantitatively the dominant element in the choice of the partner. It includes ownership of private land, where inheritance remains always egalitarian. Relocation costs capture the cost to sell your personal assets that are not mobile and relocate to another community. Losing the support network from one's community is also part of the relocation costs. Although the model assumes perfect information about potential partners, the relocation costs may also indirectly capture the difficulty in getting to meet and know people outside the community.[10] The cost is assumed equal for all destinations outside the individual's community and does not depend on distance. In short, the model assumes a global interaction across communities within the district with some friction due to a cost parameter.

Each trait is initially assigned through an individual random draw from a uniform distribution, which is U[0,20] for attractiveness and U[0,4] for the relocation costs. Individual attractiveness and

[10] While the current model treats all communities as equally distant, an alternative model could instead have a parameter to explicitly consider the distance between any two communities in order to give more importance to closer rather than to far-away communities. This parameter would affect interaction, for instance by making moving costs increasing in distance. This variation in assumptions may better capture the different frictions that a person experiences in marrying somebody outside his or her community in terms of poor information about personal traits, disruption of social networks, transportation, and costs to cash illiquid assets.

relocation costs are reassigned after each generation according to a rule where 75% of the trait is inherited from the parents and 25% is random:

$$a_{child} \equiv 0.375 \cdot a_{father} + 0.375 \cdot a_{mother} + 0.25 \cdot random(0,20)$$

$$c_{child} \equiv 0.375 \cdot c_{father} + 0.375 \cdot c_{mother} + 0.25 \cdot random(0,4)$$

Parents have an equal weight in transmitting personal traits. Attractiveness and relocation costs are *i.i.d.*, i.e. statistically independent from the random draw of community wealth and from each other. The reason why relocation costs are similar to those of one's parents lies in the path dependency in the social support network within a specific community and in the specific degree of mobility of the assets received from parents. About marriage, individuals can freely choose whom to marry and simultaneously the couple chooses where to live.

Whom to marry. An individual *i*'s choice about whom to marry depends on several elements. Everyone has a desire to get married and has identical preferences about partners, $U_i=U(a_j,w_k,c_i)$. We assume that the utility functions are additive in three components. Specifically, the utility of individual *i* and his or her potential partner *j* are:

$$U_i \equiv a_j + 2w_k - c_i$$

$$U_j \equiv a_i + 2w_k - c_j$$

Personal attractiveness of spouses is captured by a_j and a_i. The component w_k is the per-capita collective wealth of the community *k* in which the couple will settle down. Each agent suffers from his or her own relocation costs, c_i and c_j, respectively. As we will see, only one individual in the couple relocates. Hence, if *k* is the *i'*s community then *j* suffers from c_j, and vice versa.[11] If both individuals come from the same community and decide to stay, none of them has relocation costs.

The interaction at the individual level follows a two-sided matching model with transferable utility among partners, with no search costs but with relocation costs. Couples are formed following the deferred acceptance algorithm (Gale and Shapley, 1962). In a nutshell, this algorithm processes proposals such that most preferred individuals match first, while less preferred (rejected) individuals match subsequently until all individuals form a couple. We need to assume that men make proposals first; however, the outcome would not change if women were to move first.

Where to live. Recall that the decision about where to live is concomitant with the choice of the partner. Although in principle, individuals can move to any community in the district, in practice the choice is between the man or the woman's community. The reason is that individuals have no access to the commons of communities they are not themselves members of. Hence, settling in any community except where the couple can enjoy membership is a dominated choice. If both partners come from the same community, they stay where they are. If they come from different communities

[11] Notice that w_k is multiplied by 2 because the number of individuals eventually deciding to live in a community is always even and the share of collective wealth that partners can enjoy is family (couple) based, such that either both partners are members or one of them is a member, then the share is the same.

-- and relocation costs are the same for both partners --, they will usually prefer the community with highest per capita wealth but will factor in relocation costs.

Inheritance system on the commons. The inheritance system on the commons plays a crucial role on the choice of where to live. In the current investigation we consider three scenarios: (1) all communities have egalitarian inheritance on the commons; (2) all communities have patrilineal inheritance on the commons; (3) In round one, all communities have egalitarian inheritance; at the end of round one or in the subsequent rounds, a community will switch to a patrilineal system if its per-capita endowment of commons falls below a fraction of its initial (round 1) value. We refer to this fraction as the threshold for institutional change (0.7). The model keeps track of the evolving population in each community in order to update the per-capita collective wealth after each round. For patrilineal communities it also keeps track of the number of members as well.

To sum up, we provide an overview of the five key parameters in the computational model:

a) the threshold for the institutional change in a community (default H=0.7),
b) the distribution of commons endowment (default W_k~U[0,220]),
c) individual attractiveness (default a~U[0,20]),
d) individual relocation costs, (default c~ U[0,4])
e) percentage of transmission of individual attractiveness and relocation costs from parents (p=0.75).

Attractiveness is on average ten times higher than w_k, while relocation costs are on average twice as high as w_k. The yardstick in these assessments is the initial level of per-capita collective wealth w_k=W_k/110.

5. Model results

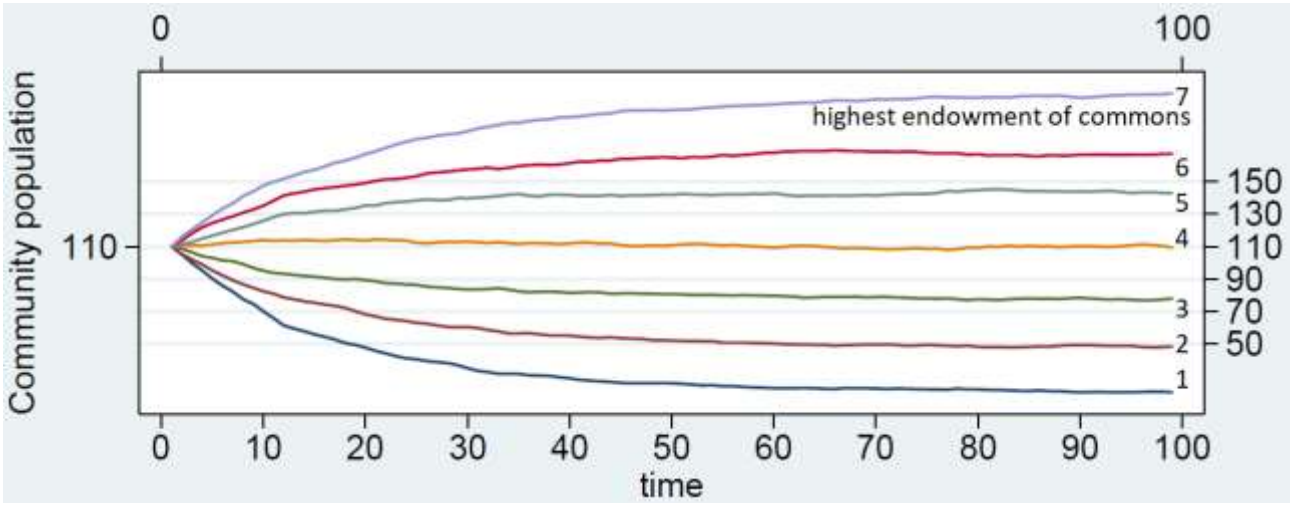
There are four main results to report from the computational model, which concern the frequency and timing of institutional change in communities. These results qualitatively replicate the historical patterns reported in Section 3. By construction, in the model, institutional change is going only in one direction, from egalitarian to patrilineal. Hence, the historical pattern 1 is embedded as an assumption rather than being explained by the model. In this section, we put forward brief reflections on the links between the model and the historical patterns 4 and 5, and will provide results related to the historical patterns 2 and 3.

The historical diffusion of institutional change had an element of local contagion (historical pattern 4). The computational model assigns no role to distance among communities within the district. One way the model can map onto the field setting is to see the Trentino region as structured into many districts, each composed of 7 communities. An individual incurs a moderate cost to relocate to another community within the district and an extremely high cost to relocate outside the district.

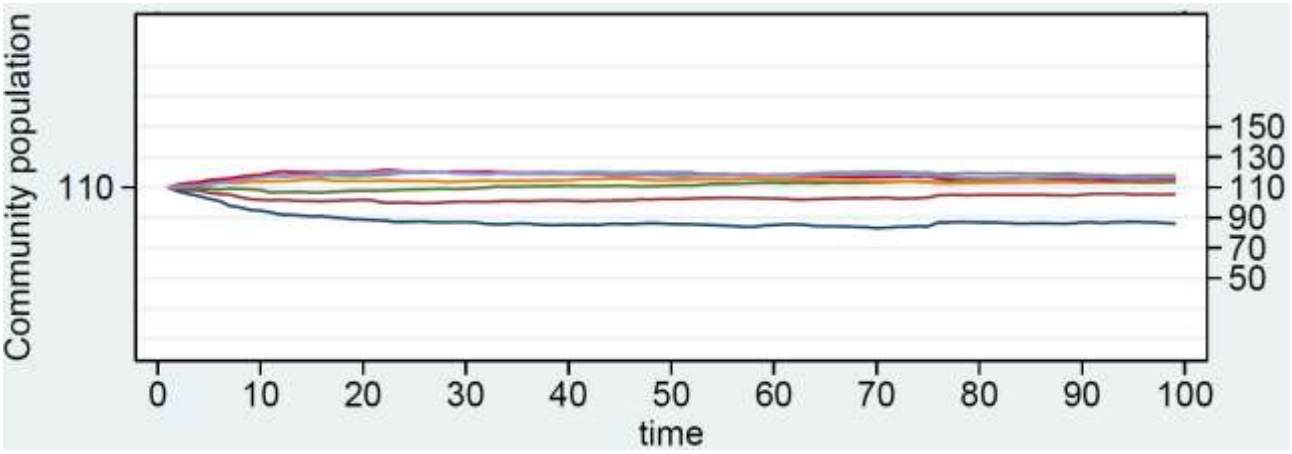
Modelling relocation costs into the model would mean to explicitly take into account an element of distance between communities.[12]

Figure 5. Evolution of community population under egalitarian and patrilineal inheritance

(a) *Egalitarian inheritance*



(b) *Patrilineal inheritance*



Notes: time evolves over the rounds (99). Each value of community population is averaged over 20 runs, where each run is a complete matching of 9 generations. Communities are ordered from 1 to 7, according to the initial per-capita collective wealth.

The results of the computational model are based on data from a series of runs using different random seeds. One run comprises a district of 7 communities interacting over time and a single run constitutes

[12] To better capture local contagion, the model could be extended, for instance, by placing communities along a circle or within a network structure.

an independent unit of observation. As mentioned above, time is structured in nine generations, where one generation comprises 11 cohorts, such that the total number of rounds is 99.

To place institutional change into context, we make a digression on the two extreme scenarios where communities are either all egalitarian or all patrilineal, and remain as such over time (no institutional change). In a scenario where all communities have an egalitarian system on their commons, individuals migrate from the relatively poorer communities in terms of per-capita collective wealth toward the relatively richer communities. As illustrated by Figure 5a, all communities start with an equal population and then diverge, depending on their ranking in terms of collective wealth (7=richest community, 1=poorest community). Each line in Figure 5 plots the average population in that round across 20 different runs. As a consequence of migration across communities through marriages, the inequality in terms of per-capita collective wealth tends to decrease. In particular, the average standard deviation goes from 0.55 in round 1 to 0.07 in round 99. This contrasts with the results from an all patrilineal inheritance system, which is illustrated in Figure 5b, where net migrations across communities are limited and the average standard deviation of the per-capita collective wealth is only slightly reduced to 0.53.

We turn below to the scenario where a decline in per-capita collective wealth in a community can trigger an institutional change from an egalitarian to a patrilineal system. The first result concerns the share of communities undergoing institutional change.

Result 1: Institutional change occurs in a minority of the communities.

In a district of 7 communities, on average 2.7 of them switches at some point from an egalitarian toward a patrilineal inheritance system, which represents 39% of communities. A switch can occur in any round between 1 and 99 and, when it occurs, it marks a permanent shift of inheritance system in the community. The pattern of institutional change is closely related to the collective wealth of communities, in terms of which community switches, and how many switches there are. First, the identity of the communities that switches is not random. The poorest community in terms of per-capita collective wealth never switches to patrilineal, while the richest one almost always does (Table 1). More generally, the frequency of institutional change is strictly increasing in the ranking of per-capita collective wealth.

Table 1. Frequency of institutional changes by community

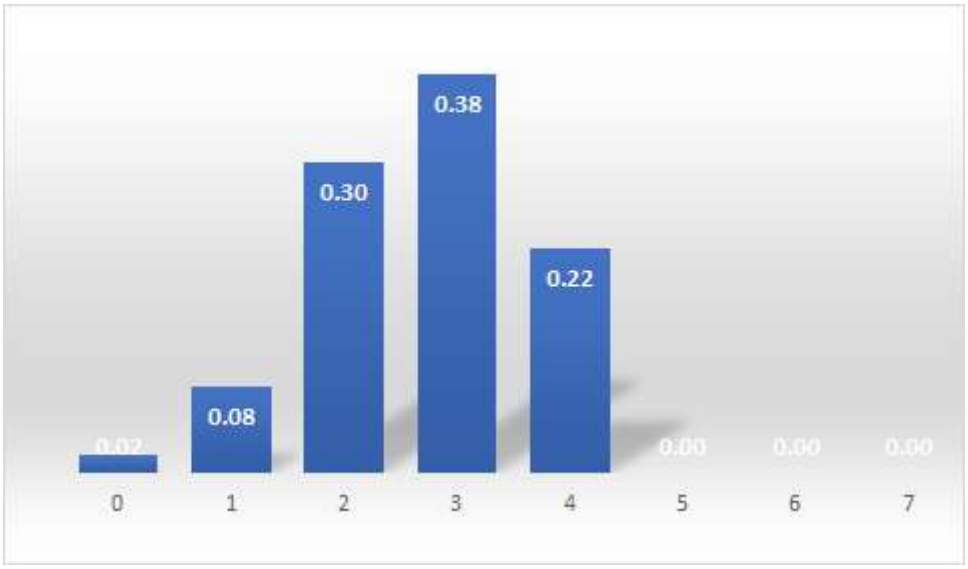
Community:	1 (poorest)	2	3	4	5	6	7(richest)
Frequency of institutional change:	0%	0%	0%	22%	62%	88%	98%

Notes: communities are ordered from 1 to 7 by increasing initial per-capita collective wealth. Elaborations are based on 60 runs.

A second regularity regards what explains the total number of institutional changes. Although in principle the number of communities switching can range from 0 to 7, the result over 60 runs shows that there are only instances of 0, 1, 2, 3, or 4 communities switching to a patrilineal system (Figure

6). In 78% of the runs, a majority of communities remained egalitarian and, overall, 61% of communities never experienced institutional change.

Figure 6. Frequency of the number of communities adopting a patrilineal inheritance system.



Notes: Elaborations are based on 60 runs.

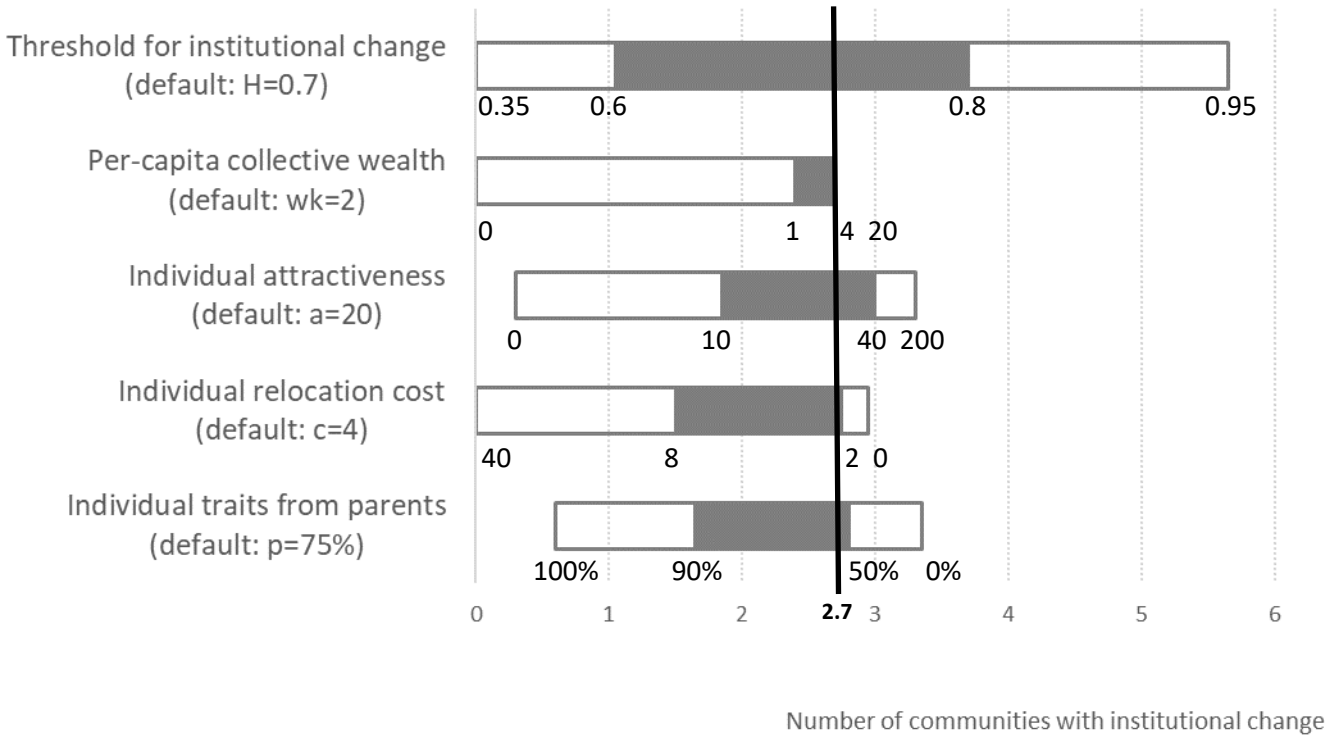
The variability in the number of institutional changes is correlated to the inequality in per-capita collective wealth. A higher inequality across communities generates more institutional changes. In particular, the number of switches to patrilineal inheritance is positively correlated with the standard deviation in initial per-capita collective wealth across communities (rho=0.62). For the runs with one institutional change, the standard deviation in initial per-capita collective wealth across communities is on average 0.44. This value monotonically increases in the number of institutional changes. For those runs with four institutional changes, it is 0.68. We now perform a robustness check and then we present other results about the timing of institutional change.

For a robustness check, we study the effect of shifting up or down the value of the main parameters on the frequency of institutional change in a district. This sensitivity analyses are performed by altering the value of one parameter at a time, while keeping all the others at their default value. In particular, for each parameter we study the effects of four different point values (Figure 7). This sensitivity analyses reveals three ways to undo Result 1, each one of them is achieved by setting one of the model parameters to an extreme value. In particular, no institutional change occurs: (*i*) when communities have no common wealth at all (W=0); (*ii*) when a community does not switch to a patrilineal system for moderate reductions in per-capita collective wealth but only for extremely severe ones, i.e. a -50% reduction or more (H=0.35); (*iii*) when individuals have very high relocation costs, which make them very unwilling to relocate to other communities ($c=40$).

Figure 7 illustrates this robustness exercise and reveals lessons both from local and extreme variations in the parameter values. For local variations (dark bars), institutional change always occurs but it rarely involves the majority of communities. More specifically, the average number of institutional changes remains in-between 1 and 4. For three parameters, we considered variations of -50% and

+100% of the default value, while for two parameters with a [0,1] range, we considered smaller variations, -33% and +20%. For extreme variations in parameter values (white bars), the model response is asymmetric as it is easier to bring the frequency of institutional changes close to zero rather than close to seven. For each parameter variation, there are less than 1 community experiencing an institutional change, while in no circumstance there are more than 6 communities switching to a patrilineal inheritance system.

Figure 7. Sensitivity of institutional change to variations of the main parameters



Notes: the vertical line at 2.7 is the average of institutional changes at the default parameters. The values for relocation costs, attractiveness, and per-capita collective wealth indicate the upper bound of the support of the statistical distribution employed (the lower bound is always 0). The labels below the bars indicate the four parameters values studied. 20 runs for each parameter value.

Result 2: Institutional change starts at a fast pace, then slows down, and eventually stops.

The process of institutional change is not linear but proceeds in stages. Figure 8 describes the cumulative number of institutional changes round after round over 60 runs. In the first stage the migratory pressure mounts, but no institutional change occurs (rounds 1-7). After this lag, there is a second stage with a sudden acceleration of switches from egalitarian to patrilineal inheritance (rounds 8-13). In a third stage, the process continues but the speed gradually slows down until it eventually stops (14-99). Hence, over time the cumulative share of communities undergoing institutional changes follows an S-shaped curve.

Figure 8. Institutional change follows an S-shaped curve.

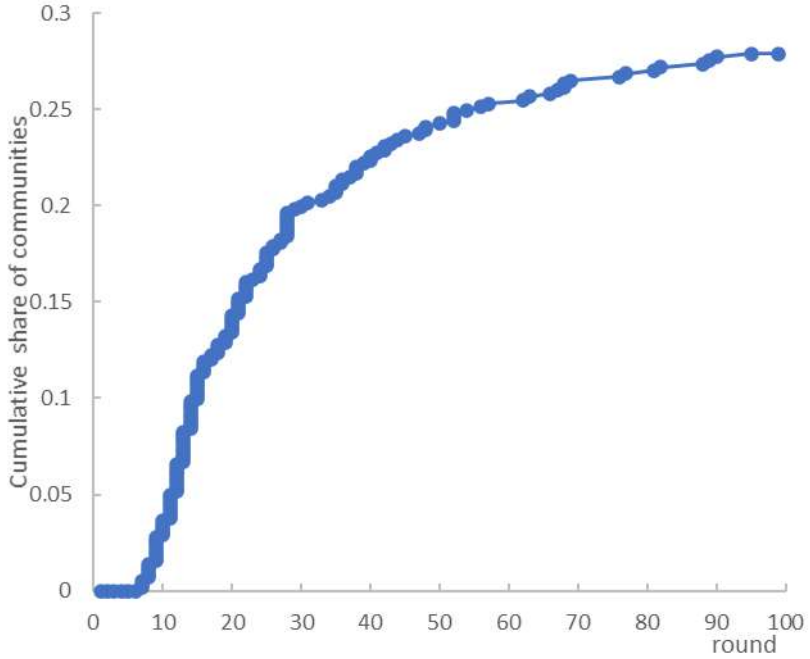
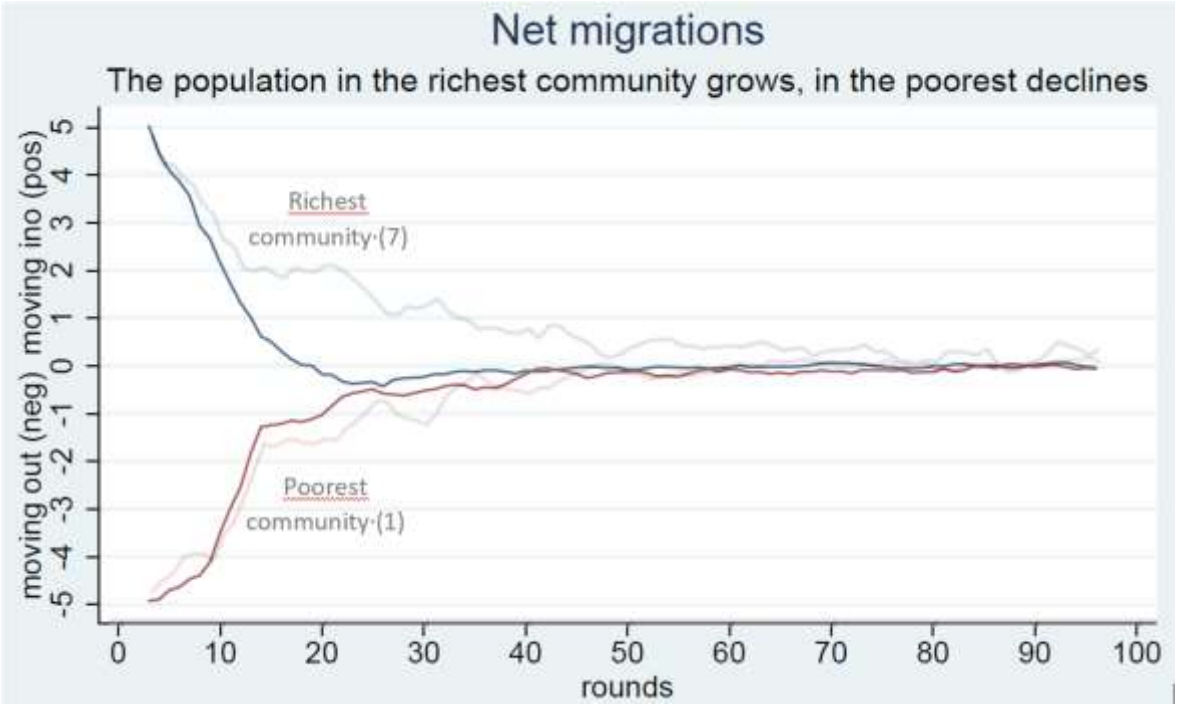


Figure 9. Migration flows of the poorest and richest communities.



Notes: The heavier line regards a district where communities are allowed to switch to a patrilineal system. The lighter line regards a district where communities are egalitarian, and no switch can occur. Heavier lines are based on 60 runs and lighter lines on 20 runs. Each line plots a 5-round moving average.

The dynamic of institutional change responds to the migratory pressure onto the richest communities. When institutional change is possible, the inequality in terms of per-capita collective wealth also

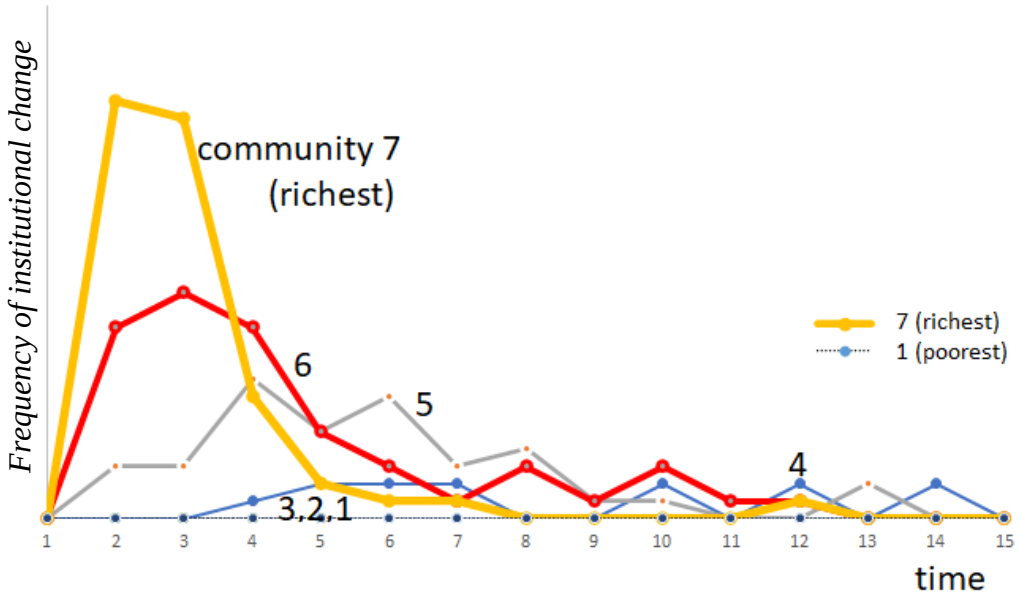
tends to decrease but to a lower extent than in a district with all egalitarian communities. In particular, the average standard deviation of per-capita collective wealth goes from 0.57 in round 1 to 0.23 in the last round, when communities can switch to a patrilineal system, while plunges to 0.07 when institutional change is not allowed.

In terms of migratory flows, Figure 9 compares the richest and the poorest communities when institutional change is allowed. We can observe that after an initial, substantial inflow of individuals into the richest community, the net immigration declines toward zero as soon as the richest community switches to a patrilineal system. At the same time, we can observe an initial outflow from the poorest community until this migratory process fades away.

Result 3: Institutional change spreads in waves from the richest community down.

While Figure 8 shows an aggregate pattern that may resemble the logistic shape of many biological phenomena, a deeper analysis at the community level suggests a pattern that is similar to the waves made by a stone thrown in a pond. Institutional change spreads by contagion from one community to another through three identifiable patterns. First, the sequence of institutional changes follows the ranking of the communities in terms of per-capita collective wealth. Second, the strength of the contagion weakens as we move down the ranking. Third, the contagion stops before reaching everyone. Figure 10 shows these patterns as a series of waves representing the frequency of institutional changes by community. In Figure 10, communities are clustered according to their ranking in terms of collective wealth. The poorest communities appear as a flat line at zero, because no institutional change occurs. There are two differences with respect to Figure 8: (*i*) it plots the frequency rather than the cumulative density, and (*ii*) a line represents one community, instead of the aggregation over the whole district.

Figure 10. Diffusion of institutional change from the richest community down



Notes: Time on the horizontal axis (seven rounds for unit). 60 runs.

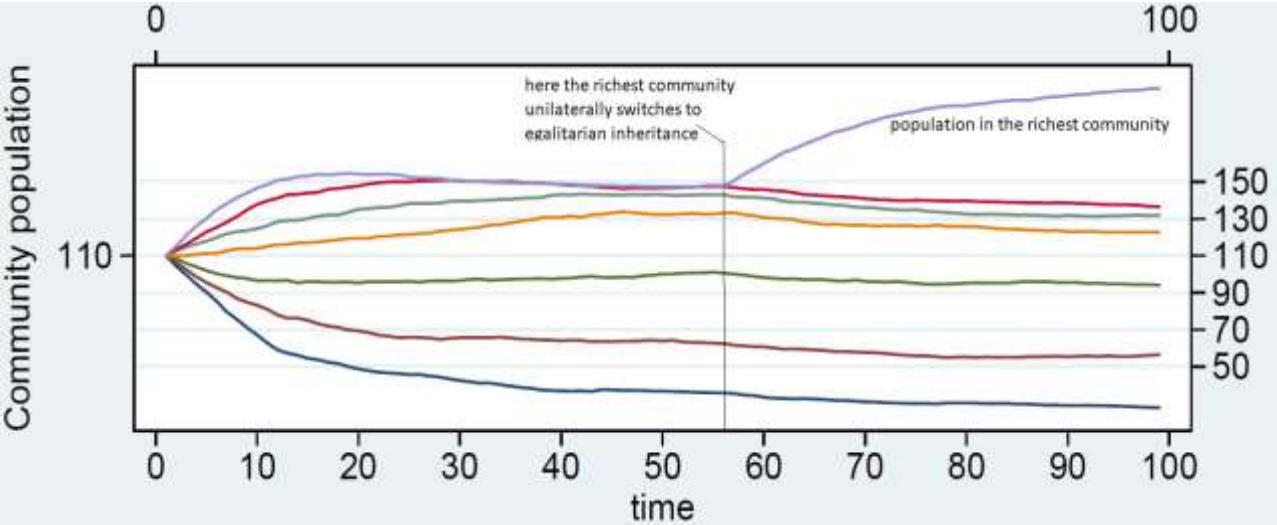
Result 4: Reversal of institutional change by a single community is very costly.

If a community undergoes institutional change toward patrilineal inheritance and then suddenly and unilaterally reverts to an egalitarian inheritance system, it will face potentially high costs because of the immigration pressure from many other communities.

Consider the standard scenario where all communities are initially egalitarian and over time can undergo institutional change. In the district, the richest communities gradually shift towards a patrilineal system (Results 1, 2, 3). Here, we introduce a breaking point at round 55, where only the richest community reverts to an egalitarian system (Figure 11). This shock creates a hypothetical scenario where an extremely high migratory pressure builds on this community, and its population quickly increases, lowering the share of resources enjoyed by the original community members. If the same mechanism that triggers institutional change at the community level still operates, this community after the shock would soon switch again to a patrilineal system.

Result 4 may justify the model assumption that institutional change moves only in one direction from egalitarian to patrilineal systems. This result explains the lock-in of the communities into a patrilineal system.

Figure 11. The richest community unilaterally switches to egalitarian inheritance



6. Discussion and Conclusion

This section puts forward some general considerations on the implications of the model results, on some of the model limitations, and of possible extensions.

In the computational model, an egalitarian system tends to equalize per-capita collective wealth across communities because of migration flows. In contrast, a patrilineal system protects the community per-capita collective wealth by restraining migration through marriages. The model shows how institutional change happens in the richest communities of a district, but never in all communities. When a community switches from an egalitarian to a patrilineal system, it restricts the

set of available destinations for migrants, and diverts potential immigrants to other communities. This process is characterized by path-dependency: the earlier decisions of some communities to change the inheritance system in favor of men sets in motion subsequent adjustments in other communities. Hence, institutional change spreads by contagion.[13] Left alone under decentralized decision-making, communities engaged in a progressive closure towards outsiders.[14]

In the computational model, decision making is decentralized: single individuals and single communities act in autonomy. This contrast with the centralized institutional change that occurred in 1800 when Napoleon restored an egalitarian inheritance system on the commons (historical pattern 5). According to the computational model, when the process of transitioning from an egalitarian to a patrilineal system is complete, the communities are in a stable state. Nobody has an incentive to switch back to an egalitarian inheritance system. If a patrilineal community does it, this course of action would expose the community to a considerable reduction in per-capita collective wealth, because individuals from other parts of the region would flock in and marry community members. The communities are effectively locked into a situation of women's discrimination and unable to move back to an all-egalitarian inheritance system.

This lock-in effect springs from the decentralized decision-making over inheritance systems. A shift from a patrilineal to an egalitarian system is particularly difficult when done unilaterally by a single community because all the migratory pressure would focus on that community. Instead, if all communities simultaneously revert to an egalitarian system, the short-time pressure on the single community would be lower, although with decentralized decision-making it would still not generate a new stable situation. Was an egalitarian system in any way optimal? Besides fairness considerations, an egalitarian system provides some insurance to individuals against shocks hitting communities asymmetrically, through the possibility to emigrate to another community. As pointed out by Casari and Lisciandra (2016), "From a long-run perspective, risk-averse individuals would prefer to live in a society without heavy costs of moving to other villages in case of exogenous shocks."

As we know from historical pattern 5, the way is which gender equality in property rights was re-established was through an act of the central state for the whole region. After the Napoleonic invasion, a modern, centralized state replaced the traditional political regime. Communities lost their

[13] In the model, the diffusion of institutional change operates in a different way than for instance in financial contagion. Consider the case of the credit crunch during the 2008 financial crisis. After some initial large bankruptcies, banks did not trust each other in the interbank lending market because of the uncertainty about the financial exposures of each financial institution. A domino effect is present in both situations, as the initial events set off a contagion of others, but the dynamic of the subsequent pressure differs in the two situations. In the Trentino case, the pressure is weakening over time while in a financial crisis it gets stronger.

[14] A matrilineal system would have also protected a community from the levelling effects of an egalitarian system. The effects, though, may or may not be identical to those of a patrilineal system because the version of the Gale-Shapley algorithm adopted in the computational model assumes that men take the initiative in finding a partner. If this assumption remains, the results of patrilineal and matrilineal inheritance may not come up symmetric. Another important qualification of the results is that the institutional choice in the model is binary. One could consider how the possibility of districts with a simultaneous presence of three types of inheritance systems (Egalitarian, Patrilineal, and Matrilineal) could impact the dynamic in a district.

autonomy of decision over the management of the commons and to customize property rights locally. This exogenous shock unlocked the situation and restored property rights for women.

The computational model presents a variety of limitations. The main one is its inability to make predictions about when an all-egalitarian district becomes unstable and the cascade of institutional changes starts. Historically, the decades before 1480 seems to divide an age of stability from an age of instability in the egalitarian system. What factors can explain this timing?

A related point regards the advantages of the egalitarian system. The Trentino communities often shifted toward a patrilineal system gradually, by first introducing what we called a soft-patrilineal system where families with only daughters could transmit membership to one or more of them (Casari and Lisciandra, 2016). Moreover, they never transitioned to primogeniture, which would have ensured an even more rigorous incentive to limit community size. A possible factor was the desire of parents to equally ensure to all their children a fair economic welfare and the possibility to have bargaining power in the choice of a partner to marry.

The computational model assumes a stationary population level to facilitate the interpretation of the basic results and highlights the mechanisms at play. This does not fit the historically data for this six-century period. A model with endogenous population growth could address this aspect. A critical parameter to consider for this exercise is whether fertility rates were the same in egalitarian and patrilineal communities. The inheritance system on the commons could affect the population level of a community through at least two channels: one that influences migration patterns across communities and the other that alters incentives for internal population growth. About the latter channel, Casari et al. (2019) showed that egalitarian communities in Trentino had a higher fertility rate than patrilineal communities. In addition, while immigration has an immediate impact on a community welfare, the impact of endogenous population growth is only visible in the long run. These elements would do nothing but reinforce the results of the model.

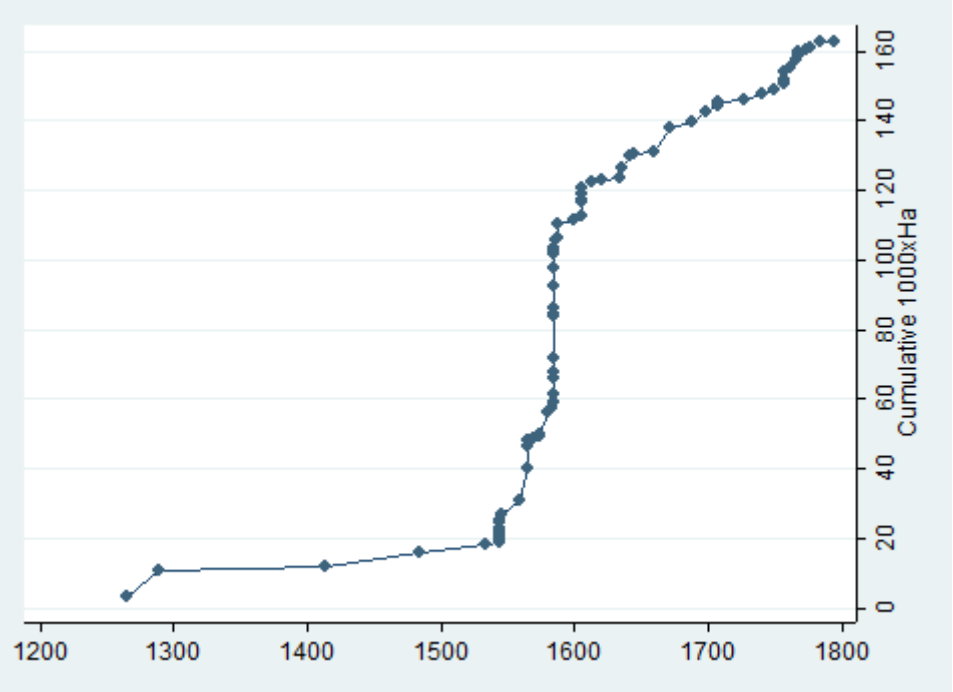
The model assumes that the total value of the commons in a community is fixed, regardless of the population level. The value of the commons, though, in terms of stream of benefits for community members, depends on the ability to avoid the tragedy of the commons. However, we know that community size plays an important role in its ability to sustain cooperation in the management of the commons (Casari and Tagliapietra, 2018). This may have played an additional role in influencing the institutional change.

One last limitation of the computational model is in the treatment of individual land. Ownership of individual land is part of individual attractiveness and it is classified as a mobile asset. The owner can sell the land in one community and buy land for an equivalent value in another community. At the margin, this reasoning can be a good approximation but for a substantial amount of migration, this may not be the case. If the amount of individual land in a community is fixed (which is debatable at least for the earlier centuries), prices will adjust to demand. Prices will go down in communities of net emigration and go up in communities of net immigration. In a sense, moving from a poor to a rich community may be more costly than assumed in the model, because one's own individual attractiveness score will be different when staying or leaving. In particular, it is higher if the person marries an insider compared to a situation of moving to a richer community.

The purpose of the model is to provide a rigorous and simple representation of the driving forces behind the institutional change in Trentino. Below, we list some extensions that may provide a better fit for the field conditions. One should always keep in mind how much making the model more complex can actually add in terms of insights on institutional change. Undoubtedly, these extensions could constitute a robustness test of the results, when read in conjunction with the baseline model. (*1*) The interaction in the district is currently global. Adding geographical or social distance between the communities will help to capture the historical pattern of local contagion. (*2*) Individual utility functions in the computational model are linear. A concave function, such as the logarithmic one, is likely to provide a more accurate description. (*3*) The environment is currently deterministic. One can consider temporary or permanent random shocks to the value of collective wealth that hit communities asymmetrically. (*4*) In the model, the collective decision for institutional change is quite simple but it has a large impact on the results. One could explore other rules.

Appendix

Figure A1: Cumulative number of villages formalizing the inheritance system on the commons weighted by land surface.



Notes: a dot represents the year when a village first formalized its inheritance system on the commons with each village weighted by its total land surface (thousands of hectares). For a similar graph where every village has the same weight, see Figure 1 in main text.

References

Alesina A, Giuliano P,., Nunn N., 2013. On the Origins of Gender Roles: Women and the Plough. Quarterly Journal of Economics, 128, 2, 469-530.

Alfani, G., 2011. Le partecipanze: il caso di Nonantola, in: Alfani, G., Rao, R., (Eds.), La gestione delle risorse collettive in Italia settentrionale, secoli XII-XVII. Franco Angeli, Milano, pp. 48–62.

Baland, Jean-Marie, and Jean-Philippe Platteau. *Halting degradation of natural resources: is there a role for rural communities?* Oxford, Claredon Press, 1996.

Bellettini, A. 1987. *La popolazione italiana: Un profilo storico*. Einaudi, Torino.

Bonan, G., 2016. The communities and the *comuni*: The implementation of administrative reforms in the Fiemme Valley (Trentino, Italy) during the first half of the 19th century. International Journal of the Commons, 10(2), 589–616.

Bromley, Daniel W. (Ed.) *Making the commons work, Theory, practice, and policy*, San Francisco, ICS Press, 1992.

Casari, M., 2007. Emergence of Endogenous Legal Institutions: Property rights and community governance in the Italian Alps. *Journal of Economic History*, 67(1), 191–226.

Casari, M., Lisciandra, M., 2011. L'evoluzione della trasmissione ereditaria delle risorse collettive in Trentino tra i secoli XIII e XIX, in: Alfani, G., Rao, R., (Eds.), La gestione delle risorse collettive in Italia settentrionale, secoli XII-XVII. Franco Angeli, Milano, pp. 17-31.

Casari, M., Lisciandra, M., 2016. Gender Discrimination in Property Rights: Six Centuries of Commons Governance in the Alps. *Journal of Economic History*, 76(2), 559–594.

Casari, M., Lisciandra, M., Tagliapietra, C. 2019. Property Rights, Marriage and Fertility in the Italian Alps: 1790-1820. *Explorations in Economic History*, (71), 72-92.

Casari, M., Plott, C.R., 2004. Decentralized management of common property resources: experiments with a centuries-old institution. Journal of Economic Behavior & Organization, 51(2), 217–247.

Casari, M., Tagliapietra, C., 2018. Group Size in Social-Ecological Systems. *Proceedings of the National Academy of Sciences USA*, 115(11), 2728–2733.

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

Consiglio provinciale d'agricoltura pel Tirolo, 1903. Tabelle sulle condizioni agricole forestali economiche, in: Bollettino del Consiglio provinciale d'agricoltura. Monauni, Trento, fasc. 4–12 del 1903 e fasc. 1–9 del 1904.

De Moor, M., Warde, P.S., Taylor, L.S., 2002. Management of Common Land in North West Europe 1500-1850, Brepols Publishers, Turnhout.

Delugan, Nadia, and Claudia Visani. "Corpi e territorio. Le trasformazione della val di Fiemme nel XVI secolo." In: *L'ordine di una società alpina. Tre studi e un documento sull'antico regime nel principato vescovile di Trento,* edited by C. Mozzarelli, Milano, Franco Angeli, 1988.

Gale, D., Shapley, L., 1962. College Admissions and the Stability of Marriage. *American Mathematical Monthly*, 69(1), 9–15.

Giacomoni, Fabio. *Carte di regola e statuti delle comunità rurali trentine,* 3 volumes, Milano, Edizioni Universitarie Jaca, 1991.

Gibson, Clark C., Margaret A. McKean, and Elinor Ostrom. (Editors). *People and Forests: Communities, Institutions, and Governance*, MIT Press, 2000.

Gordon, H.S., 1954. The Economic Theory of a Common-Property Resource: The Fishery, The Journal of Political Economy, 62(2), 124–142.

Grossi, P., 1981. An Alternative to Private Property: Collective Property in the Juridical Consciousness of the Nineteenth Century, University of Chicago Press, Chicago.

Guiso, L., Sapienza, P. Zingales, L. , 2016. Journal of the European Economic Association, 14, 6, 1401-1436

Netting, R.M., 1981. Balancing on an Alp: Ecological Change and Continuity in a Swiss Mountain Community, Cambridge University Press, Cambridge.

Netting, Robert McC. "Of Men and Meadows: Strategies of Alpine Land Use." *Anthropological Quarterly* 45, (1972): 132-144.

O'Grady, T., Tagliapietra, C., 2017. Biological Welfare and the Commons: A Natural Experiment in the Alps, 1765-1845. Economics and Human Biology, 27 (Pt A), 137–153.

Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action, Cambridge University Press, Cambridge.

Ostrom, Elinor. "Coping with Tragedies of the Commons." *Annual Review of Political Science* 2, (1999): 493-535.

Sartori-Montecroce, T. (1891). Die Thal- und Gerichtsgemeinde Fleims und ihr Statutarrecht. Innsbruck: Wagner.

Tabellini, G., 2010. Culture and Institutions, Economic Development in the Regions of Europe. Journal of the European Economic Association 8(4), 677–716.

Varanini, G.M., 2004. L'economia. Aspetti e problemi (XIII-XV secolo), pp. 461-516, in: A. Castagnetti, G. M. Varanini (Editors), Storia del Trentino. Vol. 3: L'età medievale, Il Mulino.