Let the Punishment Fit the Criminal: Punishment Progressivity in a Self-governed Community in Southeastern Spain

Donna, Javier and Espin Sanchez, Jose

The Ohio State University, Northwestern University

14 November 2018

Let the Punishment Fit the Criminal: Punishment Progressivity in a Self-governed Community in Southeastern Spain

Javier D. Donna[a]
The Ohio State University

José-Antonio Espín-Sánchez[b]
Yale University

Abstract

We investigate the roles of individual characteristics and punishment progressivity on crime. Our analysis reconciles low crime rates with light punishments in self-governed communities (Ostrom, 1990), using formal punishments to deter crime (Becker, 1968). We use a novel trial dataset on water stealing from a self-governed community in Mula, Spain. We present a model with predictions consistent with farmers' behavior in Mula: (i) judges trade off crime deterrence and insurance, recognizing that minimizing crime could be socially inefficient; (ii) punishments depend on the defendant's and victim's characteristics; (iii) recidivists are punished harsher than first time offenders for the same crime.

JEL Codes: C13, L14, N43, K14, K42.

Keywords: Self-governed communities, Crime, Punishment, Enforcement of Law

[a] Javier D. Donna, Department of Economics, The Ohio State University, 1945 N High St, 425 Arps Hall Columbus, OH 43210. Phone: 614-688-0364. Email: donna.1@osu.edu.
[b] José-Antonio Espín-Sánchez, Department of Economics, Yale University, 27 Hillhouse Ave, Room 38 New Haven, CT 06511-3703. Phone: 203-432-0890. Email: jose-antonio.espin-sanchez@yale.edu.

"[Jean Valjean] asked himself whether human society could have the right to force its members to suffer equally in one case for its own unreasonable lack of foresight, and in the other case for its pitiless foresight; and to seize a poor man forever between a defect and an excess, a default of work and an excess of punishment."

Victor Hugo, Les Misérables.

1. INTRODUCTION

Classical criminology analysis, since the seminal work by Becker (1968), argues that harsh punishments are the best crime deterrent. This is the case if the objective of the social planner is to minimize crime and punishment is costless. There are situations, however, where allowing specific types of crimes can increase social welfare by providing, for example, insurance of last resort. Consider the case of farmers who need to irrigate their trees, but might be liquidity constrained (we describe these farmers in more detail later). These farmers had two options to irrigate their trees: buy water at the auction, or irrigate without permission thus committing a crime. A poor, liquidity constrained farmer who has never stolen water may face an unusual temporary negative shock, such as a drought. A harsh punishment would deter the farmer from stealing water, but the farmer's trees would wither. A mild punishment, would allow the poor farmer to steal water during the negative shock, saving the farmers' trees. If the punishment is always mild, though, even farmers not subject to the negative shock would steal water. However, punishing recidivists more harshly will deter opportunistic farmers from stealing water today, when they do not need it. Such a progressive punishment system, which accounts for the criminal history of the individual, is more efficient than a system that always imposes a harsh punishment, because the option to steal water during a drought, acts as an insurance of last resort for liquidity constrained farmers.

In this article, we investigate the roles of individual characteristics and punishment progressivity in the determination of crime and welfare using a novel dataset of trials from a self-governed community of farmers.[1] Ostrom (1990, 1992) emphasized that, in self-governed communities, low crime can be sustained with mild formal punishments if informal punishments, such as shame, humiliation, and social ostracism, are present. As Ostrom (1990, p. 69) emphasizes:

> "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."

[1] By punishment progressivity we mean that recidivists are punished harsher than first time offenders for the same crime. The crimes analyzed in this article refer to property theft (stealing water as explained below) as opposed to, *e.g.*, murder.

In our setting, however, small fines coexist with low crime rates without the need of informal punishments.[2] We present a dynamic model, described below, where recidivists are punished harsher than first time offenders. This allows us to reconcile low crime rates with low punishments in our self-governed community, similar to Ostrom (1990), using a dynamic framework with formal punishments, similar to Becker (1968) and the literature that followed. To the best of our knowledge, we are the first to emphasize the role of punishment progressivity in self-governed communities.

Our dataset contains information from trials of farmers charged with violating the bylaws of the self-governed community of Mula (Murcia), Spain, from 1851 to 1948. On October 2nd, 2009 The Council of Good Men (*Tribunal de los Hombres Buenos*), the Water Tribunal in Murcia, was inscribed on the Representative list of the Intangible Cultural Heritage of Humanity by the United Nations (UNESCO, 2009).[3] The water tribunals in Murcia and Valencia, the two main cities in the region, were recognized as representing all the irrigation communities in the region, including the one we study in Mula. The tribunal provided justice when conflicts among farmers arose. Water rights in Mula, unlike in most towns in the area, were not attached to land rights. In the region, the scarce factor was water, not land. This circumstance created inequality between the (wealthy) owners of water rights, and the (poor) owners of land rights. Among the farmers, in 1955 over 90 percent of them owned their land (Donna and Espín-Sánchez, 2018b). The system survived, however, for over seven centuries. Our analysis helps explain this extraordinary stability of the irrigation community in Mula. The criminal system combined protection of water and land property rights, with punishments that minimized crime while creating insurance of last resort for the farmers.

Most of these conflicts resulted from farmers irrigating without the right to do so, reducing water available to other farmers. Both stealing water and detecting the theft were straightforward in this environment. Farmers could steal water by opening the gate of the canal next to their land, allowing the water to flow into their parcel. Moreover, monitors could easily identify an illegally-flooded parcel from a farmer who did not buy water for that specific day and time, conditional on rainfall. In this setting, a harsh

---

[2] Although informal punishments are not observed in our setting, our analysis remains valid absence these informal punishments.

[3] Note that UNESCO translated the name of the 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.

punishment system, such as high fines or prohibition of future water purchases, would deter farmers from stealing water. Conversely, a mild punishment system, such as a small fee, would favor high crime rates. As noted by Glick (1967, p. 56), for Castellon: "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." The punishment system in our empirical setting was characterized by three empirical regularities. First, judges imposed low punishments on poor farmers based on individual characteristics. Second, judges imposed low punishments for first time offenders. Third, judges' punishments were progressive, in that recidivists were punished more harshly than first time offenders.[4] This system resulted in both small average fines and low crime rates, as discussed below.

To analyze 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. First, we allow a transitory individual state, unobservable to the judge, to be correlated with a public signal. The transitory individual state captures whether the farmer needs water, or is *needy*. The public signal captures the state of the environment, such as whether there is a drought or a dry month. Second, we introduce a persistent individual state. The persistent individual state captures whether the farmer is dishonest, or *greedy*. Greedy farmers suffer less from punishment when they steal water. The judge is benevolent, rational, and forward looking. The optimal punishment imposed by the judge depends on the information available, which includes public signals, farmers' individual characteristics, and farmers' criminal history.[5] The first feature of the model generates an optimal punishment that depends on individual characteristics. It rationalizes the first empirical regularity of the setting, that judges rarely impose harsh punishment to poor farmers. The second feature of the model generates punishment progressivity as an optimal punishment system. It rationalizes the second and third empirical regularities of the setting, that recidivists are punished more harshly than first time offenders. Consistent with the data in our setting, our model predicts that small average fines coexist with low crime rates, in contrast to typical criminology analysis using a static Beckerian framework. The low average fine

[4] 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.

[5] Note that there are two dimensions of heterogeneity among farmers. We define efficiency based on their need of water, not on their greed. However, in equilibrium the optimal punishment punish greedy farmers more harshly.

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 the first time, the fine is low. However, the farmer loses the option value of stealing “for free” in the future, when the farmer may *need* the water the most due to a contingency, such as a drought. Losing this option value, acts as a harsh punishment, thus deterring crime. Our model also predicts that recidivists are more likely to be greedy than first time offenders. This is because the greedy type is permanent while the needy type is not. The main insight is that differences in water *needs* are “washed away” after a heavy rain, while differences in *greed* are not.

In summary, the main contribution of this paper is to reconcile low crime rates with light punishments in self-governed communities (Ostrom, 1990), using formal punishments to deter crime (Becker, 1968). To do that, we bring together a novel dataset with a new model, where judges trade off crime deterrence and water insurance. We show that the predictions of the model are consistent with farmers' behavior in Mula. First, fines are larger during a dry month, when the benefits of stealing are higher. Second, fines are larger when the defendant has a *Don* honorific title, reflecting the lower probability of needing water.[6] Third, fines are lower when the victim has a *Don* honorific title, reflecting the lower damage inflicted to a *Don*, who typically has more water and a lower marginal return on it their larger supply of water.

Related Literature

Our work is closest to that of historians studying irrigation communities in Mediterranean Spain.Alberola Romá (2015), among others, argues that Wittfogel's (1957) theory of “hydraulic empire” does not apply to the irrigation communities in Mediterranean Spain. Glick (1967) studies irrigation communities in medieval Castellon. Garrido (2011b, 2012) studies the irrigation communities near Castellon, Borriana, and Villareal. Calatayud (2016) and Sanchis-Ibor (2016) study irrigation communities in Mediterranean Spain during the 19th century. These irrigation communities, and the one we study in Mula, were governed by (elected) local boards that assigned water rights and meted out punishments. Ostrom (1990, 1992) describes eight principles of good governance that self-governed institutions should follow. However, as Garrido (2011a) notes, the Spanish orchards that make up the irrigation communities

[6] *Don* (male) or *Doña* (female) are an honorific title 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-rank civil servants, wealthy persons, or people with college degree. During our period of analysis, about 5-10 percent of the population were called *Don*/*Doña*. The term also encompassed high ranking civil servants, the wealthy, and the college-educated. Hence, it is believed that a *Don* never needed to steal water.

do not follow all Ostrom's principles. We contribute to this literature by studying an additional factor that explains the survival of the self-governed institutions for centuries: the criminal system. As Ostrom (1990, p. 69), emphasizes: "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."[7]

Ostrom (1990) has extensively studied the benefits of self-governing institutions. The Hobbesian legal centralism theory has been also criticized by Ellickson (1991), among others. For example, there are situations in which people are not constrained by formal legal institutions (Posner, 2000), but rather by commonly agreed social norms. These situations usually arise because of incomplete rules, when the law does not specify all possible contingencies or a mechanism to certify them. The solution is then to allow flexibility on the judge's ruling. We explain that fines are lower than the maximum permissible in Mula using a mechanism similar to the one in Polinsky and Shavell (2000). In their case, the punishment could be reduced by considerations of fairness. Our analysis focuses on purely on efficiency. The optimal system, however, increases both fairness while maximizing efficiency. In the presence of liquidity constraints, the market would not allocate water efficiently (Donna and Espín-Sánchez, 2018b). The main contribution to this literature is to show how the system of self-governance, via elected judges, was efficient. Thus, it helps to explain the survival of these institutions for centuries, until today. It also helps to explain why these communities thrived in international markets throughout the 20th century. Garrido (2010) expands the argument by Morilla Critz et al. (1999), that early 20th century irrigation communities in Spain remained labor intensive. This is remarkable given the competition from (capital intensive) Californian producers in European markets.

This article is also related to the literature in anthropology and sociology regarding irrigation communities. We believe the framework proposed here could be adapted to study such settings. We show that in the Mula irrigation community, the stability and fairness of the system is the result from formal,

[7] Glick (1967) 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 allow us to follow individuals over time and check for recidivists. Crimes in Glick (1967) 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 receives a large punishment. We do not find a recidivist committing a crime 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.

rather than informal, punishments. This is an important feature of our setting because informal punishments are difficult to measure.[8] Gray (1963) studies an irrigation community in Tanganika, where only individuals with the highest status were guaranteed water rights. Individuals with no rights had to buy or steal water. If they were caught, the punishment was a flat fee. Gray (1963) also emphasizes that "since water theft is usually actuated by dire necessity there is little moral stigma attached to [it]," unlike other crimes. Mula farmers also faced little moral stigma for stealing water.[9] Unlike Gray (1963), we find that higher-status individuals received heavier punishments than regular citizens. Self-governing irrigation communities also developed other ways for farmers to use water without paying for it. Allen (1965) emphasizes how the Chagga people, also in Tanzania, had "days of petition," when farmers in dire need would ask water owners to use their water. Finally, even communities where theft was not uncommon might not have a specialized court, as Coward (1976) shows for Laos.[10]

Pérez Picazo (2002) studies how conflict in Mediterranean's irrigation communities between farmers (owners of land) and Waterlords (owners of water rights) increased over the course of the 19th century. The increase in irrigable land, due to the construction of new dams, meant that in times of scarcity more farmers would not have enough water to irrigate their crops. Thus, during droughts, the level and volatility of prices rose. Although we focus on conflicts among farmers, not between farmers and Waterlords, we also study the effect of droughts on conflict. Libecap (2007) studies the conflict between farmers in Owens Valley and the city of Los Angeles, when the city bought the water rights from the farmers. The conflict deteriorated during the drought in the early 1920s. Hansen, Libecap and Low (2011) argue that climate change is reducing the supply of water and increasing its volatility. The effects will be felt more strongly in agriculture. We argue that a better understanding of conflict management on irrigation communities may help solve these conflicts in the future. More generally, we contribute to the growing economics literature on climate and conflict (*e.g.* Miguel et al, 2004; Bai and Kung, 2011; Chaney, 2013; Dell et al, 2014).

Finally, our paper is related to the literature on crime deterrence. When law enforcement is imperfect, two types of errors can occur: an innocent person may be convicted (false positive); or a guilty person may

---

[8]This is not to say that informal punishments are not important in our or other settings. We believe they are, and they are typically complements to formal punishments. Thus, the existence of informal punishments would reinforce our claims.

[9]Tan-Kim-Yong (1980) argues, however, that in Thailand, water thefts are treated as regular thefts. Thus, the lack of moral stigma does not apply to all irrigation communities in general.

[10]In other settings, fines could depend on other observables. Sutawan (1980) argues that in Bali the closer is the *subak* (community) from the dam, the higher the fine.

be acquitted (false negative). In our empirical setting, imperfect law enforcement arises due to law incompleteness or incomplete contracts. The goal of the law is to maximize welfare. However, since it is not possible to account for all possible contingencies in each case, and because judges' own information is imperfect, judges have some leeway to interpret the law. For example, a judge could decide not to punish a guilty farmer. Therefore, in our setting, the judge faces a tradeoff between false positives and false negatives, rather than minimizing crime.

In the classic economic analysis of criminal behavior started by Becker (1968), criminal histories are irrelevant and there is lack of progressivity. A large literature in the economic analysis of crime has empirically studied the responsiveness of crime to the severity of criminal sanctions.[11] There is a number of papers documenting that offenders or prisoners who face harsher sanctions are less likely to reoffend or be rearrested in certain contexts, such as three strikes laws (*e.g.* Ziming, Hawkins and Kamin, 2001; Helland and Tabarrok, 2007), clemency bills (*e.g.* Drago, Galbiati and Vertova, 2009), and using discontinuities in punishment sentencing (*e.g.* Hjalmarsson, 2009b).[12] These deterrence effects, however, do not hold universally (*e.g.* Hjalmarsson, 2009a; Lee and McCrary, 2017). Chalfin and McCrary (2017, Section 4) attribute this to differences in the responsiveness to sanctions among offenders of different ages. They emphasize that "[t]o date, the degree to which offenders are deterred by harsher sanctions remains an open question" (Chalfin and McCrary 2017, p. 32). 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 the offender's criminal history. We do this in a setting where offenders are caught with certainty, thus holding fixed the probability of being caught. The particularities in our empirical setting allow us to hold fixed the crime committed, and to study the roles of individual characteristics and punishment progressivity in the determination of crime.[13] The crime consists of stealing water at a given time. The individual characteristic is whether the offender is wealthy, as captured by the *Don* honorific title. Progressiveness arises because the judges update their beliefs about the offenders' type based on their criminal record.

[11] See Cameron (1988), Marvell and Moody (1996), and Chalfin and McCrary (2017) for comprehensive reviews of the literature.
[12] Progressivity is also present in other setting, such as the "three strikes" policy in California. Punishment in these settings is typically costly (*e.g.* overcrowded prisons). In our case punishment is costless.
[13] Our paper is also related to articles that focus on the economic factors related to crime, such as Machin and Meghir (2004), and Vickers and Ziebarth (2016).

2. BACKGROUND AND DATA

"Whiskey is for drinking; water is for fighting over."

Mark Twain

In this section, we describe the historical background, trial data, and the water auction. We combine data from different sources for our analysis. Trial and auction data, the primary sources of data for this study, are obtained from the historical archive of Mula.[14]

2.1. Institutions in Mula

The institutions for water allocation in Mula comes from the *Reconquista* (Rodríguez Llopis, 1998). After the conquest of the city, the Order of Santiago had absolute authority over Mula because the city was conquered by force.[15] The Order of Santiago separated the ownership of land and water, creating a corporation, the *Heredamiento de Aguas*, to auction access to river water. The largest shareholder in Mula was the Marquis of *Los Vélez*. Under these new Christian institutions, the owners of the water property rights, who we call Waterlords, were different than the farmers, who owned land. In Mula, the Waterlords established a corporation which, despite the many political changes that occurred in Spain, lasted until 1966 (Espín-Sánchez, 2017).

The *Heredamiento de Aguas* was divided into 832 dividend-paying shares. By contrast, all water owners had the same voting rights regardless of the number of shares they owned, *i.e.,* the democratic rule was "one man, one vote." After the corporation's bylaws changed in 1895, the new capitalistic rule allocated votes proportional to the number of shares. We do not observe a change in behavior after 1895.

The water tribunals in Murcia and Mula were similar. In Murcia water was allocated using fixed quotas (*tandas*). In Mula water was allocated by a public auction (Donna and Espín-Sánchez, 2018a). We use the auction prices as an indicator of the value of the water stolen. While all Murcia farmers have water property rights, in Mula some farmers had no water rights, *i.e.*, they had to purchase water in the auction. There were approximately 500 farmers in Mula. Whereas virtually all of them owned the land, only about 200 farmers 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

[14] From the section Heredamiento de Aguas, boxes No.: HA 167, HA 168, HA 169 and HA 170.
[15] Note that this initial shock in institutions is similar to that in Chaney and Hornbeck (2016).

responded to the demands of the water owners (Waterlords), but not necessarily to those of the farmers. In practice, however, the Waterlords who owned most of the water rights but did not themselves farm, were never members of the tribunal. The members of the tribunal were instead farmers wealthy enough to own water rights. Any individual, regardless of water ownership, could sue or be sued at court.

The water had to be bought in cash at the auction. Farmers in Mula did not have access to credit markets (see Donna and Espín-Sanchez, 2018b, for a thorough discussion about liquidity constraints in this setting). Failure to pay for the water meant the prohibition of buying water in the future, until the debt was paid. This strict rule did not apply to the fines or compensations after a trial. A defendant found guilty may take several weeks to pay the fine or the compensation, but would be allowed to buy water at the auction in the meantime. This suggests that the farmers and the tribunal saw water theft as a form of credit. On one hand, the probability of being caught after committing a crime was very high, according to the narratives in the trials. On the other, upon being caught, the farmer would have to pay the value of the water stolen plus a fine. These two circumstances, seemingly contradicting when there was an auction the weeks before the crime, are rationalized by the use of the option to steal water during a drought as an insurance of last resort by liquidity constrained farmers. This is consistent with the findings in Donna and Espín-Sánchez (2018b).

Seven elected water owners sat on the Mula tribunal. They were elected among the water-owners every year, on December 26th, and their appointment lasted for two years. In odd years, four members were elected; in even years three members were elected. Thus, in any given year there were three (four) members of the council in their first term and four (three) members in their second term. The voting was by secret ballot, writing the name of the candidate in a piece of paper. Every year, the tribunal members elected a president who appointed a vice-president and treasurer from the tribunal and a secretary, chosen from the general public. The tribunal resolved water disputes between farmers. Farmers could not appeal the tribunal's rulings to other courts. In the article, we call all the offenses "crimes." These crimes, and the bylaws that regulated them, were recognized by customary law during the *ancien régime*. Later, they were added to the Spanish Civil Code in the 19th century.

As mentioned by Garrido (2011a), there is heterogeneity in Spanish irrigation communities' monitoring and enforcement of crimes. In some communities, paid guards monitored water use, while in others, farmers took turns monitoring the canals. In many places, the watchman who caught a criminal kept a fraction of the fine, typically a half or a third. This incentive applied to both farmers and paid guards. In Mula farmers monitored water use before the bylaws of 1933, and professional guards after. We do not observe a change in farmers' behavior after 1933.

2.2. Trial Data

Figure 1 shows a trial, with the farmers as judges, and a map of the area under study. During the mid-19th century, following the French, local irrigation communities in Mediterranean Spain began to track information about their trials. The archive in Mula contains all trials spanning 1851 to 1948. Figure 2 displays a sample sentence, corresponding to a single trial, on August 12, 1906. Trial data consists of 282 trials over 97 years (approximately three trials per year). The defendant was found guilty in 174 trials, yielding approximately two guilty sentences per year. Admittedly, this is a relatively small number of trials. Note, however, that the data include all the trials in the archive over almost a century (97 years). The fact that there are few trials per year-relative to the total number of farmers who could potentially steal water during a given day-emphasizes our argument that the system deterred crime.[16] Following Ostrom (1990), 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 (52 weeks per year 500 farmers) opportunities for theft, as contrasted with the two crimes per year, which means an infraction rate of 0.00008 (2/25,000 = 0.0000769), approximately 100 times (0.008/0.00008) lower than that in Castellon considered extremely low by Ostrom (1990).[17] Mula is located in Southeastern Spain, one of the driest region in Europe. Conflicts among farmers are common in this region, and their motivation is water, rather than land, rights, as the second quote from Elinor Ostrom in the introduction emphasizes. Table 1 displays summary statistics for the variables in the dataset.[18] Note that no auction was carried out in 101 out of the 282 weeks when a crime was reported. This is because there was not enough water in the dam during those weeks. The default

[17] 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*. We recorded whether the guard or manager had a *Don* honorific title.

[17] Ostrom (1990, 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."

[18] We use nominal pesetas for all the results. Results using real pesetas with the deflator in Reher and Ballesteros (1993) are very similar, and are available upon request.

fine for any violation was 25 *pesetas*.[19] Judges could impose any fine between 0 and 25 *pesetas*. This upper bound did not change during our sample period.[20]

Trial information includes the offender's name, whether he/she was a *Don*, the plaintiff's name (a farmer or a guard) and whether he/she was a *Don*, the name of the judge (president of the council) and the verdict, the amount of the fine if any, the amount of the compensation (if any), and the date (of the trial and reported crime). When the water was stolen from a subcanal directed to a farmer's plot, that farmer was the plaintiff and the victim, *i.e.*, the farmer would receive the monetary compensation. When the water was stolen from the main canal, the guard was the plaintiff and the victim was the association, *i.e.*, the association would receive the monetary compensation.

Figure 3.A shows that the crimes with *Don* victims are more frequent during the summer months. This observation is consistent with farmers' strategic behaviors during the summer growing season. Farmers expected a lower punishment, and higher efficiency gains, if they stole from a wealthy farmer.

2.3. Water Auctions Data

Although the process of allocating water in Mula varied slightly over the years, the basic structure remained essentially unchanged from the 15th to the 20th century. Land in Mula was divided into *regadío* (irrigated land) and *secano* (dry land). Irrigation was only permitted on the former type. A canal system allowed water from the river to reach all *regadío* lands.[21] The fundamental reason for this division is that *regadío* were fertile lands that are close to rivers and, hence, allow a more efficient use of the region's scarce water. Only farmers who owned a piece of *regadío* land in Mula were allowed to buy water. For more details about the allocation mechanism see Donna and Espín-Sánchez (2018a).

Farmers bought water in a sequential English-auction. The auctioneer sold each of the units sequentially and independently of each other. They kept track of the name of the buyer of every unit and the price paid by the winner. The farmers could not store water in their plots or resell water. There was no auction in 101

[19] 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 the amounts to *pesetas*.
[20] In two instances, the judges imposed a fine greater than 25 *pesetas*. In the first one, a miller was found guilty of stealing water twice the same week. The miller was fined with 50 *pesetas*. In the other, five men, all *Don*, 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, which was forbidden. In this case, the average fine per farmer was 65 *pesetas*.
[21] The canal system was expanded from the 13th to 15th century, as a response to the greater demand for land due to the increase in population. The *regadío* land's structure has not change since the 15th century.

of the weeks during which there was a trial. The dummy variable for whether there was an auction has an average of 0.64, and we have only 181 weeks of water prices.

Farmers paid cash for their purchases. Donna and Espín-Sánchez (2018b) show that liquidity constraints prevented farmers from buying water, even when their valuations were above the equilibrium price. A system of flexible fines partially mitigated imperfect insurance and credit markets, providing farmers with insurance of last resort. When a poor farmer's crops were at risk, they could steal water for irrigation and save their crop with a minimal punishment. Thus, the results here complement and reinforce the ones in Donna and Espín-Sánchez (2018b).

Figure 3.B shows the number of trials preceded by an auction in the week before. The number of trials where there was an auction the week before increases during the dry months in the summer. Note that this figure shows the trials where there was an auction the previous week. Thus, it is not a random sample. Typically, the probability of having auctions throughout the year is high, but it decreases substantially during the summer. Conditional on a crime, the probabilities are different. The high percentage of crimes when auctions were not held during the winter might seem puzzling (*e.g.* December). Generally, in those wet months the number of crimes was low. However, if farmers could not buy water at auction, they might resort to stealing.

2.4. Rain

We complement the trial and auction data with daily rainfall data for Murcia, which we obtain from the *Agencia Estatal de Metereología*, AEMET, the National Meteorological Agency in Spain. Rainfall data from Mula is only available after 1933, while the rain data for Murcia goes back to 1865. The two cities are only 35 kilometers apart, and they are located in the same valley.[22] Mediterranean climate rainfall occurs mainly during spring and fall. Peak water requirements for the products cultivated in the region are reached in spring and summer, between May and August. In addition to the auction dummy variable, and the price of water, we also use two additional variables that are correlated with farmers' need for water. The variable season is a dummy variable that equals 1 if the crime was committed during the months of May, June, July

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

or August, and zero otherwise. The variable dry week is a dummy variable that takes the value of 1 if there was no rain the week before the trial, and zero otherwise.

3. MODEL PREDICTIONS

In this section, we describe the predictions of the model and how they fit the data. We present the details of the model in the appendix. For simplicity, we assume that the probability of a farmer being caught is equal to one.[23] In the cases were a complaint was filed but no one was accused, the complaint stated only that the water flowing through the canal was "lower than expected," but after a guard was called in and the canals inspected there was no water missing. We propose a model in which farmers are heterogeneous in two dimensions: water need and water *greed*. The first dimension measures whether the farmer is *needy*, while the second measures whether the farmer is *greedy*. Both types are private information. The judge may observe public signals that are correlated with each of them, and may adjust punishment accordingly. We assume that the two types are independent, but the predictions are similar if we allow for correlation. Farmers' utility function is concave in water consumed. Farmers' *greed* type is only relevant when they steal water. *Greedy* farmers suffer less from the 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 the information available to the judge, including public signals, farmers' individual characteristics, and farmers' criminal histories. We interpret each trial as a game between the farmer and the judge. The rain in the town the week before the crime occurred is a public signal observed by the judge. It is correlated with the idiosyncratic need of water of the farmer. Finally, past behavior and certain characteristics of the farmers, such as whether they are a *Don*, are signals that are correlated with farmer's greed.

The judge always imposes the optimal punishment. It corresponds to the first best when it is feasible, and the second best when it is not feasible. A first best, or efficient, punishment system means that farmers steal water if, and only if, it is socially optimal. There are neither false positives nor false negatives. In this case, the optimal punishment does not depend on the public signal. The first best allocation might not be

[23] A model with a probability of being caught less than one, have identical predictions to the ones we use, but the algebra is more cumbersome. Results are available upon request.

feasible, as we discuss below. Intuitively this is because the judge can implement the first best only when the farmers are relatively homogeneous in their greed, and relatively heterogeneous in their need.

3.1. Static Predictions

We now summarize the results from the static model (see the appendix for details). The first prediction of the model relates to the probability of committing a crime.

Prediction P0: *A farmer is more likely to steal water when her/his need for water is high.*

Prediction P0 is a consequence of the concavity in water of the utility function. The lower the water level in the farmer's plot, the higher the farmer's marginal utility of additional water and, thus, the more likely that he/she will steal water. The judge can impose a punishment that achieves the first best when the differences in utility due to the water need are larger than the differences in utility due to water *greed*. If the first best is not feasible, then the judge decides between two second best punishment systems for each realization of the public signal. The two possible optimal punishments are:

- Harsh punishment: the only farmers who steal water are greedy farmers who need water. This system is not efficient because not greedy farmers, who need water, do not steal water. In other words, there is "too little stealing," a false positive.
- Mild punishment: all farmers, except the not greedy farmers who do not need water, steal. This system is not efficient 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, there could not be simultaneously false positives and false negatives. In practice, however, it is likely that the judge will impose a harsh punishment in a particular week when the signal (rain) is high, and a mild punishment in another week when the signal (rain) is low. That is, the punishment would be larger when it rained the week before the water was stolen. In general, the judge is more likely to impose a harsh punishment when: i) the public signal is highly correlated with the water needs of the farmers; and ii) many farmers are *greedy*.

The intuition behind the second best punishment system is the following. Farmers in need (*i.e.* farmers who are desperate) are more likely to steal water, which is efficient. However, greedy farmers are also more likely to steal water, which need not be efficient. An intermediate punishment can always induce needy, greedy farmers to steal water and not needy, not greedy farmers not to steal it. Both scenarios are efficient.

Whether the punishment can achieve the first best depends on whether needy, not greedy farmers are more likely to steal water than not needy, greedy farmers. Intuitively, when greed does not matter, and has little impact on the decision to steal, needy farmers (greedy or not) are more likely to steal than not needy farmers (greedy or not). In that case, there is always an intermediate punishment that "separates" needy from not needy farmers. However, when greed does have a large impact on the decision to steal, not needy, greedy farmers would be more likely to steal than needy, not greedy farmers under any punishment system. In that case, there is no punishment system that would "separate" these farmers (not needy, greedy from needy, not greedy). The optimal punishment in this case would be second best, and it consists of either punishing all the farmers in this pool (harsh), or none of them (mild).

We now present the main predictions of the model. Details are in the appendix. In the next section, we relate these predictions to the empirical regularities in our setting. Predictions P1, P2, and P3 relate to the information available for the judge. They show that we need two dimensions of private characteristics to explain the empirical regularity that punishments are rarely maximal and depend on the information available to the judge. Taken together with the empirical analysis below, these predictions suggest that we are in a second-best environment. Predictions P4, P5, and P6 provide specific predictions regarding the characteristics of the crime, the victim, and the criminal's history, respectively.

Prediction P1: *If greed is perfectly observable, then the optimal punishment is independent of the public signal and positive.*

In the data, we observe that the punishment varies as a function of the previous week's rainfall, which means that the judge cannot perfectly observe *greed*, but that he/she is concerned about it.

Prediction P2: *If water needs are perfectly observable, then the optimal punishment is maximal when the signal is high and minimal when the signal is low.*

In the data, we observe that the punishment is usually low. If the punishment varies with the public signal, it does not reach a maximum even after a heavy rain. The data shows that the punishment varied with individual characteristics which, together with predictions P1 and P2, implies that the judge observed imperfect signals correlated with each dimension. We believe that both types are private information and that both shocks are idiosyncratic, or equivalently, the judge does not perfectly observe the shocks. Judges had good information about how *greedy* were each farmer, but not perfectly. Even if the rainfall is the same for the plots of all farmers, they have plots of different sizes. However, they buy units of water of the same size, which means that they have different levels of moisture in their plots in any given week. The judge does not perfectly observe the moisture level in a farmer's plot.

To rationalize predictions P1 and P2 we need at least two dimensions of heterogeneity. The following predictions relate to the particular two-dimensional model that we propose.

> **Prediction P3**: *If both greed and water need are unobservable, and we can separate not needy, greedy from needy, 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 P3. First, it complements P1 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, P3 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.

> **Prediction P4**: *If both greed and water needs are unobservable, and the first best is unfeasible, then the optimal punishment requires a mild punishment when the signal is low and a harsh punishment when the signal is high.*

Prediction P4 indicates the sign of the effect of the public signal on the punishment. The predictions of the static model refer to water need. These predictions also hold for any specific trial's observable characteristics, including the victim's individual characteristics, which convey the victim's water need. In our model, it is efficient for a farmer whose land received little rain, to steal water from a farmer whose land received heavy rain. This observation, is summarized in prediction P5 below.

> **Prediction P5**: *If both greed and water need are unobservable, and the first best is unfeasible, then the optimal punishment requires a mild punishment when the victim received heavy rain and a harsh punishment when the victim received light rain.*

In the next subsection, we discuss additional dynamic predictions. In our model, water *needs* are independent across periods, while *greed* is persistent across periods. This means that while all the predictions in the static case address the relative likelihood of water *greed* vs. water *need*, dynamic predictions address directly the likelihood that the farmer is *greedy*. That is, a recidivist is more likely to be *greedy*.

In the data, there is heterogeneity on the punishment for first time offenders, which is a direct consequence of the judge having some partial knowledge of individual characteristics. A farmer who confessed the crime would get a very low fine of less than five *pesetas*, usually followed by an admonition of the judge that he/she understood that the farmer was in dire necessity, but that the punishment will be harsher if he/she did it again:

> "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**." Obtained from authors' translation of the trial on August 12, 1906, displayed in Figure 2 (bolds are ours).[24]

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

3.2. Dynamic Predictions

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

Prediction P6: *A recidivist farmer is more likely to be greedy than a first-time offender.*

Thus, the farmer is more likely to receive a harsh punishment.

Predictions P4 and P6 imply that the judge takes observable characteristics into account when deciding the punishment. This is because these characteristics are correlated with the probability that a farmer is greedy.

---

[24] Note that the judge emphasizes, as shown in Figure 2, at the moment of the first-time offense, that recidivists will be punished more harshly. Such statements were common in judges' sentences. We interpret them as validating the punishment progressivity of the system, even in cases where the counterfactual recidivism did not materialize (*i.e.* unobserved in the data).

Thus, farmers who are more likely to be greedy are punished more harshly. Because first time offenders are not likely to be greedy, they would not receive a harsh punishment. In the trials, judges knew who were recidivists. Thus, they imposed them the maximum punishment, and mentioned this explicitly in the sentences (see, *e.g.*, Figure 2). In our data, there is only one occasion where a farmer stole a third time. This is consistent with our model where stealing a third time is unlikely.

4. 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 the available information regarding the crime, the victim, the criminal, and the criminal's history to impose the appropriate punishment. For details about the predictions of the model see the appendix.

Crime Rates

Our model produces specific predictions about how observable characteristics are correlated with committing a crime. 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 indicating whether there was an auction during the previous week. Wealthy (poor) farmers (do not) have a *Don* honorific title. Table 2 column 1 shows that on average, poor farmers are not more likely to be found guilty than wealthy farmers. This finding is consistent with the results in Vickers and Ziebarth (2016), who analyze Victorian London crime data, and also found that higher status individuals received a harsher punishment for the same offense.

Column 2 shows that poor farmers are less likely to be found guilty during wet months, and more likely to be found guilty during dry months. These findings are consistent with poor farmers being needy (they steal water during the dry season), and wealthy farmers being greedy (they steal water during the wet season). Columns 3 and 4 show that the pattern does not change when we interact the variables with the characteristics of the victim. Columns 5-8 show that the results are robust to including the auction and dry month dummy variables. The auction dummy variable is positive, but not statistically significant. It suggests that farmers are more likely to be found guilty if they had the chance to buy water at the auction, although the coefficient is not precisely estimated. The dry month dummy variable shows that water scarcity significantly increases the likelihood of being guilty, consistent with prediction P0.[25] Farmers are more likely to be in need of, and to steal, water during a dry month.

Fines

We now discuss the empirical results regarding punishment, and how they relate to the predictions from our model. The predictions are reflected in the fines imposed by the judge, as a function of the type of the crime and characteristics of the criminal. Table 3 presents the results from OLS regressions of fines on several covariates.

Fines are significantly lower when the defendant is not a *Don* (*i.e.* poor farmer). The 5.35 *pesetas* in column 1 shows that poor farmers receive a lower punishment for the same crime. Wealthy farmers are less likely to be in need of water. They usually have higher levels of moisture in their plots, because they irrigate more often (Donna and Espín-Sánchez, 2018b). Thus, their marginal utility of water is lower, the damage of their crime is larger, and the damage (or marginal disutility) of stealing from them is lower. The judges respond by inflicting lower (higher) fines when the defendant is not (is) a *Don*, consistent with prediction P4. Our analysis implicitly assumes that social punishments are the same for everyone. However, it could be that wealthy farmers suffer higher social punishments than do poor farmers. If that were the case, we would underestimate the true value of the coefficient on column 1, *i.e.*, the true effect would be even larger.

As regards individual farmer's characteristics, fines are significantly lower when the victim is wealthy, 4.53 *pesetas* lower in column 2. The judges respond by inflicting lower fines in cases where the damage is lower (column 3), consistent with prediction P5. Consistent with prediction P6, recidivists are punished more harshly. Their fines are over 15 *pesetas* higher than for first time offenders convicted of the same crime. That is, recidivists are punished with fines more than three times higher than the average. All recidivists receive fines of 20-25 *pesetas*, the maximum allowed in the bylaws. The weekly wage of a laborer was approximately 25 *pesetas* during the period under analysis.

Columns 5-8 show that the results in columns 1-4 are robust to including the auction and the dry month dummy variables. Fines for crimes reported in weeks during which no auctions were run are significantly

[25] Water prices are highly correlated with rain. Due to this collinearity, when both coefficients are included, neither is statistically significant. The null hypothesis that both are zero is rejected.

lower, 4.61 *pesetas* in column 5.[26] A farmer who stole water in a week when there was an auction, could have bought the water at the auction, unless he/she was liquidity constrained. This means that the farmer who stole water in a week with an auction was more likely to be liquidity constrained. Judges were more lenient in those cases.

There is no correlation between seasonality and fines. There are two effects at play. During a drought, the need for water is higher and, thus, the judge imposes a lower fine. However, imposing a lower fine would also make farmers who do not need water more likely to steal. The former (direct) effect makes fines lower, while the later (indirect) effect makes fine larger. The results in Table 3 suggest that the indirect effect partially offsets the direct effect.

The results in Table 3 indicate that the fines are lower when the victim is wealthy. Table 4 indicates that the amount of water stolen, and thus the compensation, is higher when the victim is wealthy. These results are consistent with our model. They may also be consistent with the following hypothesis. The judge is concerned about the total amount of the monetary punishment, fine plus compensation. In that case, the lower fines when the victim is wealthy may be a spurious correlation due to higher compensation paid when the victim is wealthy, and the negative correlation between compensations and fines. This hypothesis predicts a negative correlation between fine and compensation. It also predicts that adding compensation as a regressor in Table 3 would 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, nor statistical significance of the other coefficients.

Compensation

Fines have a punitive goal, to deter farmers from stealing. The revenue generated by the fines goes to the community. The goal of the compensation is to repair the damage inflicted to the victim of the crime: a particular farmer, if water was stolen from him/her; the community, if water was stolen from the main canal. Thus, the amount of the compensation is an estimate of the value of the water stolen. The sentences in the trials state clearly that the amount for each of these concepts. The judge separately mentions the fine

[26] In unreported results, we also find that punishments are significantly lower for water stolen from the main canal relative to water stolen from other farmers. This means that the judges consider a crime to be more severe when stealing from other farmer-who is not a *Don*-than stealing from the main canal. This is consistent with judges minimizing conflict among farmers.

and the compensation. In a typical case where a farmer steals water from another farmer, the money from the fine goes to the *Heredamiento*, whereas the money from the compensation goes to the victim. The amount of the compensation is always equal to the value of the water stolen, and the judge has no discretion over it. Therefore, one should interpret the results in Table 4 as characteristics of the crime.

The effect of offenders' individual characteristics on the amount of compensation is consistent with the model and the results in Table 3. The compensation is not affected by the characteristics of the defendant, only by the characteristics of the victim. Table 4, column 1, shows that the amount of compensation is not statistically different when the defendant does not have a *Don* honorific title. Compensation is also not affected when the defendant is a recidivist, as shown in column 4. The amount of water stolen is not correlated with the defendant's observable characteristics. This finding is consistent with compensation being equal to damage inflicted rather than a punishment based on the crime. However, when the defendant is poor and the victim is wealthy, the compensation is about 25 *pesetas* higher (column 3). Table 2 shows that a crime is more likely to occur during a dry month. However, the compensation is not affected by the dryness of the month.

The amount of the compensation is highly correlated with the victim's characteristics. The compensation is significantly higher when the victim has a *Don* honorific tittle (24.99 *pesetas* in column 2). Table 1 shows that the average compensation is 11.07 *pesetas*. This means that, when the victim is wealthy, the compensation is more than twice the average compensation. Again, one should not interpret this as *Dons* being forced to pay larger compensations. Compensations represent the estimated value of the water stolen, and the judge has no discretion over that amount. We interpret this correlation as characteristic of the crime. That is, when farmers steal from a wealthy farmer, they tend to steal about 25 *pesetas* more in terms of the value of the water, than when they steal from a poor farmer. This result suggests that when given the chance, farmers steal as much water as they can from a wealthy farmer. This is not true when stealing from poor farmers, however. This disparity could result from farmers' restraint from stealing too much water from poor farmers, or from wealthy farmers' larger plots, which require more water. This result reinforces the ones in Table 3, where fines are lower for poor defendants and wealthy victims (column 3). Not only does the poor farmer pay a lower fine when stealing from a wealthy one. The lower fine is for a crime involving a more valuable bounty.

5. CONCLUDING REMARKS

Our analysis in this paper helps explain the extraordinary stability of the irrigation community in Mula, Spain. The system combined protection of water and land property rights, with a punishment system that minimized crime while creating insurance of last resort. We believe that the results here apply to other irrigation communities in Mediterranean Spain. The results help explain the role that punishment played in the survival of self-governed irrigation communities more generally.

Punishment progressivity and information about individual characteristics are usually absent in criminology analysis of self-governed communities. We studied a particular historical setting, where judges impose low punishments for first time offenders based on individual characteristics, and recidivists are punished harsher than first time offenders. We showed that this punishment system is efficient in a model with a transitory individual state related to the need of stealing, and a persistent individual state related to the propensity of stealing, or greed. Because water was allocated using an auction, in the absence of frictions the allocation would be efficient. In the presence of frictions, we show that the system of punishment partially alleviated the inefficiency created by them. We reconciled the Beckerian insight that harsh punishments deter crime with the documented light punishments and low crime rates in self-governed irrigation communities. Average punishments are low because they are a weighted average of several small punishments for first time offenders, and a few large punishments for recidivists. Crime rates are low because the punishments for recidivists are harsh. This is a result from the particularities in our empirical setting. Due to volatile weather, the probability that a poor farmer is in need to steal water is high in the future. Losing the option value to steal in the future acts as a harsh punishment, thus deterring crime.

We showed that in our context, a positive amount of crime is socially efficient. It is optimal for farmers who are liquidity constrained and in need of water, to steal water from a neighbor, thus preventing their own trees from dying. However, whether a farmer is in need of water is not perfectly observable by the judge. Therefore, the judges trade off false positives and negatives, resulting in punishments that are neither maximal nor zero. Our empirical analysis showed that the judges in Mula trade off crime *deterrence* and water *insurance*. They made efficient use of information regarding the crime, the criminal, and the victim, to determine the optimal punishment. In our framework, legal flexibility allows judges to use their “judgment” and the information available to determine the punishment in each case. Judges used this flexibility to provide insurance of last resort to farmers, in a context of imperfect financial markets.

One important insight from our paper is that low punishments, typically viewed as evidence of suboptimal contracts, were intended to increase efficiency, not equality. The disadvantageous treatment of wealthy farmers arises as a consequence of efficiency: their marginal utility of water is lower, the damage of their crime is larger, and the damage (or marginal disutility) of stealing from them is lower. Similarly, the favorable treatment of poor farmers is a consequence of efficiency: allowing the poor farmer to steal water during the negative shock allows to save the farmers' trees.

ACKNOWLEDGEMENTS

Discussions with Juan Dubra, Joseph Ferrie, Tim Guinnane, Naomi Lamoreaux, Zachary Liscow, Trevon Logan, Joel Mokyr, Rob Porter, Yannay Spitzer, Francesca Trivellato, Chris Vickers, Bruce Weinberg and seminar participants at Northwestern University, The Ohio State University, WEHC (Stellenbosch), DDICA (Utretch), EARIE (Ebora), and Yale University have benefited this work. We would also like to express our gratitude to Fernanda Donna and Antonio Espín for superb research assistance. All errors are our own.

References

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

Allen, W., 1965. *The African Husbandman*. Edinburg: Oliver and Boyd.

Bai, Y., and Kung, J. K., 2011. "Climate Shocks and Sino-Nomadic Conflict," *Review of Economics and Statistics*, Vol. 93, No. 3, 970-981.

Becker, G. S., 1968. "Crime and Punishment: An Economic Approach," *Journal of Political Economy*, Vol. 76, No. 2, 169-217.

Calatayud, S., 2016. "Antes de la política hidráulica: la gestión del agua bajo el Estado liberal en España (1833-1866)," *Historia Agraria*, No. 68, 13-40.

Cameron, S., 1988. "The economics of crime deterrence: A survey of theory and evidence," *Kyklos*, Vol. 41, No. 2, 301-323.

Chalfin, A., and McCrary, J., 2017. "Criminal deterrence: A review of the literature," *Journal of Economic Literature*, Vol. 55, No. 1, 5-48.

Chaney, E., 2013. "Revolt on the Nile: Economic Shocks, Religion, and Political Power," *Econometrica*, Vol. 81, No. 5, 2033-2053.

Chaney, E., and Hornbek, R., 2016. "Economic Dynamics in the Malthusian Era: Evidence from the 1609 Spanish Expulsion of the Moriscos," *Economic Journal*, Vol. 126, 1404-1440.

Coward, E. W., 1976. "Indigenous organisation, bureaucracy and development: The case of irrigation," *Journal of Development Studies*, Vol. 13, No. 1, 92-105.

Dell, M., Jones, F. J., and Olken, B. A., 2014. "What do we learn from the weather? The New Climate-Economy Literature," *Journal of Economic Literature*, Vol. 52, No. 3, 740-798.

Donna, J., and Espín-Sánchez, J.-A., 2018a. "Complements and Substitutes in Sequential Auctions: The Case of Water Auctions," *RAND Journal of Economics*.,Vol. 49, No. 1, 87-127.

Donna, J., and Espín-Sánchez, J.-A., 2018b. "The Illiquidity of Water Markets: Efficient Institutions for Water Allocation in Southeastern Spain," working paper.

Drago, F., Galbiati, R., and Vertova, P., 2009. "The deterrent effects of prison: Evidence from a natural experiment." *Journal of Political Economy*, Vol. 117, No. 2, 257-280.

Ellickson, R., 1991. *Order without Law: How Neighbors Settle Disputes*. Cambridge: Harvard University Press.

Espín-Sánchez, J.-A., 2017. "Institutional Inertia: Persistent Inefficient Institutions in Spain," *Journal of Economic History*, Vol. 77, No. 3, 692-723.

Garrido, S., 2010. "Oranges or 'Lemmons'? Family Farming and Product Quality in the Spanish Orange Industry, 1870-1960," *Agricultural History*, Vol. 84, No. 2, 224-243.

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

Garrido, S., 2011b. "Governing Scarcity. Water markets, equity and efficiency in pre-1950s eastern Spain," *International Journal of the Commons*, Vol. 5, No. 2, 513-534.

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

Glick, T., 1967. *Irrigation and Society in Medieval Valencia*. Cambridge: Harvard University Press.

Gray, R. F., 1963. *The Sonjo of Tanganika*. Oxford University Press.

Hansen, A. K., Libecap, G. D., and Lowe, S. E., 2011. "Climate Variability and Water Infrastructure: Historical Experience in the Western United States," Chapter 9 in *The Economics of Climate Change*: *Adaptations Past and Present*, edited by Gary D. Libecap and Richard H. Steckel.

Helland, E. and Tabarrok, A., 2007. "Does three strikes deter? A nonparametric estimation." *Journal of Human Resources*, Vol. 42, No. 2, 309-330.

Hjalmarsson, R., 2009a. "Crime and Expected Punishment: Changes in Perceptions at the Age of Criminal Majority." *American Law and Economics Review*, Vol. 11, No. 1, 209-248.

Hjalmarsson, R., 2009b. "Juvenile jails: A path to the straight and narrow or to hardened criminality?" *The Journal of Law and Economics*, Vol. 52, No. 4, 779-809.

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

Libecap, G. D., 2007. *Owens Valley Revisited: A Reassessment of the West's First Great Water Transfer*. Palo Alto, Stanford University Press.

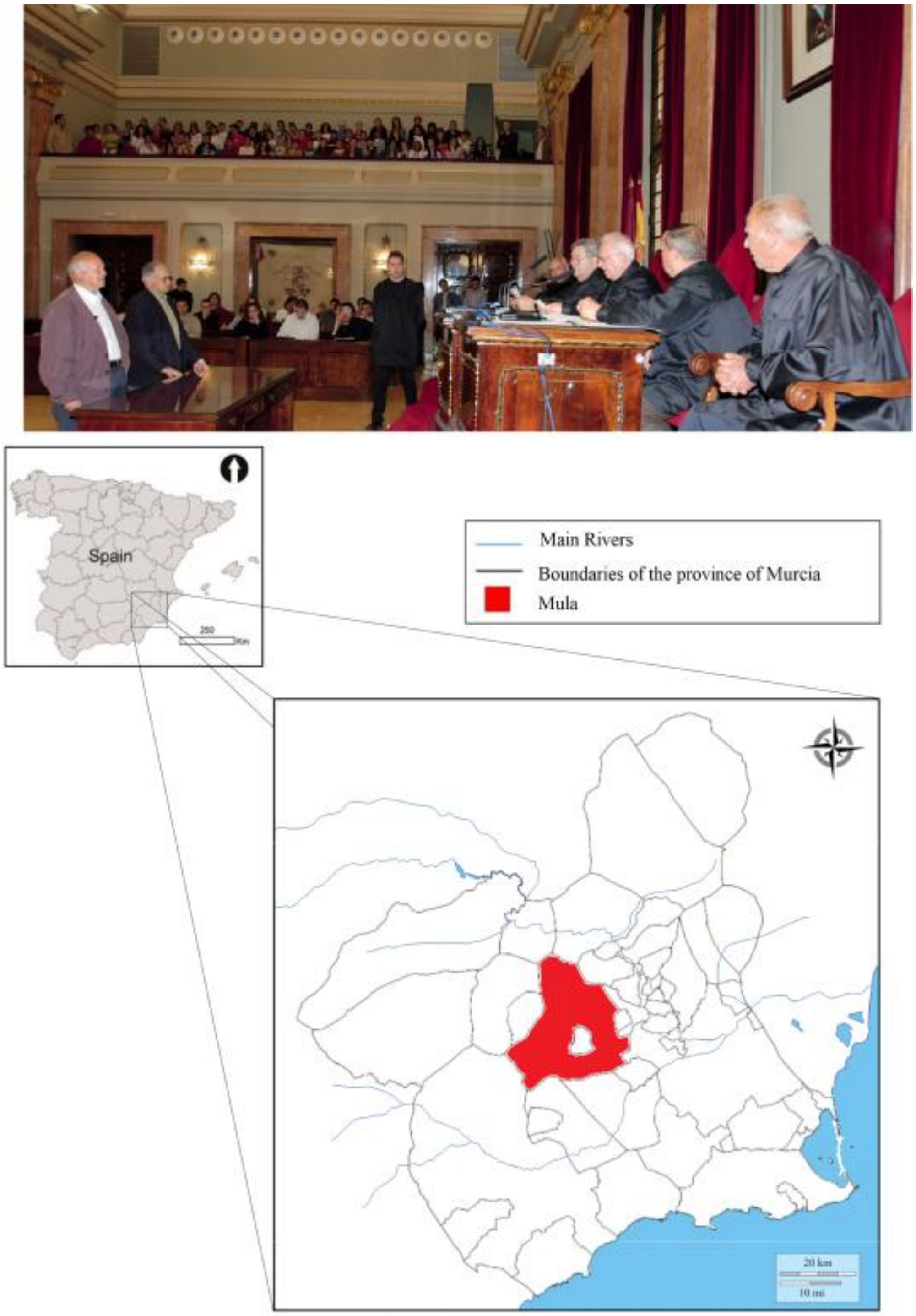
Machin, S., and Meghir, C.. 2004. "Crime and Economic Incentives," *Journal of Human Resources*, Vol. 39, 958-979.

Marvell, T. B., and Moody, C. E., 1996. "Specification problems, police levels, and crime rates." *Criminology*, Vol. 34, No. 4, 609-646.

Miguel, E., Satyanath, S, and Segenti, E., 2004. "Economic Shocks and Civil Conflict: An Instrumental Variables Approach," *Journal of Political Economy*, Vol. 112, No. 4, 725-753.

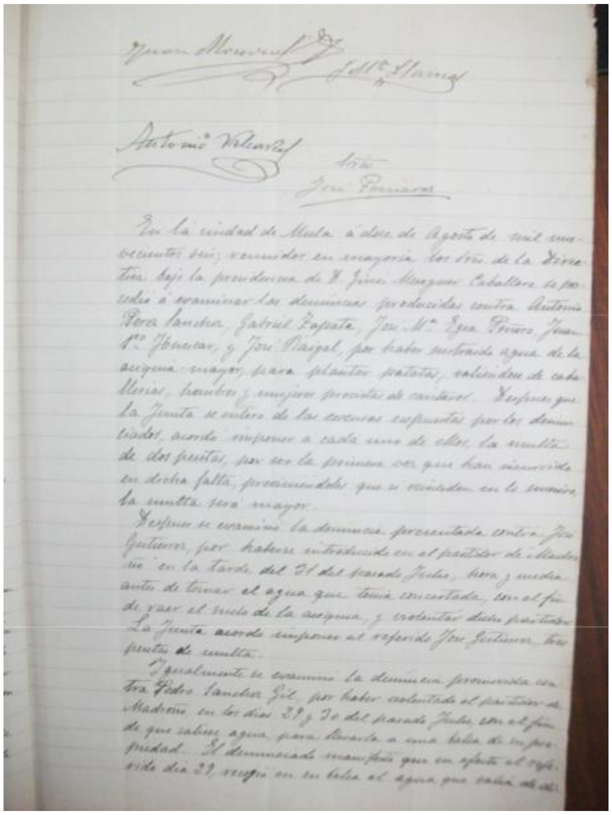
Morilla Critz, J., Olmstead, A. L., and Rhode, P. W., 1999. "'Horn of Plenty': The Globalization of Mediterranean Horticulture and the Economic Development of Southern Europe, 1880-1930," *The Journal of Economic History*, Vol. 59, No. 2, 316-352.
Ostrom, E., 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.
Ostrom, E., 1992. *Crafting Institutions for Self-Governing Irrigation Systems*. San Francisco: ICS Press.
Pérez Picazo, M. T., 2002. "La agudización de las tensiones en los regadíos deficitarios del Sureste entre 1780 y 1950-1960, ¿lucha de clases o conflictividad ecosocial?" *Ayer*, Vol. 47, 231-258.
Polinsky, M., and Shavell, S., 2000. "The Fairness of Sanctions: Some Implications for Optimal Enforcement Policy," *American Law and Economics Review*, Vol. 2, No. 2, 223-237.
Posner, E. A., 2000. *Law and Social Norms*. Cambridge: Harvard University Press.
Reher, D S., and Ballesteros, E., 1993. "Precios y Salarios en Castilla la Nueva: la Construcción de un Índice de Salarios Reales: 1501–1991." *Revista de Historia Económica,* Vol. 11, No. 1, 101–54.
Rodríguez Llopis, M., 1998. *Historia de la Región de Murcia*. Murcia, Spain: Editora Regional de Murcia, Monografías Regionales.
Sanchis-Ibor, C., 2016, "Las instituciones intercomunitarias de gestión colectiva del riego. El fracaso del Sindicato General de Riegos del Turia (1850-1883)," *Historia Agraria*, No. 68, 41-70.
Sutawan, N., 1980. "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: Institute of Philippine Culture.
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, Institute of Philippine Culture.
UNESCO, 2009. "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. Available online at http://www.unesco.org/culture/ich/doc/src/ITH-09-4.COM-CONF.209-13-Rev.2-EN.pdf#Decision1370.
Vickers, C., and Ziebarth, N. L., 2016. "Economic Development and the Demographics of Criminals in Victorian England," *Journal of Law and Economics*, Vol. 59, 191-223.
Wittfogel, K. A., 1957. *Oriental Despotism: A Comparative Study of Total Power*. New Haven: Yale University Press.
Ziming, F. E., Hawkins, G. and Kamin, S., 2001. *Punishment and democracy: Three strikes and you're out in California*. Oxford University Press on Demand.

Figure 1: Trials in self-governed communities.



Notes: Top: Caption of a trial for the Council of Good Men in Murcia. Bottom: Map of the area under study.

Figure 2: Sample of Sentence.



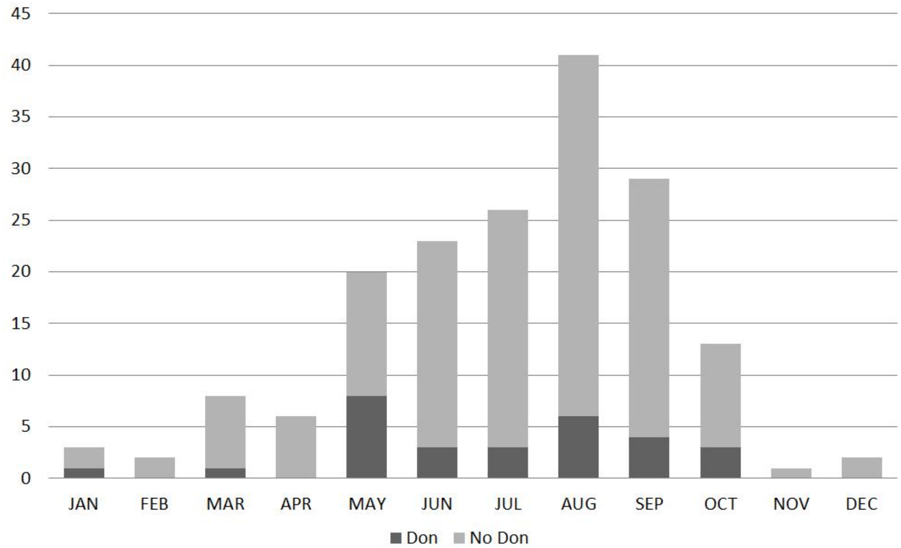
"En la ciudad de Mula a doce de Agosto de mil novecientos seis; reunidos en mayoria los señores de la Directiva bajo la presidencia de D. Gines Meseguer Caballero, se procedio a examinar las de-nuncias producidas contra Antonio Perez Sanchez, Gabriel Zapata, Jose Maria Egea Piñero, Juan Francisco Huescar, y Jose Baigal, por haber sus-traido agua de la acequia-mayor, para plantar patatas, valiendose de caballerias, hombre y mu-jeres provistas de cantaros. Despues que la Junta se entero de las excusas expuestas por los denunci-ados, acordo imponer a cada uno de ellos la multa de dos pesetas, por ser la primera vez que han in-currido en dicha falta, previniendoles que si rein-ciden en lo sucesivo, la multa sera mayor."

"In the city of Mula, on August 12, 1906; with the majority of the board under the presidency of *Don* Gines Meseguer Caballero, they proceeded to examine the accusations against Antonio Perez Sanchez, Gabriel Zapata, Jose Maria Egea Piñero, Juan Francisco Huescar, and Jose Baigal, 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."

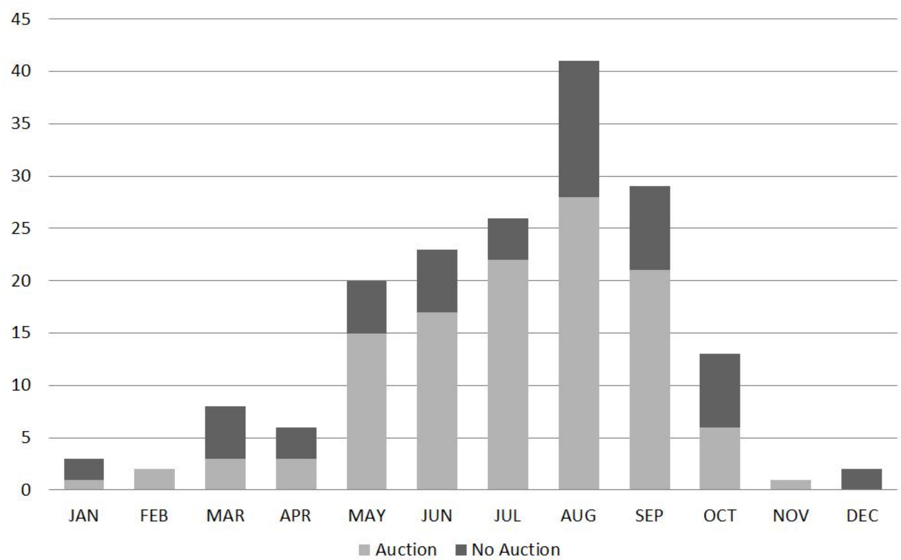
Notes: Left: Caption of the first page of a sentence, corresponding to a single trial, on August 12, 1906. Right: Transcription in the original Spanish and authors' translation of the first paragraph.

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
Victim is *Don*	0.26	0.44	0	1	282
Defendant is *Don*	0.15	0.36	0	1	282
Auction Dummy	0.64	0.48	0	1	282
Fine	6.49	10.12	0	65	174
Compensation	11.07	27.23	0	240.75	174
Recidivist	0.04	0.20	0	1	174

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. *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 Dummy* is a dummy variable that equals 1 if there was an auction in the week that the crime was reported or 0 otherwise. *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*	-0.068	-0.220	-0.086	-0.220	-0.068	0.149	-0.074	0.149
	(0.078)	(0.080)	(0.078)	(0.080)	(0.080)	(0.212)	(0.081)	(0.212)
(Defendant not *Don*) ×		0.222		0.212		-0.247		-0.255
(dry month)		(0.079)		(0.082)		(0.194)		(0.193)
(Defendant not *Don*) ×			0.092	0.040			0.029	0.038
(victim *Don*) ×			(0.074)	(0.079)			(0.080)	(0.079)
(dry month)								
Auction dummy					0.075	0.077	0.074	0.076
					(0.063)	(0.063)	(0.063)	(0.063)
Dry month					0.239	0.454	0.232	0.454
					(0.076)	(0.179)	(0.078)	(0.179)
Number of trials	282	282	282	282	282	282	282	282
Pseudo R^2	0.002	0.023	0.006	0.024	0.038	0.041	0.038	0.042

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. 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*	-5.351		-4.066		-5.693		-4.433	
	(1.579)		(1.579)		(1.520)		(1.519)	
Victim *Don*		-4.534				-4.440		
		(1.390)				(1.343)		
(Defendant not *Don*) ×			-4.778				-4.654	
(victim *Don*)			(1.412)				(1.353)	
Recidivist				15.067				14.651
				(2.872)				(2.828)
Auction dummy					-4.606	-4.348	-4.536	-4.397
					(1.237)	(1.248)	(1.199)	(1.196)
Dry month					-1.738	-1.500	-1.663	0.314
					(1.734)	(1.746)	(1.682)	(1.700)
Number of trials	174	174	174	174	174	174	174	174
R^2	0.063	0.058	0.121	0.138	0.147	0.132	0.203	0.203

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. 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*	7.321		0.456		7.766		0.862	
	(5.528)		(5.277)		(5.545)		(5.290)	
Victim *Don*		24.990				25.360		
		(4.491)				(4.483)		
(Defendant not *Don*) ×			25.524				25.495	
(victim *Don*)			(4.716)				(4.713)	
Recidivist				-10.676				-8.846
				(10.506)				(10.709)
Auction dummy					-3.177	-4.154	-3.559	-3.390
					(4.511)	(4.163)	(4.178)	(4.527)
Dry month					8.666	9.326	8.259	7.075
					(6.325)	(5.826)	(5.858)	(6.438)
Number of trials	174	174	174	174	174	174	174	174
R^2	0.010	0.153	0.155	0.006	0.022	0.168	0.166	0.015

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. See Table 1 for variable definitions.

APPENDIX: THE MODEL

"If perchance thou permittest the staff of justice to swerve, let it be not by the weight of a gift, but by that of mercy."

Miguel de Cervantes, *Don* Quixote.

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 updates their beliefs about the 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

For simplicity, we assume that the probability of a farmer being caught is equal to one. This is consistent with the empirical record where only three times in one hundred years was a case reported, and no-one was accused.[27] A model with a probability of being caught less than one has similar predictions, but would make the algebra more cumbersome. Farmer *i* has the following expected utility function:

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

where $r_i \in \{r_L, r_H\}$ is the individual state of the farmer, *i.e.*, the amount of rain he/she received in his plot and uses for irrigation, 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 ($H > L$); $F(R) \in \{0, F\}$ is the fine imposed to the farmer if 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 farmers type θ_i only affects the farmer's utility when he/she steals and is convicted.[28] That is, the utility of two farmers that receive the same amount of rain and do not steal water is the same, regardless of their type.

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 deviates the 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 the water is not. The water used by the farmer would be highly correlated with the amount of rain in the town, but not perfectly. Some farmers, for example, have irregular land and they cannot take advantage of all the water they get. Alternatively, the farmer may not be able to go to the plot and plow the water the day of the rainfall due to a contingency, such as sickness. More generally, r_i captures idiosyncratic component for farmer *i* of rainfall used for irrigation. r_i is the usage of the observed rainfall, R. Both the judge and the farmer observe the public signal, R. It is correlated with the individual state r_i as follows:

$$P\ (r_i = r_L | R = R_L) = q_L,$$
$$P\ (r_i = r_L | R = R_H\ ) = q_H.$$

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 the 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.*, $\text{Prob}(\theta_i = \theta_H) = \pi$, which is common knowledge. Without loss of generality, let us normalize the most informative signal, R_L, thus, $q_L \geq q_H$. This

[27]These cases are false claims according to the guards.

[28]We do not distinguish between the case where farmers suffer if they steal but are not caught (self-ashamed), from the one where they suffer only if they are caught and convicted (social-ashamed). This is because the probability of being caught is 1 because of the technology to detect crime in our empirical setting. Cases where farmers stole water and they are not caught are not observed in the data and it is not possible to distinguish self-ashamed from social ashamed cases.

is equivalent to say that it is more likely that the farmer receives low water when the rain in the town is low than when the water in the town is high.

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

$$u(r_i,. , 0).$$

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

$$u(r_i + W, \theta_i, F (R)),$$

where u(. ,. ,.) is the Bernoulli utility function. Note that, when a farmer does not steal water, her/his utility only depends on her/his private amount of water r_i. When a farmer steals water, however, in addition to her/his private amount of water r_i, her/his utility also depends on her (*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.[29]

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) $u_2(.,.,0) = 0$: 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.

Example:

Let $u (r_i + W, \theta_i, F (R)) = (r_i + W)^\alpha - \theta_i F (R)$, with $\alpha \in (0, 1)$. It is straightforward to verify that the assumptions hold:

1. $u_1(.,.,.) = \alpha(r_i + W)^{\alpha-1} > 0$;
2. $u_{11}(.,.,.) = \alpha(\alpha - 1)/ (r_i + W)^{\alpha -2} < 0$;
3. $u_2(.,.,.) = -F (R) \leq 0$;
4. $u_2(.,.,0) = 0$;
5. $u_3(.,.,.) < \theta_i$;
6. $u_{23}(.,.,.) = -1 < 0$.

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 he/she received low rain:

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

where $P_R(W)$ is the social value of W units of water when the public signal is R, *i.e.*, $P_R = q_R(u(r_L + W) - u(r_L))+ (1 - q_R)(u(r_H + W) - u(r_H + W))$.

The public signal can be reinterpreted as the proportion (rather than the probability) of farmers who received low rain. 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 he/she 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 he/she used the water that was stolen.

Example:

Let $u (r_i + W, \theta_i, F (R)) = (r_i + W)^\alpha - \theta_i F (R)$, with $\alpha \in (0, 1)$, $r_L = 0$, and $W \approx 0$. Then, $u(r_L,\theta_i, .) = 0$ and $u_{11}(.,.,.) < 0$, and both assumptions are satisfied. Moreover, this decision is socially efficient.

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, he/she cannot be caught; her/his utility is $u(r_i, ., 0)$. If the farmer chooses to steal, *i.e.*, w = W, he/she is caught and her/his utility is $u (r_i + W, \theta_i, F (R))$.

Thus, the farmer steals if, and only if:

[29] In one of the trials, the method to steal the water 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.

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

If the judge were to observe θ_i, the judge could choose F(R) so that the farmer find 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.

Prediction P0: A farmer is more likely to steal water when r_i is small.

Prediction P0 is a direct consequence of the concavity in water of the utility function. The lower the water in the farmer's plot, the higher her marginal utility of additional water and, thus, the more likely that he/she will steal water.

A.1.2. The Judge's Problem

The judge's objective is to achieve social efficiency. The judge wants to punish the farmer if he/she 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 individual state of the farmer, r_i. Instead, the judge only observes a signal, R, which is positively, but not perfectly, correlated with the rainfall in the farmer's plot, r_i.[30] 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 state of water available to farmer *i*, we show as benchmarks the cases where either the greed type θ_i or the water need type 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 the water needs, but not about the greed of the farmer. This is for the following three reasons. First, we do not have data regarding the greed of the farmers, thus we 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, he/she 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 water available to the farmer, r_i, but the judge observes the greed type of the farmer. Thus, the farmer can condition the punishment both in the greedy type the farmer, r_i, and the public signal, R. The judge chooses the punishment so that only a farmer in need of water, *i.e.*, $r_i = r_L$, would find it profitable to steal. The optimal punishment satisfies:

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

Now assume that the judge would like to choose the minimum punishment, $F(R, \theta_i)$, that satisfies this condition, for example, because farmers are poor. Then $F(R, \theta_i)$ solves $u(r_L + W, \theta_i, F(R, \theta_i)) = u(r_L, \theta_i, 0)$. Since u(., ., .) is concave in its first argument, a sufficient condition for such a punishment to exist is that u(., ., .) is linear in its third argument, *i.e.*, that utility is quasi-linear on the fine.

Example:

Let $u(r_i + W, \theta_i, F(R, \theta_i)) = (r_i + W)^\alpha - \theta_i F(R)$

Then, the optimal punishment is:

$$F(R, \theta_i) = \min \{\bar{F}, (1/\theta_i)((r_L + W)/r_L)^\alpha\}.$$

The punishment does not depend on the public signal because the judge can separate between greed types, by imposing different punishments. The optimal punishment is increasing in the amount of water stolen, W; decreasing in θ_i, and decreasing in the amount of rain received by the farmer 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. But 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. In the example above the optimal punishment would be $F(R, \theta_i) = (1/\theta_i)((r_L + W)/r_L)^\alpha$.

Prediction P1: If greed were perfectly observable, the optimal punishment is independent of the public signal and positive.

Water type is Perfectly Observable. In this case, the judge knows the rain in the farmer's plot, 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: $q_L = q_H = 1$. The judge allows farmers

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

to steal when $r_i = r_L$, but not when $r_i = r_H$. The first result holds if $u(r_L + W, \theta_i, F(r_L)) \geq u(r_L, \theta_i, 0)$, for all θ_i. To obtain the latter, the judge imposes a fine sufficiently high, $F(r_H) = \bar{F}$. In general, efficiency is not guaranteed. Following the intuition 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 with the state is high, *i.e.*, $F(r_H) = \bar{F}$. However, if $\bar{F}$ 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, the farmer will always steal water, regardless of the punishment implemented by the judge. In the empirical setting the judges never impose the maximum punishment for the first offense. That means that the case where the maximum punishment is very low is not relevant empirically.

Example (continued):

The inequality above implies $(r_L + W)^\alpha - \theta_i F(r_L) \geq (r_L)$, for all θ_i. A greedy farmer has less disutility from stealing water, thus it is only necessary to check that the inequality holds for greedy farmers, *i.e.*, $(r_L + W)^\alpha - \theta_L F(r_L) > (r_L + W)^\alpha - \theta_i F(r_L) \geq (r_L)^\alpha$. The optimal punishment satisfies $F(R_L) \leq (1/\theta_H)((r_L + W)/r_L)^\alpha$. Any punishment that satisfies this condition would deter crime. In practice, and given that the judge knows that the farmer needs the water, it is likely that the chosen punishment would be the minimum available, *i.e.*, $F(r_L) = 0$.

Note that the predictions are different from the previous case. If rain is high, punishment is maximum and nobody steals in equilibrium. If rain is low, punishment depends on the rain received 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 amount of rain received by the farmer in the bad state, r_L.

Prediction P2: 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, $F(r_H) = \bar{F}$ and $F(r_L) = 0$.

Greed and Water types are Unobservable. Now the judge only observes the public signal about the rain in the town, R, neither the farmer's type, θ_i, nor the farmer's individual rain, 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 all farmers steal for all realizations of R, no farmer steals for any realization of R, or, more interestingly, farmers steal when R = L, and they do not steal when R = H. We focus on the latter case. In the discussion that follows it is useful to simplify the notation as follows. Define the gains from stealing water for type (r_i, θ_j) as $\Delta(r_i, \theta_j) \equiv u(r_i + W, \theta_j, F(R)) - u(r_i, \theta_j; 0)$.

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

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 with the following assumption.

Assumption A2: The parameters are such that the following relation holds for any punishment, F (R): $\Delta(r_L, \theta_H) > \Delta(r_L, \theta_L)$.

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 the decision on whether to steal water or not. When assumption A2 holds, the differences in utility from stealing water are ranked as follows:

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

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 is monotonically decreasing in F(R), it is straightforward to see that an optimal punishment exist that can "separate" the needy from the not needy farmers. Such punishment would be high enough to make needy farmers steal water, and not needy farmers not steal so that in equilibrium:

$\Delta(r_L, \theta_L) > \Delta(r_L, \theta_H) > 0 > \Delta(r_H, \theta_L) > \Delta(r_H, \theta_H)$. (1)

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:
$\Delta(r_L, \theta_L) > \Delta(r_H, \theta_L) > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_H)$,

Note that now no punishment can "separate" the needy from the not needy farmers. However, we can still characterize the second-best punishment, for each signal realization. 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 to steal water to all types except (r_H, θ_H). This can be achieved with a low punishment. The second (harsh) punishment allows to steal water only to farmers of type (r_L, θ_L). In equilibrium, these second-best punishments imply:

Mild $\Delta(r_L, \theta_L) > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_L) > 0 > \Delta(r_H, \theta_H)$. (2)

Harsh $\Delta(r_L, \theta_L) > 0 > \Delta(r_L, \theta_H) > \Delta(r_H, \theta_L) > \Delta(r_H, \theta_H)$. (3)

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, with the punishment. 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 "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 "needy and not greedy" (r_L, θ_H) type. So, 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, he/she 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.

Example (continued):

Using the middle inequalities in equation (1) we obtain:

$$((r_L - W)^\alpha - (r_L)^\alpha)/\theta_H \geq F(R) \geq ((r_H - W)^\alpha - (r_H)^\alpha)/\theta_L$$

This condition holds when the difference between r_L and r_H is large; when the amount of water stolen, W, is high; or when the greed are types similar, $\theta_H \approx \theta_L$.

Example (continued):

Using If the judge imposes a high fine, $F(R) > ((r_H - W)^\alpha - (r_H)^\alpha)/\theta_L$, both types will not steal when $r_i = r_H$. This is optimal. However, *greedy* farmers steal when $r_i = r_L$ if $((r_L - W)^\alpha - (r_L)^\alpha)/\theta_H \geq F(R)$. The outcome is inefficient only when the farmer is *needy* but not *greedy*, $\theta_i = \theta_H$ and $r_i = r_L$, which happens with probability $q_R\pi$ when the public signal is R. The fine is $F(R) = ((r_L - W)^\alpha - (r_L)^\alpha)/\theta_L$. If this condition does not hold, the fine is deterring all farmers from stealing at all times. This is not what we observe in the data, where fines are low and there is some crime. If the judge imposes a low fine, $F(R) \leq ((r_L - W)^\alpha - (r_L)^\alpha)/\theta_H$, both types steal when $r_i = r_L$. This is also optimal. The *greedy* types steal when $r_i = r_H$ if $F(R) \leq ((r_H - W)^\alpha - (r_H)^\alpha)/\theta_L$. The outcome is inefficient only when the farmer is *greedy* and receives high rain, $\theta_i = \theta_H$ and $r_i = r_H$, which happens with probability $(1- q_R)(1- \pi)$ when the public signal is R. The fine is now $F(R) = ((r_L - W)^\alpha - (r_L)^\alpha)/\theta_H$.

Prediction P3: If both the greed type and the water type are unobservable, and equation A2 holds, then the optimal punishment is efficient and does not depend on the public signal.

Prediction P4: If both the greed type and the water type are unobservable, and equation 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.

The analysis for 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 rain, 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 rain, 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 it is intermediate for the average farmer. Thus, A1 implies that it is also efficient to steal water from farmer that received high rain, *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 rain r_L steals water, would be greater when the victim is a farmer that received high rain. Finally, the lower the probability q_R that the victim received low rain 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 low or high rain, *i.e.*, the higher the probability that the defendant received low rain, 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 low or high rain, *i.e.*, the higher the probability that the victim received high rain, the lower the punishment. This intuition is summarized in the prediction P5 below.

Prediction P5: If both the greed type and the water type are unobservable, and equation A2 does not hold, then the optimal punishment requires a mild punishment when the victim received high rain r_H and a harsh punishment when the victim received low rain r_L.

A.2. Dynamic Model

We extend now 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 then 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 he/she was caught in the second period. The prior belief comes from a situation where the farmer has not been caught before, thus there should be no update.

We focus on the case where the agent has been caught twice, $(y_R^1, y_{R'}^2) = (1,1)$.[31] 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 being *greedy* for a farmer who stole water 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 being *greedy* from a farmer who stole water is higher than the unconditional probability, π.

Prediction P6: A recidivist farmer is more likely to be greedy than a first-time offender. Thus, he/she is more likely to receive a harsh punishment.

[31] The model is solved by backward induction. Define the posterior probability:

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

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 he/she was not caught at t=1 is:

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

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 proceed now to rank these probabilities. Then we use the results from the static model. Using 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.