Water Theft As Social Insurance: Southeastern Spain, 1851-1948

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WATER THEFT AS SOCIAL INSURANCE:
SOUTHEASTERN SPAIN, 1851-1948[1]

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Abstract

For centuries, irrigation communities in southeastern Spain were socially stable and economically efficient. In this article, we show how these self-governing institutions persisted by resolving conflicts over scarce resources with flexible punishment for water theft. We argue that variable penalties for violating irrigation rules provided social insurance to farmers during droughts. We develop a dynamic model where judges trade off crime deterrence and social insurance, and test its predictions using a novel dataset on water theft in the self-governed irrigation community of Mula, Spain from 1851-1948. For the same offense, we show that recidivists were punished more harshly than first-time offenders. When the defendant was wealthy, as indicated by the *Don* honorific title, or the victim was poor, judgements were stricter.

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The tragedy of the commons, when all members of a community suffer from each other's overuse of a common good, is a pervasive problem. Communities that use a common good seem doomed to conflict and overuse. Conflict resolution with imperfect information in self-governed communities poses an important trade-off. Low punishments encourage overuse while high punishments inflict pain on those who *need* resources. Historically, however, many self-governed communities have managed to solve the collective action problem.

Among self-governed communities, irrigation districts in Mediterranean Spain stand out for having lasted the longest, from the Middle Ages to the current day. Given the remarkable duration and social stability of these communities, many scholars have examined features of their success.[1] In this article, we study conflict resolution in one self-governing agricultural region of Spain, the city of Mula. We find that the irrigation community's flexible justice system permitted farmers, who took turns as judges, the discretion to impose sentences that varied with circumstance. Judges ordered farmers who stole for the first time or from the wealthy to pay small fines while meting out severe punishments to repeat offenders, the wealthy, and farmers who stole from the poor. We argue that the system provided social insurance to poor farmers while deterring opportunistic farmers from taking advantage of this leniency.

A progressive justice system that accounts for an individual's criminal history is more efficient than uniform mandates for harsh punishment. Following Gary Becker classic work, the economics of crime argues that harsh punishments lower offense rates.[2] We argue that allowing certain property crimes can increase social welfare. Consider the case of farmers who *needed* to irrigate their fruit trees but were liquidity constrained and unable to purchase water after an idiosyncratic, temporary negative shock. These farmers had two options: bid for water in the Mula auction or steal from their neighbours' irrigation ditches. A harsh punishment would deter the farmer from stealing but their trees would wither without water. A mild punishment, by contrast, would allow

[1] Ostrom, *Governing the commons*.
[2] Becker, 'Crime and Punishment'; This is the case if the social planner's objective is to minimize crime and if the punishment is costless.

the farmer to save their trees during the negative shock. If the punishment were always mild, however, farmers not subject to the negative shock would also steal. Punishing recidivists more harshly would deter opportunistic farmers from taking what they did not *need*.

In this article, we investigate the roles of individual characteristics and progressive punishments in the determination of crime/offense and social welfare. We use evidence from civil trials in a self-governed community of farmers.[3] Elinor Ostrom emphasized that, in self-governed communities, mild formal punishments can maintain low crime rates when informal punishments including shame, humiliation, and social ostracism are present.[4]

> 'For at least 550 years, and probably for close to 1,000 years, farmers have continued to meet with others sharing the same canals for the purpose of specifying and revising the rules that they use, selecting officials, and determining fines and assessments'.[5]

In our setting, however, small fines coexisted with low offense rates. We develop a dynamic model in which recidivists are punished more harshly than first-time offenders in equilibrium. In the self-governing community of Mula, our model allows us to reconcile low offense rates with low punishments, similar to Elinor Ostrom, while using a dynamic framework with formal punishments, similar to Gary Becker. Although one of Elinor Ostrom's principles for successful commons governance is that of 'graduated sanctions (depending on the seriousness and context of the offence)', she does not mention punishment progressivity.[6] To the best of our knowledge, we are the first to analyse the role of punishment progressivity in self-governing communities.

Our dataset contains information from trials of farmers charged with violating the bylaws of the self-governed irrigation community of Mula (Murcia), Spain, from 1851-1948. Recently, the United Nations recognized the importance of Murcia's water tribunal by listing the Council of

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[3] By punishment progressivity we mean that recidivists were punished more harshly than first-time offenders for the same offense. The offenses analysed in this article are property theft (stealing water as explained below) as opposed to, *e.g.*, murder.
[4] Ostrom, *Governing the Commons* and *Crafting Institutions*.
[5] Ostrom, *Governing the Commons*, p.69.
[6] Ibid.

Good Men (*Tribunal de los Hombres Buenos*) as representative of the Intangible Cultural Heritage of Humanity.[7] Murcia's water tribunals, including the one we study in Mula, provided justice when conflicts among farmers arose.

Water rather than land was the scarce factor of production in arid southeastern Spain. Mula is a particularly interesting case for two reasons: unique property rights and available price data. First, unlike most towns in the area, Mula's water rights were not attached to land rights. Owners of water rights were wealthy while owners of land rights were poor. In 1955, over 90 per cent of farmers owned their land.[8] Despite high levels of inequality and conflict, this split system of property rights survived for over seven centuries. Inequality and conflict was higher in towns like Mula, where water ownership was independent of land ownership, therefore making institutional survival less likely.[9] The justice system protected water and land property rights at the same time it offered social insurance to farmers. Our analysis helps explain the extraordinary stability of Mula's irrigation community.

Second, because water rights were independent of land rights, water was sold at public auction. Auction prices provide information on the value of water in addition to the existence of an auction during the prior week. In a competitive setting, the price equals the marginal productivity of water. In towns where land rights were tied to water rights, water availability and scarcity were typically not measured systematically.[10] Our results may not directly apply to irrigation communities that attached water rights to land rights, like most of those in Mediterranean Spain. Punishment for water theft in these communities is an important area for future research.

Most conflicts that came before the irrigators' tribunal resulted from farmers who irrigated without rights and thereby depleted water available to others. Both stealing water and detecting

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[7] UNESCO, 'Convention'. On 2 Oct. 2009, the UN recognized water tribunals in Murcia and Valencia as representative of irrigation communities in the region. Note that UNESCO translated the name of Murcia's tribunal as 'Council of Wise Men' instead of 'Council of Good Men', which would be the proper translation. The distinction is important because the tribunal is not composed of *Wise Men*, but of farmers whose role is to increase welfare by being merciful, thus *Good Men*. A summary and video can be found in the UNESCO webpage, here.

[8] Donna and Espín-Sánchez, 'Illiquidity'.

[9] Pérez Picazo, 'Agudización de las tensiones'.

[10] Water prices are also useful to measure the value of farmers' punishments in comparison with the value of stolen water.

theft were straightforward. Farmers could steal water by opening the gate of the irrigation canal next to their land, allowing water to flow into their parcel. Conditional on rainfall, monitors could easily identify an illegally-flooded parcel when a farmer did not purchase water for that specific day and time at auction. In this setting, a harsh punishment system, such as high fines or prohibition against future water purchases, would deter farmers from stealing water. Conversely, a mild punishment system, such as a small fee, would encourage high offense rates. There was precedent for a mild punishment system, as in nearby Castellon where 'the actual fines assessed were very low (a few pennies at the most) and also variable, depending on the gravity of the offense, on general economic conditions, and probably on the individual's ability to pay'.[11] In our setting, we observe three empirical regularities. First, judges imposed mild punishments on poor farmers. Second, judges imposed mild punishments on first-time offenders. Third, judges' punishments were progressive, with recidivists punished more harshly than first-time offenders.[12] As discussed below, this system resulted in both small average fines and low offense rates.

To analyse welfare, we present a model with rational and forward-looking farmers who respond to judges' optimal punishment in a dynamic setting. We introduce two features motivated by the empirical regularities of our setting: a transitory individual state that captures whether the farmer *needs* water, and a persistent individual state that describes whether the farmer is dishonest, or *greedy*, and thus suffers less from punishment. The optimal punishment depends on available information, which includes public signals, farmers' individual characteristics, and farmers' offense history.[13] The model rationalizes the main empirical regularities in the data: judges rarely impose harsh punishment on poor farmers, and recidivists are punished more harshly than first-time offenders.[14] In a Beckerian world, only *greed* matters. In an Ostromian world, only *needs*

[11] Glick, '*Irrigation and Society*', p. 56.
[12] Judges have full discretion on the amount of the fines in the trials up to the maximum established in the ordinances, 25 *pesetas* in Mula, equivalent to a weekly wage. Fines were low, 5 *pesetas* on average, equivalent to a daily wage. In addition to the fine, the accused had to pay the value of the water stolen. The fine is not correlated with the value of the water stolen.
[13] Note that there are two dimensions of heterogeneity among farmers. We define efficiency based on their *need* for water, not on their *greed*. In equilibrium, however, the optimal punishment punishes *greedy* farmers more harshly.
[14] Our model also predicts that recidivists are more likely to be *greedy* than first-time offenders because the *greedy* type is permanent while the *needy* type is not.

matter. Our model combines both worlds to account for the specifics of judges and farmers' behaviour.

Consistent with the data in our setting, our model predicts that small average fines coexist with low offense rates as defined by Elinor Ostrom.[15] The average fine is a weighted average of many small fines for first-time offenders and a few large fines for recidivists. When a farmer is caught stealing for the first time, the fine is low. However, when the farmer steals, the option value of *free* stealing is lost. Losing this option value can be costly in the future, when the farmer may *need* the water more due to a contingency like a drought. Thus, losing the option value acts as a harsh punishment deterring the commission of offenses.

In summary, the main contribution of this article is to help explain the remarkable stability of irrigation communities in Mediterranean Spain. The key feature of our analysis is reconciling low offense rates with light punishments in self-governed communities which use formal punishments to deter crime with low-cost conflict resolution. We combine a novel dataset with a new dynamic model, in which judges trade off crime deterrence and social insurance. We show that the model's predictions are consistent with farmers' behaviour in Mula. First, fines were very low for first-time offenders but high for recidivists. Second, fines were larger when the defendant had a *Don* honorific title, reflecting their lower probability of *needing* water.[16] Third, fines were lower when the victim had a *Don* honorific title, indicating they typically had more water with a lower marginal return, and thus fewer damages.

The rest of the article is organized as follows. In Section I, we discuss the related literature. In Section II, we present the institutional background and describe the data. Section III presents the model and the main predictions. Section IV presents the empirical analysis and tests the

[15] Ostrom, *Governing the Commons*.

[16] *Don* (male) or *Doña* (female) are honorific titles in Spanish. They are used with the person's name, *e.g.*, *Don* Juan Zapata. Originally, they were reserved for the aristocracy in Spain. During the period under analysis, the terms also encompassed high-ranking civil servants, the wealthy, or college graduates. About 5-10% of the population was called *Don*/*Doña* during our time period. Hence, we believe that a *Don* never *needed* to steal water.

predictions of the model. Section V concludes. The proofs and details of the model are in the appendix.

I Related Literature

Our work is closest to that of historians studying irrigation communities in Mediterranean Spain. Armando Alberola Romá, among others, argues that Karl August Wittfogel's theory of *hydraulic empire* does not apply to Mediterranean Spain.[17] Thomas Glick studies irrigation communities in medieval Castellon and Samuel Garrido studies irrigation communities near Castellon in Borriana and Villareal.[18] All of these irrigation communities, and the one we study in the city of Mula in Murcia, were governed by elected local boards that assigned water rights and meted out punishments. [19] Samuel Garrido notes that irrigated Spanish orchards do not follow all eight of Elinor Ostrom's principles of good governance for self-governing institutions.[20] We contribute to this literature by studying an additional factor that explains the survival of self-governed institutions for centuries: the justice system. As Elinor Ostrom notes: 'Despite this high potential for conflict—and its actual realization from time to time—the institutions devised many centuries ago for governing the use of water from these rivers have proved adequate for resolving conflicts, allocating water predictably, and ensuring stability in a region not normally associated with high levels of stability.'[21]

Among others, Robert Ellickson has criticized Hobbesian legal centralism.[22] For example, there are situations in which people are not constrained by formal legal institutions but rather by commonly agreed upon social norms.[23] These situations usually arise when the law does not specify all possible contingencies or a mechanism to evaluate them, resulting in incomplete rules.

[17] Alberola Romá, 'Propiedad, control y gestión'; Wittfogel, *Oriental Despotism*.
[18] Glick, *Irrigation and Society*; Garrido, 'Governing Scarcity' and 'Ampliación del regadío'.
[19] Espín-Sánchez et al. 'Income Inequality', analyse labour income inequality in eighteenth century Murcia.
[20] Ostrom, *Governing the Commons* and *Crafting Institutions*; Garrido, 'Reflexión'.
[21] Glick, *Irrigation and Society*, uses two cross sections of fines (1443 and 1486), which are far apart, to cross check individuals. We use a continuous panel spanning a century, which allows us to follow individuals over time and check for recidivists. Crimes in ibid. are more common than in our case. He finds recidivists within the same year, some of them committing multiple crimes in the same year, but none of them receiving a large punishment. We do not find a recidivist stealing more than once in the same year. Finally, he finds no relation between the severity of the punishment and the socioeconomic status of the thief, contrary to our case.
[22] Ellickson, *Order without Law*.
[23] Posner, *Law and Social Norms*.

When the market does not allocate water efficiently in the presence of liquidity constraints, the solution is to allow judges flexibility in ruling.[24] Our main contribution to this literature is to show how self-governance through elected judges was both efficient and cost effective. Thus, this article helps to explain how institutions survived for centuries. Additionally, Samuel Garrido expands this argument by showing that early-twentieth century irrigation communities in Spain survived despite having labour intensive production structures.[25]

This article is also related to the anthropological and sociological literature on informal punishments. We show that in the Mula irrigation community, the system's stability and fairness results from formal, rather than informal, punishments. This is an important feature of our setting because informal punishments are difficult to measure. This is not to say that informal punishments are not important in our or other settings. We believe that informal punishments are important, and that they are typically complements to formal punishments. Thus, the existence of informal punishments would reinforce our claims. Our contribution is to show that the punishment system works even in the absence of informal punishments.

While studies of irrigation communities around the world find features of its system, Mula appears to be unique. Robert Gray studies an irrigation community in Tanganika (Tanzania), where only individuals with the highest status were guaranteed water rights. Individuals with no rights but enough money could buy water.[26] If farmers stole water, they were punished with a flat fee. Moreover, 'since water theft is usually actuated by dire necessity there is little moral stigma attached to [it]', unlike other offenses.[27] Mula farmers also faced little moral stigma for stealing water. However, we find that higher-status individuals received harsher punishments than regular citizens.[28] Self-governing irrigation communities also developed other ways for farmers to use water without paying for it. The Chagga people, also in Tanzania, had *days of petition*, when

[24] Donna and Espín-Sánchez, 'Illiquidity'.
[25] Garrido, 'Oranges or "Lemons"?'; Morilla Critz et al., 'Horn of Plenty'.
[26] Gray, *The Sonjo of Tanganika*.
[27] Ibid.
[28] Tan-Kim-Yong 'Problems and Strategies' argues, however, that in Thailand, water thefts were treated as regular thefts. Thus, the lack of moral stigma does not apply to irrigation communities in general.

farmers in dire *need* would ask water owners for water.[29] Finally, even communities where theft was common might not have a specialized court, as is the case in Laos.[30]

Finally, our article is related to the literature on crime deterrence. In the classic economic analysis of criminal behaviour, criminal histories are irrelevant and punishments are not progressive. A large empirical literature evaluates how the severity of criminal sanctions affects crime.[31] A number of studies find that offenders or prisoners who face harsher sanctions are less likely to reoffend or be rearrested in certain contexts, such as three strikes laws.[32] These deterrence effects, however, do not apply universally.[33] Aaron Chalfin and Justin McCrary argue that offenders' response to sanctions varies by offender age while emphasizing that '[t]o date, the degree to which offenders are deterred by harsher sanctions remains an open question.'[34] Our contribution to this literature is to study a setting where we follow individual offenders who, upon being detected committing a crime, face different sanctions for the same crime based on their criminal history. The particularities in our empirical setting allow us to hold fixed the crime committed to study the roles of individual characteristics and punishment progressivity in the determination of crime.[35]

II Background and Data

In this section, we describe Mula's historical background, tribunal hearings, and water auction. Trial and auction data, the primary sources of data for this study, are obtained from the historical archive of Mula.[36] According to the 1955 agricultural census of Mula, 97 per cent of farmers owned the land they cultivated. The remaining 2.6 per cent were tenants, and only 0.4

[29] Allen, *The African Husbandman*.
[30] Coward, 'Indigenous Organisation'. In other settings, fines could depend on other observables. Sutawan, 'Farmer-Managed Irrigation', argues that in Bali the closer the *subak* (community) was to the dam, the higher the fine.
[31] See Cameron, 'The economics of crime deterrence', Marvell and Moody, 'Specification problems', and Chalfin and McCrary, 'Criminal deterrence', for comprehensive reviews of the literature.
[32] Ziming, Hawkins, and Kamin, *Punishment and* democracy; Helland and Tabarrok, 'Does three strikes deter?'. Punishment in settings like the 'three strikes' policy in California is typically costly (*e.g.* overcrowded prisons). In our case, punishment is costless.
[33] Hjalmarsson, 'Crime and Expected Punishment'; Lee and MacCray, 'The deterrence effect of prison'.
[34] Chalfin and McCrary, 'Criminal deterrence', p. 32.
[35] Our article is also related to articles that focus on the economic factors related to crime, such as Machin and Meghir, 'Crime and Economic Incentives', and Vickers and Ziebarth, 'Criminals in Victorian England'.
[36] From the section *Heredamiento de Aguas*, boxes No.: HA 167, HA 168, HA 169 and HA 170.

per cent were sharecroppers.[37] We do not have data on land ownership before the 1955 census. However, from the distribution of water rights, we know that the system was very stable during the nineteenth century and the first half of the twentieth century.[38] Thus, we are confident that there were no significant changes in the structure of land ownership during our period of study.

While we do not have detailed information on crops for our period of study, we do have individual records for each Mula farmer from the agricultural census of 1955. For most of the first half of the twentieth century, Mula farmers planted apricot and orange trees.[39] In previous centuries, the most common crops were white mulberry trees, olive trees, and grape vines. Farmers lined their plots with white mulberry trees next to irrigation ditches and planted garden vegetables on the remaining irrigated land.[40] In the early twentieth century, farmers in Mula and most of Mediterranean Spain transitioned to stone fruit and citrus trees to export fruit to Northern Europe.[41]

Institutions in Mula

The institutions for water allocation in Mula come from the *Reconquista*.[42] After the reconquest of the city, the Catholic Order of Santiago had absolute authority over Mula because the city was taken from its Islamic rulers by force.[43] The Order of Santiago separated the ownership of land and water, creating the corporation *Heredamiento de Aguas* to auction access to river water. Of the 832 dividend-paying shares in the *Heredamiento de Aguas*, the Marquis of *Los Vélez* held the largest number. Under these new Christian institutions, the owners of water property rights, who we call Waterlords, were different than the farmers who owned land. The Mula Waterlords established their own corporation which, despite the many political changes that occurred in Spain, lasted until 1966.[44] All water owners had the same voting rights regardless of the number of shares

[37] Espín-Sánchez, 'Institutional Inertia'.
[38] Ibid.
[39] Donna and Espín-Sánchez, 'Illiquidity'.
[40] González Castaño and Llamas Ruiz, *El agua*.
[41] Garrido, 'Oranges or 'Lemons'?'; idem, 'Governing Scarcity'.
[42] Rodríguez Llopis , *Historia*.
[43] Note that this initial shock in institutions is similar to that in Chaney and Hornbeck, 'Moriscos'.
[44] Espín-Sánchez, 'Institutional Inertia'.

they owned, *i.e.*, the *democratic* rule was one-man-one-vote. After the corporation's bylaws changed in 1895, the new *capitalistic* rules allocated votes proportional to the number of shares.

The water tribunals in Murcia and Mula were similar despite the differences in water allocation. In Murcia, water was allocated using fixed quotas (*tandas*). In Mula, water was allocated by a public auction. We use the Mula auction prices as an indicator of the value of stolen water. While all Murcia farmers had water and property rights, in Mula some farmers had to purchase water in the auction because they held no water rights. Of the approximately 500 farmers in Mula, virtually all of whom owned land, only about 200 also owned water rights. An individual *needed* to own water rights, *i.e.*, own one of the 832 shares in the corporation, to be a member of the *Heredamiento* and to be a judge in Mula. Thus, judges may have responded to the demands of the water owners who we call Waterlords, but not necessarily to those of the farmers. Some of the Waterlords were disinterested. In fact, the Marquis of the Velez, and later the Marquis of Pidal, owned more than half of the corporation shares but never joined the water tribunal themselves. The Marquises did not endorse or for that matter even vote for candidates for membership in the tribunal. Instead, farmers wealthy enough to own water rights were elected to the tribunal. Any individual, regardless of their water ownership, could sue or be sued at the tribunal’s court hearings.

By secret write-in ballot, water owners elected their peers to staggered two-year terms on the Mula tribunal. Seven members served at a time, with four elected on 26 December in odd years, and three elected on 26 December in even years. Thus, in any given year there were three or four members in their first term and four or three members in their second term. Each year, tribunal members elected a president who in turn selected a vice-president and a treasurer from the tribunal membership, and appointed a secretary chosen from the general public. The tribunal resolved water disputes between farmers, who could not appeal rulings to other courts. During the *ancien* *régime*, customary law recognized the tribunal's bylaws (*Ordenanzas*) and the offenses they regulated. In the nineteenth century, these bylaws were added to the Spanish Civil Code.[45]

There was heterogeneity in Spanish irrigation communities' monitoring and enforcement of offenses. In some communities, paid guards monitored water use, while in other communities, farmers took turns watching the canals.[46] In many places, a watchman who caught an offender kept a fraction, typically one-half or one-third, of the fine. This financial incentive applied to both volunteer farmers and paid guards. In Mula, farmers monitored water use before the bylaws of 1933, and professional guards after. Our data span 1851-1948; however, we do not observe a change in farmers' behaviour after 1933.

Trial Data

Figure 1 shows a trial with farmers as judges, and a map of the area under study. During the mid-nineteenth century, local irrigation communities in Mediterranean Spain began to keep written records about their trials. The municipal archive in Mula contains information on all trials from 1851-1948. We read through trial notes and constructed the variables as explained below. Each observation in our data corresponds to one trial. We then supplement these administrative data with climate and auction records. Trial information includes the offender's name and their *Don* status, the plaintiff's name, their occupation as a farmer or a guard, and their *Don* status, the judge's name, the verdict, the amount of any fines, the amount of any compensation, and the date of both the trial and the offense. There were 282 trials over 97 years, approximately three trials per annum. The defendant was found guilty in 175 trials, roughly twice per annum. This is a relatively small number of trials.

The fact that there were few trials per annum relative to the hundreds of farmers who could potentially steal water every day supports our argument that the flexible punishment system

[45] Ruiz-Funés, '*Derecho Consuetudinario*'.
[46] Garrido, 'Reflexión'.

deterred crime.[47] There were approximately 500 farmers at any given period of time in our case, with 40 auctions held every week, so the roughly 500 farmers would have had 26,000 opportunities for theft. The infraction rate of 0.00008 (2/25,000 = 0.0000769), was approximately one-hundred times (0.008/0.00008) lower than that in Castellon, which Elinor Ostrom considered extremely low.[48] Table 1 displays summary statistics for the variables in the dataset.[49] *Guilty* is a dummy variable that equals 1 if the defendant was found guilty during the trial, which happened in 62 per cent of the 282 trials, and 0 otherwise. There are two potential cases where a trial could end without a guilty verdict. In the most common case, a farmer who thought that the amount of water he received from the irrigation canal was insufficient summoned a guard. Even if the guard did not find a suspected thief, the case was brought to trial and farmers in neighbouring plots were called as witnesses. In the second case, the guard found a suspect whose plot was flooded, who was subsequently tried before the tribunal. In these cases, the judges did not hand down a guilty verdict because the plot was watered by leakage from a rabbit hole in the canal or by leftover supply from another farmer. *Dry Month* is a dummy variable that equals 1 if the alleged offense was committed during a dry month, from May to October, and 0 otherwise. *Victim is Don* is a dummy variable that equals 1 if the victim of the offense was an individual referred to as *Don*, and 0 otherwise. *Defendant is Don* is a dummy variable that equals 1 if the defendant was an individual referred to as *Don*, and 0 otherwise. *Fine* is the penalty imposed on guilty defendants measured in absolute

[47] In the other 108 cases, nobody was brought before the judge. The typical case involved a farmer complaining that he/she did not receive enough water when irrigating. The guards would testify that, after inspecting the area, they found no flooded plot. In other words, a complaint was filed but no charges were brought. In those cases, the defendant would be the guard on duty on that day, the manager responsible, or the whole *Heredamiento*. In these cases, we recorded whether the guard or manager had a *Don* honorific title.

[48] Ostrom, *Governing the Commons*, p. 75, emphasizes: 'There were approximately 1,000 [irrigators] in Castellon in the fifteenth century (T.F. Glick, personal communication). If the rotation system took about two weeks, each of the roughly 1,000 irrigators would have had about 25,000 opportunities for theft occurred, as contrasted to 200 recorded instances of illegal taking of water. That would give a recorded infraction rate of 0.008.' The implicit assumption here is that farmers always had the option of stealing water, which might produce a very low infraction rate. In practice, farmers could only steal water running through a canal connected to their own plot. Note that as long as geography was not a function of social status or wealth, the chances of stealing may vary according to a farmer's location within the canal system, but not according to social status or wealth. In other words, with no guards, anyone could have opened the irrigation gate next to their plot. Although both in Castellon and in Mula offense rates would have been slightly larger, the ratio of offense rates would likely have been unaffected.

[49] We use nominal *pesetas* for all results. Results using real *pesetas* with the deflator in Reher and Ballesteros, 'Precios', are very similar, and are available upon request.

terms, *i.e.*, total amount of *pesetas* paid. The default fine for any violation was 25 *pesetas*.[50] Judges could impose any fine between 0 and 25 *pesetas*, an upper bound that did not change during our sample period.[51] *Compensation* is the total amount that the defendant paid to the victim, representing the trial judge's determination of the stolen water's value. In most cases, the judge determined the total amount to be paid. In the few cases where the judge established only the amount of water stolen, they decreed the auction price should determine total damages. In such cases, we find the water price the victim paid at auction to compute compensation. For example, in the 27 October 1861 case where Salvador Ferez accused Francisco Moreno, the judge declared that the defendant (Francisco Moreno) had stolen one *cuarta*, and ordered him to pay Salvador Ferez the value of the water at the price that he purchased it ('*al precio al que lo compraran*'). *Recidivist* is a dummy variable that equals 1 if the offending farmer also committed an offense in the past, and 0 otherwise. The last row in Table 1 shows that there were only seven cases involving recidivists, all of whom were second-time offenders. Thus, we find no farmer committed three or more infractions.

Table 1 shows heterogeneous punishments for first-time offenders with a standard deviation of 10.12 in fines, which we argue were a direct consequence of judges' partial knowledge of farmers' individual characteristics. A farmer who confessed to stealing would be fined less than five *pesetas*. Usually, a judge would tell the farmer that while the tribunal understood they were in dire *need*, the punishment would be harsher if they stole again. Take, for example, this warning from the 12 August 1906 trial displayed in Figure 2:

> 'After the board learned about the excuses claimed by the defendants, they agreed to impose a fine of *two pesetas*, to each of them, *because it was the first time* that they

[50] The *peseta* was introduced in 1868. Before that, the payments were made in *reales*. 1 *peseta* is equivalent to 4 *reales*. For simplicity, we transformed all amounts to *pesetas*.

[51] In two instances, the judges imposed a fine greater than 25 *pesetas*. In the first, a miller was found guilty of stealing water twice during the same week and was fined 50 *pesetas*. In the other, five men, all *Dons*, were found guilty of a plot to block the main canal, and of cheating in the auction. One of them bid for several units in a row, then the others used this water for irrigation, a forbidden act. In this case, the average fine per farmer was 65 *pesetas*.

incurred in such a misdemeanour, warning them that *if they recidivate in the future, the fine would be larger'* (authors' translation and emphasis).[52]

This warning motivates the main prediction of the dynamic model: that recidivists are more likely to be *greedy* than first-time offenders.

***Don* status**

Don (male, from the latin *domĭnus* shortened *Dom*, 'master or owner') and *Doña* (female, from the latin *domĭna*) are prefixes used as honorific titles in Spain and Spanish-speaking countries and territories. In the Late Middle Ages, the King recognized individuals due to personal merit, distinguishing commoners from aristocrats (or *hidalgos,* from *fidalgo* and this from *fijo dalgo*, 'son of something'). Over time, *hidalgos* came to be associated with social class, with *Don* recognizing lineage, place of origin, wealth, education (such as becoming a doctor), or religious vocation (all priests were *Dons*).[53] In practice, the title was always up for sale, either directly through purchase or indirectly through bribes to certify a noble family origin.[54] Therefore, the title is a good measure of wealth.

Farmers with the honorary title *Don* were wealthier than farmers without the title. As an imperfect measure of wealth, this proxy could introduce attenuation bias into our results relative to using a direct measure of wealth. We interpret the fact that we find large and statistically significant results using such an indirect measure as an indication of the robustness of our results. Figure 3.A shows that offenses against *Don* victims were more frequent during the summer growing season, when water was most valuable. This observation is consistent with farmers' strategic behaviours. Farmers expected a lower punishment, and higher efficiency gains, if they stole from a wealthy farmer.

[52] As shown in Figure 2, the judge emphasized during the trial of the first offender that recidivists would be punished more harshly. We interpret such common statements by judges as validating the punishment progressivity of the system, even in cases where the counterfactual recidivism did not materialize (*i.e.* were unobserved in the data).
[53] Pita Pico, 'Nobleza'.
[54] Soria Mesa, 'Genealogía'.

Water Auction Data

Although the process of allocating water in Mula varied slightly over the years, the basic structure remained essentially unchanged from the fifteenth to the twentieth century. Land in Mula was classified as *regadío* (irrigated land) or *secano* (dry land). The fundamental reason for this division is that *regadío* were fertile lands closest to rivers and, hence, more efficiently used the region's scarce water. Irrigation by river water transported through canals was only permitted on *regadío*.[55] Only farmers who owned *regadío* land in Mula were allowed to purchase water at auction.[56]

Farmers' water allocation mechanism was an English auction. The auctioneer sold each of the units sequentially and independently of each other. The auctioneer tracked the name of the buyer of each unit and the price they paid. Reselling water was forbidden. The basic sale unit was a *cuarta* (quarter), which represented the right to use water flowing through the main channel for three hours.[57]

Auction is a dummy variable that equals 1 if there was an auction in the week that the offense was reported or 0 otherwise. Note that no auction was carried out in 101 out of the 282 weeks when an offense was reported because there was not enough water in the dam. When there was an auction and a trial, we also recorded the water price paid at auction. *Price* is a continuous variable equal to the average price in pesetas paid during the weekly auction.

The auction requirement of cash payment was a barrier to Mula farmers shut out of credit markets. After their trial for water theft, a guilty defendant could take several weeks to pay any fines or compensation. During this extended payment period, a guilty defendant could nevertheless buy water at the auction. This prioritization of irrigation over punishment suggests that farmers

[55] The canal system was expanded between the thirteenth and fifteenth centuries in response to greater demand for land resulting from population growth. The *regadío* land structure has not changed since the fifteenth century.

[56] For more details about the allocation mechanism see Donna and Espín-Sánchez, 'Water Auctions'.

[57] Water was stored in the *Gallardo* dam until 1931, when the new *De La Cierva* dam was constructed. Water flowed from the dam through the canals at approximately 40 liters per second. As a result, one *cuarta* carried approximately 432,000 liters of water. During each auction, held every Friday afternoon, 40 *cuartas* were auctioned: four *cuartas* for irrigation during the day (from 7:00 AM to 7:00 PM) and four *cuartas* for irrigation during the night (from 7:00 PM to 7:00 AM) on each weekday (Monday to Friday). The auctioneer first sold the 20 nighttime *cuartas*, and then the 20 daytime *cuartas*.

and tribunal members saw water theft as a form of insurance. On one hand, according to trial narratives, the probability of being caught committing an offense was very high. On the other, farmers who were caught had to pay for the stolen water plus a small fine. In other words, some farmers stole water knowing that they would be caught and that they would have to pay a higher price for the water due to the fine. This behaviour can be explained as the system providing poor farmers with insurance. During a negative shock, liquidity-constrained farmers had the option to steal water to prevent their trees from withering. A credit market would have been the first-best outcome. However, poor farmers in Mula did not have access to credit markets. A system of flexible fines acted as social insurance and was the second-best outcome.[58]

The auctioneer managed the water allocation system. Because members of the *Heredamiento* appointed the auctioneer, and the Marquis held a majority of voting shares, the Marquis selected the auctioneer. The auctioneer was responsible for collecting cash and deciding whether an auction would take place or not. There was no discretion in the decision to hold an auction. According to an interview with the last surviving auctioneer, an auction could occur only when the dam held enough water to allocate all 40 units. Note that this rule might not maximize profits in a static framework because the seller (*Heredamiento*), like any monopolist, could receive higher profits by reducing the quantity offered. In our particular case, seasonality could further increase the seller's profits. The seller could reduce the amount sold and set the sale date during the critical season when crops *needed* water the most and demand was highest. However, decreasing the amount of water offered would be inefficient in this setting, *i.e.*, would damage farmers' crops and put their trees at risk of dying. If the seller considered their relationships with buyers over the long term, it is not clear that they would choose to maximize static profits by generating conflict. By damaging farmers' crops and trees, the seller would reduce future demand for water. In addition, the increased likelihood of conflict could be costly for the seller.

[58] This is consistent with the findings in Donna and Espín-Sánchez, 'Illiquidity'.

The policy of allocating rather than storing available water is thus efficient and reduces conflict. From a physical point of view, moving water from dam to soil as soon as possible reduces evapotranspiration because the rate of evaporation in an open dam is higher than for water stored in the soil. The amount of water wasted due to evaporation is smallest under full allocation. Javier Donna and José-Antonio Espín-Sánchez show that liquidity constraints prevented farmers from buying water, even when their valuations were above the equilibrium price.[59] In this article, a system of flexible fines provided farmers with social insurance: When a poor farmer's crops were at risk, they could steal water for irrigation and save their crops with minimal punishment. Thus, the results here complement and reinforce the previous results.[60]

Figure 3.B shows the number of trials held the week after an auction. During the dry summer months, these trials happened more frequently. The sample of trials immediately following auctions is not random, however. While the probability of holding auctions throughout the year is typically large, it decreases during the summer. Conditional on offense rates, fewer auctions during the summer also means fewer trials held the week after auctions. The high offense rate during wet winter months like December, when few auctions were held and offense levels were generally low, might seem puzzling. However, if farmers could not buy water at auction, they might resort to stealing.

Rainfall Data

We complement the trial and auction data with daily rainfall data for Murcia from Spain's National Meteorological Agency, the *Agencia Estatal de Metereología*. Murcia, the region's capital city, has rainfall data on record since 1865 while in Mula, rainfall data are only available after 1933. Thus, Murcia is the nearest city to Mula with rainfall data for the period of interest. The two cities are located in the same valley, 35 kilometres apart.[61] In the Mediterranean climate,

[59] Ibid.

[60] Ibid.

[61] The correlation of rain in the two cities is 0.82 for the period 1933-66. The monthly average (standard deviation) rain were 257.7*mm* and 261.2*mm* (322.3 and 362.1) for Murcia and Mula, respectively.

rainfall occurs mainly during spring and fall while peak water requirements for the region's agricultural products are in spring and summer, between May and August. Note that the Murcia rainfall data is available at a daily frequency. For the empirical analysis, we aggregate the rainfall data to a weekly frequency to match the trial and auction data. *Rain* is a dummy variable that equals 1 if it rained in the week before the trial, and 0 otherwise.

III Model Predictions

We now describe the predictions of the model and how they can be tested in our empirical setting. We present the details of the model in the appendix. Farmers have two types or dimensions of heterogeneity: water *need* and water *greed*. The first type is transitory and measures whether the farmer is *needy*, while the second type is permanent and measures whether the farmer is *greedy*. Both types are private information. The judge may observe public signals that are correlated with each type, and may adjust punishment accordingly. For simplicity, we present the case where the two types are independent (among themselves) and binary (high or low). Similar results are obtained allowing for correlation and/or using continuum types but the model becomes more cumbersome. A farmer's utility function is concave in water consumed. A farmer's *greed* type is only relevant when they steal water. *Greedy* farmers suffer less from punishment.

The farmers are rational and forward looking. They steal water whenever it is profitable, conditional on expected punishment. The judge is benevolent, rational, and forward looking. The optimal punishment depends on what information the judge observes, including public signals, farmers' individual characteristics, and farmers' offense histories. We interpret each trial as a game between the farmer and the judge. The rain during the week before an offense is a public signal observed by the judge, and is correlated with the farmer's idiosyncratic productivity shock. Past behaviour and the farmer's characteristics (such as whether a farmer is a *Don*) are correlated with the farmer's *greed*. This feature is a direct consequence of *greed* being a permanent type.

In a Beckerian world, only *greed* matters. In an Ostromian world, only *needs* matter. As we explain below, results R1, R2, and R3 in the appendix suggest that the farmer's behaviour is inconsistent with a model that only has one dimension of heterogeneity. Our model combines both worlds to account for the specifics of judges' and farmers' behaviour. The judge always imposes the optimal punishment, which corresponds to the first-best when feasible and to the second-best when not. A first-best, or efficient, punishment system means that farmers steal water if, and only if, it is socially optimal.[62] In the first-best allocation, there are neither false positives nor false negatives. However, as we discuss in detail below, the first-best allocation may not be feasible. Intuitively, the judge can achieve the first-best outcome only when farmers are relatively homogeneous in their *greed* and *need*.

The judge can impose a punishment that achieves the first-best outcome when utility differs more due to water *need* than to water *greed*. If the first-best is infeasible, the judge decides between two second-best punishment systems for each realization of the public signal. The two possible optimal punishments in the second-best outcome are:

- **Harsh** punishment: the only farmers who steal water are *greedy* farmers who *need* water. This system is inefficient because farmers who are *not greedy* but who do *need* water will not steal water. In other words, there is too little stealing, which is a false positive.
- **Mild** punishment: all farmers, except those who are *not greedy* and also do not *need* water, steal. This system is inefficient because *greedy* farmers, who do not *need* water, steal. In other words, there is too much stealing, a false negative.

For a given amount of rain, simultaneous false positives and false negatives cannot not exist. In practice, however, a judge could impose a harsh punishment in a given week when the public signal (rain) was high, and a mild punishment in another week when the public signal (rain) was low. That is, the punishment would be more severe if it rained the week before the water theft. In general, the judge was more likely to impose a harsh punishment when: i) the public signal was highly correlated with farmers' water *needs*; and ii) many farmers were *greedy*.

[62] Note that the first-best outcome here is not defined as all farmers having the same marginal returns on water. The latter is infeasible in this setting due to the discrete nature of the units of water.

The intuition behind the second-best punishment system is the following. Farmers who were desperately in *need* were more likely to steal water, an efficient outcome. However, *greedy* farmers were also more likely to steal water, which was not necessarily efficient. An intermediate punishment could induce *needy*, *greedy* farmers to steal water and prevent *not needy*, *not greedy* farmers from stealing it. Both scenarios are efficient. Whether the punishment could achieve the first-best outcome depends on whether *needy*, *not greedy* farmers were more likely to steal water than *not needy*, *greedy* farmers. When *greed* had little impact on their decision to steal, *needy* farmers were more likely to steal than farmers who were *not greedy*. In that case, there was always an intermediate punishment that *separated* farmers based on *need*. However, when *greed* did have a large impact on the decision to steal, under any punishment system, *not needy*, *greedy* farmers would be more likely to steal than *needy*, *not greedy* farmers under any punishment system. In that case, there was no punishment system that separated these *greedy* but *not needy* farmers from *needy* but *not greedy* farmers. Thus, the optimal system would be a second-best outcome that either punished all farmers in this pool (harsh) or none of them (mild).

We now present the main predictions of the model. See the appendix for details. Results R1, R2, and R3 show that we need two dimensions of private characteristics to explain the empirical regularity that punishments are rarely maximal and depend on the judge's information. Taken together with the empirical analysis below, these predictions suggest that we are in a second-best environment. Predictions P1, P2, and P3 provide specific predictions regarding the nature of the offense, the victim's characteristics, and the offender's history, respectively. In the next section, we relate these predictions to the empirical regularities in our setting.

Result R1: *If* greed *is perfectly observable, then the optimal punishment is independent of the public signal and positive.*

Result R2: *If water* needs *are perfectly observable, then the optimal punishment is maximal when the signal is high and minimal when the signal is low.*

To rationalize predictions R1 and R2 we need at least two dimensions of heterogeneity. The following predictions relate to the particular two-dimensional model we propose.

> **Result R3**: *If both* greed *and water* need *are unobservable, and we can separate* not-needy-and-greedy *from* needy-and-not-greedy *farmers, then the first best is feasible and the optimal punishment does not depend on the public signal.*

There are two implications from R3. First, the prediction complements R1 in that even if *greed* is unobservable, first-best punishment may still be independent of the public signal. In the data, we observe that punishment varies as a function of rainfall during the previous week. This means that we are in the second-best scenario. Second, R3 formalizes the intuition above that punishment is efficient if, and only if, we can separate *not needy*, *greedy* from *needy*, *not greedy* farmers. This occurs when *not needy*, *greedy* farmers are more sensitive to punishment than *needy*, *not greedy* ones. For the predictions below, we assume that both *greed* and water need are unobservable and that the first-best is infeasible.

> **Prediction P1**: *The optimal punishment requires a mild punishment when the signal is low and a harsh punishment when the signal is high.*

Prediction P1 indicates the sign of the effect of the public signal, *e.g.*, the *Don* status in our empirical setting, on punishment. Prediction P1 refers to water *need* and holds for any specific trial's observable characteristics, *i.e.*, farmers with the *Don* status are less likely to be in need of water. In our model, it is efficient for a farmer who received a negative idiosyncratic productivity shock to steal water from a farmer who received a positive idiosyncratic productivity shock, or who otherwise has a high soil moisture level. This observation is summarized in prediction P2 below.

> **Prediction P2**: *The optimal punishment requires a mild punishment when the victim received a positive idiosyncratic productivity shock and a harsh punishment when the victim received a negative idiosyncratic productivity shock.*

In our model, water *need* is independent across periods while *greed* is persistent across periods. While all predictions in the static case address the relative likelihood of water *greed* vs. water *need*, dynamic predictions directly address the likelihood that a farmer is *greedy*. That is, a recidivist is more likely to be *greedy*.

The main prediction of the dynamic model is that recidivists are more likely to be *greedy* than first-time offenders. Whereas the *greed* type is permanent, the *need* type is not. In our model, we assume that the *needy* type is independent across periods. The main insight is that differences in water *needs* were 'washed away' after a heavy rain, while differences in *greed* were not. In general, it is not possible to narrow down predictions without knowing the punishment system. The following prediction holds, however, under any optimal punishment system.

Prediction P3: *A recidivist farmer is more likely to be* greedy *than a first-time offender. Thus, the recidivist farmer is more likely to receive a harsh punishment.*

Predictions P1 and P3 imply that the judge takes a farmer's observable characteristics into account when deciding their punishment. Because these characteristics are correlated with the probability that a farmer is *greedy*, those more likely to be *greedy* are punished more harshly. Because first-time offenders are less likely to be *greedy*, they will not receive a harsh punishment. As mentioned in the sentencing documents, judges knew who the recidivists were, and imposed the maximum punishment on them (see, *e.g.*, Figure 2). The model predicts that recidivism is extremely unlikely because it involves two negative shocks.

IV Empirical Analysis

In this section, we perform the empirical analysis. The results are consistent with the predictions from our model, in which judges maximize efficiency under limited information. Judges use available information regarding the offense, the victim, the offender, and the offender's history to impose the appropriate punishment.

Offense Rates

Table 2 presents marginal effects from probit regressions of the farmer being guilty on several covariates. The dependent variable, *Guilty*, is a dummy variable identifying whether the farmer was found guilty. The covariates include a seasonal dummy, an indicator for the honorific title of the victim and defendant, and a dummy variable for whether there was an auction during the previous week. Wealthy farmers have a *Don* honorific title, while the poor do not. Table 2, column 1 shows that on average, poor farmers are not more likely to be found guilty than wealthy farmers.

Column 2 shows that poor farmers are less likely to be found guilty during wet months but more likely to be found guilty during dry months. Columns 3 and 4 show that the pattern does not change when we interact the variables with the characteristics of the victim. Columns 5 through 8 show that the results are robust to including the control variables.

Fines

Table 1 shows that punishment is usually mild. Even if the punishment varies with the public signal, it still does not reach a maximum after a heavy rain. Table 3 shows that fines varied with individual characteristics which implies that judges observed imperfect signals correlated with each type (*need* and *greed*). Both types are private information and both shocks are idiosyncratic. Equivalently, judges imperfectly observe shocks. Fines are significantly lower when the defendant is not a *Don*. The coefficient of 7.02 *pesetas* in column 1 shows that poor farmers receive a lesser punishment than wealthy farmers for the same offense. In both the model and the data we see that while *Dons* are less likely to steal water, they steal with positive probability. In Table 1 we see that 15 per cent of the defendants are *Dons*. Consistent with prediction P1, judges respond by inflicting lower fines when the defendant is not a *Don*, and higher fines when they are.

Farmers have plots of different sizes, but buy the same size units of water, which means that farmers have different levels of moisture in their plots in any given week. The judge does not perfectly observe the main determinant of farmers' water *needs*, their plot's soil moisture level. Our analysis implicitly assumes that social punishments are the same for everyone. However, wealthy farmers could suffer higher social punishments than poor farmers. If that were the case, we underestimate the true value of the coefficient on column 1, *i.e.*, the true effect would be larger in such cases.

Fines are significantly lower, 4.93 *pesetas* lower as column 2 shows, when the victim is wealthy. Judges imposed smaller fines in cases with less damage (column 3), consistent with prediction P2. Consistent with prediction P3, recidivists are punished more harshly, with fines around 15 *pesetas* higher than those for first-time offenders convicted of the same offense. That is, recidivists are fined approximately three times as much as the average. All recidivists received fines of 20 to 25 *pesetas*, the maximum allowed in the bylaws. The weekly wage of a labourer was approximately 25 *pesetas* during our time period. Columns 5 through 8 show that the results in columns 1 through 4 are robust to including the *Auction* and *Dry Month* dummy variables. The results in Table 3 also indicate that fines are lower when the victim is wealthy.

Table 4 shows that the value of water stolen, and thus the compensation, is higher when the victim is wealthy. These results are consistent with our model, and may also be consistent with the following hypothesis. The judge is concerned about the total amount of monetary punishment, the fine plus compensation. In that case, lower fines when the victim is wealthy may be a spurious correlation due to higher compensation when the victim is wealthy, and the negative correlation between compensation and fines. This hypothesis predicts a negative correlation between fine and compensation. Thus, adding compensation as a regressor in Table 3 should have a negative coefficient that is statistically different from zero. However, the correlation between fine and compensation is zero. Including compensation as a regressor in Table 3 produces a coefficient that is not statistically different from zero, and does not change the magnitude, sign, or statistical significance of the other coefficients.

Compensation

While fines simultaneously punish and reward, deterring farmers from stealing and sharing revenue with the irrigation community, compensation repairs damage either to a particular farmer or the community at large. Compensation is an estimate of the value of the stolen water. In trial sentencing documents, judges separated the amount of the fine and of the compensation. When a farmer stole water from another farmer, in the typical case, the fine went to the *Heredamiento* whereas the compensation went to the victimized farmer. The amount of compensation always equalled the value of the water stolen, which the judge had no discretion over. Therefore, we can interpret the results in Table 4 as offense characteristics.

Compensation is not affected by the offender's characteristics. Table 4, column 1 shows that the amount of compensation is not statistically different when the defendant is a *Don*. This finding counters the reasoning that *Dons* receive higher fines because when they steal, they steal more. Compensation, which measures the value of the water stolen as indicated above, is independent of the defendant's wealth. Compensation is also unaffected when the defendant is a recidivist, as shown in column 4. The amount of water stolen is uncorrelated with the defendant's observable characteristics. This finding is consistent with our interpretation of compensation as a response to damages rather than offenses. When the defendant is poor and the victim is wealthy, compensation is about 25 *pesetas* higher in column 3. While Table 2 shows that an offense is more likely to occur during a dry month, compensation is not affected by dryness.

The compensation amount is highly correlated with the victim's characteristics. Compensation is significantly higher when the victim has a *Don* honorific title, 25.03 *pesetas* in column 2. Table 1 shows that the average compensation is 11.00 *pesetas*, less than half that for wealthy victims. Judges have no discretion over the amount of compensation. Again, we interpret this correlation as characteristic of the offense. That is, when farmers steal from the wealthy, they take about 25 *pesetas* worth of water more than when they steal from the poor. This result suggests that when given the chance, farmers steal as much water as they can from a wealthy farmer but not a poor farmer. This disparity could result either from farmers' selective restraint or from wealthy farmers' larger plots, which require more water. In any case, this result reinforces the ones in Table 3, column 3 where fines are lower for poor defendants with wealthy victims. A poor farmer's smaller fine is for a more damaging offense.

In summary, we have shown robust empirical evidence that, for the same offense, recidivists were punished more harshly than first-time offenders and that the punishments were stricter when the defendant was wealthy or the victim was poor. This evidence is consistent with the theoretical model presented, where judges trade off crime deterrence and social insurance focusing purely on efficiency. In other words, our evidence is consistent with judges implementing a progressive punishment system to account for the fact that a positive number of offenses was socially optimal. Allowing farmers in extreme *need* to commit offenses created an efficient insurance of last resort in a volatile environment.

V Concluding Remarks

Our analysis may help explain the stability of the irrigation community in Mula, Spain. Mula's water allocation system combined protection of water and land property rights with flexible punishments that minimized offense rates while creating social insurance. Expanding the institutional analysis of self-governed communities begun by Elinor Ostrom, we show that fair and efficient punishments, maintained at low cost, contributed to the survival of irrigation communities.

Analyses of self-governed communities often overlook punishment progressivity and individual characteristics. We study a particular historical setting where judges imposed mild punishments on first-time offenders based on their individual characteristics and harsher punishments on recidivists. Our model features a transitory individual state related to the farmer's *need* to steal and a persistent individual state related to the farmer's propensity to steal, or *greed.* We reconcile the Beckerian insight that harsh punishments deter crime with the mild punishments and low offense rates documented in self-governing communities by Ostrom. Average punishments seem light because they were a weighted average of several small punishments for first-time offenders and a few large punishments for recidivists. Offense rates were low in equilibrium because punishments for recidivists were harsh, as both judges and farmers internalized. Due to volatile weather, the probability that a poor farmer would *need* to steal in the future was high. Losing the option value to steal in the future acted as a harsh punishment, thus deterring offenses.

In the empirical setting studied, a positive number of offenses is socially efficient. It is optimal for farmers who are liquidity constrained and in *need* of water to steal water from a neighbour, thus preventing their own trees from dying. However, a judge cannot perfectly observe whether a farmer *needs* water. Therefore, judges trade off false positives and negatives, resulting in punishments that are neither the maximum or zero. Our empirical analysis shows that the judges alternated between offense *deterrence* and water *insurance*, efficiently using information about offenses, offenders, and victims to determine the optimal punishment. In our framework, legal flexibility allows judges to use their judgement in addition to available information. When financial markets were imperfect, judges' decisions provided farmers with social insurance.

One important insight from our article is that low punishments levels, typically viewed as evidence of suboptimal contracts, were intended to increase efficiency rather than equality. In other words, the disadvantageous treatment of wealthy farmers as captured by the *Don* honorific title, whether as defendants or victims, was a consequence of efficiency. For the wealthy, their marginal utility of water was lower, the damage inflicted by their stealing was higher, and the damage or marginal disutility they experienced from theft was lower. Similarly, favourable treatment of poor farmers was a consequence of efficiency. Allowing poor farmers to steal water during a negative, idiosyncratic productivity shock helped them keep their crops and trees alive.

References

Alberola Romá, A., 'Propiedad, control y gestión del agua en regadíos deficitarios del Sureste español: la huerta de Alicante durante la Edad Moderna,' *Minius*, 23, (2015), pp. 7-40.

Allen, W., *The African Husbandman* (Edinburg, 1965).

Becker, G. S., 'Crime and Punishment: An Economic Approach,' *Journal of Political Economy*, 76, 2 (1968), pp. 169-217.

Cameron, S., 'The economics of crime deterrence: A survey of theory and evidence,' *Kyklos*, 41, 2 (1988), pp. 301-323.

Chalfin, A., and McCrary, J., 'Criminal deterrence: A review of the literature,' *Journal of Economic Literature*, 55, 1 (2017), pp. 5-48.

Chaney, E., and Hornbeck, R., 'Economic Dynamics in the Malthusian Era: Evidence from the 1609 Spanish Expulsion of the Moriscos,' *Economic Journal*, 126 (2016), pp. 1404-1440.

Coward, E. W., 'Indigenous organisation, bureaucracy and development: The case of irrigation,' *Journal of Development Studies*, 13, 1 (1976), pp. 92-105.

Donna, J., and Espín-Sánchez, J.-A., 'Complements and Substitutes in Sequential Auctions: The Case of Water Auctions,' *RAND Journal of Economics*, 49, 1 (2018), pp. 87-127.

Donna, J., and Espín-Sánchez, J.-A., 2019. 'The Illiquidity of Water Markets: Efficient Institutions for Water Allocation in Southeastern Spain,' working paper.

Ellickson, R., 1991. *Order without Law: How Neighbors Settle Disputes* (Cambridge, Mass., 1991).

Espín-Sánchez, J.-A., 'Institutional Inertia: Persistent Inefficient Institutions in Spain,' *Journal of Economic History*, 77, 3 (2017), pp. 692-723.

Espín-Sánchez, J.-A, Gil-Guirado, S., Giraldo-Paez, D., and Vickers, C., 'Labor income inequality in pre-industrial Mediterranean Spain: The city of Murcia in the 18th century,' *Explorations in Economic History*, *73* (2019).

Garrido, S., ‘Oranges or 'Lemons'? Family Farming and Product Quality in the Spanish Orange Industry, 1870-1960,’ *Agricultural History*, 84, 2 (2010), pp. 224-243.

Garrido, S., ‘Las instituciones de riego en la España del este. Una reflexión a la luz de la obra de Elinor Ostrom,’ *Historia Agraria*, 53 (2011a), pp. 13-42.

Garrido, S., ‘Governing Scarcity. Water markets, equity and efficiency in pre-1950s eastern Spain,’ *International Journal of the Commons*, 5, 2 (2011b), pp. 513-534.

Garrido, S., ‘Ampliación del regadío, regulación institucional y sostenibilidad en las huertas tradicionales de la España mediterránea,’ *Investigaciones de Historia Económica*, 8 (2012), pp. 94-103.

Glick, T., *Irrigation and Society in Medieval Valencia* (Cambridge, Mass., 1967).

González Castaño, J., and Llamas Ruiz, P., *El agua en la Ciudad de Mula, S. XVI-XX* (Mula, Spain, 1991).

Gray, R. F., *The Sonjo of Tanganika* (Oxford, 1963).

Helland, E. and Tabarrok, A., ‘Does three strikes deter? A nonparametric estimation.’ *Journal of Human Resources*, 42, 2 (2007), pp. 309-330.

Hjalmarsson, R., ‘Crime and Expected Punishment: Changes in Perceptions at the Age of Criminal Majority.’ *American Law and Economics Review*, 11, 1 (2009), pp. 209-248.

Lee, D. S., and McCrary, J., ‘The deterrence effect of prison: Dynamic theory and evidence.’ In *Regression Discontinuity Designs: Theory and Applications* (Emerald Publishing Limited 2017).

Machin, S., and Meghir, C., ‘Crime and Economic Incentives,’ *Journal of Human Resources*, 39 (2004), pp. 958-979.

Marvell, T. B., and Moody, C. E., ‘Specification problems, police levels, and crime rates.’ *Criminology*, 34, 4 (1996), pp. 609-646.

Morilla Critz, J., Olmstead, A. L., and Rhode, P. W., ‘'Horn of Plenty': The Globalization of Mediterranean Horticulture and the Economic Development of Southern Europe, 1880-1930,’ *The Journal of Economic History*, 59, 2 (1999), pp. 316-352.

Ostrom, E., *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge, Mass., 1990)

Ostrom, E., *Crafting Institutions for Self-Governing Irrigation Systems* (San Francisco, 1992).

Pérez Picazo, M. T., ‘La agudización de las tensiones en los regadíos deficitarios del Sureste entre 1780 y 1950-1960, ¿lucha de clases o conflictividad ecosocial?’ *Ayer*, 47 (2002), pp. 231-258.

Pita Pico, R., ‘Nobleza y limpieza de sangre en el nororiente neogranadino, 1710-1810: entre la segregación y la amenaza étnica,’ *Procesos históricos*, 24 (2013), pp. 16-43.

Posner, E. A., *Law and Social Norms* (Cambridge, Mass., 2000).

Reher, D. S., and Ballesteros, E., ‘Precios y Salarios en Castilla la Nueva: la Construcción de un Índice de Salarios Reales: 1501–1991.’ *Revista de Historia Económica,* 11, 1 (1993), pp. 101–54.

Rodríguez Llopis, M., *Historia de la Región de Murcia* (Murcia, Spain, 1998).

Ruiz-Funés, Mariano, *Derecho Consuetudinario y Economía Popular de la Provincia de Murcia* (Madrid, 1916).

Soria Mesa, E., ‘Genealogía y poder. Invención de la memoria y ascenso social en la España Moderna,’ *Revista de Historia Moderna*, 30 (2004), pp. 21-56.

Sutawan, N., ‘Farmer-Managed Irrigation Systems and the Impact of Government Assistance: A Note from Bali, Indonesia,’ in *47 communal gravity systems: Organization profiles*, by Romana P. de los Reyes (Queron City, Philippines, 1980).

Tan-Kim-Yong, U., 1980. ‘Problems and Strategies in Management of Communal Irrigation Systems: The Experience in Joint Decision-Making by Farmers and Agencies,’ in *47 communal gravity systems: Organization profiles*, by Romana P. de los Reyes (Queron City, Philippines, 1980).

Vickers, C., and Ziebarth, N. L., ‘Economic Development and the Demographics of Criminals in Victorian England,’ *Journal of Law and Economics*, 59, 2016, pp. 191-223.

Wittfogel, K. A., *Oriental Despotism: A Comparative Study of Total Power* (New Haven, 1957).

Ziming, F. E., Hawkins, G. and Kamin, S., *Punishment and democracy: Three strikes and you're out in California* (Oxford, 2001).

Official Publications

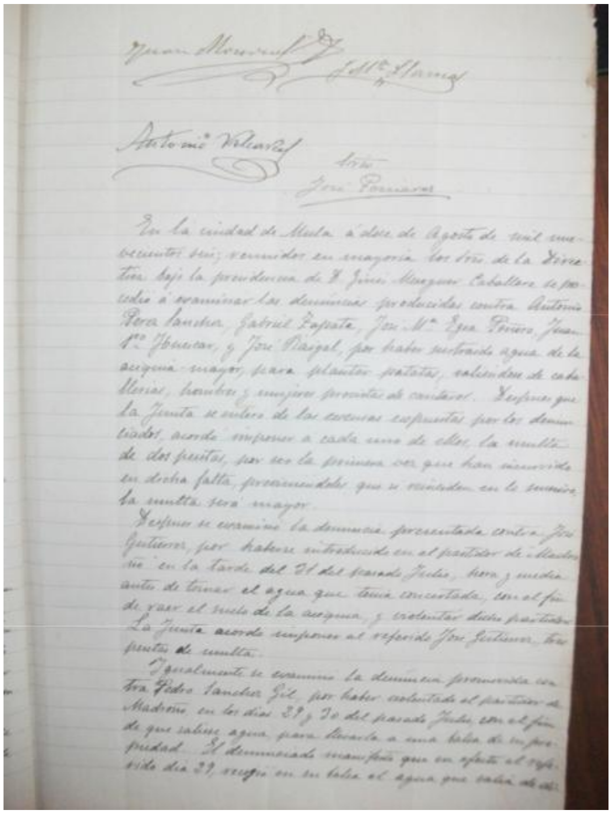
UNESCO, 'Convention For The Safeguarding Of The Intangible Cultural Heritage,' Decision for inscription on the Representative List in 2009, ITH/09/4.COM/CONF.209/13 Rev.2. http://www.unesco.org/culture/ich/doc/src/ITH-09-4.COM-CONF.209-13-Rev.2-EN.pdf#Decision1370.

FIGURE 1
Trials in self-governed communities.

Notes: Top-Left: Painting “Juicio del Consejo de Hombres Buenos” by Fulgencio Saura Mira. Hosted by Servicio de patrimonio Histórico, Dirección General de Cultura Región de Murcia. Top-Right: Caption of a trial for the Council of Good Men in Murcia. Bottom: Map of the area under study.

FIGURE 2

Sample of Sentence.



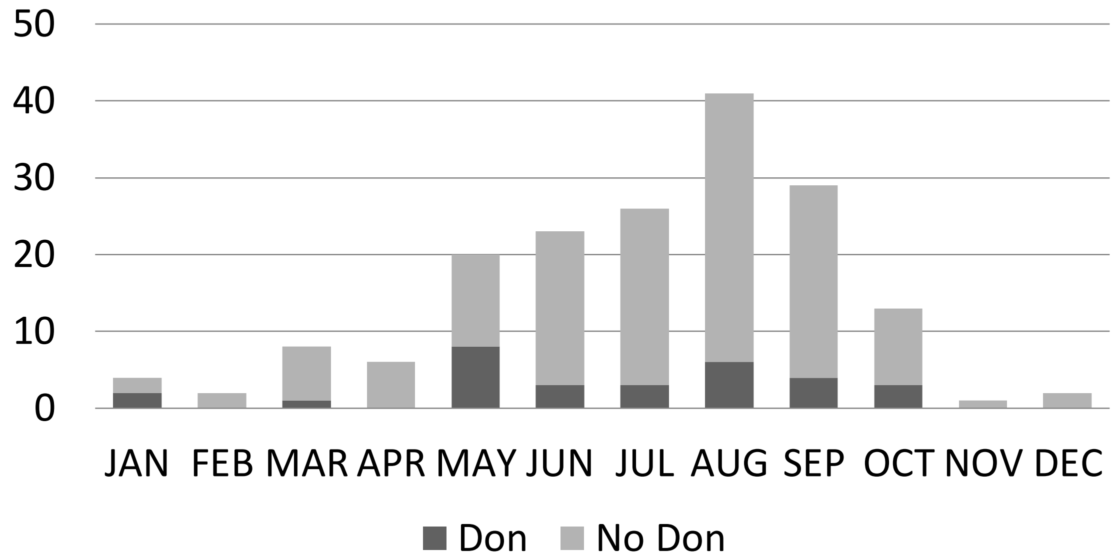
"En la ciudad de Mula a doce de Agosto de mil novecientos seis; reunidos en mayoría los señores de la Directiva bajo la presidencia de D. Ginés Meseguer Caballero, se procedió a examinar las denuncias producidas contra Antonio Pérez Sánchez, Gabriel Zapata, José María Egea Piñero, Juan Francisco Huéscar, y José Raigal, por haber sus-traído agua de la acequia-mayor, para plantar patatas, valiéndose de caballerías, hombre y mujeres provistas de cantaros. Después que la Junta se enteró de las excusas expuestas por los denunciados, acordó imponer a cada uno de ellos la multa de dos pesetas, por ser la primera vez que han incurrido en dicha falta, previniéndoles que si reinciden en lo sucesivo, la multa será mayor."

"In the city of Mula, on August 12, 1906; with the majority of the board under the presidency of Don Ginés Meseguer Caballero, they proceeded to examine the accusations against Antonio Pérez Sánchez, Gabriel Zapata, José María Egea Piñero, Juan Francisco Huéscar, and José Raigal, because they stole water from the main canal, to irrigate potatoes, using horses, men and women with jugs. After the board learned about the excuses claimed by the defendants, they agreed to impose a fine of two pesetas, to each of them, because it was the first time that they incurred in such a misdemeanor, warning them that if they recidivate in the future, the fine would be larger."

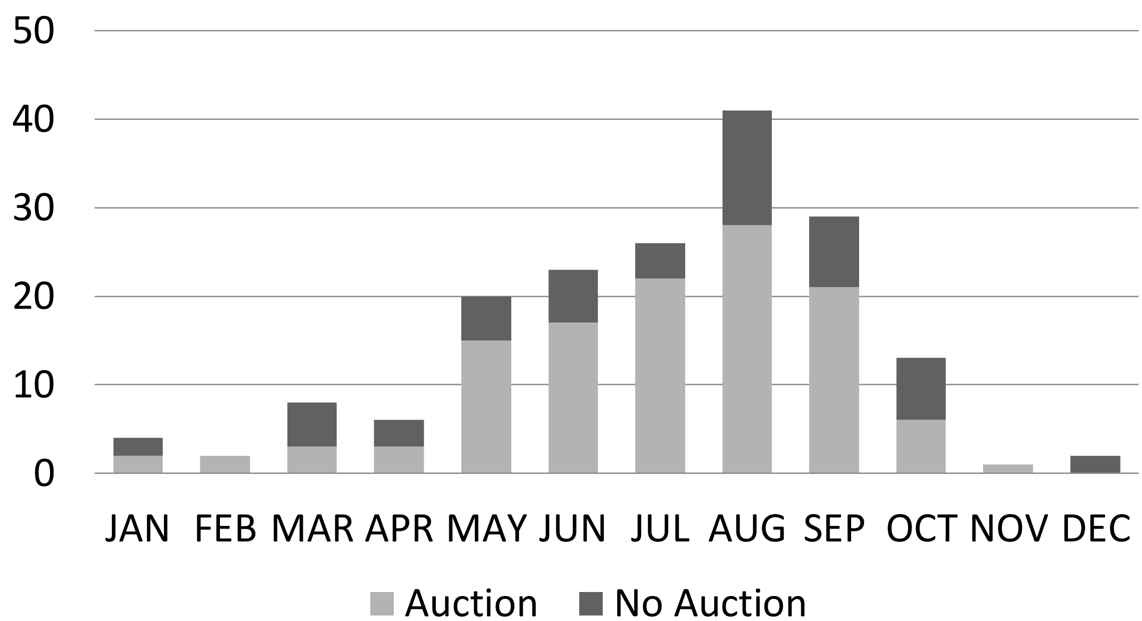
Notes: Left: Caption of the first page of a sentence, corresponding to a single trial, on August 12, 1906, from the *Archivo Municipal de Mula*, section *Heredamiento de* Aguas, in Mula (Spain). Right: Transcription in the original Spanish and authors' translation of the first paragraph.

FIGURE 3
Seasonality of Auctions and Guilty *Dons*.

Panel A. Crimes: Seasonality of crimes where the defendant had *Don* honorific title.



Panel B. Trials where there was an auction the previous week.



Notes: Data using the 174 trials where the defendant was found guilty. Panel A shows the number of crimes (subset of trials where the defendant was found guilty), where the victim had a *Don* honorific title (dark) or not (light), for each month. Panel B shows the number of trials where there was an auction the previous week, for each month.

TABLE 1
Summary Statistics.

Variable	Mean	SD	Min	Max	Obs.
Guilty	0.62	0.49	0	1	282
Dry month	0.81	0.39	0	1	282
Rain	0.22	0.42	0	1	282
Victim is Don	0.26	0.44	0	1	282
Defendant is Don	0.15	0.36	0	1	282
Auction	0.64	0.48	0	1	282
Price	29.00	25.99	0.2125	112.84	181
Fine	5.85	9.11	0	65	175
Compensation	11.00	27.17	0	240.75	175
Recidivist	0.04	0.20	0	1	175

Notes: Summary statistics for selected variables. *Guilty* is a dummy variable that equals 1 if the defendant was found guilty during the trial. *Fine* is the amount of fine imposed on guilty defendants. *Dry Month* is a dummy variable that equals 1 if the alleged crime was committed during a dry month, from May to October, and 0 otherwise. *Rain* is a dummy variable that equals 1 if there was rain the week before the trial, and 0 otherwise. *Victim is Don* is a dummy variable that equals 1 if the victim of the crime was an individual referred to as *Don*, and 0 otherwise. *Defendant is Don* is a dummy variable that equals 1 if the defendant was an individual referred to as *Don*, and 0 otherwise. *Auction* is a dummy variable that equals 1 if there was an auction in the week that the crime was reported or 0 otherwise. *Price* is a continuous variable equal to the average price paid at the auction the week before the trial, if there was an auction. *Compensation* is the amount that the defendant paid to the victim as recompense for the loss suffered; it represents the value of the water stolen. *Recidivist* is a dummy variable that equals 1 if the farmer who committed the crime had also committed a crime in the past, and 0 otherwise.

TABLE 2
Probability of Being Guilty and Farmers' Characteristics.

Dep. variable: guilty	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Defendant not Don	-0.091	-0.238	-0.109	-0.238	-0.097	-0.001	-0.105	-0.001
	(0.077)	(0.078)	(0.077)	(0.078)	(0.079)	(0.099)	(0.080)	(0.000)
(Defendant not Don) ×		0.222		0.211		-0.120		-0.132
(dry month)		(0.079)		(0.082)		(0.207)		(0.206)
(Defendant not Don) ×			0.091	0.040			0.038	0.044
(victim Don) ×			(0.074)	(0.079)			(0.081)	(0.081)
(dry month)								
Controls	N	N	N	N	Y	Y	Y	Y
Number of trials	282	282	282	282	282	282	282	282
Pseudo R^2	0.003	0.025	0.007	0.025	0.040	0.041	0.041	0.046

Notes: All specifications are probit regressions, and include a constant that is not reported. Marginal effects are reported. Dependent variable is *Guilty*, a dummy variable that equals 1 if the defendant was found guilty during the trial. Standard errors corresponding to the marginal effects are in parenthesis. We obtain similar results using logit specifications. Control variables include a constant *Dry Month*, *Rain*, *Auction* and *Price*. See Table 1 for variable definitions.

TABLE 3
Fines and Farmers' Characteristics.

Dep. variable: Fine	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Defendant not Don	-7.018		-5.733		-7.841		-6.381	
	(1.754)		(1.769)		(1.735)		(1.777)	
Victim Don		-4.933				-4.867		
		(1.586)				(1.540)		
(Defendant not Don) ×			-4.778				-4.404	
(victim Don)			(1.603)				(1.562)	
Recidivist				14.74				14.24
				(3.342)				(3.274)
Controls	N	N	N	N	Y	Y	Y	Y
Number of trials	175	175	175	175	175	175	175	175
R^2	0.085	0.053	0.130	0.101	0.191	0.144	0.227	0.184

Notes: Sample restricted to trials where the defendant was found guilty. All specifications are OLS regressions, and include a constant not reported. Dependent variable is Fine, the amount of fine, measured in *pesetas* imposed to defendants when they were found guilty. Standard errors are in parenthesis. Control variables include a constant, *Dry Month*, *Rain*, *Auction* and *Price*. See Table 1 for variable definitions.

TABLE 4
Compensations and Farmers' Characteristics.

Dep. variable: Compensation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Defendant not Don	7.487		0.622		8.959		0.368	
	(5.435)		(5.193)		(5.658)		(5.477)	
Victim Don		25.03				25.48		
		(4.475)				(4.502)		
(Defendant not Don) ×			25.52				25.91	
(victim Don)			(4.703)				(4.812)	
Recidivist				-10.61				-8.640
				(10.48)				(10.70)
Controls	N	N	N	N	Y	Y	Y	Y
Number of trials	175	175	175	175	175	175	175	175
R2	0.011	0.153	0.155	0.006	0.032	0.174	0.175	0.021

Notes: Sample restricted to trials where the defendant was found guilty. All specifications are OLS regressions, and include a constant not reported. Dependent variable is compensation, the amount that the defendant must pay to compensate the victim for the loss inflicted; it represents the value of the water stolen. Standard errors are in parenthesis. Control variables include a constant, *Dry Month*, *Rain*, *Auction* and *Price*. See Table 1 for variable definitions.

APPENDIX: THE MODEL

In this appendix, we present the theoretical model. First, we introduce the main features in a static framework. Then, we extend the model to a dynamic setting. This allows us to capture the progressiveness of the punishment system that we observed in the empirical setting. Progressiveness arises because judges update their beliefs about farmers' type based on their criminal record. In the empirical analysis, we assume that individual trials are independent. Thus, in the dynamic model we consider the case with one type of farmer. The independence assumption would be violated if, for instance, the number of offenses provides information about the unobserved state, in additional to the public signal. In those cases, we incorporate this information and reinterpret the public signal. That is, trials are conditionally independent.

A.1. Static Model

Notice that we model farmers as being heterogeneous in two dimensions, their need for water r_i and their disutility from punishment (or greed) θ_i. Farmer *i* has the following expected utility function:

$$U_i\ (r_i + w,\ \theta_i,\ F\ (R),\ \gamma(R)) \quad (1),$$

where $r_i \in \{r_L, r_H\}$ is the individual state of the farmer, *i.e.*, the idiosyncratic productivity shock, which can be high or low ($r_H > r_L$); $w \in \{0, W\}$, with $W > 0$, is the amount of water stolen by the farmer; $\theta_i \in \{\theta_H, \theta_L\}$ is the type of the farmer (either not greedy, $\theta_i = \theta_H$, or greedy, $\theta_i = \theta_L$); $R \in \{H, L\}$ is a public signal about the individual state, *i.e.*, the amount of rain in the town, which can be high or low ($H > L$); $\gamma(R) \in [0, 1]$ is the probability that a farmer is caught if she/he steals water; $F(R) \in [0, F]$ is the fine imposed on the farmer caught stealing water, which is a continuous variable capped at F as prescribed in the bylaws of the *Heredamiento* and can depend on the public signal. The farmer's type θ_i only affects the farmer's utility when she/he steals and is convicted.[1] That is, the utility of two farmers that receive the same idiosyncratic productivity shock and do not steal water is the same, regardless of their type. Notice that we allow the probability of being caught $\gamma(R)$ to vary as a function of the public signal R. This means that the monitoring done by the guards or by the other farmers might vary as a function of weather conditions.

A farmer can steal from the main canal when no other farmer is irrigating, in which case the whole community suffers. The most common case, however, happen when a farmer diverts water from the main canal or a sub-canal when another farmer is irrigating, and effectively steals water from another farmer. Only farmer *i* observes r_i. Rainfall, *R*, is a public signal. However, the way the farmer uses water is private information. The water used by the farmer would be highly but not perfectly correlated with the amount of rain in the town. Some farmers, for example, have irregular land and cannot take advantage of all the water they get. Alternatively, the farmer may not be able to plow the watered plot the day of the rainfall due to a contingency, such as sickness. More generally, r_i captures the idiosyncratic component for farmer *i*'s plot moisture, or an idiosyncratic productivity shock.

Both the judge and the farmer observe the public signal, *R*, which is correlated with the individual state r_i as follows:

$$P\ (r_i = r_L | R = R_L) = q_L \text{ and } P\ (r_i = r_L | R = R_H) = q_H. \quad (2)$$

Note that, even when the judge observes the public signal, in equilibrium there would be false negatives and positives, *i.e.*, guilty farmers will be set free and innocent farmers will be punished. Our model nests the following special cases:

- $q_H = q_L = 1/2$: in this case the signal is uninformative. This is the case in the existing literature, when one does not take into account the possibility of public signals about criminal type.
- $q_H = 1 - q_L = 0$: in this case the signal reveals the type perfectly. This is an implicit assumption in Beckerian models, in which the trial will determine whether the defendant is guilty or not, without error.

Let $\pi \in (0, 1)$ be the probability that a farmer is not *greedy*, *i.e.*, $Prob(\theta_i = \theta_H) = \pi$, which is common knowledge. Without loss of generality, let us normalize the most informative signal, R_L, thus, $q_L \geq q_H$. This is equivalent to saying that it is more likely that the farmer receives little water when rainfall is light than when rainfall is heavy.

If a farmer does not steal water, her/his utility is:

$$u(r_i,\ \theta_i,\ 0,\ 0). \quad (3)$$

If a farmer steals an amount of water equal to *w*, her/his utility is:

[1] We do not distinguish between the case where farmers suffer if they steal but are not caught (self-shamed) and the case where they suffer only if they are caught and convicted (social-shamed). Cases where farmers stole water and were not caught are not observed in the data and it is not possible to distinguish self-shamed from social-shamed cases.

$$u(r_i + W, \theta_i, F(R), \gamma(R)) = \gamma(R)\, u(r_i + W, \theta_i, F(R)) + [1 - \gamma(R)]\, u(r_i + W, \theta_i, 0), \quad (4)$$

where $u(.\ ,.\ ,.)$ is the Bernoulli utility function. Note that, when a farmer does not steal water, her/his utility only depends on her/his idiosyncratic productivity shock r_i. When a farmer steals water, however, in addition to her/his idiosyncratic productivity shock r_i, her/his utility also depends on her/his (greed) type θ_i and on the public signal R through the punishment received. We interpret θ_i in terms of the marginal returns derived from an additional unit of water stolen. In that sense, a higher θ_i is related to a better technology when stealing water. It could capture, for example, that the farmer has several workers (sons) who help her/him irrigate within a short period of time, or an idiosyncratic advantage due to the shape of the farmer's plot.[2]

We assume $u(.,.,.,.)$ is strictly increasing and concave in its first term, strictly decreasing in its third term, and has a negative cross-derivative between the second and third term:

(a) $u_1(.,.,.,.) > 0$: The farmer receives a positive utility from water, stolen or not.
(b) $u_{11}(.,.,.,.) < 0$: Water has diminishing marginal returns.
(c) $u_2(.,.,.,.) \leq 0$: Greedy farmers suffer less from stealing than not greedy ones.
(d) $u_2(.,.,0,0) = 0$: If a farmer does not steal water, her/his utility is not affected by her/his (greedy) type.
(e) $u_3(.,.,.,.) < 0$: The farmer receives a negative utility from the punishment.
(f) $u_{23}(.,.,.,.) < 0$: Greedy farmers suffer less from a given punishment than greedy ones.

A.1.1. The Farmer's problem

To make the problem relevant for the empirical application, we restrict attention to the parameters that would create incentives to steal water and where it would be efficient for them to do so. In particular, we make the following assumption about the parameter space:

Assumption A1: It is efficient that the farmer steals water if she/he received low idiosyncratic productivity shock:

$$u(r_L + W, \theta_i, F(R), \gamma(R)) - u(r_L, \theta_i, 0, 0) \geq P_R(W), \text{ for all } F(R), \theta_i \quad (5)$$

where $P_R(W)$ is the social value of W units of water when the public signal is R, *i.e.*, $P_R(W) = q_R(u(r_L + W) - u(r_L)) + (1 - q_R)(u(r_H + W) - u(r_H))$. Notice that, unlike in other models, the fine is not a costless transfer because farmers, especially non-greedy farmers, suffer from the fine.

The public signal can be reinterpreted as the proportion (rather than the probability) of farmers who received a low idiosyncratic productivity shock. Hence, the social value $P_R(W)$ equals the average utility that the amount of water W adds. The left-hand side of the equation in A1 represents the increase in utility that farmer i received when she/he steals W units of water. The right-hand side of the equation represents the expected increase in utility that a random farmer would have received had she/he used the stolen water.

The timing of the game is as follows. First, nature draws $\{r_i, R\}$; the farmer observes $\{r_i, R\}$. Second, the farmer chooses whether to steal, *i.e.*, $w \in \{0, W\}$. Third, if the farmer stole water, the judge observes R and chooses a policy function $F(R)$. Fourth, payoffs are given. If the farmer does not steal, she/he cannot be caught; her/his utility is $u(r_i, ., 0, 0)$. If the farmer chooses to steal, *i.e.*, $w = W$, she/he is caught with probability $\gamma(R)$ and her/his utility is $u(r_i + W, \theta_i, F(R), \gamma(R))$.

Thus, the farmer steals if, and only if:

$$u(r_i + W, \theta_i, F(R), \gamma(R)) \geq u(r_i, ., 0, 0). \quad (6)$$

If the judge were to observe θ_i, the judge could choose $F(R)$ such that the farmer finds it profitable to steal water if $r_i = r_L$, and does not steal water if $r_i = r_H$. This is the first-best outcome, and is a consequence of the concavity of the utility function with respect to water. However, the judge does not know θ_i. Thus, in general, the first-best outcome is not attainable.

A.1.2. The Judge's Problem

The judge's objective is to achieve social efficiency. The judge wants to punish the farmer if she/he steals water when $r_i = r_H$, and not to punish her/him when $r_i = r_L$. But the judge does not observe the idiosyncratic productivity shock of the farmer, r_i. Instead, the judge only observes a signal, R, which is positively but not perfectly correlated with idiosyncratic productivity shock, r_i.[3] Although we are interested in the more realistic case where greed is not fully observable and the public signal is imperfectly correlated with the individual

[2] In one of the trials, the theft method was particularly innovative. The defendant told three children to "swim" in the canal that was next to his plot in such way that the canal was blocked. The water then overflowed the canal and spilled over the defendant's plot.

[3] If we consider the case with asymmetric farmers, whose characteristics are observed by the judge, the public signal is still a sufficient statistic for all relevant information observable by the judge.

state of water available to farmer i, we show as benchmarks the cases where either the greed type θ_i or the idiosyncratic productivity shock r_i is observable. The benchmarks highlight why we need a model with two dimensions of unobserved heterogeneity to obtain testable predictions in our setting.

We allow the judge to observe a noisy signal about water needs but not about greed for the following three reasons. First, we do not have data regarding farmers' greed and cannot test the predictions of such an extension. Second, although the judge does not observe a direct signal related to the greed of the farmer, she/he observes an indirect signal in the dynamic game. Greed is a permanent state, while water needs are not. Therefore, a recidivist is more likely to be greedy than a first-time offender. Recidivism can then be interpreted as an indirect greed signal. We explore this in the next section, when we introduce dynamics. Finally, the model would be more complicated to solve, but the intuition regarding the signal about would be similar.

Greed is Perfectly Observable. In this case the judge does not observe the idiosyncratic productivity shock, r_i, but the judge observes the greed type of the farmer. Thus, the judge can condition the punishment both on the greedy type, θ_i, and the public signal, R. Result **R1** below, however, shows that in this case the optimal punishment is independent of the public signal.

Result R1: If greed were perfectly observable, the optimal punishment is independent of the public signal and positive.

Proof: The judge chooses the punishment such that only a farmer in need of water, *i.e.*, $r_i = r_L$, would find it profitable to steal. The optimal punishment satisfies:

$$u(r_L + W, \theta_i, F(R, \theta_i), \gamma(R)) \geq u(r_L, ., 0, 0), \quad (7)$$
$$u(r_H + W, \theta_i, F(R, \theta_i), \gamma(R)) < u(r_H, ., 0, 0). \quad (8)$$

The punishment does not depend on the public signal because the judge can separate greed types by imposing different punishments. In this case, the first-best allocation is achieved. The intuition is simple: efficiency dictates that only farmers in need would steal water. When greed is observable, the judge tailors the punishment to each greedy type. The solution would be the same as if there were no differences in greed, where farmers needing water self-select into stealing. □

The optimal punishment is increasing in the amount of water stolen, W; decreasing in θ_i, and decreasing in the idiosyncratic productivity shock in the bad state, r_L. The last result says that punishment is lower when the farmer needs less water, *i.e.*, when the gains from stealing water are smaller. This is because, as long as r_L is sufficiently lower relative to r_H, it is optimal that the farmer steals water. However, the gains of stealing water are smaller when r_L is greater. Thus, the judge imposes a smaller punishment. Note that if greed is irrelevant, *i.e.*, $\theta_L = \theta_H$, then the same results apply. In that case, the optimal punishment would always be the same.

Water type is Perfectly Observable. In this case, the judge observes the idiosyncratic productivity shock, but not whether the farmer is greedy. Thus, the judge can condition the fine on the individual state, that is, $F(R) = F(r_i)$. This is equivalent to having a perfectly correlated public signal: $q_L = q_H = 1$. Result **R2** below characterized the optimal punishment when water need is perfectly observable.

Result R2: If the water type is perfectly observable, the optimal punishment is maximum when the type is high and minimum when the type is low, that is, $F(r_H) = F$ and $F(r_L) = 0$.

Proof: The judge allows farmers to steal when $r_i = r_L$, but not when $r_i = r_H$. The first result holds if $u(r_L + W, \theta_i, F(r_L), \gamma(R)) \geq u(r_L, \theta_i, 0, 0)$, for all θ_i. To obtain the latter, the judge imposes a fine sufficiently high, $F(r_H) = F$. The intuition here is similar to the intuition in **R2**. When there is only one dimension of heterogeneity, it is easy to separate each type. Without restrictions on the maximum punishment, the outcome achieves first-best, *i.e.*, imposing a sufficiently high punishment for farmers who do not need water will prevent them from stealing. When there is a restriction on the maximum punishment available, however, efficiency is not guaranteed. Following the intuition from before, the judge can impose the minimum punishment possible when the state is low, *i.e.*, $F(r_L) = 0$, and the maximum punishment available when the state is high, *i.e.*, $F(r_H) = F$. However, if F is sufficiently small, then a farmer with $r_i = r_H$ would find it optimal to steal water in the high state, and in that case, every farmer will always steal water, regardless of the punishment implemented by the judge. □

Note that the predictions are different than in the previous case. If rainfall is heavy, punishment is maximum and nobody steals in equilibrium. If rainfall is light, punishment depends on the idiosyncratic productivity shock in the bad state. Optimal punishment is increasing in the amount of water stolen, W; decreasing in the greed of the greediest farmer θ_H; and decreasing in the idiosyncratic productivity shock in the bad state, r_L.

Greed and Water types are Unobservable. This is the most realistic case and the one we focus on in the empirical section. Now the judge only observes the public signal about rain, R, not the farmer's type, θ_i, nor the farmer's idiosyncratic productivity shock, r_i. Thus, the judge can only condition the fine on the public signal, $F(R)$. Given R, the farmer is not greedy with probability π. Depending on the parameters, the judge may impose a fine such that i) all farmers steal for all realizations of R; ii) no farmer steals for any realization of R, or; iii) farmers steal when $R = L$, and they do not steal when $R = H$. We focus on the latter, more realistic case. In the discussion below it is useful to simplify the notation as follows. Define the gains from stealing water for type (r_i, θ_j) as

$$\Delta(r_i, \theta_j) \equiv u(r_i + W, \theta_j, F(R), \gamma(R)) - u(r_i, \theta_j, 0, 0). \quad (9)$$

In general, an efficient punishment deters not needy types, r_H, from stealing and encourages needy types, r_L, to steal. Thus, an efficient punishment satisfies the following inequalities, depending on the four realizations of the two types:

- Greedy and not needy: $\Delta(r_H, \theta_L) < 0$, *i.e.*, $u(r_H + W, \theta_L, F(R), \gamma(R)) < u(r_H, \theta_L, 0, 0)$.
- Greedy and needy: $\Delta(r_L, \theta_L) \geq 0$, *i.e.*, $u(r_L + W, \theta_L, F(R), \gamma(R)) \geq u(r_L, \theta_L, 0, 0)$.
- Not Greedy and needy: $\Delta(r_H, \theta_H) < 0$, *i.e.*, $u(r_L + W, \theta_H, F(R), \gamma(R)) < u(r_L, \theta_H, 0, 0)$.
- Not Greedy and needy: $\Delta(r_L, \theta_H) \geq 0$, *i.e.*, $u(r_L + W, \theta_H, F(R), \gamma(R)) \geq u(r_L, \theta_H, 0, 0)$.

Depending on whether the greed effect is important, the judge could apply an optimal punishment. If greed has a small effect on the utility of the farmers, the judge would be able to implement the efficient punishment. However, if greed affects the utility of the farmers more than their individual state, then the optimal punishment would not be efficient. We formalize this intuition with the following assumption.

Assumption A2: The parameters are such that the following relation holds for any punishment,

$$F(R): \Delta(r_L, \theta_H) > \Delta(r_L, \theta_L). \quad (10)$$

Assumption **A2** implies that a farmer who is "needy but not greedy" benefits more from stealing water than one who is "greedy but not needy." In other words, the "need of water" effect is stronger than the greed effect for farmers' decision to steal water or not. Result **R3** below shows that when **A2** holds, *i.e.*, when need is *more important* than greed, the results are similar to the case in which greed is observable.

Result R3: If both the greed type and the need type are unobservable, and equation **A2** holds, then the optimal punishment is efficient and does not depend on the public signal.

Proof: When assumption **A2** holds, the differences in utility from stealing water are ranked as follows:

$$\Delta(r_L, \theta_L) > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_L) > \Delta(r_H, \theta_H), \quad (11)$$

where the first and the third inequality follow from the fact that greed types suffer more from the stealing than greedy types, and the second inequality comes from **A2**. In this case, and using that Δ is monotonically decreasing in $F(R)$, it is straightforward to see that an optimal punishment exists that can "separate" the needy from the not needy farmers. The punishment would be high enough to make needy farmers steal water, and not needy farmers not steal such that in equilibrium:

$$\Delta(r_L, \theta_L) > \Delta(r_L, \theta_H) > 0 > \Delta(r_H, \theta_L) > \Delta(r_H, \theta_H). \quad (12)$$

In this case, the optimal punishment does not depend on the public signal, and the first-best can be achieved with a fixed punishment. □

When **A2** does not hold however, the rank between the differences in utility from stealing water is as follows:

$$\Delta(r_L, \theta_L) > \Delta(r_H, \theta_L) > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_H), \quad (13)$$

Note that now there is no punishment that can "separate" the needy from not needy farmers. However, we can still characterize the second-best punishment for each signal realization. Prediction **P1** below shows that when assumption **A2** does not hold, the optimal punishment depends on the public signal.

Prediction P1: If both the greed type and the need type are unobservable, and assumption **A2** does not hold, then the optimal punishment requires a **mild** punishment when the signal is low and a **harsh** punishment when the signal is high.

Proof: Using again the monotonicity of punishment it is easy to see that there are two second-best punishments that could be applied here. The first (mild) punishment allows stealing water to all types except (r_H, θ_H). This can be achieved with a low punishment. The second (harsh) punishment allows stealing water only to farmers of type (r_L, θ_L). In equilibrium, these second-best punishments imply:

Mild $\Delta(r_L, \theta_L) > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_L) > 0 > \Delta(r_H, \theta_H)$. (14)

Harsh $\Delta(r_L, \theta_L) > 0 > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_L) > \Delta(r_H, \theta_H)$. (15)

One can see that when the public signal is not informative, *i.e.*, $q_L \approx q_H$, the optimal punishment would be either always **mild** or always **harsh**. However, when the public signal is informative, *i.e.*, $q_L >> q_H$, the optimal punishment would typically imply a **mild** punishment when the signal is low, *i.e.*, $R = L$, and a **harsh** punishment when the signal is high, *i.e.*, $R = H$. The intuition is straightforward. Note that in any optimal punishment system and under any signal "needy and greedy" (r_L, θ_L) types always steal water and "not needy and not greedy" (r_H, θ_H) types never steal water, both of which are efficient. The inefficiency arises because the judge cannot distinguish "not needy and greedy" (r_H, θ_L) from "needy and not greedy" (r_L, θ_H) types. The judge would like the former to steal water, but not the latter. However, these two types are pooled together. When the signal is low, a high fraction of the farmers in the pool are the "needy and not greedy" (r_L, θ_H) type. Thus, it is optimal for the judge to allow "everyone" in the pool to steal water. When the signal is high, a small fraction of the farmers in the pool are the "needy and not greedy" (r_L, θ_H) type. Then, it is optimal for the judge to allow "no one" in the pool to steal water.

"High" and "Low" fractions here are relative. The actual threshold depends on the preferences of the judge, and the number of farmers of each type, conditional on the signal. For example, the judge objective function could be uniformly utilitarian. In that case, she/he wants to allow the farmers in the pool if there are more than 50 percent of "needy and not greedy" types. Then, it could be that $q_L > q_H > 0.5$, and the judge wants to always implement the **mild** punishment, for both signals. Alternatively, if $0.5 > q_L > q_H$, then the judge always wants to implement the **harsh** punishment. The more interesting and realistic case happens when $q_L > 0.5 > q_H$. In that case, the judge implements the **mild** punishment when the signal is low, and the harsh punishment when the signal is high, *i.e.*, $F(L) < F(H)$. The optimal punishment would depend on the fraction of farmers who are not greedy, π. When π is small, most farmers in the pool would be greedy, and the judge would impose a harsher punishment. □

Prediction P2: If both the greed type and the water type are unobservable, and equation **A2** does not hold, then the optimal punishment requires a **harsh** punishment when the victim received high idiosyncratic productivity shock r_H and a **mild** punishment when the victim received low idiosyncratic productivity shock r_L.

Proof: The analysis of the judge's behavior above is related to the characteristics of the crime and of the criminal. However, the efficiency of the system also depends on the characteristics of the victim. Assumption **A1** means that it is efficient for a farmer that received low idiosyncratic productivity shock, r_L, to steal water from an "average" farmer. A direct consequence is that it is also efficient for a farmer to steal water from a farmer that received high idiosyncratic productivity shock, r_H. Due to the concavity of the utility function on water, the marginal utility of water is highest for a farmer that received r_L, is lowest for a farmer that received r_H, and is intermediate for the average farmer. Thus, A1 implies that it is also efficient to steal water from a farmer that received a high idiosyncratic productivity shock, *i.e.*, $u(r_L + W, \theta_i, F(R)) - u(r_L, \theta_i,.) \geq P_R^H(W) \equiv u(r_H + W) - u(r_H)$. Moreover, following the same logic, the gain in efficiency when a farmer that received low idiosyncratic productivity shock, r_L steals water would be greater when the victim is a farmer that received high idiosyncratic productivity shock, r_L. □

In addition to Prediction **P2** above, we can also see some comparative statics. In particular, the lower the probability q_R that the victim received low idiosyncratic productivity shock, r_L, the higher the efficiency gains from stealing, and the less likely is that judge would impose a harsh punishment. The intuition is the same as above. Before, when deciding between a harsh and a mild punishment the judge takes into account the probability that the defendant received a low or high idiosyncratic productivity shock, *i.e.*, the higher the probability that the defendant received a low idiosyncratic productivity shock, the lower the punishment.

Now, when deciding between a harsh and a mild punishment, the judge takes into account the probability that the victim received a low or high idiosyncratic productivity shock, *i.e.*, the higher the probability that the victim received a high idiosyncratic productivity shock, the lower the punishment.

A.2. Dynamic Model

We now extend the previous static model to a dynamic setting with two periods. The same qualitative results hold in a general model with multiple, finite periods. In the second period, the state space of the public signal is: $RR' \in \{HH, HL, LH, LL\}$. Let y_R^t be a dummy equal to 1 if the farmer was caught in period t and the public signal at time t was equal to R, and 0 otherwise. Then: $(y_R^1, y_R^2) \in \{(1,1), (1,0), (0,1), (0,0)\}$.

When $(y_R^1, y_R^2) = (1,0)$ or $(y_R^1, y_R^2) = (0,0)$ the farmer was not caught (hence, not punished) in the second period, and we cannot say anything about the dynamics of the punishment. When $(y_R^1, y_R^2) = (0,1)$ the agent was not caught in the first period, but she/he was caught in the second period. The prior belief comes from a situation where the farmer has not been caught before, and thus there should be no update.

We focus on the case where the agent has been caught twice, $(y_R^1, y_R^2) = (1,1)$. Based on the results above, when **A2** does not hold, farmers who steal water are more likely to be greedy. When the punishment is mild, all farmers steal water except "not needy and not greedy" (r_H, θ_H) types. Thus, under the mild punishment system, the probability of a farmer who stole water being greedy is higher than the unconditional probability, π. When the punishment is harsh, only "needy and greedy" (r_L, θ_L) types steal water. Thus, under the harsh punishment system, the probability of a farmer who stole water being greedy is higher than the unconditional probability, π.

Prediction P3: A recidivist farmer is more likely to be greedy than a first-time offender. Thus, she/he is more likely to receive a harsh punishment.

Proof: The model is solved by backward induction. Define the posterior probability:

$$\sigma_{RR'} \equiv P(r_i^2 = r_L^2 \mid RR', y_R^1 = 1). \quad (16)$$

This is the probability that the farmer needs water in the second period, conditional on the public signal being R in $t=1$ and R' in $t=2$, given that the farmer was caught at $t=1$. Similarly, the probability that the farmer needs water in the second period, conditional on the public signal being R in $t=1$ and R' in $t=2$, given that she/he was not caught at $t=1$ is:

$$\tau_{RR'} \equiv P(r_i^2 = r_L^2 \mid RR', y_R^1 = 0). \quad (17)$$

Once we adjust the prior probability, the problem at $t=2$ is the same as in the static model. In the static model, the probability that the farmer was in need of water was $q = q_R$. Now $q = \sigma_{RR'}$ or $q = \tau_{RR'}$, depending on whether the farmer is a first-time offender. We rank these probabilities and use the results from the static model to apply Bayes' rule:

- $q_{RL}^2 < q_{RH}^2$: Regardless of the state at $t=1$, the probability that the farmer is a greedy is higher when $R' = H$, if the farmer was caught in both periods.
- $q_{Ls'}^2 < q_{HR'}^2$: Regardless of the state at $t=2$, the probability that the farmer is a greedy is higher when $R = H$, if the farmer was caught in both periods.
- $p_{RL}^2 > p_{RH}^2$: Regardless of the state at $t=1$, the probability that the farmer is a greedy is higher when $R' = L$, if the farmer was not caught in the first period.
- $p_{LR'}^2 > p_{HR'}^2$: Regardless of the state at $t=2$, the probability that the farmer is a greedy is higher when $R = L$, if the farmer was not caught in the first period.

Then, we obtain the following ranking: $q_{LL}^2 < q_{LH}^2$, $q_{HL}^2 < q_{HH}^2$ and $p_{LL}^2 > p_{LH}^2$, $p_{HL}^2 > p_{HH}^2$. Without further assumptions, we cannot rank q_{LH}^2, q_{HL}^2 and p_{LH}^2, p_{HL}^2. □