# Let the Punishment Fit the Criminal*

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**Abstract**

We investigate the role of punishment progressivity and individual characteristics in the determination of crime. We model individuals' response to judges' optimal punishment in a dynamic setting. Agents have both persistent and transitory unobservable components. Judges observe a public signal that is correlated with the transitory component and update their beliefs about the persistent component based on past behavior. For the empirical analysis we examine a novel trial data set from a self-governed community of farmers in Spain in which: (i) judges usually impose low fines even though punishment is not costly; (ii) recidivists are punished harsher than first-time offenders for the same crime; (iii) judges vary the degree of punishments based on individual characteristics—such as when victims or accused have a *Don* honorific title indicating they are wealthy. Punishments are harsher when the accused is a *Don* and are milder when the victim is a *Don*. All these empirical facts can be explained by a model in which the community trades off deterrence and insurance.

**JEL Codes**: D44, C13, L14, K14, K42

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# 1 Introduction

The lack of progressivity that predicts traditional crime analysis entails that criminal histories do not matter. However, when unobservable individual characteristics are persistent, a progressive punishment system that accounts for individual criminal history should be implemented. On the other hand, when temporary and unobservable individual characteristics that affect crime are correlated with the environment, the maximum punishment that predicts traditional crime analysis generates that neither honest nor dishonest types commit a crime, regardless of the environment. This is a suboptimal low crime level: during a temporary negative shock, honest types should be allowed to commit a crime.

This paper empirically investigates the role of punishment progressivity and individual characteristics in the determination of crime. To analyze welfare implications we model individuals' response to judges' optimal punishment in a dynamic setting. We introduce two distinctive features motivated by our empirical setting. First, judges rarely imposes maximum punishment for first time offenders. Instead, we observe low fines (or just a warning) even when crime detection technology is efficient and punishment is not costly. We account for this by allowing an unobservable (to the judge) individual state to be correlated with a public signal (the environment). This generates an optimal punishment that is conditional on individual observables. Second, judges punishments follow a progressive system: conditioning on type, recidivists are punished harsher than first-time offenders for the same crime. We account for these dynamics by introducing a persistent unobservable (to the judge) component. Judges update their beliefs about individuals depending on whether they committed a crime in the previous period; this gives rise to progressivity in the optimal punishment system.

For the empirical analysis we examine a novel trial data set from a self-governed community of farmers in Mula, Spain. The data consist of all water trials—282 in total—over 97 years spanning 1851 to 1948. Water crime trials are trials of farmers charged with criminal violation of the laws of the self-governed community. On October $2^{nd}$ 2009, The Council of Wise 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. This tribunal is an institution that has been active since the $13^{th}$ century. It is composed by elected members among the farmers' community. The tribunal provides justice when conflicts among farmers arise. Most of these conflicts are due to farmers irrigating without the right to do it, reducing water available to farmers.

The water tribunal in the city of Mula has a similar structure. There is, however, a difference. While in Murcia water was allocated using fix quotas (*tandas*), in Mula it was done using a public auction.[1] Prices in the auction reflect farmers' valuation for the water. The water tribunal in Mula consists of seven members. They are elected among the water-owners every year, on December $26^{th}$, and their appointment lasts for two years. In odd years, four members are elected; in even years three members are elected. Thus, any given year there are three (four) members of the council in their first term and four (three) members in their second term. After this election, the members of the council elect a president (among them) who will serve for one year. The president appoints a vice-president and a treasurer (among the council members) and a secretary (outside the council). The role of the council is to resolve water disputes among farmers. Appealing to other courts is not possible.

The irrigation system consists of a dam, a main channel, and smaller sub-channels connecting to the individual plots. The old dam (*Gallardo*) was built around the $9^{th}$ century by the Arabs and it was used until 1931 when the new dam (*De La Cierva*) was finished. As Ostrom (1990), p. 69, emphasize:

> 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.
>
> Water was never abundant in this region, conflict over water has always been just beneath the surface of everyday life, erupting from time to time in fights between the irrigators themselves, between the irrigators and their own officials, and between groups of irrigators living in the lower reaches of the water systems and their upstream neighbors. 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.

Stealing water is straightforward in this environment. Farmers can steal water opening the gate next to their parcel; then, water will just flow in. But the technology to detect this crime is very effective: since irrigation is done by flood irrigation it is easy to find who stole water by identifying a flooded parcel from a farmer who did not buy water in the auction for that specific day-schedule (conditioning on rainfall). We would expect high fines to prevent stealing of water. Conversely, if fines are low, we would expect high crime rates. However, "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" (Glick (1967), p. 56).

[1] Also note that, while in Murcia all the farmers have water property rights, in Mula some farmers have no water rights; they have to buy water through auctions.

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. Fines were, in general, low (5 *pesetas* on average). In addition to the fine, the accused had to pay the value of the water stolen. To get a sense of the magnitude of these fines note that the daily wage for an unskilled worker during the period under analysis was 5 *pesetas*; hence, the maximum amount corresponds to a weekly wage.

As noted by Anderson and Maass (1978) and Glick (1967), punishment was progressive: recidivists received more severe punishment than first time offenders. Fines for recidivists varied between 20 and 25 *pesetas* in Mula.

Law and Economics literature, since the seminal work of Becker (1968), argues that maximum punishment is the best crime deterrent. This is the result we obtain when the social planner's objective is to minimize crime. However, empirical studies show that punishments are, in general, smaller than the maximum. The usual explanation is that punishment is costly (for example, maintaining the prisons and guards). But even in cases where punishment is costless—such as traffic fines—, we do not observe the maximum punishment rule.[2]

If law enforcement technology is imperfect, two types of errors can be committed: an innocent may be found guilty, or a guilty person may be acquitted. The first case is a type I error, a false positive: we reject the null hypothesis when it is true (null hypothesis: innocent; reality: not guilty; test-result: guilty). The second case is a type II error, a false negative: we accept the null hypothesis when it is false (null hypothesis: innocent; reality: guilty; test-result: not guilty; action: acquit). In our empirical setting, this imperfection occurs because law incompleteness (that is, incomplete contracts), not from imperfect observability of the crime. This is because the technology to detect crime is effective.

In our model, the social planner minimizes type I and type II errors, rather than minimizing crime. This is motivated by the above mentioned trade-off. The social planner cannot account in the law for all possible contingencies in each specific case. Thus, the social planner allows for judges' discretion to determine the punishment based on the contingencies of the case—in our empirical setting, damages that the crime caused and benefits that the accused obtained.

The optimal mechanism exhibits progressiveness: small fines for first time offenders; bigger fines for recidivists. It predicts that small fines coexist with low crime rates. 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 she may need the water the most due to a contingency, i.e., negative shock. We find that judges vary the degree of imposed punishments based on individual characteristics—such as when victims or accused have a *Don* honorific title indicating they are wealthy. Recidivists are punished harsher than first time offenders.[3]

[2]Sometimes, it is the law that establishes no penalty in certain cases. In Germany, for example, it was not a crime to steal food in case of extreme need (Ostrom (1990)).

[3]This is analogue to a yellow card in soccer. It indicates that the player who has committed the infraction (crime) has been cautioned. It is innocuous, unless the player receives a second yellow card, in which case the

# 2 The Model

In this section we present the theoretical model. First, we introduce the main features in a static framework and extend it to an infinite-period model. Then, we proceed with the extension to a dynamic setting. This allow 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 every individual trial is 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 state. In those cases we incorporate this information and reinterpret the public signal. That is, the exclusion restriction is that trials are conditionally independent.

## 2.1 Static Model

Farmer $i$ has the following expected utility function:

$$U_i\left(r_i, \theta_i, \gamma\left(R\right), F\left(R\right), w\right)$$

where $r_i \in \{r_H, r_L\}$ is the individual state of the farmer (the amount of rain she received in his plot and uses for irrigation, which can be high or low); $\theta_i \in \left\{\underline{\theta}, \overline{\theta}\right\}$ is the type of the farmer (either honest, $\theta_i = \overline{\theta}$, of dishonest, $\theta_i = \underline{\theta}$); $R \in \{H, L\}$ is a public signal about the individual state (the amount of rain in the town can be high or low); $\gamma\left(R\right) \in [0, 1]$ is the probability that a farmer is caught is she steals water; $F(R) \in \left[0, \bar{F}\right]$ is the fine imposed to the farmer if caught stealing water; and $w \in \{0, W\}$, $W > 0$ is the amount of water stolen by the farmer. Type $\theta_i$ only affects the farmer's utility when she steals and is convicted.[4] 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.

We interpret stealing as stealing water either from the dam or the channel. Thus, the social cost is shared equally among all farmers. The case where a farmer steals from another farmer is analogous; however, the loss for the community is different. Assume, without loss of generality: $r_H > r_L$ and $H > L$.

Only farmer $i$ observes $r_i$. Although rainfall, $R$, is public knowledge, the way the farmer uses the water is not. Some farmers, for example, have in irregular land and they cannot take

player is sent off and has to leave the game.

[4]We do not distinguish between the case where honest farmers suffer if they steal (self-ashamed), from the one where they suffer only if they are caught and convicted (social-ashamed). This is because, first, the probability of being caught is virtually 1 as a consequence of the technology to detect crime in our empirical setting. Second, because the cases where farmers stole water and they are not caught are not observed in the data. The latter implies that, even if the probability of being caught were less than one, we would not be able to identify those cases in the the data. This implies that it is not possible to distinguish self-ashamed from social ashamed cases.

advantage of all the water they get. Alternatively, the farmer may be 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. Thus, we interpret $r_i$ as 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 as follows[5]

$$\mathbb{P}\left(r_i = r_L | R = R_H\right) = q_H$$

$$\mathbb{P}\left(r_i = r_L | R = R_L\right) = q_L$$

Let $\pi \in (0,1)$ be the prior probability of being honest, which is common knowledge. Without loss of generality, let us normalize the most informative signal, $R_L$. Hence, $q_L \geq q_H$. This is equivalent to say that it is more likely that the farmer receives low water when the water in the town is low than when the water in the town is high. Then:

$$U_i\left(r_i, \theta_i, \gamma\left(R\right), F\left(R\right), w\right) = \gamma\left(R\right) u\left(r_i + w, \theta_i, F\left(R\right)\right) + \left[1 - \gamma\left(R\right)\right] u\left(r_i + w, \theta_i, 0\right)$$

where $u\left(\cdot,\cdot,\cdot\right)$ is the Bernoulli utility function. We can interpret it in terms of the marginal returns derived from an additional unit of water stolen. In that sense, a higher $\theta_i$ is related to a better technology when stealing water rather than to shame reduction. They are idiosyncratic to each farmer. They could capture, for example, that the farmer has several workers (sons) who help him irrigate within a short period of time, or an idiosyncratic advantage due to the shape of the farmer's plot.[6]

We assume $u\left(\cdot,\cdot,\cdot\right)$ 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:

- $u_1\left(\cdot,\cdot,\cdot\right) > 0$: The farmer receives a positive utility from water, stolen or not.
- $u_{11}\left(\cdot,\cdot,\cdot\right) < 0$: Water has diminishing marginal returns.
- $u_2\left(\cdot,\cdot,\cdot\right) \leq 0$: Honest farmers suffer more from stealing than dishonest ones.

[5]This generalization includes other modeling choices as special cases:

- $q_H = q_L = \frac{1}{2}$: in this case the signal is uninformative. This is the case in most of the existing literature that 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 (without error) whether the defendant is guilty or not.

[6]In one of the trials, the method to steal the water was particularly innovative. The defendant told his three children to "swim" in the channel that was next to his plot in such way that the channel was block. Then, the water overflowed the channel and spilled over the defendant's plot.

- $u_2(\cdot,\cdot,0)=0$: All farmers utility are zero when they are not fined.
- $u_3(\cdot,\cdot,\cdot)<0$: The farmer receives a negative utility from the punishment.
- $u_{23}(\cdot,\cdot,\cdot)<0$: Honest farmers suffer more a given punishment than dishonest ones.

From the last assumption, honest farmers suffer when caught stealing, while dishonest ones do not. Alternatively, we could assume that honest farmers suffer when they steal water (caught or not) while dishonest ones do not. This assumption is not distinguishable within our model given the data available (see footnote 4).

### 2.1.1 The Farmer's problem

We make the following assumptions about the parameter space:

Assumption 1: It profitable to steal water if the farmer received low rain[7]

$$u(r_L,\theta_i,) < u\left(r_L+W,\theta_i,\overline{F}\right), \forall R,\theta_i$$

Assumption 2: It is optimal to steal water if the farmer received low rain[8]

$$u(r_L+W,\theta_i,F(R)) - u(r_L,\theta_i,F(R)) \geq P_R(W), \forall F(R),\theta_i$$

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

**Example:**

Let $u(x,\theta_i,F(R)) = ln(x) - \theta_i F(R)$ and $r_L = 0$. Then, $u(r_L) = -\infty$ and both assumptions are satisfied. Moreover, this decision is socially optimal (in the low-rain state a farmer would die if she does not receive extra water for his crops).

The timing of the game is as follows. At $t=0$, nature draws $\{r_i,R\}$; the farmer observes $\{r_i,R\}$. At $t=1$, the farmer chooses $w$. At $t=2$, the judge observes $R$ and chooses a policy function $F(R)$. Finally, at $t=3$, payoffs are given. If the farmer does not steal, she cannot be caught; his utility is $U_i(r_i,\theta_i,\gamma(R),F(R),w=0) = u(r_i,\theta_i,0)$. If the farmer chooses to steal $w=W$, she is caught with probability $\gamma(R)$ and his utility is $U_i(r_i,\theta_i,\gamma(R),F(R),w=W) = \gamma(R)u(r_i+W,\theta_i,F(R)) + [1-\gamma(R)]u(r_i+W,\theta_i,0)$.

Thus, the farmer will steal if, and only if:

[7] A sufficient condition for Assumption 1 is $\bar{F} < w$.

[8] A sufficient condition for Assumption 2 is $u(r_L+w) - u(r_L) \geq w$.

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

Taking $\theta_i$ and $\gamma(R)$ as given, the judge can change $F(R)$ 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 (with respect to water) of the Bernoulli function. However, the judge does not know $\theta_i$. Thus, in general, the *first-best* outcome is not attainable.

### 2.1.2 The Judge's Problem

The judge's objective is the social optimum: she wants to punish the farmer if she steals water when $r_i = r_H$, and not to punish 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, $r_i$. 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.

### 2.1.3 Honesty is Observable

The judge chooses the punishment so that only a farmer in need (of water), $r_i = r_L$, find it profitable to steal. This is the optimal punishment:

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

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

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 $u(r_L+W,\theta_i,F(R,\theta_i))\geq u(r_L,\theta_i,0)$. Since $u(\cdot,\cdot,\cdot)$ is concave in its first argument, a sufficient condition for such a punishment to exist is that $u(\cdot,\cdot,\cdot)$ is linear in its third argument.

**Example:**

$$u(r_L+W,\theta_i,F(R,\theta_i))=(r_L+W)^{\alpha}-\theta_i F(R,\theta_i)$$

with $\alpha\in(0,1)$.

Then, the optimal punishment is:

$$F(R,\theta_i)=\frac{1}{\theta_i}\left(\frac{r_L+W}{r_L}\right)^{\alpha}$$

The punishment does not depend on the public signal because the judge can separate honest from the dishonest types, by imposing a different punishments. The optimal punishment is increasing in the amount of water stolen, $W$; decreasing in the honesty of the farmer, $\theta_i$; 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 need less water (that is, when the gains from stealing water are smaller). This is because, as long as $r_L$ is sufficiently lower than $r_H$, 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.

#### 2.1.4 Individual State is Observable

In this case the judge knows the rain in the farmer's plot, but not whether the farmer is honest. The judge condition the fine on the individual state, that is, $F(R, \theta_i) = F(r_i)$. This is equivalent to having a perfect public signal: $q_L = q_H = 1$. The judge allows farmers to steal when $r_i = r_L$ but not when $r_i = r_H$. The first result holds if: $u(r_L + W, \theta_i, F(r_L)) \geq u(r_L, \theta_i, 0)$, $\forall \theta_i$. To obtain the latter, the judge imposes a fine sufficiently high: $F(r_H) = \overline{F}$.

**Example (continued):**

The inequality above implies: $(r_L + W)^\alpha - \theta_i F(r_L) \geq (r_L)^\alpha$, $\forall \theta_i$. Thus: $(r_L + W)^\alpha - \underline{\theta} F(r_L) > (r_L + W)^\alpha - \overline{\theta} F(r_L) = (r_L)^\alpha$.

The optimal punishment is:

$$F(r_L) = \frac{1}{\overline{\theta}} \left( \frac{r_L + W}{r_L} \right)^\alpha$$

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 honesty of the most honest farmer $\overline{\theta}$; and decreasing in the amount of rain received by the farmer in the bad state, $r_L$.

#### 2.1.5 Honesty is Unobservable

Now the judge only observes the public signal about the rain in the town, $R$, not the farmer's type, $\theta_i$, nor the farmer's individual rain need, $r_i$. Given $R$, the farmer is honest with probability $\pi$. 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 $R = H$. In the latter, punishment satisfies:[9]

[9] In general punishment must satisfy the following inequalities: $u(r_H + W, \underline{\theta}, F(R)) < u(r_H, \underline{\theta}, 0)$, $u(r_L + W, \underline{\theta}, F(R)) \geq u(r_L, \underline{\theta}, 0)$, $u(r_H + W, \overline{\theta}, F(R)) < u(r_H, \overline{\theta}, 0)$, $u(r_L + W, \overline{\theta}, F(R)) \geq u(r_L, \overline{\theta}, 0)$. But, honest types suffer more from stealing than the dishonest ones, $u(r_L + W, \overline{\theta}, F(R)) < u(r_L + W, \underline{\theta}, F(R))$, which implies the second inequality. Similarly, the third inequality is not binding.

$$u\left(r_H+W,\underline{\theta},F\left(R\right)\right)<u\left(r_H,\underline{\theta},0\right) \tag{1}$$

$$u\left(r_L+W,\overline{\theta},F\left(R\right)\right) \ \ \geq \ \ u\left(r_L,\overline{\theta},0\right) \tag{2}$$

Given that honesty is not observable, existence of a punishment satisfying both inequalities is not, in general, guaranteed.

**Example (continued):**

Combining inequalities 1 and 2 we obtain:

$$\frac{\left(r_L+W\right)^{\alpha}-\left(r_L\right)^{\alpha}}{\overline{\theta}}\geq F\left(R\right)>\frac{\left(r_H+W\right)^{\alpha}-\left(r_H\right)^{\alpha}}{\underline{\theta}}$$

This condition holds when the difference between $r_L$ and $r_H$ is big; when the amount of water stolen, $W$, is high; and when the honest and dishonest are types similar, $\overline{\theta}\simeq\underline{\theta}$.

If inequalities 1 and 2 do not hold, the first-best cannot be achieved. If the fine is too low, dishonest types will steal when $r_i=r_H$; this is suboptimal. It the judge imposes a fine that is too high, honest types will not steal when $r_i=r_L$; this is also suboptimal. The judge must decide.

**Example (continued):**

If the judge imposes a high fine, $F\left(R\right)>\frac{\left(r_H+W\right)^{\alpha}-\left(r_H\right)^{\alpha}}{\underline{\theta}}$, both types will not steal when $r_i=r_H$; this is optimal. However, dishonest types steal when $r_i=r_L$ if $\frac{\left(r_L+W\right)^{\alpha}-\left(r_L\right)^{\alpha}}{\underline{\theta}}\geq F\left(R\right)$. The outcome is inefficient only when the farmer is honest and receives low rain, $\theta_i=\overline{\theta}$ and $r_i=r_L$, which happens with probability $q_R\pi$ when the public signal is $R$. The fine is: $F\left(R\right)=\frac{\left(r_L+W\right)^{\alpha}-\left(r_L\right)^{\alpha}}{\underline{\theta}}$. 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 crime. The judge imposes a low fine and allows certain farmers to steal when $r_i=r_L$.

If the judge imposes a low fine, $F\left(R\right)\leq\frac{\left(r_L+W\right)^{\alpha}-\left(r_L\right)^{\alpha}}{\overline{\theta}}$, both types steal when $r_i=r_L$; this is optimal. Now the dishonest types steal when $r_i=r_H$ if $F\left(R\right)\leq\frac{\left(r_H+W\right)^{\alpha}-\left(r_H\right)^{\alpha}}{\underline{\theta}}$. The outcome is inefficient only when farmer are dishonest and receive high rain, $\theta_i=\underline{\theta}$ and $r_i=r_H$, which happens with probability $(1-q_R)(1-\pi)$ when the public signal is $R$. The fine is now: $F\left(R\right)=\frac{\left(r_L+W\right)^{\alpha}-\left(r_L\right)^{\alpha}}{\overline{\theta}}$.

## 2.2 Dynamic Model

We extend now previous static model to a dynamic setting with two periods.[10]

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; we cannot say anything about the dynamics of the punishment. When $(y_R^1, y_{R'}^2) = (0,1)$ the agent was not caught in the first period, but she was caught in the second period. The prior belief comes from a situation where the farmer has not been caught for an infinite number of periods, then there should be no update.

We focus on the case where the agent has been caught twice, $(y_R^1, y_{R'}^2) = (1,1)$. We solve the model by backward induction. Define the posterior probability:

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

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

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

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 bad type 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 bad type 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 bad type 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 bad type is higher when $R = L$, if the farmer was not caught in the first period.

Then, we obtain the following ranking:

[10]The same qualitative results hold in a general model with more periods.

- $q_{LL}^2 < q_{LH}^2, q_{HL}^2 < q_{HH}^2$

- $p_{LL}^2 > p_{LH}^2, p_{HL}^2 > p_{HH}^2$

Without further assumptions we cannot rank $q_{LH}^2, q_{HL}^2$ and $p_{LH}^2, p_{HL}^2$ .

## 2.3 Empirical Predictions

We summarize now the results from the static model.

The judge imposes a fine system that achieves the *first-best* when the difference between $r_L$ and $r_H$ is big, the amount of water stolen, $W$, is big and when the honest and dishonest types similar, $\overline{\theta} \simeq \underline{\theta}$; then, farmers steal water if, and only if, it is optimal to do it.

If these conditions are not satisfied, the judge decides between two *second-best* schemes. If the judge imposes

- High punishment: the inefficient outcome happens with probability $q_R\pi$. The loss is that an honest farmer is able to irrigate when $r_i = r_L$ (type I error).

- Low punishment, the inefficient outcome happens with probability $(1 - q_R)(1 - \pi)$. The loss is now that a dishonest farmer steals when $r_i = r_H$ (type II error).

The judge is more likely to impose a high punishment scheme, when both $q_R$ and $\pi$ are low. Low $q_R$ means that $r_i = r_L$ is unlikely. Also, since $q_L \geq q_H$, the judge is more likely to impose a high-punishment scheme when $R = H$.

**Recidivism:** $\pi$ is the prior probability that a farmer is dishonest; the lower $\pi$, the more likely the farmer is dishonest. If the farmer is convicted in the previous period, judges update their beliefs: they assign a probability lower than $\pi$. This is because, among those farmers who steal water, the proportion of dishonest farmers is greater than $\pi$.

In general, it is not possible to narrow the predictions without knowing the relevant punishment scheme. The following predictions hold, however, under any punishment scheme:

- Observable characteristics correlated with the probability that a farmer is dishonest are taken into account when deciding the punishment.

- The punishment for a first-time offender is not the maximum punishment.

- Recidivists get greater punishment than first-time offenders:

  - The higher the probability that a farmer is dishonest, the higher the optimal punishment.

  - Conditional on observables, the probability of being dishonest is higher for recidivists than for first time offenders.

# 3 Data Description

In this section we describe the trial data and the auction allocating system. 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.[11]

## 3.1 Trial Data

During the mid $19^{th}$ century, following the French influence, local irrigators communities in mediterranean Spain began to keep track of the information about their trials. The archive in Mula contains all trials spanning 1851 to 1948.

A crime could be reported either by farmers or guards. When farmers report it, water was stolen from them. It could be that she accuses a particular farmer (private v. private) or just the lack of water. In the latter the farmer accuses the Heredamiento (private v. public). A guard reports a crime when water is stolen from the main channel; the guard accuses a specific farmer (public v. private).

*Don* (male) or *Doña* (female) is an honorific title in Spain; it is used with the person's name, e.g., *Don* Juan Zapata. Originally it was reserved for aristocracy. During the period under analysis the term also encompassed high-rank civil servants, wealthy persons or people with college degree. Hence, it is generally believed that a *Don* is never in need to steal water. In most of the trials accusing a *Don*, the person who physically stole the water was some of his servants or a tenant of the *Don*'s land, not himself.

Trial information includes the offender's name and whether she was a *Don*, the plaintiff's name (a farmer or a guard) and whether she was a *Don*, judges' name and their verdict, the amount of the fine (if any), the amount of the indemnification (if any), and the date (of the trial and reported crime).

Trial data consists on 282 trials over 97 years (approximately 3 trials per year). In 174 of them (62%) the accused was found guilty, approximately two positive sentences per year. Table 1 displays summary statistics of selected variables. Note that no auction was carried out in 101 weeks, out of the 282 weeks when a crime was reported; this is because there was not enough water in the dam in those weeks.[12] The local Ordinance established that the default fine for any violation was 25 *pesetas*. Judges could lower the fine (that is, they could impose any fine between 0 and 25 *pesetas*).[13]

[11]From the section *Heredamiento de Aguas*, boxes No.: HA 167, HA 168, HA 169 and HA 170.

[12]There is a case where the same name appears twice, being both crimes 29 years apart. The name is Antonio García Zapata. Antonio is the second most common name in the sample; García and Zapata are the two most commons last names. It is unlikely that both crimes were committed by the same person; we treat this last case as a first time offender.

[13]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; she was fined with 50 *pesetas*. In the other, five men, all *Don*, were found guilty of a plot to block the main channel and 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

Table 1: Summary Statistics

| Variable | Mean | SD | Min | Max | Obs |
|---|---|---|---|---|---|
| Guilty | 0.62 | 0.49 | 0 | 1 | 282 |
| Fine | 5.77 | 8.95 | 0 | 65.20 | 174 |
| Indemnification | 9.26 | 25.44 | 0 | 240.75 | 174 |
| Drought | 0.64 | 0.48 | 0 | 1 | 282 |
| Victim is *Don* | 0.26 | 0.44 | 0 | 1 | 282 |
| Defendant is *Don* | 0.15 | 0.36 | 0 | 1 | 282 |
| Price of Water | 29.00 | 25.99 | 0.02 | 112.84 | 181 |
| Auction Dummy | 0.64 | 0.48 | 0 | 1 | 282 |
| Public | 0.46 | 0.50 | 0 | 1 | 282 |
| Private | 0.42 | 0.49 | 0 | 1 | 282 |
| 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 to defendants when they were found guilty. *Indemnification* is the amount that the defendant must pay as indemnification; it represents the value of the water stolen. *drought* is a dummy variable that equals 1 if during the year of the crime the rain was lower than average and 0 otherwise. *Victim is Don* is a dummy variable that equals 1 if the victim of the crime is an individual that is refereed as a *Don*, and 0 otherwise. *Defendant is Don* is a dummy variable that equals 1 if the defendant is an individual refereed as a *Don*, and 0 otherwise. *Price of Water* refers to the average price of the water sold during the week when the reported crime occurred. *Auction* is a dummy variable that equals 1 if there was an auction in the week that the crime was reported or 0 otherwise. *Public* is a dummy variable that equals 1 if the water was stolen from the community (from the main canal), and 0 otherwise. *Private* is a dummy variable that equals 1 if the water was stolen from an individual farmer, and 0 otherwise. *Private* and *Public* are not perfectly collinear since there are other crimes, mainly by millers. *Recidivist* is a dummy variable that equals 1 if the farmer who committed the crime has also committed a crime in the past, and 0 otherwise.

## 3.2 Water Auctions as Allocation System

Although the process of allocating water in Mula has varied slightly over the years, its basic structure has remained, essentially, unchanged since the $15^{th}$ century. Land in Mula is divided into *regadío* (irrigated land) and *secano* (dry land). Irrigation is only permitted in the former. A channel system allows water from the river to reach all *regadío* lands.[14] The fundamental reason for this division is that *regadío* are fertile lands that are close to rivers and, hence, allow a more efficient use of scarce water in the region. Since it is forbidden to irrigate lands categorized as *secano*, only farmers who own a piece of *regadío* land in Mula are allowed to buy water.

The mechanism to allocate water to those farmers is a sequential English-auction. The auctioneer sells by auction each of the units sequentially and independently of each other. She keeps track of the name of the buyer of every unit and the price paid by the winner. The farmers cannot store water in their plots. Reselling water is forbidden.

The basic selling unit is a *cuarta* (quarter), the right to use, during 3 hours, water that flows through the main channel. Water storage is done in the *De La Cierva* dam. Water flows from

fine per farmer was 65 *pesetas*.

[14]The channel system was expanded from the $13^{th}$ to $15^{th}$ century, as a response to the greater demand for land due to the increase in population. The *regadio* land's structure has not change since the $15^{th}$ century.

the dam through the channels at approximately 40 liters per second. As a result, one *cuarta* carries, approximately, 432,000 liters of water. Traditionally, auctions were made every 21 days to complete a *tanda* (quota), which is the basic aggregate unit of irrigation time. During our sample period auctions were carried out once a week, every Friday.

In every session, 40 *cuartas* were auctioned: 4 *cuartas* for irrigation during the day (from 7:00 AM to 7:00 PM) and 4 *cuartas* for irrigation during the night (from 7:00 PM to 7:00 AM), every weekday (Monday to Friday). The auctioneer sells, first, 20 *cuartas* corresponding to the night-time and, afterwards, 20 *cuartas* corresponding to the day-time. Within each of these groups (day and night), units are sold beginning with Monday (4 *cuartas*), and finishing with Friday's *quartas*.

### 3.3 Rain, Price Indexes

We complement auctions data with daily rainfall data for Mula and monthly price indexes for Spain, which we obtain from the *Agencia Estatal de Metereologia*, AEMET (which is the National Meteorological Agency), and the *Instituto Nacional de Estadística de España*, INE (which is the National Statistics Institute of Spain), respectively. Mediterranean climate rainfall occurs mainly in Spring and Fall. Peak water requirements for the products cultivated in the region are reached in Spring and Summer, between April and August.

## 4 Estimation Results

In this section we present the estimation results using a reduced-form specification. This provide us with valuable information for the estimation of the structural model associated with the theoretical benchmark of Section 2 (under estimation).

#### Crime Rates

The model in Section 2 give us specific predictions about how observable characteristics are correlated with the probability of being guilty. Table 2 presents marginal effects from probit regressions of a dummy variable identifying whether the farmer was found guilty on and indicator of low rain, indicator for the honorific title of the victim and defendant, price of water and other covariates. The table shows that water scarcity significantly increases the likelihood of being guilty. In the specification in column 3, the probability of being guilty is 28% higher on years with lower than average rain (drought). In terms of the model, we would expect the monitoring level, $\gamma(R)$, to be higher during a dry season. Water prices are highly correlated with rain. Due to this collinearity, when both coefficients are included, neither is statistically significant; although the null hypothesis that both are zero is rejected.

The dummy variables capturing honorific titles—a proxy for wealth—for defendants and victims are not statistically significant. This is consistent with Garrido (2011), who analyzes at Victorian London crime data.

Consistent with the literature we find no correlation between that crime rates and business cycle. Column 4 show that water auction equilibrium prices are not statistically significant.[15]

Table 2: Probability of Being Guilty and Farmers Characteristics

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Drought | 0.128** | 0.128** | 0.108* | 0.019 | 0.008 |
| | (0.158) | (0.158) | (0.162) | (0.213) | (0.215) |
| Victim is Don | | -0.060 | -0.058 | | 0.000 |
| | | (0.176) | (0.176) | | (0.226) |
| Defendant is Don | | 0.050 | 0.058 | | 0.175* |
| | | (0.219) | (0.221) | | (0.309) |
| Auction Dummy | | | 0.091 | | |
| | | | (0.162) | | |
| Water Price | | | | 0.001 | 0.000 |
| | | | | 0.004 | 0.004 |
| Pseudo $R^2$ | 1.19 | 1.56 | 2.13 | 0.01 | 1.41 |
| Number of Trials | 282 | 282 | 282 | 181 | 181 |

Notes: All specifications are probit regressions; they include a constant (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 are in parenthesis. We obtain similar results using logit specifications. See Table 1 for variable definitions.
*** p<0.01, ** p<0.05, * p<0.1.

### Fines

We present now the empirical results on optimal punishment, as described by the model. They will be reflected in the fines imposed by the judge. Table 3 present the results from an OLS regression of fines on several covariates. Fines are significantly higher for crimes reported during dry seasons, 2.82 *pesetas* higher in the specification in column 4. This represents 78% of the average fine that is 3.63 *pesetas*.

As regards individual farmer characteristics, fines are significantly lower when the victim has a *Don* honorific title, 4.03 *pesetas* lower in the specification in column 4 (111% lower than the average). Fines are significantly higher when the accused is a *Don*, 7.50 *pesetas* in column 4 (152% higher than the mean). Similar to Garrido (2011), this result reflects that wealthy

[15]Note the drop in the number of trials when there was an auction in the week that the crime was reported (columns 4 to 6). There are no recorded prices when there is no auction.

people receive a greater punishment for the same crime. Fines on crimes reported in weeks where no auctions were run are significantly lower (5.50 *pesetas* in column 4).[16]

Finally, consistent with the model, recidivists received the most severe punishments. For the same crime, the judge punished recidivists with fines 12.02 *pesetas* higher, conditional on covariates. That is, recidivists are punished with fines that are 3.3 times higher; this represents 63% of a weekly worker wage ($\frac{15.02+3.63}{25}$).

Table 3: Fines and Farmers Characteristics

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| drought | 2.273 | 1.934 | 2.527* | 2.819** | 1.294 | 0.698 | 0.698 | 0.678 |
| | (1.460) | (1.382) | (1.321) | (1.267) | (1.070) | (1.000) | (1.000) | (0.815) |
| Victim is Don | | -4.358*** | -4.134*** | -4.033*** | | -2.215** | -2.215** | -2.563*** |
| | | (1.527) | (1.452) | (1.392) | | (1.068) | (1.068) | (0.871) |
| Defendant is Don | | 5.712*** | 5.985*** | 5.057*** | | 4.740*** | 4.740*** | 3.156*** |
| | | (1.742) | (1.657) | (1.605) | | (1.248) | (1.248) | (1.038) |
| Auction Dummy | | | -5.744*** | -5.497*** | | | | |
| | | | (1.313) | (1.259) | | | | |
| Recidivist | | | | 12.021*** | | | | 15.616*** |
| | | | | (2.998) | | | | (2.037) |
| Water Price | | | | | 0.021 | 0.001 | 0.001 | 0.018 |
| | | | | | (0.019) | (0.019) | (0.019) | (0.016) |
| $R^2$ | 0.014 | 0.131 | 0.219 | 0.287 | 0.021 | 0.184 | 0.184 | 0.463 |
| Number of Trials | 174 | 174 | 174 | 174 | 119 | 119 | 119 | 119 |

Notes: Sample restricted to trials where the defendant was found guilty. All specifications are OLS regressions; they 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.
*** p<0.01, ** p<0.05, * p<0.1.

### Indemnification

Fines have a punitive goal: to deter farmers from stealing. Their revenue goes to the community. Indemnifications' objective is to compensate victims of a crime (the farmer if water was stolen from him, or the community if water was stolen from the main channel). Thus, the amount of the indemnification is an estimate of the value of the water stolen.

The effect of offenders individual characteristics on the amount of indemnification is consistent with the model: the amount of indemnification is not statistically different when the

[16] Punishments are significantly lower for water stolen from the main channel than for water stolen from other farmer (not reported). This means that the judge considers a crime to be more severe when stealing from other farmer—who is not a *Don*—than stealing from the main channel; this is optimal if the judge wants to minimize conflict among farmers.

offender has a *Don* honorific titles or when she is a recidivist. This is consistent with the indemnification being a compensation, not a punishment.

Note, however, that the amount of the indemnification is positively correlated with victim's characteristics. Indemnification is significantly higher when the victim has a *Don* honorific tittle (25.42 *pesetas* in column 4). We obtain similar results if we use as dependent variable the net effect of both fines and indemnifications. This is consistent with the fine being lower when stealing from a farmer with a *Don* honorific title: given the lower fine, the offender steals more water from *Don* (recall that farmers can only steal from a neighbor farmer who is irrigating down the channel; thus, the choice of whom to steal is restricted).

Table 4: Indemnification and Farmers Characteristics

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| drought | 2.052 | 2.324 | 2.759 | 2.606 | -0.386 | 3.301 | 3.301 | 3.307 |
| | (4.177) | (3.805) | (3.823) | (3.835) | (3.685) | (3.178) | (3.178) | (3.189) |
| Victim is Don | | 25.307*** | 25.470*** | 25.418*** | | 20.713*** | 20.713*** | 20.805*** |
| | | (4.204) | (4.204) | (4.211) | | (3.393) | (3.393) | (3.408) |
| Defendent is Don | | -1.568 | -1.368 | -0.883 | | -7.076* | -7.076* | -6.655 |
| | | (4.798) | (4.798) | (4.856) | | (3.966) | (3.966) | (4.060) |
| Auction Dummy | | | -4.210 | -4.339 | | | | |
| | | | (3.801) | (3.811) | | | | |
| Recidivist | | | | -6.284 | | | | -4.148 |
| | | | | (9.071) | | | | (7.972) |
| Water Price | | | | | 0.088 | 0.090 | 0.090 | 0.086 |
| | | | | | (0.067) | (0.061) | (0.061) | (0.061) |
| $R^2$ | 0.001 | 0.185 | 0.191 | 0.193 | 0.015 | 0.301 | 0.301 | 0.303 |
| Number of Trials | 174 | 174 | 174 | 174 | 119 | 119 | 119 | 119 |

Notes: Sample restricted to trials where the defendant was found guilty. All specifications are OLS regressions; they include a constant (not reported). Dependent variable is *Indemnification*, the amount that the defendant must pay as indemnification; it represents the value of the water stolen. Standard errors are in parenthesis. See Table 1 for variable definitions.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

# 5 Concluding Remarks

We developed a model that explains two empirical regularities we observed in the data: the punishment that the judge imposes is not the maximum and it is progressive.

Empirical studies have shown that maximum (available) punishment is rarely observed. The first response to reconcile it to Becker's seminal model is that punishments are costly. This is typically the case when punishment is imprisonment but not in our setting with monetary punishments: all fines have the same implementation costs at the margin.

Empirically, we know little about the the optimality of a progressive punishment system. In this paper we study an empirical setting where recidivists receive, for the same crime, substantially higher punishments than first time offenders.

Our a model accounts for these two issues. We incorporate two unobservable individual characteristics that affect crime. One component is temporary, but correlated with the environment. The second component is persistent; this component explains the optimality of progressive the punishment system. Without the temporary component the optimal policy is maximum punishment because the probability that the accused is a criminal equals one. Without the persistent component, criminal histories do not matter; hence, there is no progressive punishment system.

For the empirical analysis we combine these components to explain the behavior of irrigators communities in Southern Spain. The only crime that farmers report is to steal water; the amount of water they steal is quantifiable. We show that judges, who have discretion on the punishment, vary the degree of punishment they impose based on individual characteristics—such as when the victim or the accused have an honorific title that indicates she is a wealthy person. Recidivists are punished harsher than first time offenders.

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