WHO NEEDS FORMAL REGULATIONS TO MANAGE THE COMMONS? THE RURAL CHARTERS IN NORTHERN ITALY

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Abstract:

According to the Folk theorems, a 'tragedy of the commons' outcome can be avoided provided that the users are sufficiently patient and that their interaction is infinitely repeated. That seems to have been the situation of the villages on the Italian side of the Alps (Trentino), which held forests and pastures in common for centuries (1200-1800).

Instead of relying on informal regulations, however, the users created formal institutions to limit the over-exploitation of the resources through written legal documents called rural Charters (*Carte di Regola*). Was the choice inefficient or were informal regulations not able to support full cooperation?

Some degree of formal regulations was necessary to ensure that basic requirements of the Folk theorem, such as repeated interaction and protection from outsiders, were met. Through the rural Charters the local communities obtained from the political authorities some legislative power to self-regulate and locally enforce formal institutions. For instance, the long-term relationship within a community was ensured by a specific property rights arrangement on the land that locked-in the insiders.

Since the resource users could only imperfectly monitor one other, the outcome of informal institutions was in general sub-optimal. I adopt the Green-Porter model to interpret the historical situation. The alternative of a legal sanctioning system entailed explicit costs to be set up and maintained but might have provided a better arrangement also because it avoided the deadweight losses associated with punishment actions of informal regulations.

In conclusion, it is well possible that formal regulations could have performed better on an efficiency ground than informal regulations.

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1. INTRODUCTION

On July 18, 1589 the *Giurato* of the community of Mezzolombardo recorded that a gentleman named Michel paid a fine for an amount of *troni* 4 and *carantani* 10. Michel had been caught while illegally collecting firewood on common land. In one of the general meetings the men of Mezzolombardo had regulated the use of the community forests, pastures, and wastelands restricting it to the residents of the village, to designated months of the year, and to maximum individual quantities. They had also appointed an administrator (*Giurato*) to properly enforce such rules. Mezzolombardo was just one of the hundreds of villages in the Trentino region of the Italian Alps to establish formal regulations on the village commons [2].

It is well known that the unregulated interaction of users of a common resource leads to a detrimental over-exploitation of the resource that is usually called the 'tragedy of the commons' (Hardin, 1968) to emphasize its nature of social dilemma. That is why, one might argue, the Trentino villages like Mezzolombardo felt the need to set explicit quotas and fines in order to limit the socially harmful over-use of forests and pastures that were communally owned.

And yet, on a closer inspection, the quota and fine system becomes more perplexing. Why have them set up formal institutions in a village where everyone knew one another and villagers interacted repeatedly? The Folk theorem implies that an optimal outcome can be attained provided that the interaction is infinitely repeated and individuals are sufficiently patient. Suppose both conditions were satisfied. Why then were formal institutions such as quotas and fines necessary to improve efficiency? The aim of this paper is to explore possible answers to this question.

In the paper I claim that the contradiction between the implications of the Folk theorem (Rubinstein, 1979, Fundenberg and Maskin, 1986) and the observed institutions is only apparent. The basic line of argument relates with the assumptions needed for the standard Folk theorem to hold. In general, formal institutions fulfilled some of the requirements for the efficiency informal regulations or, when too costly, replaced informal regulations in the management of the commons.
An essential condition to apply the standard Folk theorem is that each person in the group can tell whether others are cooperating. Without this information, cooperation among self-interested agents will break down. I argue that this condition was not met – at least not in full – in the Trentino villages. The disloyal Michel was probably caught by one of the guards routinely sent out by the *Giurato* to patrol the common land. Ordinary members of the village were also encouraged though a system of explicit incentives to keep an eye on the common land. In both cases, the information was not readily available but gathered through costly monitoring activities.
One might take for granted the fact that the interaction among the villagers was repeated an indefinite number of times because it can be observed that over time the same families are in a community, years after year and generation after generation. Far from being "natural", this pattern was the result of a specific form of property rights on the common land that locked-in people into their community. In the absence of such institution, after having taken full advantage of the collective resources in total disregard of an eventual informal cooperation agreement, our brave Michel could have simply moved to another village and easily escaped any punishment based for instance on a trigger strategy, leaving the faithful cooperators who remained in the village to bear the

[2] Libretto di Amministrazione (1589): "*per una codanaza fatta per aver menado entro legna da le giare del nos*", which literarily means "for a penalty inflicted for having removed firewood from the bank of the river Nos".
For the rural Charters of Mezzolombardo see Devigili(1979).

costs of the punishment. To rule out such hit-and-run behavior, the Trentino communities made migration a difficult and costly activity.

The governance regime considered in this paper was widely adopted in the management of a common resource. Formal self-government regulations similar to the one here described were a widespread form of management of the commons in the Alps both on the Italian and German speaking sides[3]. Ostrom (1990) and Bromley (1992) have reported of other cases of self-government all around the world, from farmers in the Andes, to fishermen in Turkey, to villages in Modern Age Japan. The villages of the Trentino region are an ideal laboratory to tackle the above research question because of the rich documentation that has survived.

Modeling mostly illiterate peasants of the Middle and Modern age as utility optimizing neoclassical agents requires a leap of faith. The point that I want to make here is that even when we do, informal cooperation does not seem alone to be a viable alternative and it might have been inferior to explicit formal regulations. Hence, in the historical case here under scrutiny formal institutions could be justified merely on efficiency grounds and without the need to introduce bounded rationality. I believe, however, that other motives besides efficiency, such as fairness or social cohesion, had been important in shaping the observed institutions[4]. Notwithstanding, in this paper I have simply taken one of the goals, efficiency, and explored how far I could go in explaining the empirical phenomenon.
To some extent, this paper follows the line of analyses that Milgrom and others (1990) and Greif (1997) have adopted for Medieval and Modern Age merchant institutions.

2. OVERVIEW

This section describes the line of argument of the paper in a non-formal way, while the following sections will discuss in more depth specific aspects and provide empirical support for the claims made.

A well-known body of the scientific literature suggests avoiding holding a resource as an unregulated common ownership when the goal is efficiency (Gordon, 1954; Clark, 1990; Hardin, 1968). The use of a common resource by a group of people is a typical social dilemma situation because the individual incentives lead to a sub-optimal outcome, or to a "tragedy" in Hardin's words. As in the prisoner dilemma's case, the equilibrium outcome in a non-cooperative game is different from the socially optimal one. I will not discuss here the details of the model, which is fairly standard, but I point the interested reader to the appendix where there is a derivation of the efficiency levels attained in the one-stage game under three types of ownership structures: individual ownership, unregulated common ownership, open access. I will only mention that the growth of a renewable resource is modeled as an inverted "U"-shaped function of the resource stock, which is a good approximation of the phenomena here studied (see figure 1 for biological data about forest).

[3] For documents relative to some other regions in the Alps, see Batl (1951), Cortesi (1983), and Pototshing (1953); for monographic studies on Switzerland see Netting (1981) and Stevenson (1991).
[4] Social institutions are created also to handle problems of pure coordination – I think at the traditional village meetings in given days - or function as devices to preserve inequality – for instance through male lineage inheritance (Schotter, 1981). For an interesting view on peasant economies see also Georgescu- Roegen (1965).

< Figure 1 about here>

The fact that the interaction among the villagers in Trentino was indefinitely repeated might provide a possible escape to the 'tragedy'. A discussion of the legal arrangements to ensure repeated interaction, and in particular emigration regulations, is postponed to the sections 3 and 5. Here I want to underline that under given conditions, the repeated use of the commons by the same group of agents does not have to be a 'tragedy' but it can be indeed optimal. This result has been proven under a variety of assumptions in the General Feasibility Theorems, better known as Folk theorems. "The general feasibility theorem can be interpreted as a statement about the power of social norms in small groups, such as families, partnerships, and cliques. According to the general feasibility theorem, if the individuals in a group know one another well, can observe one another's behaviors, and anticipate a continuing relationship with one another, then social norms can sustain any pattern of group behavior, provided it makes each individual better off than he would be without the group. When we go from small groups into larger social structures, however, the assumption that everyone can observe everyone else may cease to hold, and general feasibility can fail" (Myerson, 1991, p. 349-50). In other words, the socially optimal outcome is attainable when the agents can observe all of each other's past moves, that is in standard repeated games, while it might not be reached under conditions of imperfect information. In the next section I argue that imperfect information was the prevailing condition in the Trentino communities. If the people in the group cannot tell whether others are cooperating, the optimal outcome cannot be credibly sustained.

In order for the Folk theorem to operate the agents involved in the social dilemma ought to be able to detect if the others cooperate at a good enough level in order to decide whether keep cooperating or switch to punishing. This requirement is of course satisfied when there is full information about the individual actions of the agents. Perfect information is however only a sufficient condition. What is strictly necessary is knowledge of the aggregate cooperation level of all the other agents.
Once having showed that the peasants could not perfectly observe one another is not enough to claim that the Folk theorems do not apply to this case. The peasants could have used the stock of the resource as a signal for the cooperation level of the community. An excessive harvesting by any member of the community would have reduced the stock of the resource. By simply observing the status of the forest or the pasture, a villager could have inferred the amount that the others collected given that he knew the growth pattern of such resources. In other words, instead of observing the people he could have observed the land.

I claim that the signal about the stock of the resource was observed with some noise. A villager sampled the status of the common land in a given number of locations while doing his daily activities and did not usually cover systematically the whole land and count every tree in order to find out the exact quantity of the leftover timber or grass. The signal can be model as a random variable, which yields different draws to different villagers because the sampled areas were in general different.
If we set aside the issue of the individual heterogeneity of the signal, a noisy knowledge of the stock of the resource might have been enough to sustain some cooperation, although not in general full cooperation. This result is a straightforward application of the Green-Porter model - which was developed to explain collusion pattern in an oligopolistic market with imperfect monitoring - to the exploitation of a renewable resource by a group of users[5] (Green and Porter, 1984, Abreau, Pearce,

[5] There is a perfect formal symmetry between firms competing on quantity in an oligopolistic market and users exploiting a common resource. See appendix for a more extensive explanation.

and Stacchetti, 1986). In general, the higher the noise and the lower is the best attainable cooperation level. Given the information available, the Green-Porter model could have ensured a better outcome than the "tragedy of the commons" situation but it would still a sub-optimal one.

The outcome could be improved through a process of splitting of the common land and of the group of users into multiple smaller units. This action of partitioning could be beneficial both in the case of the existence of some cooperation of the Green-Porter type among the users and in the case of a 'tragedy'.
If the community was already able to sustain some degree of cooperation, partitioning could increase the cooperation level because of the more precise signal about the stock of the resource in terms of both its statistical variance and its homogeneity across individuals. The users could more easily survey a resource of a smaller size and hence get a signal with less noise about the extent of the cooperation of the other agents. According to the Green-Porter model such change raises the welfare properties of the best attainable outcome [6].
In a 'tragedy of the commons' situation the overuse of the resource is less severe after partitioning because the single user takes more into consideration the damage that his action is having on himself. As we will see in section 4, this result is a direct implication of the standard model of a renewable resource. At the same time this result poses the question of why the process of partitioning does not proceed until we have individual instead of common ownership. I claim that the increasing cost of enforcing borderlines made excessive partitioning inefficient.

The paper then compares the economic static efficiency of formal and informal regulations of the commons for the specific case of the village forests and pastures in Trentino. With the term formal regulations I refer to the presence of rules with legal value whose enforcement is guaranteed by the threat of a court injunction. In general, formal regulations can either come from an authority external to the users or be set up by the users themselves. I will consider just this second type of formal regulations (self-governance). On the contrary, informal regulations are self-enforcing rules that can be applied without external authority interventions. In short, they are equilibria of a game among the users. Social sanctions are part of this category but I will focus mainly on strategies that can support Folk theorems' best outcomes.

The comparison between formal and informal regulations is done in reference to a well-defined group of users of a common resource (the *vicini*) under the assumption of a relative isolation of the insiders from the outside world. A meaningful comparison requires that a formal system to enforce property rights toward outsiders be in place. Without such enforcement, informal cooperation among insiders is doomed to fail because any effort to limit the over-use of the commons would be compensated by an increased harvesting activity by outsiders. Consider a situation where there are N legal owners of the land and M potential trespassers. In the absence of external enforcement the number of users is in practice N+M, where M would increase whenever a cooperation agreement is successful in limiting the use of the common resource and hence makes trespassing profitable for new people[7].

[6] One of the extensions of Abreu, Pearce, and Stacchetti (1986) to the Green-Porter model was to prove the continuity of this kind of Folk theorem result to the noise level of the cooperation signal that the agents receive. As the signal noise increases, the best attainable outcome smoothly decreases.
[7] It is a similar logic to the supply side of a market where there is free entry. If for any reason the outsiders have a discount rate lower than the insiders (for instance because of their temporary stay), the 'tragedy of the commons' is even more likely.

The only effective way to deter trespassing is with formal regulations. Trespassers could easily escape the punishment of the community. For instance, an occasional traveler could stay few days in a community, free ride, and never show up again. Another way is to free ride temporarily on other communities until the original one has reverted to a cooperative mode.

The comparison between formal and informal regulations is meaningful once a framework is provided to ensure a long-term relationship among insiders and to enforce property rights against outsiders. If nothing else, the rural Charters were a low-cost legal device for defining and enforcing property rights in order to provide such framework. That was precisely the aim of regulations contained in the Charters about emigration from and immigration to the community and about trespassing on the common land by outsiders (section 5). In addition to that, however, the Charters contained specific legal rules to limit the use of the common resource by insiders. The question is whether that way to manage the commons was a better than an informal regulation system.

Stating that property rights were enforced toward outsiders does not mean that the enforcement was perfect. In general, some illegal harvesting by outsiders was still taking place and that decreased the stock of the resource. The Green-Porter equilibrium could be affected by this additional source of "noise". When we treat the illegal harvest as a stochastic variable, there is a worsening of the Green-Porter equilibrium in comparison with a perfect enforcement situation because the inference from the status of the resource signal to the degree of cooperation of insiders was more "noisy". Furthermore, under the assumption that higher monitoring efforts generated a less variable pattern of trespassing actions, the efficiency of the enforcement of property rights toward outsiders would be positively correlated with the degree of cooperation in the Green-Porter equilibrium. In conclusion, the existence of this additional and variable source of noise makes the welfare property of the Green-Porter equilibrium worse and the problem of assessing change in the degree of cooperation less tractable.

Formal regulations of insiders exhibit advantages and disadvantages in comparison with informal regulations. The two advantages are that the punishment for free riding is directed only toward the free rider and the punishment is not a deadweight loss for the group. The threat of punishment is usually targeted at the violator of a rule and not, like in the Folk theorem, directed toward the whole group. Since with imperfect monitoring of insiders the group does engage in retaliatory periods in equilibrium, informal regulations entail widespread losses also for faithful cooperators. Moreover, the legal punishment is usually directed at modifying individual incentives while avoiding destruction of resources. In fact, a fine is a transfer of money from one member of the community to the others. The two disadvantages of formal regulations are the need to monitor individual actions of insiders and to build institutions to prosecute free riders and enforce payments. Monitoring outsiders is valuable for both formal and informal regulations. I assume that there were strong economies of scale in monitoring outsiders and insiders at the same time. The additional cost of monitoring insiders was likely to have been small. Setting up rules to use the commons and a court system to enforce them was costly and tuning the institutions to changing external conditions was also costly. Given the deadweight losses of developing the formal institutions and the recurrent cost of monitoring insiders, formal institutions could at best deliver a sub-optimal outcome.

This paper claims that in the distinctive situation of the Trentino communities, we cannot in general state the superiority of informal regulation in the management of the commons over formal regulations. The comparison is between two second-best outcomes and the arrangement that can deliver a higher income stream to the owners of the resource is likely to vary according to

environmental conditions such as for example informational conditions and monitoring technologies. The fact that through the rural Charters formal institutions were established does not clearly contradict economic efficiency.

Yet, there is something that needs an explanation. Through the whole discussion it seemed that all the pieces of evidence where fitting together to frame the interaction in a way to crop the sweet fruits promised by the Folk theorems. If the peasants chose formal regulations instead, believing they were superior to informal regulations, all those "pieces of evidence" like the mechanism to lock-in insiders in the community or the partitioning process need an alternative explanation.
I argue that only individuals motivated by the expectation of long-term future benefits would engage in irrecoverable costly investments in building and maintaining institutions needed for formal regulation.
Partitioning instead could have been a way of reducing bargaining costs in building the institutions. The higher the number of people involved and the distant they were, the more difficult it was to meet regularly and reach an agreement.

To sum up, in a context of repeated interaction among insiders, the tragedy of the commons might be avoidable if the Folk theorem applies. If it did apply, though, the best attainable outcome would have still been sub-optimal because the cooperation level of insiders could be only imperfectly observed, either through the individual actions of the agents or through the status of the common resource.
Whether the Folk theorem applied or not, some degree of partitioning was beneficial for the insiders. The implicit assumption is that outsiders were kept off the common land and this task could be performed only with formal regulations. In case some outsiders still free-rode on the resource, insiders were more uncertain than before about the cooperation level of the others.
The informal regulations outlined above exhibit both advantages and disadvantages in comparison with the formal regulations described in the rural Charters. In general, I cannot rule out the possibility that the best choice for the Trentino villages was a formal regulation system.

3. THE RURAL CHARTERS

This section provides the historical context necessary to discuss the choice between formal and informal regulations in the Trentino communities.

The current Trentino region is a mountain area on the Italian side of the Alps that covers a surface of 1,465 squared miles, equivalent to less than the area of a 40-mile side square. The population in 1754 was 206.000 (table1). Most of the land was either forest or meadow. The 1897 land register data record only 8% of plow land in the whole region (Figure 2).

< Figure 2 about here>

An overwhelming part of the forest and most of the grazing land was owned in common on a village basis. Quantitative evidence for a systematic test of the ownership structure village by village can be obtain from the 1780 land registers. As an example, in the relatively large village of Levico 95% of the forests and 66% of the meadows and pastures were common ownership while the

analogous share in the high mountain village of Predazzo were 100% and 60% [8]. In 1897 about 76% of the forests in the region was owned by the municipality or by the State (Consiglio Provinciale d'Agricoltura, 1903). There are good reasons to believe that this figure is an underestimation of communal ownership a century before [9].

< Table1 about here>

We cannot discard the common ownership as a temporary phenomenon given how extensive it was and how long it lasted among these Italian villages. There is little disagreement about the persistence of village ownership for centuries up to the early 1800s.
To avoid the 'tragedy of the commons', the village forests and pastures were managed with a formal system of regulations that will be described in some detail. We are able to know the village institutions of Trentino with a very high degree of accuracy because regulations were coded in formal documents called *Carte di Regola*, or rural Charters. The oldest of such Charters dates back to 1202 and was drawn by the peasants of Civezzano, a small village nearby the administrative center of Trento, where the document was sent for the official approval of the Prince. The phenomenon lasted about six centuries and involved at least three quarters of the villages in the region but probably almost all of them [10]. In the decade between 1796 and 1805, first the political turmoil brought by the Napoleonic army and then the sweeping reforms of the Enlightments put an end to the self-government regime of the Trentino communities [11].

The rural charters were a codification of the rules established by the village assembly for managing all the economic resources of the village, both individually and commonly owned resources. Such rules were aimed at excluding non-owners from the use of the land and, in various ways, limit the exploitation level of the resources held in common. To make sure rules were enforced, villagers appointed officials to police the land and eventually impose cash fines in case violations occurred.
A Charter was an agreement between a community and the Prince in order for the community to administer local justice on economic matters and as such was drawn like an official deed [12].

[8] The manuscripted books recording property rights are in the *Archivio di Stato di Trento,* under *Catasti Teresiani of 1780-90*. The references are Goio(1978) for Levico and Varesco (1981) for Predazzo.
[9] The ownership structure I attempt to sketch refers to the situation up to 1803. After that date, both political and economic shocks have occurred. Part of the village estates were divided or sold after the end of the Principality of Trento. An increasing population and more generally and increasing logging activity have reduced the extension of the village forests (Perini, 1852, Monteleone, 1964). The 1780-90 land registers can provide unbiased data. To my knowledge, no general summary of those data has been yet published.
[10] 284 villages out of 377 had a Charter by 1803. The count is approximate for two reasons: it takes as total number of villages the land register units in which the province of Trento was divided in 1897, which might not exactly correspond to the number of actual villages in 1803. More importantly, it considers only the villages for which I have sure notice of the existence of a Charter. Other Charters could have been in place, but I was simply not able to know it. Both factors suggest that the actual ratio is above 75%.
[11] The Prince of Trento approved the last Charter in 1796 (Breguzzo and Marano). In 1805 the new Austrian government outlawed peasant assemblies and with it one of the essential pillars of the self-government system. A rural Charter in this paper is conventionally identified by <village name>,<year of original draft>. Most of the Charters mentioned in the paper can be found in Giacomoni (1991). That book contains 189 Charters about the Trentino region.
[12] A notary recorded in a written document the will of a group of people in the presence of external witnesses and, sometimes, of a representatives of the feudal powers. To be effective, every charter needed to be confirmed by the Prince or, in some cases, by its feudal lord. Through this confirmation, the Prince stated the compatibility between

The group of legitimate users and regulators of the commons were called the *vicini* ("the neighbors", insiders) while all the others were the *forestieri* ("the strangers", outsiders)[13]. The interaction among the *vicini* can be confidently considered indefinitely repeated because the probability that the interaction took place the following year was so high that we are as close as we can get in a real world setting to the theoretical assumptions of the Folk theorems. The same family names can be found in the same small village and nowhere else literally for centuries[14].
Emigration was a potential threat to the expectation of a repeated interaction and because of that property rights on the common land were crafted in a way to make exiting the community costly. The crucial point is that there was no individual right to secession from the community. Anybody could leave, but no claim could be made of the community common resources. The villagers were locked-in into a long-term relationship one with another because the decision to individually leave the community in which a peasant was born involved losing the right to use the common land. No Charters ever mentions the right of a *vicino* to be refunded of the value of his share of common land in case he leaves the community, let alone the procedures to satisfy that right. When a member left the community he had no right to obtain a refund of his share of the common land. He could not sell or rent his membership right either. He could sell his individually owned house and fields but no benefits could be obtained from the common land while he was away and the right to return was sometimes restricted.

Given a practically infinitely repeated interaction and assuming that the peasants were sufficiently patient, the Folk theorem suggest that they could have overcome the 'tragedy of the commons' without the need of formal regulations.
Individual actions were however not fully known and that makes the standard Folk theorems not applicable to the specific historical situation. There are several traces in the rural Charters and elsewhere that the individual actions of the peasants were sometimes hard to observe. One of these traces is the widespread fear of thefts from the fields. Reports from the beginning of the XIX century points out the frequent robbery of fruits and vegetable from gardens and orchards and even of the wooden supports from the vineyards. Peasants adopted inefficient agricultural practices in order to reduce this risk, such as very small vegetable gardens and very few orchards [15]. Many

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the charter and the laws in force and promised to enforce the rules contained in the charter against resistant violators, on a community request.

13 The *vicini* were also called *terrieri* ("the ones who belong to that land") or *originari* ("the first settlers"). Sometimes outsiders were called *camerlenghi*, a negatively charged term. Example of *forestieri* were the residents of neighboring villages, seasonal workers living in the village, occasional travelers.
The *vicini* were men representing their family. In particular circumstances the family could be represented by a woman (in particular, the widow, if her male children were still too young). For a more detailed discussion on the recognition of the peculiar nature of these historical forms of collective properties in the Alps, see Grossi (1982) and Capuzzo (1985).

14 Some Charters report at the opening the list of the heads of the families present at the meeting.

15 For references from rural Charters, see for instance Malosco 1593, c.25, 26 and Tres 1551, c.53, 54, and 55.
Monteleone (1964) provides clear comments about the years immediately following the end of the rural Charter phenomenon about the thefts in the vineyards: "*… il timore dei furti, a tal punto incruditi negli ultimi anni [1812, ndr], da convincere il contadino di non poche regioni che pali e tronconi 'sarebbero rubati, se non il primo, certamente il secondo inverno seguente'*"(p.34). He writes about the thefts in the vegetable gardens: "*L'istituzione dell'orto nel Trentino era ritenuta particolarmente rischiosa per la facilità e la frequenza dei furti che sconsigliavano l'agricoltore non solo dal dargli il desiderabile respiro superficiale ma anche dall'erigerlo in aperta campagna e distante dagli abitati.*" (p.37) and again about fear of thefts on fruit trees in the same page: "*Un altro*

apparently odd rules in the rural Charters can be rationalized once we assume that monitoring individual actions was problematic. An example is the rule that nobody could stay in the high mountain meadows and forest overnight or during religious holidays. In the 1586 Charter of the parish of Sanzeno it is explained that the reason being to avoid unobservable free riding on the common resource or thefts in the private fields[16]. Another example is the common practice to publicly decide and then announce the starting day of grape harvesting and to sanction anybody who began before that day. The sanction applied even if a peasant was picking from his individually owned vineyard (see table 2)[17]. If the harvest was uncoordinated, it was easy for a peasant to pick the grape of his neighbors without being noticed, but when everybody was harvesting during the same days, they could check one another's behavior basically at no additional cost. When the grapes were getting ripe, a special guard had to police the vineyards during the day and sometimes during the night[18]. The existence of guards indicates that monitoring was costly but necessary.

Whenever the community wanted to assess who was responsible for a violation, the Charters stressed that witnesses needed to have a "good reputation" and were oftentimes required to testify under sword[19]. If the whole community or at least many of its members could observe individual actions on the village land, there was no need to be suspicious of false accusations.

Another piece of evidence about the difficulty to monitor some actions comes from the levels of the sanctions. If we want to equally deter actions that have a different degree of observability, the punishment needs to be higher the more difficult is to detect them. In the rural Charter, oftentimes the amount of the sanctions for the same violation was higher if the action was done at night or by an outsider (see table 2)[20].

In conclusion, individual past actions were not public information. On the contrary their knowledge required in general costly monitoring activities.

< Table 2 about here>

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ramo redditizio della produzione era costituito dal frutteto, la cui diffusione, in generale notevole, trovava però una limitazione comprensibile in non poche regioni caratterizzate da alti indici di delinquenza, che inibiva col timore dei furti l'iniziativa del contadino".

[16] Pieve di Sanzeno, 1586, ch.23: "*Item per tor via molti abusi et cative usanze et cativi costumi che per alcuni che per il passato si ha fatto, si statuisce che niuno della pieve non debba, né anco forestiero ardisca, di stare di notte, né dì di festa, eccetto che il gazaro, uno over più, in la montagna predetta ed massime nel tempo della segagion ed mentre è ancor il fieno nelli pradi: sotto penna de lire cinque per cadauna persona; ed se fosse rubato fieno ad alcuno over legnami over anco taiato legnami (…) che si imputi tal furto ed contrafacion a quello over quelli che si trovarono esser stati la note over il giorno di festa sul monte*", see Cagnò, 1587, c.43 for a more generic rule against working during holidays.

[17] This rule was almost always there if there were vineyards in the village (see table 2). For an example see Tassullo, Rallo, Pavillo and Sanzenone, 1586, c.30, 52, 60. One reason was to collect the *decima* (tax on the harvest) but fear of thefts were relevant as Sanzeno (villa), 1586, c.27 makes clear: in case somebody needs to harvest a day before"*che ogn'uno sia obligato lasciar da vendemar appresso li suoi confinanti: che non debba integralmente vendemare in un luogo, havendo confinanti, et questo si apparerà alli regolani; et che quello il quale vendemerà sia obligato avisar li decimani che vengino pigliar la sua decima*".

[18] For an example Vigolo Vattaro, 1496, c.22

[19] The definition of a relyable witness are various "*si deve credere … anche a un testimonio solo col giuramento, quando sii di buona fama*" (Cles, 1641, c.8), "*… gli sia creduto si è persona degna di fede*" (Salter and Malgolo, 1586), "*si crederà a cadauno che sia maggior di anni quattordeci e di buona fama, mediante giuramento*" (Mortaso, 1558,c.96)

[20] For two among many: Salter and Malgolo, 1586, c.26 (fines doubled at night); Sanzeno (villa), 1586, c.13 (fines doubled for outsiders).

One of the curious features of the rural Charters is the small size of the average community under their jurisdiction. In the village of Don just twelve people gathered to draw a new Charter in 1493 [21]. As early as the XIVth century, the Trentino region was already divided into many communities each one with exclusive property rights on their own communal land. A community under the jurisdiction of the same Charter could include one or more villages [22]. The process of partitioning continued in the following centuries.
The 1350 tax register for the Valley of Non, a district that represents less than one fifth of the area, mentions 38 villages of a size variable between 5 to 59 families (*foci*) (Bezzi, 1964). In the Valley of Non, I have traced three cases of community splitting between 1300-1800 and here is one of them. In 1483 the three villages of Coredo, Smarano, and Sfruz managed together their common forest and pastures. A century later the two smaller villages of Smarano and Sfruz separated their common belonging from Coredo through a consensual drawing of new property borderlines. Three decades after the first division there was a further split between Smarano and Sfruz.[23].
In other instances the division of the land between neighboring villages was an internal business regulated by the rural Charter and not by external property borders. In Fiemme valley, for instance, there were four areas of forest and each area was used by rotation by only some villages [24]. The 1611 rural Charter of the communities of Rumo had assigned portions of the forest to its small villages called *colomelli*. In the case of complete division, we would observe an increase in the number of independent communities. In the case of an internal division instead, we need to look at the content of the specific rural Charter.

The smaller the community size and the more important was to safeguard the land from outside intrusions. Borderlines were a continuous source of troubles for the communities in a struggle to clearly mark where they stood and in legal battles against claims of the neighboring communities. Some Charters list among the duties of the community officials the periodic surveying of the borderlines of the common land and the refreshing of the identifying marks when necessary. The endless fights inside and outside courts on borderline issues are testified by the incredible amount of documents that can still be found in the archives nowadays regarding the matter.

Appointed guards (*saltari)* were in charge of the practical enforcement of the legal no-trespassing prohibition. Some would patrol the high mountain pastures and forests (*saltari del monte*) while others would patrol the meadows nearby the village (*saltari di campagna*)[25]. They acted under the supervision

[21] A participant was there to represent his family. Local historians (for instance Bezzi, 1964) adopt the convention of five people in every family. There was no requirement to own land individually in order to participate to the meetings.
[22] In a few cases, the land was owned by a sub-set of villagers (see *Regola Feudale di Predazzo, vicinia di Pieve Tesino, Spinale*, or *Manez*) (Nequirito, 1988). I define community as the single village or cluster of villages under the jurisdiction of the same Charter and village as a group of households living in the same settlement, usually identified as a parish or a tax reference unit.
[23] See the rural Charters: Coredo, Smarano and Sfruz, 1483; Coredo, 1581 and Sfruz, Smarano, 1580; moreover see Sfruz, 1609 (Recla, 1989). In another case the six villages of Bresimo, Scanna, Cassino, Livo, Preghena, and Cis had a common management of forest and pasture in 1309 (Conter, 1913). Three century later, in 1611, there was at least a partial division among some villages. The village of Cis was probably alone by 1536. The third case involved the three villages of Revò, Cagnò, and Romallo. They divided up the high mountain forest and pastures shortly before 1740 (see Romallo, 1598).
[24] Valle di Fiemme, 1480
[25] There were also guards for the vineyards (*saltari delle vigne*). Vineyards were nearly all in individual hands but there still was a need to enforce the property rights toward trespassers. This activity was organized collectively and

of the community's governor (*regolano*) but had powers to impose the payment of fines on anybody caught breaking one of the Charter's regulations. A share of the fine, usually a third, was retained by the *saltaro* as compensation for his service.
Ordinary villagers were encouraged to report observed violations committed by outsiders to the governor's officials. If after a brief assessment the trespasser was found guilty, a share of the cashed fine would be paid to the one who prosecuted the claim. In this way, every *vicino* had incentives to monitor the common land.
Free riding by outsider could also occur in the form of immigration to the village and subsequent acquisition of the status of legitimate user. To prevent this behavior, some rural Charters required a payment of an annual fee for using the commons and the approval of the other *vicini*.

To sum up, the rural Charters are contracts - among the insiders on one hand and with the political authority on the other hand - that contain the formal regulations established to manage the common forests and pastures, beside other things.
People were either *vicini* (insiders), legitimate users of the resource, or *forestieri* (outsiders). The interaction among the *vicini* was repeated thanks to a specific design of the property rights on the common resources. The *vicini* knew one another since the average size of a community was small because of the partitions. They did not however perfectly observe all the actions of the others. Guards were appointed to monitor the actions of both *vicini* and *forestieri*.

4. PARTITIONING, AN INSTITUTIONAL INNOVATION

Partitioning the commons was a beneficial process provided that the common land was sufficiently extended and the group of users sufficiently large. Most of the splitting process was completed relatively early in time (XIVth century) and continued later on at a slow pace [26]. This section shows with a simple formal model the gains from partitioning in the case of 'tragedy of the commons'. An unavoidable question to answer is why the process did not lead to individual ownership, since according to the model it is the optimal arrangement. I will argue that partitioning entailed additional costs to enforce property rights toward outsiders not considered in the simple model, which made extreme partitioning inefficient.
Anecdotal evidence suggests the importance of the topography of the region and of the length of borderlines in affecting the cost to restrict trespassing by outsiders.

What does 'partitioning' mean, anyway? Given a group of N people and a resource L, a partition involves the division of the resource L into P mutually disjoint parts, $L = \cap_{i=1,..,P} L_i$, $L_i \cup L_j = \varnothing$ for

regulated in the rural Charters (see table 2). Switching from village to individual ownership would does not exempt from the need for external enforcement of property rights.

[26] Rural charters provide some but not complete information about splitting among villages and tax registers could give data about residents at a village level. Partitions should depend on population size only if there was no cooperation in the use of the commons (the tragedy outcome) or if bargaining costs for formal institutions were growing with the group size. No correlation should exist if splitting was done to reduce the noise level of the signal about the stock of resources (informal regulation).
I did not test the conjecture that the number of partitions was positively correlated with the population of the communities. For the pattern of population growth see table 1.

any $i \neq j$, and the allocation of the people to P distinct groups, $N = \cap_{i=1,..,P} N_i$, $N_i \cup N_j = \varnothing$ for any $i \neq j$, such that people in N_i have the exclusive right to use just the resource portion L_i.[27]

The potential benefits of partitioning originate from a different source according to the initial level of cooperation in the use of the commons. This section addresses only the case where there is no cooperation among the insiders. Partitioning is beneficial because the single user takes more into consideration the damage that his action is having on himself and hence reduces the overuse of the resource. To give an example of the magnitude of the gain consider a group of 100 users of a resource L, that is split into two groups of 50 people each using half of the resource L/2. The increase in the rent overall extracted from the resource L is more than 96%, according to the simple model that is described below.

Consider a common resource L that yields revenues according to a parabola function similar to the one in figure 1. A group of N identical users take simultaneously and independently the decision to harvest a quantity q_j of resource. Harvesting involves a positive cost linear in the quantity q_j and the users are left with a profit given by the difference between the revenues appropriated and the costs borne (rent). We can compute the maximum group rent $\Pi(L)$ that can be extracted from the resource, which is a technical parameter, and the rent extracted in the symmetric Nash equilibrium of this game, $\pi(N,L)$.

$$\pi(N,L) = NE(N)\ \Pi(L)$$

where $NE(N) = \frac{4N}{(N+1)^2} \leq 1$ is the coefficient that rescales the maximum rent to its Nash equilibrium value. It is easy to verify that the rent extracted is negatively correlated with the group size, $\partial NE/\partial N < 0$. The mathematical details of the derivation can be found in the appendix. After a partition, the total effective rent will be:

$$\pi(P, \{N_i,L_i\}_{i=1,..P}) = \Sigma_{i=1,..,P}\ [NE(N_i)\ \Pi(L_i)]$$

If we assume constant returns to scale in the technology of the resource $\Pi(L) = \Sigma_{i=1,..,P}\ \Pi(L_i)$ then partitioning induces an overall higher rent, $\pi(P, \{N_i,L_i\}_{i=1,..P}) > \pi(1, \{N,L\})$ for any number of sub-units $P>1$. In practice, the smaller the sub-units and the better the outcome.

< Figure 3 about here>

When does the partitioning process stop? Partitioning could go on until there is individual ownership on the land.[28] One of the limiting factors is the increasing cost of enforcing new external borderlines. This cost was a real burden of resources. The expression of the total rent after partition should include an additional component $B = \Sigma_{i=1,..,P}\ B_i$ representing the extra costs, induced by the partitioning, for enforcing property rights toward trespassing from outsiders, $\pi_B(P, \{N_i,L_i\}_{i=1,..P}) = \pi(P, \{N_i,L_i\}_{i=1,..P}) - \Sigma_{i=1,..,P}\ B_i$.[29]

[27] I use the symbol N_i to indicate both the set and the number of elements in that set.

[28] In this paper, I do not tackle the question of the efficiency comparison between individual and common ownership of the land. I had discussed it in a related paper (Casari, 1998).

[29] Given a number of units P, the rent extracted $\pi_B(P, \{N_i,L_i\}_{i=1,..P})$ can be thought as the optimal rent for all the possible partitions and borderlines $\{N_i,L_i,B_i\}_{i=1,..P}$. The cost of enforcing borderlines B is obtained through the above joint optimization procedure. B is affected by the topography of the region and so different region can result in different π_B.

I model the cost of keeping outsiders from trespassing on the land B as affected by both the length of the borderlines and the topological features of the land nearby the borderline. Both involved costs increasing in the number of parts P.
It is a simple geometrical consideration that the ratio between the length of borderlines in an area goes up as the area is divided into more parts. Whenever the cost of enforcing property rights is positively correlated with the length of borderlines, partitioning will cause an increase in B.
The cost of a partition was also heavily affected by the topography of the area. In a mountain region like the Trentino, drawing property borders can be very easy if a river or a mountain range is taken as a reference. Natural landmarks often provided very effective barriers against trespassing and as such substantially decreased enforcement costs toward outsiders. There are several clear examples. A colorful one is the case of the villages of Romeno, Don, and Amblar that owned together a side valley mainly covered by forest. The valley was delimited on three sides by steep mountains and in the only side where the access was feasible, the entrance was so narrow that villagers built a gate on it and provided the gate with a lock. As the 1459 Charter states, the only key was kept in the church of the village. In this way the community governor could have easily controlled everybody who went into the valley to log trees[30]. There are other examples. The village of Daone was located at the sole entrance of a side valley of which the villagers were the exclusive owners. The *Comun Comunale* was a cluster of several villages whose borders were the Adige River on one side and a mountain range on the other side. They had a unified administration of the common land. The topographical structure of the territory often provided an answer to how to partition the land. Once the "best" natural landmarks had already been used to mark property borders, however, further splitting of the communities involved greatly increasing costs.

The increasing costs to enforce property rights toward outsiders ($\partial B/\partial P>0$) could be the crucial factor in explaining why we still observe communal ownership, that is $P<<N$, when the production technology exhibits constant returns to scale. When the initial size of the land L was already small, however, splitting forests and pastures into smaller plots resulted, if something, in a loss in the total rent. Under conditions of increasing returns to scale, $\Pi(L) > \Pi(L_1) + \Pi(L_2)$, the production technology of forests and pastures makes the claim that there were increasing costs associated with partitioning stronger.

In the absence of regulations, the arrangement of a region into many small units each one holding common ownership on forest and pasture could have an advantage over a single large unit. When there are formal or informal regulations, a pattern of small communities could be seen as a safety net in case cooperation, formal or informal, breaks down.

5. LONG-TERM RELATIONSHIP OF INSIDERS

We observe a de-facto long-term relationship among the *vicini*, which is a necessary requirement to apply the Folk theorem. That was not a 'natural' condition but the intended consequence of the type of chosen property rights arrangements on the commons. This section illustrates the specific content of those property rights in terms of freedom to leave the village, to sell and divide up the common land. Emigration - the freedom of individual insiders to leave the village if they wish - was possible

[30] The reference is to the villages of Romeno, Don, and Amblar. Regulation of the gate is mention in the 1459 rural Charter (chapter 24: *Item che la chiave della porta di Vallavena sia tenutta et conservatta nella sacrestia della chiesa di santa Maria di Romeno*).

but costly. Selling or dividing the common land was possible only with the consent of a large majority of the owners. These details were as important as few in ensuring that the interaction was repeated and hence that we can apply Folk theorems to this situation.

I have assumed so far that the interaction among the *vicini* was indefinitely repeated because the probability that the interaction took place the following year was so high that we are as close as we can get in a real world setting to the theoretical assumptions of the Folk theorems. The same family names can be found in the same small village and nowhere else literally for centuries [31]. What was the reason for not leaving the original community? People had the political freedom to leave the village if they wanted and the option to leave could have wrenched agreements based on the assumption of an infinitely repeated interaction.
I will argue that it was costly for single members to abandon the community because of the specific form of property rights on the commons. It was precisely the content of the communal ownership rights that locked-in the peasants in a community and ensured a long-term relationship.

The peasants were not forced to live in the village. They used to migrate seasonally to the nearby Veneto and Lombardia. In the beginning of the Nineteenth century, every winter there was a flow of few thousand workers going outside Trentino (Perini, 1852). This temporary emigration activity had been going on for a long time (Grosselli, 1999).
Emigration could take place also toward villages within the Trentino, granted that the newcomers would be accepted. The multiplication of the number of separate communities might have made the assumption of an infinitely repeated interaction *within the same unit* more problematic.

The crucial point is that there was no individual right to secession from the community. Anybody could leave, but no claim could be made of the community common resources. The villagers were locked-in into a long-term relationship one with another because the decision to individually leave the community in which a peasant was born involved losing the right to use the common land. No Charters ever mentions the right of a *vicino* to be refunded of the value of his share of common land in case he leaves the community, let alone the procedures to satisfy that right. On the contrary, there are indications of additional punishments added to the decision to leave. The 1647 Charter of Nago and Torbole dictates that if a community member did not live any more in the village (*non ha fuoco*), he could not use the common resources. In addition, if he returned to the village, he had to contribute since the year of his return to the community chores (*obblighi* or *fattioni*) but could not use the common forest and pasture for one additional year [32].

An issue related to the freedom to emigrate was the right to sell or divide up the commons. They constitute two different ways to terminate the interaction in the use of the commons through an internal decision of the *vicini*.

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[31] Some Charters report at the opening the list of the heads of the families present at the meeting.

[32] From Statuti et Ordini della Spet. Communità di Nago e Torbole (1683): Nago and Torbole, 1647: "*Cittadini, che non habitaranno non possino goder beni communi*" (c.73: They cannot bring timber outside the village borders; they can use the common land only if they still have individually owned land in the village). "*Cittadini, che partono dal commune, et ritornano, che non possino goder beni communi, se non passato un anno*" (c.74). There is probably a relationship between the location of these two communities nearby the huge Garda lake and the very detailed regulations contained in their Charter for people who where leaving the community, temporary or definitely.
See also Tres, 1551 (the 1599 modifications regulates the *vicino* status).

Was the right to sell or divide up the common land a threat for repeated interaction? It could have been because absolute inalienability and indivisibility of the commons were not cornerstones of the historical form of common ownership in Trentino. On the opposite, a community had usually the right to sell the common land and to divide up the land into individual portions. This right to sell the land was sometimes subjected to the authorization of the feudal authorities. The right to sell was not undermining a repeated interaction because the right to sell did not entitle a *vicino* to alienate his share of common land to others but it was a collective right that belonged to the community as a whole. Such right was not a threat for a long-term relationship as long as the consent of a wide majority of the owners was needed for the alienation decision[33].
Parcels of the common forest and pasture were sometimes assigned to the members of the community in exclusive individual use[34]. This assignment has been interpreted as an early form of individual ownership (Papaleoni, 1892) but it remained in many ways closer to common than to individual ownership. The assignments were internal arrangements and the external legal property rights on the land always belonged to the community. In fact, when a member left the village, he had to return also his individual assignment to the community because it constituted a proper portion of the common resource. Whenever the single peasant could transfer his rights on the assignment, the buyer had to be a member of the community. The villages of Nago and Torbole for instance sold part of their common forest to an outsider and divided up another portion of their forest into individual assignments[35].

The individual *vicino* had the right to use the common resources according to the community rules and the right to participate in shaping those rules. Only the group could decide to rent or sell the common land or to partition it and assign the parts to a temporary individual use.

All those rights did not undermine the basic lock-in effect just described because the legal property rights of the common land belonged to the community *as a whole* and when a member left the community he had no right to obtain a refund of his share of the comm on land. He could not sell or rent his membership right either. He could sell his individually owned house and fields but no benefits could be obtained from the common land while he was away and the right to return was sometimes restricted.[36]

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33 For an example in Cagnò 1587, selling the land was subject to the approval of the local landlord (c. 3, modification of 1693). Some authors interpret the absolute prohibition to sell the common land as a pivotal aspect of the traditional land management of the Trentino communities (Andreatta and Pace, 1981). In this paper I argue that this statement is not empirically correct and that it is not a requirement from a theoretically point of view to ensure a long-term relationship among users. A qualified majority of at least 2/3 was required to sell the common land in Cles 1641, c.5 and in Cis 1587, c.80. See also note 11. An interesting discussion about the role of tradability of property rights in the commons can be found in Seabright (1993). Notice, that the right to be a user or a *vicino* were not tradable.

34 Individual assignments were in fact family assignments. Meadow assignments can be found in Pradibondo 1221, Condino 1340-3, Storo 1347, Nago-Torbole 1533, Caderzone 1591 (Papaleoni, 1891, Papaleoni, 1892, Valenti, 1911, Dossi, 1927). Forest assignments can be found in Storo 1347, Nago-Torbole 1541. Many other rural Charters mentioned temporary assignments of meadows (*sort*), though sometimes the wording is ambiguous.

35 See Dossi (1913) and Dossi (1927)

36 In the modern regulation of joint ownership on land, any owner can usually ask to leave the group and obtain a fraction of the estate or a cash refund equivalent to her ideal share of ownership of the estate. Moreover, the ideal share can be sold to an outsider in exchange of money. None of these options were available in the Trentino villages.

6. TRESPASSING AND MIGRATIONS

What makes the difference between an open access resource and a common ownership resource is the effective exclusion of non-legitimate users that characterize the latter arrangement. With open access, it is useless for the insiders to limit the overuse of the resource or partition the land. The very same legal distinction of insiders from outsiders is meaningless. In the rural Charters there are provisions to stop immigration and trespassing from outsiders. Immigration was kept under co ntrol both through a request of a payment of an annual fee for using the commons and the acceptance of the newcomer by the *vicini*. Trespassing was everywhere illegal and appointed guards were in charge of enforcing the ban.

The common forests and pastures were not open access resources, neither legally nor in practice. The commons had a well-delineated group of users and defined boundaries. Their access was closed to outsiders since there were restrictions on moving taking place across community borders an d a virtual prohibition of trespassing on the common land. Without close access, partitioning the commons would have not brought any benefit.

The rural Charters contain legal regulations aimed against free riding by outsiders on the community resources. In particular, the Trentino communities developed a form of village citizenship that heavily limited the rights of any stranger to enter a new community. Moreover, guards were appointed every year in order to patrol the common land and practically enforce the legal prohibition of trespassing especially when the purpose was of stealing or damaging village properties[37].

The most rewarding free-riding action was probably to settle down in a new village and after a while being admitted as *vicino* and with it acquire full rights in the use of the commons. That was apparently a fashion in the late Sixteenth century and the preferred destination was the high mountain Fiemme Valley. Up to 1582, in the Fiemme Valley the right to be a *vicino* was inherited by both sons and daughters of a *vicino*. Since the endowment of common forests and pastures was definitely richer in Fiemme than in other communities, men from other villages tried to marry women from the Fiemme Valley. The practice became so widespread that the assembl y of the *vicini* of Fiemme decided at one point to restrict the inheritance of commons' rights to sons only, as it generally was in most of the other Trentino communities. The community governor argues for the need of the new rule in a letter to the Prince dated 16 November 1583. [38]
More generally, there were incentives for some people to "vote with their feet" when the per capita income from the common resources was different across communities. We might expect an attempt

[37] When the community size shrank, the efforts required to enforce such regulations in general increased because by definition there were more outsiders and borderlines were longer relative to the land size.

[38] A letter from the governor (*Scario*) to the Prince dated 16 November 1583: "*Et perché da uno tempo in qua molti forestieri se maridano in done de Fieme solamente per haver detta vicinanza, et questi tali forestieri continuamente hanno fato e fano assai desordeni et dani in li boschi de essa Comunità* …". Reported in Delugan and Visani (1988), p.54.
For an example of male inheritance of the right to use the commons see Tres 1551 (and modification of 1599, chapter 102 and 103).

of the members from the "poorest" communities to move toward the "richest" communities. As a consequence, we are more likely to observe explicit immigration regulations where highest was the per capita endowment of common forest and pasture. Some rural Charters do not mention rules to accept newcomer and the reason might well have to do with the fact that nobody ever wanted to move into those "poor" communities[39].

In short, immigration regulations consisted in requiring a payment of an annual fee for using the commons and in obtaining the approval of the *vicini*. Admission of a new user on the commons reduced the amount of resources appropriated by the older users. The newcomer annual fee was a compensation for that loss.[40] Admitting additional users meant giving away a share of the claims on the resource profits that is alienating a portion of the property rights. Interesting enough, in 1671 the peasant assembly of the village of Cis stated - in the very same article of their Charter - that admitting a new member had to be deliberated with the same majority as the one adopted for selling the common land[41].
The annual fee was usually assessed on a case-by-case basis and in proportion to the expected use of the forest and pasture, looking at the size of the family or the number of animals owned [42].

Some Charters make the consent of the general assembly of the *vicini* an essential condition for admission. When required, the needed consent had to be unanimous or nearly so [43]. A point that was stressed in the evaluation process of a newcomer was his reputation as an honest man. The assembly of Cles required from prospective residents convincing proofs of an honest life and of decency [44]. Reputation was highly estimated in other aspects of the community life: only somebody with good reputation (*buona fama*) or worthy of trust (*degno di fede*) could be accepted as a witness in trials (see

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39 See lines 4 and 5 of table 2 for the frequency of immigration regulations. I did not test the conjecture mentioned in the text. McNetting (1976) noted in reference to Swiss peasant communities that empirically the closing of the community to immigration appears to have been an internal decision. I hereby suggest why that was the case in the Trentino communities. Other scholars (Wolf, 1966) argue that the decision to close the community was due to the external influence of the political authority whose goal was to make the village responsible for the payment of tributes and corvee labor.

40 When the overall annual income from the common resources is represented as a pie of a given fixed size, the addition of another user reduces the share of the others. In the case of no cooperation among the insiders, not only the slices of the pie of the old members would thin but the very same pie would shrink in size.

41 See the modification to Cis, 1587, chaper 80: "*… alienare beni comunali o ricevere alcuno forestiero per vicino se meno di 3 vicini son contrari*" .

42 For example Cles, 1641,c.57: "*Che li forestieri habitanti nella communità di Cles siino colettati dalla regola per l'honesto in loro arbitrio, considerando la loro qualità et animali che tengono sopra li comuni, et in più concorrino ad ogni cosa ordinaria et straordinaria come li vicini,…*". See also Tres, 1551 and following modifications.

43 Cis, 1587 (all but 3 dissenters), Cles,1641, Tres, 1551 (unanimity required in 1599)

44 Cles 1641 (modification 1719, c.2, "*attestati autentici della sua buona vita et costumi*"). In addition from requiring the prospective member to give good references about his reputation, Nago and Torbole required some form of real warranty in case of mis-behavior. For instance, see Nago and Torbole 1647, modified in 1670, c. 72: outsiders cannot stay in the village for more than 3 days unless they own a piece of land or a house (*stabili*) worth at least 200 *fiorini* . No outlaw could be accepted (*banditi* or *ricercati*).

table 2). Those who have been proven to be of the non-cooperative type could be potentially disruptive for the whole community[45].
The right to use the common land was tied to the designated person. The right belonged to an individual because of the very fact he was an original or adopted member of the community and could not be alienated neither to an outsider nor to an insider. The right was not contingent to the ownership of land in the village[46]. The new users were still considered outsiders, *forestieri,* and could not transmit to their offsprings the right to use the commons.

While sneaking into the community as a new member would hardly go unnoticed, outside free-riders could devote their attention to a more classical activity, trespassing. A stranger was never allowed to enter the common land to harvest or damage village resources. The rural Charters are unanimous on this point (see table 2). Outlawing the activity though was not enough to eliminate it. Appointed guards (*saltari)* were in charge of the practical enforcement of the legal no-trespassing prohibition.
Not all trespassers were caught. If that was the case, nobody would have dared into the village land with bad intentions since a trespasser was asked to refund the market value of whatever harvested and in addition to pay a penalty. We know from historical records that there were violations of the established rules about the use of the common resources by both outsiders and insiders. For example in the 1634-35 administration booklet of the community of Coredo, there is a note that Mr. Berto Sichero gave *troni* 3 and *carantani* 4 because he illegally cut a larch tree in the forest. In the year 1677-78, there is a list of ten fines cashed from outsiders[47].
Catching an intruder who appropriated the common timber or hay was beneficial for the community. Detecting and convicting him were, however, costly. We could assume that the trial involved a constant cost while the cost of monitoring the land was increasing with the degree of its completeness. If we assume that as the enforcement of property rights becomes complete its cost

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45 I will advance three reasons for it, not incompatible between them. Since individual actions could not be fully monitored, the community wanted to screen-out people that systematically cheated in the past. They did not want temporary members that could not be punished after they left the community. More generally, they wanted to exclude persons that exhibit weak incentives to cooperate, such as those who would succumb to violent angers or revenge feelings.

46 The right of being a *vicino* (*diritto di vicinia*) was not tradable and could not be cumulated so that one had multiple rights in the community. In a more general comparison, Stevenson (1991) reports that grazing rights on the commons were personal in Switzerland while praedial in England.
In Trentino the right was not linked to the ownership of land (Delugan and Visani , 1988). In the village of Tres (Tres 1599, c.101, 107, 108), the benefits from the common land were suspended when a member lived outside the village, unless he had individual ownership over land or houses. This fact does not contradict the argument that the right was personal and not real. As some Charters makes clear (Cavareno 1632, c.70, Romallo 1598, c. 81, and a 1710-32 modification to the same rural Charter of Tres), the estates were just a warranty that the person would contribute as he promised to the costs of the collective institutions of the community ("*Item se alcuno vicino della villa di Cavareno, non possedendo beni in detta villa, habitasse fuori di detta villa, non possi godere né meno prevalersene delle sorti, né meno quelle ad altri vendere, perché non possono fare le fattioni ordinarie et extraordinarie come fanno gli altri vicini che habitano in detta villa: ma, presentando una segurtà idonia laudatta dalla comunità, se gli debbano dare le sue sorti: altrimenti sia excluso delle dette sorti*.").

47 In the *Libri de Conti della Honoranda Comunità di Coredo* there are many reports of fines: "*per due larici taliati nel ingazato, e venduti a Sfruz*" (1672-73), "*per haver tagliato un pez dent in sas nella sorte*" (1673-74), "*per il valor di legni menati dal monte con buoi forestieri senza licenza*" (1677-78), "*ricevuto per condane fatte alli sottoscritti come forestieri*" (1677-78). The record for Berto Sicher, which is a typical last name of inhabitants of Coredo, is "*per un lariseto taiato nel Boscho*" (1634-45).

goes to infinity, a partial enforcement was socially optimal and that might explain why outsiders s till attempted to trespass.

I assume that (i) outsiders' actions were detectable at a cost, (ii) such monitoring cost was increasing in the probability to detect the trespassing action and moreover (iii) as the probability *po* to observe the action approaches one, monitoring costs *mo* go to infinite. We can model this concept with the function $mo(po) = \frac{po}{1-po}$, where $po \in [0,1)$.

The interaction between the potential trespassers and the community is modeled as a game where the community has the powers to impose and cash fines on trespassers when they are caught. A trespassing action involved harversting a given amount of resources *d* that is subtracted to the community profits. As explained monitoring was costly, but no extra deadweight loss i s in the model for the activity of collecting the fine. A decision based on a cost-benefit analyses would have considered the loss of resource caused by trespassing, the revenues from the fines, as well as the monitoring costs:

$\max_{\{po\}} \{-d \cdot M(po) + f \cdot po \cdot M(po) - mo(po)\}$

Where M is the expected number of trespasser attempts, $M = \pi^* / (d + f \cdot po)$ and π^* is the actual rent enjoyed by the insiders from the common resource. The number of trespassing attempts in equilibrium M* is a proxy for the degree of enforcement of the property rights toward outsiders. The enforcement could be improved by increasing the expected sanction of trespassing $f \cdot po$.which could be done either by boosting monitoring activity or increasing the nominal sanction *f*. I call the enforcement complete when there is no expected attempt to trespass, M*<1, but it is not clear if complete enforcement is the optimal policy. Given a level of punishment f, the optimal monitoring policy in general involves some positive effort but not detecting every sing le trespassing, $0 < po^* < 1$.[48]

In theory, raising the nominal amount of the fine *f* could ensure complete enforcement. Figure 4 illustrate the relationship between the number of trespassing attempts and the amount of the fine.

< Figure 4 about here>

In practise, there was a ceiling to the maximum fine due both to economic and legal reasons. Most of the peasants were poor and did not own much that could be taken away in order to pay the fine. Setting a fine higher than the value of their belonging did not nece ssarily increase the threat of the punishment. Moreover, the enforcement formula above do not explicitly include a measure for the cost of collecting the fine from the trespasser, which was probably increasing with the amount extracted[49].

Besides these economic considerations, the rural communities in Trentino could not legally establish fines above a maximum amount set by the central political authority. A 1586 ordinance of the Prince of Trento called the *Moderatio Betta* sets a limit of 5 *ragnesi* for any fine stated in the rural Charters. The Prince granted some self-governance powers to the local communities but did not want them to substitute the ordinary courts and laws on more relevant issues. Physical punishments, for instance, were not allowed becaus e criminal law was the exclusive realm of feudal authorities.

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[48] Under some quite reasonable conditions ($f > d/2 \cdot \pi^*$ and $f+d>0$) there exist only one acceptable solution $0 < po^*_1 < 1$ while the other solution is too big, $po^*_2 > 1$. The solutions are both equal to 1 in the degenerate case when f+d=0, which is not possible since by assumption d >0 and f≥0.

[49] A different enforcement formula could be:$\max_{\{po\}} \{-d \cdot M(po) + f \cdot po \cdot M(po) - mo(po) - k \cdot f^2 \cdot po \cdot M(po)\}$, with k >0.

The provision of a maximum fine was an external constraint mainly dictated by political reasons. The rule was binding on the communities as it is evident by the many attempts to include higher fines and from the subsequent censoring from the Prince burocrats when approving the Charters. Once we introduce a binding ceiling *f "* to the amount of the fine, then enforcement of property rights toward outsiders could have been incomplete[50].

The rural Charters contain vigorous rules to enforce property rights of the common land toward outsiders. There is a universal concern for trespassing and a more selective regulation of immigration by outsiders. In general, enforcement of borderlines was incomplete because of monitoring technology and because of the upper limit on punishments available to the community.

7. REGULATIONS OF THE INSIDERS: FORMAL OR INFORMAL?

This paper claims that in the distinctive situation of the Trentino communities, we cannot in general state the superiority of informal regulation in the management of the commons over formal regulations. The comparison is between two second-best outcomes and the arrangement that can deliver a higher income stream to the owners of the resource is likely to vary according to environmental conditions such as for example informational conditions and monitoring technologies. The fact that through the rural Charters formal institutions were established to manage the commons instead of relying on informal regulations does not clearly contradict economic efficiency.

By informal regulations I mean self-enforcing rules that do not require an authority external to the individual and in particular I refer to those strategies adopted to reach the best outcome in an infinitely repeated social dilemma. I will discuss the specific version of the Folk theorem that applies to a situation of imperfect monitoring of the individual actions that characterized the rural communities that I have described, namely the Green-Porter model.[51] The basic relationship stated in the model is that the noisier the signal about the status of the resource and the worse will be the best feasible outcome that can be reached. In equilibrium, agents cooperate as long as they observe that the resource is in good enough status and they revert to a punishment mode for T periods otherwise. In general the best Green-Porter outcome while in the cooperative mode is sub-optimal and has of course very poor performances during the punishment mode. Both types of cost increase with the noise level.

When I apply the Green-Porter model, I consider a small community with a group of users engaged in an infinitely repeated interaction among them. The insiders cannot observe each other's actions but can rely on the noisy observation of the status of the resource to infer the cooperation level of the group. There could be an additional source of noise about the stock of the resource signal given

[50] For the text of the *Moderatio Betta* see for instance Salter e Malgolo, 1586. For a comment on the *Moderatio Betta* see Welber (1992). Did the case of censored fines refer to enforcement toward outsiders? The punishment ceiling f" is binding when the amount f* defined by M(f*,po*(f*))=1 is such that f*>f".

[51] There might be other possible variations of Folk theorems that are more suitable to this specific case but either I am not aware of them or they have not been proven yet. The fact that high levels of cooperation are not sustainable according to the Green-Porter model does not mean that they are impossible to achive. In particular some combinations of partial knowledge of individual actions and noisy knowledge of the status of the resource might be enough to improve the set of Green-Porter feasible outcomes. To sum up, the Green-Porter model provides sufficient but not necessary conditions for a given outcome.

by the chance of thefts from outsiders. This additional noise might lower the level of attainable cooperation levels.

In a deterministic situation the appropriation level of insiders can be unmistakably inferred from the observation of the status of the resource $Q=f^{-1}(S)$, when the technology f is common knowledge. In practice, the signal about the status of the resource is perturbed by some white noise: $S+\varepsilon = f(Q)$, where $\varepsilon \sim N(0, \sigma^2)$. In addition, when outsiders trespass and appropriate some resource without being observed they add an independent source of noise on the above relationship: $S+\varepsilon = f(Q+Z)$, where $Z \equiv d \cdot A$ is the quantity of resource illegally harvested by outsiders. The variable M is the expected value of the random variable A, $M=E[A]$. The appropriation from outsiders can be model as a non-negative random variable $Z \geq 0$, $Z \sim (z, \eta^2)$ that is independently distributed from the observational error ε, $Z \perp \varepsilon$. Given what we observe about the resource $(S+\varepsilon)$ the inference about the appropriation level of insiders is now more uncertain [52].
The level of uncertainty in the relation between the cooperation level Q and the signal about the status of the resource is affected by both the size of the commons (which is related to σ, the standard deviation of ε) and by the efforts in enforcing property rights toward outsiders (which is reflected in η, the standard deviation of Z). Suppose that the variance term η is negatively correlated with the level of monitoring of trespassing actions *po*. In that case a higher monitoring effort generates a less variable pattern of trespasses, which in turn improves the signal about the cooperation level of the other agents in the group and hence raises the attainable rent.
When a higher monitoring efforts generated a less variable pattern of trespassing actions, the efficiency of the enforcement of property rights toward outsiders would affect the Green-Porter equilibrium. In particular, the existence of this additional and variable source of noise makes the welfare property of the Green-Porter equilibrium worse and the problem of assessing change in the degree of cooperation less tractable.
What is the effect of partitioning on the Green-Porter equilibrium? Partitioning is likely to reduce the noise related to ε because of the smaller size of the commons. It is however likely to increase the noise related to Z because partitioning makes monitoring trespassing actions more costly. The net effect on the best feasible outcome is ambiguous when we take into consideration the external enforcement of property rights.

I define formal regulations as rules with legal value that rely on the threat of a court injunction. In the management of the commons they were typically individual quotas as well as temporal or spatial limits to appropriation. "Nobody can cut more than three trees in a year, except if they have to build a house", "Nobody can mow the hay on the high mountain meadows before July 15", "Nobody can graze with goats in the woods nearby the village". If anybody was caught doing so, he would be asked to refund the damage and pay a fine to the community officer.
Hence there is a restriction in the use of the commons, an explicit effort to observe individual actions, and an individual fine in case of an observed violation.

Formal regulations of insiders exhibit advantages and disadvantages in comparison with informal regulations.
The basic two advantages of a legal enforcement system over informal regulations are that punishment is tailored on the individual responsible for the socially harmful activity and that part of

[52] Because $Var[Q] = Var[f^{-1}(S+\varepsilon)] + Var[Z]$ and $Var[Z]>0$.

the punishment is a simple transfer of resources to the community as a whole. Targeting the individual allows to modify her incentive structure without harming the others in the group. Ideally the whole punishment should be a transfer of resources but the resources necessary to run the institutions responsible for the enforcement are a deadweight loss for the community [53].
The two disadvantages of formal regulations are the need to monitor individual actions of insiders and to build institutions to prosecute free riders and enforce payments. Monitoring outsiders is a pre-requisite also for informal regulations. I assume that there were strong economies of scale in monitoring both outsiders and insiders and so the additional cost of monitoring insiders was likely to be small. Setting up rules to use the commons and a court system to enforce them was costly and tuning the institutions to changing external conditions was also costly.
Given the deadweight losses of developing the formal institutions and the recurrent cost of monitoring insiders, formal institutions could at best deliver a sub-optimal outcome.

The costs to monitor insiders *mi* could be thought as similar to the one for outsiders, *mo*. I assume that the joint activity of monitoring outsiders and insiders, *m*,
(i) exhibits some economies of scale because the guards that are on the common land to patrol for trespassers can detect violations by insiders at a low additional cost, $m(po,pi) < mo(po) + mi(pi)$, for any $po,pi>0$;
(ii) The function *m* should reduce to the elementary functions *mo* and *mi* when one of the target groups, either insiders or outsiders, is not monitored, $m(po,0) = mo(po)$ and $m(0,pi) = mi(pi)$;
(iii) The joint activity should be still more expensive than one single component carried out independently, $m(po,pi) > mo(po)$ and $m(po,pi) > mi(pi)$, for any $po,pi>0$.
The cost function $m(po,pi) = mi(pi) +(1- s\cdot pi)\, mo(po)$, where $0<s<1/2$ for example satisfies properties (i) through (iii) [54].

Formal regulations rely on a set of institutions that need to be built, which are a sunk cost. The vicini had to agree upon a set of rules and finance the monitoring activity and the court system. Writing an official document like a rural Charter involved non-recoverable costs and spending time in the community meetings to listen and vote on an endless list of small issues was also costly [55]. This form of organization was efficient only when the number of interactions among the insiders was above some threshold. If that was the case, we could also explain why social sanctions were not the main way to enforce rules.

Social sanctions are an alternative informal way to enforce rules that could be use for instance instead of a tit-for-tat strategy. There was no shortage of social sanctions that could have backed up the enforcement of the desired outcome because the people living in the same village were involved at in several other interactions besides the use of the common resource. A free-riding behavior on the common resource could have been punished with a denial of a credit, with the refuse to rent a

[53] The fact that we do not often observe formal regulations also in oligopolistic markets is because cartels are illegal contracts. In order to overcome the unavailability of the otherwise convenient way of enforcing the agreement through courts, the oligopolistic firms use Folk-theorem type strategies.

[54] The function is $m(po,pi)= \frac{pi}{1-pi} + (1-s\cdot pi)\frac{po}{1-po}$. Property (i) is obvious since $(1-s\cdot pi)<1$. The two properties (ii) can be easily verified by substituting pi=0 or po=0. The first of properties (iii) is verified when $m(po,pi) - mo(po)>0$, which reduces to $x>1-(1-s)/s\cdot po$, which is true when $s<1/2$. The second of properties (iii) is verified when $m(po,pi) - mi(pi)>0$, which reduces to $x<1/s$, which is true when $s<1$.

[55] There was often a fine for the vicini that did not show up at the village meetings (Table 2).

privately owned field, or the rejection of a marriage proposal. Inflicting individual punishments requires knowledge of individual actions and hence monitoring was still necessary but there was no need to build costly institutions as with legal regulations.
Despite this advantage, the community adopted formal sanctions where community officials were in charge of punishing the individual defector through a monetary fine. In fact, when violations of rules were sufficiently common, a social sanctioning system was less efficient than a legal one. A social sanction entails a loss for the agent who inflicts it as well as for the targeted agent. At the societal level social sanctions bring to destruction of resources. A legal sanction instead is often voluntarily paid (under the threat of violence by higher authorities) and is a transfer. Its aim is to be costly for the targeted agent, but at the community level there is no destruction of resources besides collecting costs.[56]

In conclusion, given the data available I cannot state that the choice of formal regulations was inferior to informal regulations on efficiency grounds.

8. CONCLUSIONS

I have analyzed in some detail the institutions governing the use of the common forests and pastures in the Trentino communities in Northern Italy. The evidence reported from the rural Charters roughly ranges between the year 1200 and 1800 and has focused on the relation between two different theoretical ways of managing the commons through formal or informal regulations, respectively. The initial lead was to find out why the peasants decided to set up costly formal regulations instead of relying on informal self-enforcing cooperation agreements. As we know, when the interaction is infinitely repeated and the agents are sufficiently patient "almost any feasible payoff allocation that gives each player at least his minimax security level can be realized in an equilibrium of the repeated game" (Myerson, 1991).

The paper has two main conclusions. The first is that informal regulations of the Folk theorem type would have not been possible in the vacuum of institutions. Formal regulations were needed to ensure that some fundamental requirements for informal cooperation were met in the field. In the peasant communities studied, two features were essential in order to implement any informal agreement:

(a) A specific property rights arrangement on the commons to lock-in the insiders in a long-term relationship
(b) A formal system of enforcing property rights toward outsiders, in particular against trespassing.

Through the rural Charters the central political authority granted to the local communities the powers to craft property rights on land and establish low-cost enforcement mechanisms.

[56] In addition to this economic reason there are probably sociological and anthropological aspects that deals with the risk of social disruption due to unlimited revenge (Girard, 1972). The risk is higher when there is not a well-defined norm for how much punishment should be considered enough. I will not enter into this debate that I consider relevant for a better explanation of the institutions we observed. I will only mention that in the Trentino region there were more than one instance of witchcraft craze during the period here under scrutiny: Fiemme Valley, 1501; Valley of Non,1612 (Cole and Wolf, 1974, Stella, 1987).

The second conclusion is that the preference for formal over informal regulations made by the Trentino communities has turned out not to be a puzzle. Because of the imperfect informational conditions, it is well possible that formal regulations could have performed better than informal regulations on efficiency grounds. Both forms of regulation were sub-optimal because their implementation involved costs.
In the specific case, the choice might have been dictated by reasons different from efficiency such as bounded rationality, need to coordinate on a common equilibrium, distributional issues, or relation with the political authority. Efficiency, however, might as well have been the most important issue. This study was unable to prove that the choice of formal institutions in that historical context was inefficient.

If static efficiency was the actual reason for the chosen institutional arrangement, we need to address the question of why there was a need of repeated interaction and partitioning at all since the actual choice of the communities was for formal regulations. In my opinion there was a need of a long-term relationship because of the cost of creating and maintaining the formal institutions. Only individuals motivated by the expectation of long-term future benefits would engage today in irrecoverable costly investments like serving a term in a community office with no honorarium or struggling to craft better institutional rules. Partitioning might have been instead an attempt to reduce bargaining costs within the community. These explanations need however to be better investigated.

I will mention three limitations of the study. I assumed that the main economic focus of the peasant communities was how to manage given resources instead of how to increase them. Dynamic efficiency is an issue that was left out of the discussion. That is not to say it was unimportant. Growth is the reference performance index taken by neo-institutional economics (North, 1981).
Showing that an institution performs better does not imply that it will replace worse institutions and does not explain how this process would eventually take place. It is a simple static comparison between two "points".
The "points" explicitly analyzed are, in fact, just two: formal self-governed regulations and informal Folk-theorem type regulations. I did not consider the options of an external formal regulation or of privatization. As a consequence, this paper does not constitute a general comparison of all possible types of property rights arrangements.

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Appendix

MODEL OF A RENEWABLE RESOURCE

1. Technology

The purpose of this appendix is to describe the model of a renewable resource that is used in the main part of the paper.

The production function is a relation between the quantity of input (level of effort in exploiting the resource) and the quantity of output (amount of resource obtained in harvesting) and such relation will be constructed into three steps. The first is to model the growth o f a renewable resource, the second step is to introduce a harvesting technology, and the third step will consider prices.

To describe a biologic dynamic of a renewable resource over time, I will use the logistic equation $\frac{dx}{dt} = r\,x\left(1 - \frac{x}{K}\right)$ that is widely employed in the literature (Gordon, 1954; Clark, 1990; Baland and Platteau, 1996). The evolution of the population x over time t is a quadratic function of x itself. The parameter K is the maximum size of the population level (or resource stock) that is u sually called the carrying capacity. Loosely speaking, the parameter r measures the growth rate, that is, the time needed to reach K. the dynamic of a resource according to a logistic equation is depicted in figure 1A.

< Figure 1A about here >

What I have described so far, is the dynamic of a biological resource, which is not subject to harvesting activity. The next step is to model the harvest function. I assume that the marginal return of one unit of effort q is proportional to the population level x: $S = n\,x$, where S stands for the physical amount of the harvest. In other words, the higher the stock of the resource, the more productive will be harvesting activity.

The production function is obtained by solving the zero-growth condition $\frac{dx}{dt} = S$ in the equilibrium population level x^*: $S = qx^* = qK - q^2\frac{K}{r}$. In general, there is also the solution $x^{**}=0$., when the resource is totally depleted and the harvest is zero. The zero-growth condition implies that, in a given period of time, the natural growth of the resource must be equal to the quantity of resource harvested. The stock level x^* is the steady state equilibrium and $S = qx^*$ is the perpetual constant flow of harvest that the resource yields in equilibrium.

From the graph, we can see that "at any population below a certain level K, a surplus production exists that can be harvested in perpetuity without altering the stock level. If the surplus is not harvested, on the other hand, corresponding increase occurs in the stock leve l, which ultimately approaches the environmental carrying capacity K, where the surplus is reduced to zero." (Clarke, 1990, p.1) The maximum surplus that can be obtained in perpetuity is called MSY (Maximum Sustainable Yield) and is reached at $x = \frac{K}{2}$.

The last step is the introduction of prices. Let c be the cost of one unit of effort and p the selling price of one unit of harvest. The sustainable level of revenues from the application of q units of effort to the resource is $Y = pS$ or $Y = aq - bq^2$, where $a = Kp$ and $b = \frac{Kp}{r}$ (see figure 2A).

I assume that every unit of effort has the same return, namely $\frac{Y}{q}$.

< Figure 2A about here >

To sum up, the assumptions about technology are:
(1) Resource dynamic is logistic
(2) Harvesting efficiency is linear in the population level
(3) Marginal cost of one unit of effort is constant
(4) Earnings are divided in proportion of harvesting efforts

2. Exploitation levels

Depending upon the governance regime of the resource, the equilibrium exploitation level varies greatly. The minimum exploitation occurs in the individual ownership regime and the maximum in the open access regime. All the other cases follow somewhere in-between these two extremes. I will present a simple model for the unregulated common ownership regime and starting from there we obtain the individual ownership solution, on one side, and the open access solution, on the other side as limiting cases.

In the common ownership regime, we deal with a well defined group of appropriators, say of size N. The total effort q exerts on the resource is the sum of the individual efforts q_i of appropriators $i=1,....,N$: $q = \sum_{i=1}^{N} q_i$. The corresponding production is: $Y = a\left(\sum_{1}^{N} q_i\right) - b\left(\sum_{1}^{N} q_i\right)^2$

and the payoff function for appropriator i is: $\pi_i = \frac{q_i}{q} Y - cq_i \quad i = 1,..., N$

From the first order condition of the maximization of π_i in the individual effort level q_i, we can derive the best response of appropriator i to a collective effort q_{-i} of all the other appropriators:

$$q_i = \frac{a - c - bq_{-i}}{2b}$$

From the best response function, it is easy to compute the *symmetric* Nash equilibrium of the exploitation game, using $q_{-i} = (N-1)\, q_i$: $q_i^c = \frac{a-c}{b(N+1)}$

In order to better specify it, I introduce three indexes: the total effort exert on the resource, the amount of the rent extracted, and the physical level of the stock of the resource.

UNREGULATED COMMON OWNERSHIP

(a) Total effort $q^c \equiv Nq_i^c = \frac{N}{N+1}\frac{a-c}{b}$ (b) Rent $\pi^c \equiv \sum_{1}^{N} \pi_i^c = \frac{N}{(N+1)^2}\ \frac{(a-c)^2}{b}$

(c) Resource stock $x^c \equiv \frac{1}{p}\left(a - bq^c\right) = \frac{1}{p}\frac{a+Nc}{N+1}$

The effort q^c is positive whenever the exploitation is profitable ($\pi > 0$), which occurs when $\frac{p}{c} < K$.

Notice that when the number of appropriators N increases, so does the total effort q^c and the resource stock x^c decreases. The joint gain from harvesting the resource - that is here called rent - is also negatively affective by a growth of N.

When there is just one appropriator (set $N=1$), we obtain the individual ownership solution and when the number of appropriators is not well defined, we obtain the open access solution (conventionally it is simulated with $N \to \infty$). The corresponding indexes for those regimes are computed below.

INDIVIDUAL OWNERSHIP

(a) Total effort $q^* = \frac{a-c}{2b}$ (b) Rent $\pi^* = \frac{(a-c)^2}{4b}$ (c) Resource stock $x^* = \frac{a+c}{2P}$

The individual ownership solution turns out to be the one that maximizes the rent, because all the effects of exploitation are taken into account by the appropriator.

OPEN ACCESS

(a) Total effort $q_o = \frac{a-c}{b}$ (b) Rent $\pi_o = 0$ (c) Resource stock $x_o = \frac{c}{p}$

In this case the rent is completely destroyed and so the exploitation of the renewable resource - a potentially profitable activity - becomes a game where in equilibrium nobody gains.

The solutions in the individual ownership case and open access case are depicted in the graph below (Figure 3A).

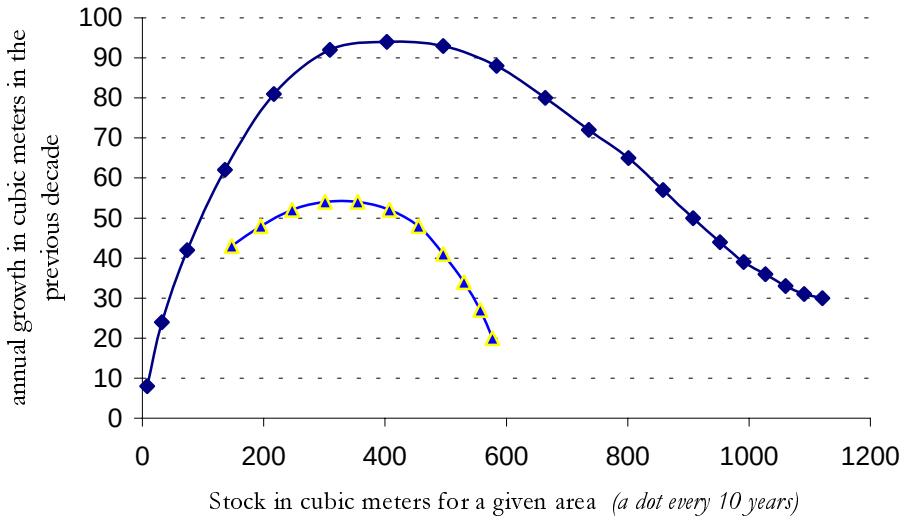
< Figure 3A about here >

In the individual ownership regime, the effort level q^* is such that the marginal revenue from the exploitation $\frac{dY}{dq}$ equal the marginal cost c. In the open access regime the effort level q_o is pushed until an additional unit of effort costs more than the additional return per unit $\frac{Y}{q}$. The unregulated common ownership case is in-between these two cases. The exact value depends on the number of appropriators N.
The quantity NE(N) in section 3 of the paper is defined as π^c/π^*, while SO is simply equal to π^*.

The problem faced by appropriators of a renewable resource is the same problem that firms face when they decide the amount of goods they want to sell in a market. The unregulated ownership solution is the Cournot equilibrium of an oligopoly when the competition in on quantity and entrance of new firms is blocked. The reinterpretation of the parameters is straightforward: q_i is the quantity sold by firm i in a market with a linear demand function $Y = a - bq$ and a constant returns to scale technology. The individual ownership case corresponds to a monopoly and the open access case is like a market with perfect competition. While the formal analysis of the two problems is exactly the same, the welfare evaluation of the different regimes is opposite. In the case of a monopoly, the solution is not optimal because the firm does not consider the consumer surplus, while in the case of a renewable resource the rent - the new label for firm profits - is the only welfare consequence to consider and so its maximization leads to the socially optimal solution. In the new setting, a zero-profit outcome means complete rent dissipation.

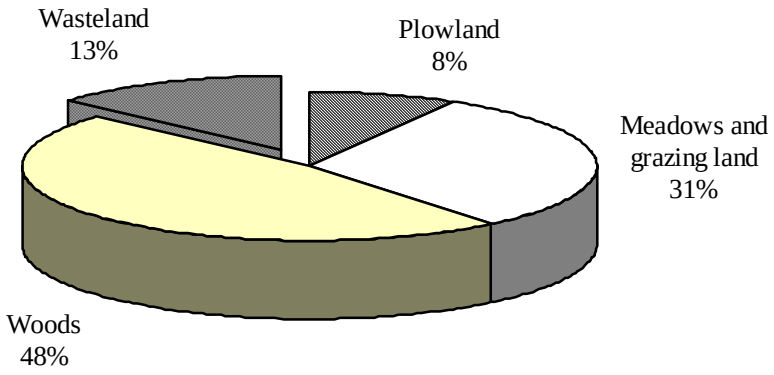
TABLES AND FIGURES

Figure 1: FOREST GROWTH



Source: *the empirical data for red fir (upper line) comes from Trentino and for beech (lower line) from another region of Italy. The maximum sustainable yield (MSY) for the fir is at 70 years. ISAFA (82)*

Figure 2: USE OF THE LAND IN THE REGION IN 1897



Source: *Consiglio Provinciale d'Agricoltura pel Tirolo (1903). The current surface of Trentino is 1,465 squared miles. Land Register data that used here covers a slightly larger area.*

Table 2: ORGANIZATIONAL FEATURES OF FORMAL INSTITUTIONS

(SUB-SAMPLE: rural Charters from Valley of Non, 1581-1644)

	Feature	*Number of doc. (tot.of 23)*	*% of relevant doc.*	*Relevant documents*
	SIZE AND PARTITIONING			
1	• One Charter regulated more than one village	10	43%	All (= 23)
2	• There was an internal partition of the land among villages	3	30%	(1)
	TRESPASSING AND IMMIGRATION			
3	• Monetary sanction imposed on outsiders who trespassed on the common land	23	100%	All
4	• Non-member residents had to pay an annual fee to use the common land	10	43%	All
5	• Explicit consent of village members (*vicini*) was required to use the common land	5	22%	All
	OBSERVABILITY OF INDIVIDUAL ACTIONS			
6	• Higher sanction for violations at night	12	52%	All
7	• Higher sanction for violations committed by outsiders	16	70%	All
8	• Guards for vineyards	15	100%	Where vineyards were mentioned
9	• Prohibition against harvesting grapes before a publicly announced day	13	87%	Where vineyards were mentioned
10	• Guards for high mountain meadows and forests	15	-	
11	• Prohibition against mowing hay before a publicly announced day	12	80%	(10)
	OTHERS			
12	• Participation at meetings was compulsory for all village members	19	83%	All
13	• A share of the monetary sanctions had to be given to the Prince or to the Landlord	8	35%	All
14	• Only witnesses with a good reputation can be accepted in the village court	9	39%	All

Notes: *The 23 Charters analyzed are all the documents published in Giacomoni (1991) concerning the Valley of Non (current administrative district of the Val di Non) in the years 1560-1660 with the exclusion of 3 Charters that were in Latin (Sarnonico and Ronzone, 1586; Mechel, 1587; Bresimo, 1603). Subsequent modifications to the original Charter up to the year 1800 have not been counted in the table. That would add 3 to column (4) , 2 to (5), and 1 to (10) and (11)*

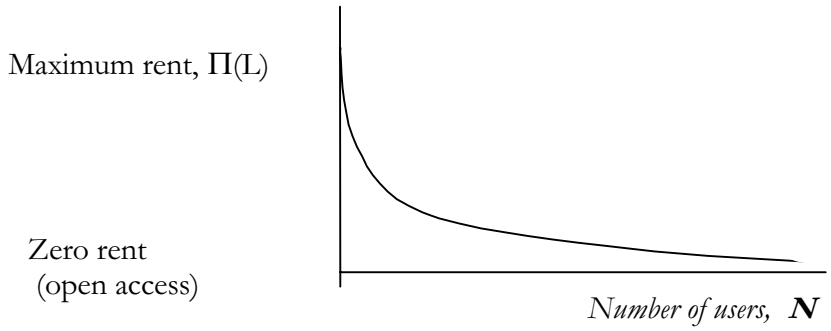
Table1: POPULATION OF TRENTINO

Year	Population *(in thousands of inhabitants)*
1312	83^
1427	125^
1650	174^
1754	206
1835	290

Source: *Cole and Wolf (1974)*

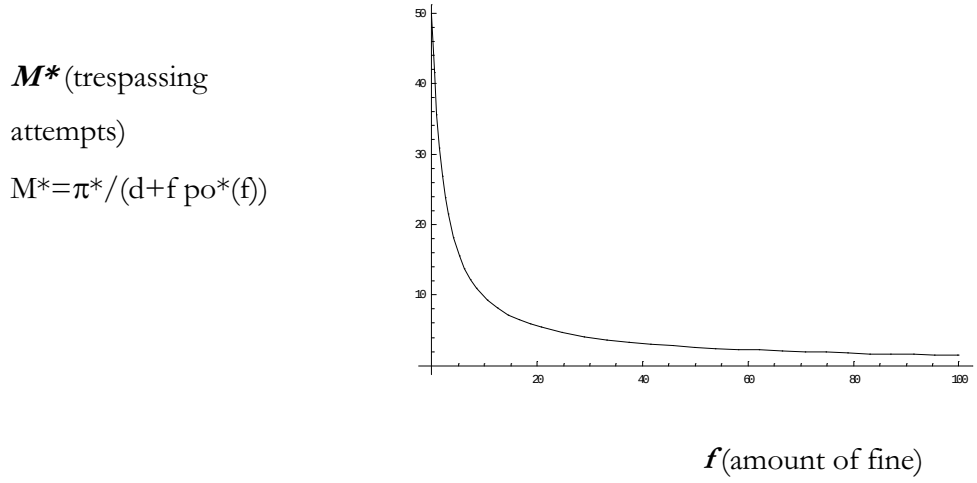
Notes: ^ *Figures computed as fraction of the total Tyrol population. The share of population living in Trentino has been assumed equal to the 1754 share.*

Figure 3: TRAGEDY OF THE COMMONS AND GROUP SIZE



Note: π(N,L) = NE(N) Π(L)*; see appendix for a description of the model.*

Figure 4: ENFORCEMENT OF PROPERTY RIGHTS



Notes: *for example if d=2 and π*=100 a fine of f=161.551 is required to lower M to 1. The amount of the fine is more than 80 times the damage d and more than the rent of the whole resource π*.*

Figure 1A: BIOLOGICAL DYNAMIC OF A RENEWABLE RESOURCE

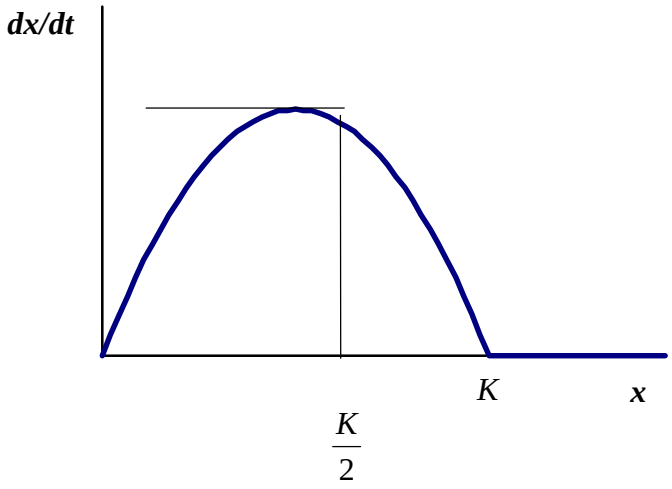


Figure 2A: PRODUCTION OF A RENEWABLE RESOURCE

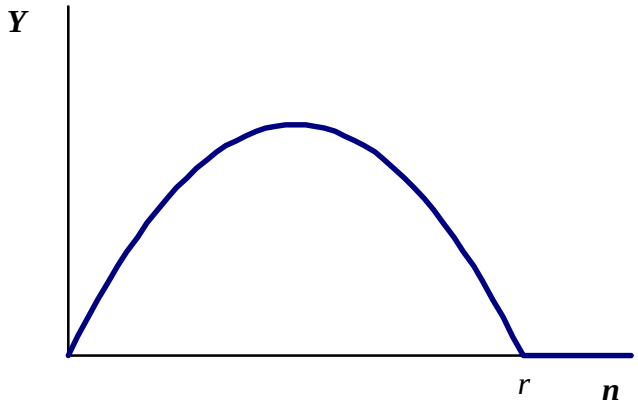
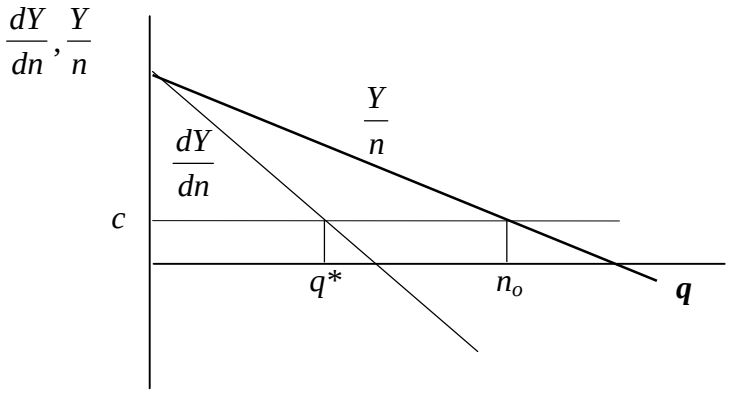



Figure 3A: MARGINAL AND AVERAGE RETURN ON EFFORT