

# Institutional Change and Institutional Inertia: Auctions, Contracts and Property Rights

José Antonio Espín Sánchez\*

## Abstract

There is ample evidence that institutions governing human relationships are persistent over time. In this paper, I address this issue by stressing the role of commitment after a change in institutions is made. When there is a change in technology, the current institution need not be the best-fit for the new technology. I explore under what conditions a new institution that is a best-fit for the new technology will emerge. I accommodate claims made in the Political Economy literature, by focusing on the individuals that have the right to decide the change, and claims made in the New Institutionalism Economics literature, that more efficient institutions will tend to emerge. I propose a general model and two different institutions. One institution is a market mechanism while the other requires a ban on trading. Depending on the parameters of the model one mechanism is more efficient than the other. Moreover, each mechanism could achieve full efficiency under different parameter sets. The non-market mechanism requires an egalitarian distribution of property rights. I use this fact to show that a transition into a more efficient (and more equal) institution may not happen because of commitment problems when the new institution requires the owners of property rights to sell them to other agents with limited liability. Hence, the model predicts that an old institution will persist, even though the new institution could be adopted without any cost, and the old institution is both less efficient and less egalitarian. I use a particular historical episode, irrigators communities in southern Spain, that went from a market institutions (auctions) to a non-market institution (fix quotas) in the 1960s. I show that by focusing only of the distribution of power or the efficiency of each available institution we are unable to explain the institutional change. Moreover, I show how the role of collateral, due to the increase in savings, solve the commitment problem and lead to a change to a more efficient institution.

“There is nothing more difficult to arrange, more doubtful of success, and more dangerous to carry through, than to initiate a new order of things.” N. Machiavelli, *The Prince*.

## 1 Introduction

Institutions governing human relationships, and specially those related to economic issues, are influenced by the environment around them and restricted by initial (historical) conditions. While the influence of the former in current institutions is intuitive and has been the focus of much research, the latter has always been taken as exogenous. Historically determined initial conditions affecting current institutions are considered as given, a factor outside of the scope of the model, not an intrinsic part of it. The aim of this paper is to consider historical factors as part of the framework and analyze where and how historical factors will affect current institutions.

Although the aim is ambitious, the approach is modest. This paper analyzes a very particular setting, with a specific set of institutions and one important change in the environment. I will argue that the

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\*PhD student in Economics at Northwestern University. e-mail: joseespin2013@u.northwestern.edu; phone: 847-471-2755.

historical factors in this environment take the form of (historically) allocated property rights. This “initial” allocation of property rights was originally established as a response to the “initial” environment. However, over time, when the environment changed, they were no longer efficient. I will show that a particular initial allocation of property rights (initial conditions) may make the transition to a more efficient set of institutions unfeasible.

In this environment, the communities all face a similar problem: how to allocate the water from the river among the farmers? However, different towns adopt different solutions. Some towns run auctions for the water, hence allocating the water to the highest bidder, while other towns ban trading on water and impose a fix quota of water for each farmer. This multiplicity of institutions for towns that are seemingly identical (same weather, same size, same crops...) is interesting by itself. However, what is even more interesting is that some of the towns did change the allocation mechanism (institution) after more than seven centuries under a different institution.

Both solutions to the problem have been persistently used in each town. However different, what both institutions have in common in that both are self-governed and self-regulated. The farmers get together and get the water through one mechanism or the other without the intervention of a third party. Moreover, the farmers, under each regime, establish their own courts and appoint their own judges. Elinor Ostrom (1990) has extensively studied benefits of self-governed institutions like the one I am studying here, unlike most scholars that rely on a Hobbesian Leviathan. The Hobbesian *legal centralism* theory has been criticized during the second half of the twentieth century (see Ellickson (1991)). That is, there are situations in which people are not constrained by formal legal institutions (see Posner (2000)), but according to some (commonly agreed) social norms. This point of view about social organization is consistent with the point I am making here. Since both mechanisms (auctions and quotas) belong to the class of self-governed institutions. Moreover, the internal institutional norms (Ordinances) that the farmers in Mula had before and after 1966 are both consistent with the eight points required by Ostrom (2005) for an self-governed institution to be robust. This literature is of little help when deciding which of the two self-governed institutions will survive. Thus, the literature in self-governed institutions is useful to understand the persistence/optimality of the self-governed characteristics of the institution but it is mute about the optimality or adequacy of markets.

This paper is not about a trade-off between efficiency and equality. One could argue that inequality is important when analyzing the likely survival of any institution. However, most people argue that, there is a tendency in the long run, everything else equal, for the most efficient institutions to survive. Moreover, as I will argue, the new institution could be both more efficient and more equal, and yet, unlikely to emerge. This is not a general feature of most institutions discussed in the literature. When concerns about efficiency and equality are present, scholars are concerned about an efficiency-equality trade-off, unlike in the present setting.

In Mula, nominal prices of water begin to rise in the 1950s, more than a decade before the change in the institution, and real prices remained unchanged after controlling for the rain cycle. But even if water was becoming more valuable, unlike North (1990) and Libecap (1978), the new institution produced a weakening of the definition of property rights, because it required a ban on water trading and a joint ownership of water and land. Hence, we have a vacuum in the theory here. New Institutionalism Economics (NIE) predicts that an increase in the value of the underlying resource will generate a new institutional arrangement with more precise definitions of property rights. NIE does not predict what would happen if the underlying resource is less valuable over time (maybe an institution with a less precise definition of property rights or maybe no change at all?).

The situation I am trying to study here has some facts that are not satisfactorily explained by current theories of institutional change. Hence, I need to create a model of endogenous institutional change, a

model that predicts institutional change in the absence of a technological breakthrough or a revolution. The model also has to explain institutional persistence even when the old institution produces both inequality and inefficiency compared to the new institution. The model need to be about institutional diversity and not institutional knowledge, since the “new” institution have been used in the surrounding towns for centuries before the change. As I will show the key to such a model lies in a commitment problem.

In the 13<sup>th</sup> century the Christians conquered the Kingdom of Murcia from the Muslim rulers. The towns and cities in the Kingdom were then settled with Christians from northern Spain (mainly from the Castille and Aragon Kingdoms). The new settlers had to create new institutions to allocate water from scratch. In some places they adopted a market mechanism (auctions) and in other places they adopted a non-market mechanism (quotas). From the 13<sup>th</sup> century until the end of the 15<sup>th</sup> there was some experimentation in some towns with both mechanisms, some of them (like Totana and Librilla) switching back and forth (see Vera Nicolas (2005)). By the end of the 15<sup>th</sup> century the institutions that were in use in every place remained unchanged until the 20<sup>th</sup>. Only the cities of Mula and Lorca kept the auction mechanism, and did not change until the second half of the 20<sup>th</sup> century. In the 1960s the cities of Mula and Lorca switched to the quotas mechanism.

These are the facts to be explained:

- Why did some of the towns originally (13<sup>th</sup> century) used auctions while others used quotas?
- Why did some of the towns that originally had auction changed to quotas before the 16<sup>th</sup> century, while other towns with auctions did not? Moreover, why none of the towns that originally had quotas ever changed to auctions?
- Why there was no institutional change, in any direction, from the 16<sup>th</sup> century until the 1960s?
- Why did Mula and Lorca, the only remaining towns using auctions, changed to quotas in the 1960s?

The rest of this section provides a brief overview of the related literature and why it does not provides a satisfactory explanation to the previous facts.

Old Institutionalism (OI) emphasizes the distinctions between organic (spontaneous) and designed (pragmatic) institutions. The work by Schotter (1981) and others looks at the world as an organic body. They abstract from the fact that human beings can communicate, can talk and reach agreements that will be honored later. This literature considers social institutions not as the constrains by which the game is played, that is constrains in the actions that players can make, but some selection of equilibria that players decide, and the ways by which (iteratively) these sets survive. In the same vein, they do not consider institutions that are the result of bargaining or the rational outcome of some social organization with the right to rule. They argue that institutions are created spontaneously, without active behavior (by the players) to create them. The technology available and the productive environment (weather and soil conditions) is (and has been) very similar across cities and (arguably) across time. The same applies to the crops harvested. Hence, a different productive system is not the reason why some places choose different institutions in the first place, nor is the reason why they switched in the 1960s since there is no evidence of any technological breakthrough. Moreover, Mula and Lorca abandoned the auctions at different times and there is no evidence of any change in production patterns. The main critic of OI with the non-organic literature is that it seems more the study of the planner’s preferences (and its evolution) rather than the study of institutions itself. I hope that the frame I propose here, which also abstracts from the planner’s preferences, may serve to embody both points of view and help us to better understand when the active impulse by players to create an institution will be relevant.

Why was there a ban in water trading in some of the towns, making it a very inflexible mechanism, while in other towns the allocation methods, such as auctions, were more flexible? Since both types of

allocations methods have survived through time and have persisted in places with apparently very similar characteristics, this is an interesting puzzle to solve.

NIE (see Menard and Shirley (2005) for a detailed survey) emphasizes studying the micro-foundation of contract-enforcement institutions (Williamson (1985)) and the inter-relationships between the polity and the economy (North and Thomas (1973)). According to Williamson, it is the tradeoff between a cheap form of production (markets) without any commitment from the seller and another (more expensive) form of production (firm) with perfectly aligned incentives that determines both the organization structure of the firm and its mere existence. Hybrid modes of contracting are then everything in the middle, in which partial commitments can be reached, then incentives are partially aligned, but are made through the market, which is cheaper.

According to North (1990) institutions fail to adjust in response to exogenous changes due to sunk costs, coordination costs and network externalities. I will argue that commitment problems are at least as big a concern as any of these costs. The inability to commit to a future payment can be interpreted as a greater risk premium ask by the lender. The question, then, is not whether the borrower will pay or not, but the probability that the borrower will pay back and the risk premium associated with that probability. The lower the probability that the borrower will pay, the greater is the premium ask by the lender and thus, the greater are the gains in efficiency for a transition to take place. Hence, one could interpret the model presented here as an attempt to endogenize some type of transaction costs.

What Eggerston (1990) calls the “naive” theory of NIE view of the world focuses on the efficiency of each contractual arrangement, here: market, hybrid or firm, and in which cases each of them will be the most efficient (cheapest) form of production. It implicitly assumes that there is only one decision maker and that the objective function of this decision maker is to maximize efficiency (minimize costs). Less naive theories of NIE have no such narrow view, but they still focus on efficiency and neglect the conflicts that can arise between different groups of people with different interests. However, as political economists emphasize, the identity of the decision maker(s) will matter if players do not have the ability to commitment or if the players affected by the change in the institution are not the same player with the power to change the institution. Technology or production alone is not sufficient to explain the survival of an institution for more than seven centuries and its abrupt end in the 1960s. Moreover, NIE has no explanation for the emergence of an institution that implies a less precise definition of property rights.

Mass and Anderson (1978) claim that the two institutions (Quotas and Auctions) can be ranked in terms of efficiency and equality, auction being the most efficient and unequal allocation system. According to this theory, we observe both systems because the less efficient systems are also more simple and easier to maintain (lower operational costs). This hypothesis predicts that we will observe auctions in places where water is extremely scarce. Although this is a very appealing hypothesis, it has some flaws. The size of the land used for irrigation is (at least partially) endogenous. Farmers could, and actually did, increase the land designated for irrigation (*regadio*) if needed. Moreover, the first settlers could have imposed limitations on the size and the number of the parcels assigned to the newcomers, as farmers did in the American frontier. Hence, “scarcity” is also endogenous. Moreover, as some recent researchers (see Vohra and Pai (2010)) have pointed out, an auction mechanism need not be efficient (although it may yet be revenue maximizing) if some of the bidders are financially constrained.

The Political Economy (PE) view of institutional change is best exemplified in Acemoglu and Robinson (2008). They see the world as a zero-sum game (or negative-sum game in case of a revolution). The elites have the political power (*decision rights*) and are concerned only about their revenues, regardless of the overall efficiency in the society. Hence, all that matters is how the society divided the cake. The size of the cake does not change with different institutional arrangements. This hypothesis is very appealing because it explains why inequality persists over time and why the elites did not want the institutions to

change. Actually, it might be the reason why, in the first place, Mula and Lorca ended up with private property rights on water and other cities did not. Politics might have been very different in these two towns in the 13<sup>th</sup> – 16<sup>th</sup> centuries due to their strategic position in the border between a Christian and a Muslim kingdom.

However, this hypothesis is not able to explain why the situation changed in the 1960s, and not before, given that the border disappeared in 1492 with the unification of Spain. PE models will predict an institutional change to happen after (and only after) a revolution or the threat of a revolution. Political instability was the rule and not the exception in Spain from all 19<sup>th</sup> century and the first third of the 20<sup>th</sup> after the civil war ended in 1939 with a long-lived dictatorship. Hence, by 1966 the citizens of Mula have enjoyed 25 years of political stability for the first time in almost two centuries and the threat of a revolution was not in the minds of anyone at this time. Another flaw of this theory is shown in Espin-Sanchez (2012). When a farmer accused another farmer of stealing water, the fine was substantially greater when the defendant is a “Don” than when it is a regular farmer. The fine is smaller the accuser is a “Don”. There is no relation between being a “Don” and the probability of being found guilty. This suggests that the institution was intended to be efficient, imposing bigger fines in individuals that are wealthier than “extractive”, serving as a mean for the wealthy to extract resources from the poor.

Along the same line, some authors (see Garrido (2011b)) have claimed that auctions were used in places where the local elite has a lot of power. Auctions then may create both inefficiency and inequality. We will expect a quotas system only when/if the local elite is not so powerful. This way of thinking was the main point of view of (mainly 19<sup>th</sup> century) contemporary observers as Juan Subercase (Cited by Muñoz (2001)), Aymard (1864) and Brunhes (1902). This literature properly criticizes the flaws of the NIE view. Their main point is that auctions are a bad way to allocate water. Compared with quotas, auctions will produce higher inequality and mild or no increases in efficiency. It is so because very few people owns all the water, and the tradable water rights may even increase inequality over time. The Waterlords are a minority in power and will not abandon their right without resistance.

However, this view fails to provide a proper model of minority resistance and institutional persistence. It implicitly assumes that the farmers (minorities) are unable to commit to a future payment to the Waterlords (elites) after the institution has change. This might be a reasonable assumption when the old institution is a dictatorship and the new institution is a democracy, i.e. it is unlikely that the new formed government will pay the former dictator an amount greater or equal that the rents the dictator was obtaining from the country, even in form of a lump-sum subsidy. However, in the micro-setting I am presenting here the commitment ability of the players is not exogenous. Moreover, if the auction is such a “bad” mechanism to allocate water, and a better system was in use in the surrounding towns, why did it survive at all? If a system with quotas produces greater output and more equality (than auctions) in any place that it is established (Pareto Improvement), the Waterlord could have signed a contract with the farmers and sold the water to them. With the increased output the farmers will be able to repay at a higher price than the Waterlords are obtaining with the auction system. However, this did not happen until the 1960s. I will argue that the Quotas and the Auction systems need not be ranked in terms of efficiency. I will show that each of them fits best in a different environment. Hence, I agree with the NIE that different environments would shape different institutions. However, the existence of an institution that will increase efficiency is only a necessary condition but not sufficient to trigger institutional change. Without the commitment to payback the new acquired property rights, an increase in efficiency will not produce the change in the institutions. We need to identify the winners and the losers under the new regime and whether the winners could credibly compensate the losers.

All the previous theories are theories of exogenous institutional change, thus, they are unable to explain an institutional change without a exogenous change in (payoff-relevant) technology or a revolution.

However, as the timing of the institutional change here suggests, the reason for that change must be in “the dog that didn’t bark”, thus, a theory of endogenous institutional change is needed. According to these exogenous institutional change models, the change of institution will occur in a mechanical way, after a shock occurs. They focus on the payoffs of each agents or in the total payoffs that each institution can generate, but not in technological changes that leave payoffs unaffected while changing the commitment ability of the players involved.

I will show that no payoff-related technological shock happened in 1966 that caused the change in institutions in Mula. On the contrary, a slow process that began in the previous decades, of improvement of financial institutions and the welfare of the farmers was the cause of the institutional change, by solving the commitment problem. To the best of my knowledge Greif (2006) is the only attempt towards a theory of endogenous institutional change. He proposes an endogenous change based on cognitive ability and unintended consequences of previous institutional arrangements. Although my approach is different, what both approaches have in common is that it is not a change in the payoffs or the available set of actions of the players what make a new institution possible.

Although not directly related to the Institutions or Institutional Dynamics literature I make use of some results that are common in other areas of research in economics. I use standard results from General Equilibrium (GE) theory. The presence of liquidity shocks and its effects in markets (market failures) have been extensively studied by macro-economists: sometimes using models of Cash-In-Advance (CIA) (Lucas and Stokey (1987)) or exogenous liquidity constrains (Krusel and Smith (1998)). The result that collateral can be used to improve the efficiency in the allocation of resources is not new in the literature in Finance. Moreover, there is recent and active research area in Finance/Mechanism-Design that deals precisely with the problems that arise when the agent is penniless (limited liability) and how to enforce the optimal (or efficient) dynamic contract (see De Marzo and Fishman (2004) and De Marzo and Sanikov (2007) among others). This paper also aims to contribute to the short but growing literature in empirical studies in institutional change. A good review and a explicit path for research is found in Alston, Eggerstsson and North (1996). Finally, the paper is consistent with the comments and findings of both contemporaneous (Diaz Cassou (1889) and Brunhes (1902)) and current (Gonzalez-Castaño (1991) and Vera-Nicolas (2005)) historians that have look extensively at the traditional organizations of the *Huertas* in Murcia and southeastern Spain (Passa (1844), Glick (1967), Gil-Olcina (1994) and Garrido (2011b)).

The rest of the paper is structured as follows. Section 2 presents the main theoretical analysis, it presents the framework of study, the general model and the properties of both mechanisms (auctions and quotas). Based on the theoretical results from Section 2, Section 3 analyzes the conditions needed for an institutional change. Section 4 present the details of the case of study. Section 5 provides a description of the data used here. Section 6 provides the empirical results. Section 7 concludes.

## 2 Analysis

“They say that to do injustice is, by nature, good; to suffer injustice, evil; but that the evil is greater than the good. [...] [The origin of justice] is a mean or compromise, between the best of all, which is to do injustice and not be punished, and the worst of all, which is to suffer injustice without the power of retaliation; and justice, being at a middle point between the two, is tolerated not as a good, but as the lesser evil, and honored by reason of the inability of men to do injustice. For no man who is worthy to be called a man would ever submit to such an agreement if he were able to resist.” Plato, 427? BC-347? BC, *The Republic*.

I begin this section with the above quotation from Plato because it best exemplify the framework I want to propose here and because it shows that it is hardly new. The origins of any organization is to balance

between the recognition that the world is a positive-sum game (“the evil is greater than the good”) and the selfishness nature of men. The key to sustain such a balance is commitment (“compromise”) and the commitment ability of the parties is what will determined whether an organization exists and survive.

This section presents the analytical framework of study. The results from this section will be useful later when I discuss the properties of each institution. In Sub-section 2.1, I propose a general framework to analyze institutional change. In Sub-section 2.2, I present the model and the definition of efficiency. In Sub-section 2.3, I solve the model for the case when the institution is an auction for the water. Finally, in Sub-section 2.4, I solve the model for the case when the institution is a fix quota for every farmer.

## 2.1 The Framework

I have argued above that current theories of institutional change cannot explain the observed pattern in the case presented here. Most of them do not account for endogenous institutional change. They assume that all institutional changes will happen suddenly and due to external factors, directly related to the payoffs of the agents involved. Now I will present a general framework to analyze institutional change. It is simple and general, but it can accommodate endogenous institutional change and explain the pattern observed.

An institution is the set of rules that govern social behavior between individuals. However, not all individuals in an economy are affected or affect the institution in the same way. The *stakeholders* are all individuals whose payoffs are directly affected by the choice of an institution, that is, different institutions may imply different payoffs for those individuals. The *decision-makers* are all individuals that are entitled with decision rights over the choice of the institution. These two set of individuals need not be disjoint. On the contrary, in most cases, we will expect that they overlap, but not perfectly.

Using the terms employed by Acemoglu and Robinson (2006), one can think on the *decision-makers* as having *de iure* power, since they are entitled with the authority to make the decision. The *stakeholders* could have *de iure* or *de facto* power, depending on the situation. If the situation is one in which a country has to decide to pass a new law, then the *decision-makers* are the congressmen and have *de iure* power. If the citizens/voters (the *stakeholders*) do not like the new law, they can use their *de iure* power and vote for a different representative. However, the citizens also have the option to revolt and overturn the government before (or despite) the elections. In this case the *stakeholders* are using their *de facto* power.

Since their payoffs are affected by the decision made by the *decision-makers*, the *stakeholders* could offer a (maybe monetary) transfer to the *decision-makers* in order to affect their decisions. The transfer could be positive (bribe, lobbying...) or negative (violence, boycott...). This distinction between players and the (in)ability of the players to make credible commitments would be key in the analysis.

The previous setting is useful in order to construct a definition of (Pareto) Efficiency or (Pareto) Efficiency Improvement. The structure of the game is sequential. In the first stage, the *decision-makers* will (simultaneously) decide whether or not to change the institution. In the second stage, the *stakeholders* will (simultaneously) decide the transfer. Since the structure of the game is sequential, the ability to commit of the *stakeholders* will play an important role in the institutional change. I will consider all *stakeholders* to be (*ex-ante*) identical and all *decision-makers* to be also (*ex-ante*) identical. This will allow me to focus on the relations between this two groups and not within each group.

Traditional analysis in economics considers only the first stage. Hence, a change of institution is considered as a Pareto Improvement only if there are no “losers” after the change in institution. Here, “losers” refers to the *stakeholders*. *Stakeholders* are the only players that are affected directly through the change in institution. We can think of the *decision-makers* that are not *stakeholders* as *rent-seekers*.<sup>1</sup> I

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<sup>1</sup>The traditional literature does not make distinction between the players that participate in the game.

will refer to this situation as Interim Pareto Improvement (IPI). However, a more reasonable criteria to analyze institutional change would be to consider the whole game. A change of institution is considered as a Ex-Post Pareto Improvement (EPPI) if there are no “losers”, after the transfers are made.

The most interesting cases happen when the new institution will make some *stakeholders* worse-off and some *stakeholders* better-off in the interim, i.e. before the transfers are made, but will make all players better-off after the transfers are made. Hence, I will focus on situation in which the new institution is a EPPI but not an IPI. This restriction is not without loss of generality but will help me to focus on situations in which it would be technologically efficient to change to the new institution (EPPI) but it is not in the interest of the *decision-makers* to do so, without being compensated. In this situation, a complete lack of commitment power from the *stakeholders* will prevent such a change to occur, even if it will imply a EPPI with respect to the old institution. NIE assumes that *decision-makers* and *stakeholders* completely overlap, hence the concepts of IPI and EPPI are identical. PE assumes a zero-sum game, thus all institutions create no improvement but just a redistribution of rent (positive transfer) or a revolution (negative transfer).

History plays a fundamental role in economic activity and previous institutions will shape the form of new institutions. Let consider some situation, coming from the past, in which there is a particular environment E1 and a particular institution A. This institution need not be efficient, but assume that A achieves full efficiency under E1. A prescribes some distribution of property rights in general. Then consider an exogenous change in the environment. Now the environment is E2. Let further assume that there exist some new institution B that can achieve full efficiency under E2 and A is no longer efficient. The question is now: Under which circumstances, if any, we will expect/predict an institutional change from A to B? If *stakeholders* have full commitment, they can write a contract with the *decision-makers* and commit to pay back a transfer of an positive amount but lower than the efficiency gap between both institutions. Hence, the relevant criterion should be EPPI (not IPI) and a change of institution will always occur.

In a world like the one I just described, contracts and property rights are easily enforceable. Then, where does the commitment problem comes from? It could be that some commitments are illegal (bribes) or that some transfers need coordination between the *stakeholders* (revolution). In the real world, even if the legal and technological environment create no constraints, limited liability may. I use the term limited liability here to stress the fact that any contract signed by a penniless agent, under limited liability, imposes an upper bound in the punishment that the agent can receive in every state. In particular, the claimant of a debt contract could seize all the wealth of the debtor, but cannot physically punish him or impose a burden in future potential earnings. In many real life situations this restriction will be rather implicit, due to the factual impossibility of such punishment. If a *stakeholder* commits to pay a transfer to the *decision-makers* in the future, but at this point in the future he has no money, then the transfer will not be made. Hence, in this situation, the role of financial markets and limited liability are key in understanding when credible commitments can be made and, thus, when mutually beneficial institutional arrangements will emerge.

The benchmark, in human relations, is the lack of commitment. Having this in mind we have to look to mechanism that prevent this lack of commitment, rather to look for causes of lack commitment. Thus, institutions are no more than commitment devices. Whether in the form of “rules” (North (1990)) or “beliefs” (Greif (2006)) institutions act as the support for the actions that each player will play. In the present case, I will argue, it is financial institutions acting as an intermediary and an up-front payment what act as a commitment device.

Ronald Coase’s (1937) famous theorem establishes that well-defined property rights would always overcome problems with externalities, in the absence of transaction costs. According to Coase’s theorem,



assigning full property rights about the water to either the irrigators or the Waterlords would eliminate the negative effects. The theorem only holds under perfect commitment to honor agreements. However, under limited liability rules and the uncertainty in the environment, the probability that an agreement will be honor is always lower than 1. Some stakeholders might not be able to pay only due to an exogenous shock. Different *stakeholders* may have different level of wealth, that they can use as collateral. Hence, the probability  $\alpha$  that a given stakeholder will make a transfer in the second stage is interior  $\alpha \in (0, 1)$ . Hence, the issue here is not whether there is commitment or not, but what is the minimum level of  $\alpha$  that makes the *decision-makers* willing to change the institution.

The present framework is also useful to make explicit the distinction of the planner’s preferences (here the *decision-makers*) and the player’s preferences (here the *stakeholders*) in the economics literature. In this framework, both the preferences of the *decision-makers* and those of the *stakeholders* will matter in a non-trivial way. Once we take as given the identities of the *decision-makers*, we can accommodate both Hobbesian and Lockean views of the world here: If the decision rights go from the top to the bottom, the government is the *decision-maker* and the citizens are the *stakeholders*, this means that the stakeholders are better off this way than making (maybe negative) transfers to the decision makers. If the decision rights go from the bottom to the top, the citizens are the *decision-makers* and the government is the *stakeholder*, this means that the government have to give transfers to the citizens in order to keep the power (the rich guys pay transfers to the poor guys, so that the poor guys let them do their business). This framework can then accommodate existing theories of institutional change whether they are based on the cost of overcoming the objections of those who benefit from the existing institutions (Olson (1982)) or the difficulties associated with buy-out potential losers (Fernandez and Rodrik (1991)).

Finally, one can be uncomfortable with the assumption that some players are given (exogenously) decision power while others are not. This is just a starting point. One could go one step further and allow for “tradable” decision rights. Grafe (2011) has shown how in pre-modern Spain positions as government officials were often sold. In the particular case where decision rights are property rights, it is clear that the *decision-makers* are the property rights claimants. If the new institution specifies a different distribution of property rights, then the identities of the *decision-makers* will also change. In this framework we can make a distinction between *decision-makers* and *rent-seekers*. *Rent-seekers* are *decision-makers* that are not willing to allow for a change to a more efficient institution if this change implies that they will get a lower utility under the new institution. *Rent-seekers* will use their decision rights to veto such change. Under this view, *rent-seekers* are not “bad boys”, they are only selfish rational agents that are willing to allow for a change in institution only if they think they will be compensated. Hence, both *rent-seekers/decision-makers* and *stakeholders* are victims of the *stakeholders’* inability to commit.

## 2.2 Model

Let there be an economy in which there is one Waterlord and a continuum of farmers of mass equal 1. All players are risk neutral. Time is discrete and there is an infinite horizon. All players discount the future with a common discount rate  $\beta$ . Only farmers can produce goods. There is only one output good in this economy, food, with price normalized to 1. Individual output is perfectly observable by all players. The production function of food depends on two factors: capital  $k_{it}$  and effort  $e_{it} \in \mathbb{R}^+$ , and in some random technology parameter  $A_{it}$  which probability distribution is common knowledge. Effort  $e_{it}$  is chosen by farmer  $i$  and is only observable by him. Each farmer is entitled with some irrigation rights  $\theta_i$ . For simplicity, I assume that the amount of water available for irrigation is the same every period, hence,  $\int_0^1 \theta_i di = \theta$ . This assumption is not important for the results but will simplify the analysis.

The production function of food is  $f(A, k, e)$ , with  $f(A, 0, e) = f(A, k, 0) = 0$ . I assume that this

function is increasing and concave in each capital and effort, i.e.  $f_k, f_e, \geq 0$  and  $f_{kk}, f_{ee} \leq 0$ . A farmer working on a plot will receive a (dis) utility from effort equal to  $-e$ . Inada conditions (marginal productivity is infinite at zero and is zero at infinite, for each factor) are sufficient to guarantee an interior solution if there is a market for water. A simple function that has all those properties is:  $f(A, k, e) = (Ake)^\lambda$ , with  $\lambda < 1$ . The random technology parameter will change the relative utility of water for each farmer, since it is idiosyncratic, as well as their effort choice. One can think on  $A_{it}$  as measuring relative prices for different crops that farmers have (since the distribution on different crops among farmers is not homogeneous), differences in rain in each plot or in the relative water exploitation of each plot or a technological (common or idiosyncratic) state.

In the example of the farmers I assume that capital is equal to water  $k_{it} = w_{it}$  and the randomness (technology) takes the form of rain water. Water comes from two sources: rain and irrigation, i.e.  $w_{it} = r_{it} + \gamma_{it}$ . Rain  $r_{it}$  is a random variable and has a finite mean every period  $\int_0^1 r_{it} di = R_t$ , while the total amount of irrigating water is  $\theta$ . The production function of food is then  $f(A, k, e) = f(w, e)$ , with  $f(0, e) = f(w, 0) = 0$ . We will assume that this function is increasing and concave in each argument, i.e.  $f_w, f_e, \geq 0$  and  $f_{ww}, f_{ee} \leq 0$ . A farmer working on a plot will receive a (dis) utility from effort equal to  $-e$ . Inada conditions (marginal productivity is infinite at zero and is zero at infinite, for each factor) are sufficient to guarantee an interior solution if there is a market for water. A simple function that has all those properties is:  $f(w, e) = (we)^\lambda$ , with  $\lambda < 1$ .

The utility for the Waterlord is just the expected discounted sum of present and future earnings:  $U_t^L = E_t \left[ \sum_{t=0}^{\infty} \beta^t \pi_t^L \right]$ , where  $\pi_t^L$  represents the Waterlord earnings (in food) at period  $t$ . The utility for farmer  $i$  is also the expected discounted sum of present and future earnings:  $U_t^i = E_t \left[ \sum_{t=0}^{\infty} \beta^t \pi_t^i \right]$ .

In this model, all the uncertainty in production comes from the rainfall. Introducing another source of uncertainty in the amount of irrigating water  $\theta$  available every period or in the production function  $f(\cdot)$  will not change the results but the notation will be more complicated. Nonetheless, it would be interesting to see the relationship between rainfall and irrigation water when both are random and possibly correlated.

It is important to distinguish between aggregate uncertainty and idiosyncratic uncertainty. Aggregate uncertainty measures the differences in the total rain that farmers receive every period  $r_t$ . Idiosyncratic uncertainty measures the differences in individual rain among farmers for a given period. The rain that every farmer receives in every period can then be decomposed in two components: the aggregate component  $r_t$  and the idiosyncratic component  $\epsilon_{it}$  such that  $r_{it} = r_t + \epsilon_{it}$ . I assume that the upper bound of  $r_{it}$  is such that there is never too much rain in any plot, i.e.  $r_{it} < r_t + \theta$ .<sup>2</sup> This assumption implies that there is not a corner solution, so that one farmer has too much (rainfall) water, and he would like to sell some of this (rainfall) water.

The random variable  $r_t$  can take only two values at every period:

$$r_t = \begin{cases} r_H & \text{with prob. } q \in [0, 1] \\ r_L & \text{with prob. } (1 - q) \in [0, 1] \end{cases}$$

The random variable  $\epsilon_{it}$  comes from a distribution with density function  $h(\epsilon) > 0$ ,  $E_t(\epsilon_{it}) = 0, \forall t$  and  $Var(\epsilon_{it}) = \sigma^2$ . The distribution function  $h(\epsilon)$  is the same every period (otherwise it will not represent pure idiosyncratic shocks) and is the same for all farmers farmers.

At every period  $t$  a farmer is hit with a ‘‘liquidity shock’’ with probability  $\pi \in [0, 1]$ .<sup>3</sup> I assume that a

<sup>2</sup>This assumption is not crucial for the results. Whenever one farmer has so much rain, he would just sell all his water rights and the remaining farmers will have the same amount of water for irrigation. This assumption is needed because we think that rain water is difficult to trade.

<sup>3</sup>The assumption of a liquidity shock is introduced to be consistent with the speech of 19<sup>th</sup> century historians about the

liquidity shock is uncorrelated with the rainfall that a farmer receives. A liquidity shock can be thought of as any unexpected situation (independent of the rain) that affects the ability of the farmer to make payments: a cow died, his son or himself got ill or he lost the previous harvest for any reason. This assumption is very conservative. If I assume that it is only the rain that affects the ability to payback of the farmer, that would be like assuming perfect correlation between the liquidity shock and the idiosyncratic shock. In this situation, the financial exposure of the farmer would be much worse: in periods when rain is low he needs more water, but those would be precisely the periods in which he cannot buy water. In other words, the inefficiency caused by the inability of the farmer to buy water would be worse in the case when the liquidity shock and the low rain periods are positively correlated, because the average unmet needs of water will be greater than average during the low rain periods. When both shocks are independent, the unmet needs of water will be equal to the average, given  $\theta_i$ . The average is taken across periods.

This probability  $\pi$  is equal for all farmers. If a farmer is hit with a liquidity shock, she cannot buy any water during this period. She could still sell some water if she chooses to. This means that, for farmers that are financially constrained, the amount of water they can use is also limited, i.e.  $w_{it} \leq r_{it} + \theta_i$ . It should be noticed that, because there is a continuum of farmers with mass equal 1, the parameters  $\theta$  and  $r_t$  refer to both the total amount and the average amount, per farmer.

**Full Efficiency:** Ideally, a planner would like to choose a continuum of vectors  $\left[ \{w_{it}, e_{it}\}_{i=0}^{i=1} \right]_{t=0}^{\infty}$  one for each farmer and each period, to maximize:

$$\text{Max}_{\left[ \{w_{it}, e_{it}\}_{i=0}^{i=1} \right]_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left\{ \int_0^1 E_w [f(w_{it}, e_{it}) - e_{it}] di \right\}$$

Notice that the uncertainty that comes from the liquidity shock is absent here. Since there is no market, just an almighty planner, a liquidity shock has no impact here. Also, the expectation about rainfall is meaningless, because the planner can always allocate the water ex-post.

Due to the concavity of the production function in each element, it is a necessary condition for efficiency that at every period  $w_{it} = w_t$  and  $e_{it} = e_t$ . The concavity of the production function in  $e$  and the previous result also imply that a necessary condition for efficiency is  $1 = f_e(w_{it}, e^{FB})$ , where  $f_e(\cdot)$  is the partial derivative of  $f(\cdot)$  with respect to  $e$ . Considering the constraints we have that the First Best efficient allocation is:  $w_{it}^{FB} = w_t = R_t + \theta$  and  $e^{FB}$  such that  $1 = E_w [f_e(r_t + \theta, e^{FB})]$ .

In the next two sections I discuss two different mechanisms used to allocate the irrigation water and the parameters space under which each of them achieve full efficiency.

### 2.3 Market Mechanism: Auctions

In this section, I solve for the equilibrium when there is a market for water and discuss under which parameters a market institution will achieve efficiency. If there is no market for water, the individual production in every period is  $f(r_{it} + \theta_i, e)$  and there are no decisions to be made. This could be clearly inefficient. Since  $f$  is concave, a necessary condition for efficiency is that the marginal value of water is the same for all farmers:  $w_{it} = w_t = r_t + \theta$ . Hence, a market for water will always increase efficiency with respect to the case when no market for water is available.

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negative consequences of the auction in the “illiquid” farmers as well as for simplicity, since we can summarize the inefficiency in a single parameter. The whole analysis as well as all the results will not change qualitatively if we assume that there are no liquidity shocks but the farmers are risk-averse.

### 2.3.1 No Liquidity Constraints, $\pi = 0$

If we assume that farmers have no liquidity constraints, i.e.  $\pi = 0$ . By the First Welfare Theorem (FWT) we know that in this economy an equilibrium exists and that it is efficient. An equilibrium in this economy is fully characterized by a market-clearing price  $p_t$ . Furthermore, given the distribution of rainfall we know that the equilibrium price will be  $p_H = f_w(r_H + \theta, e)$  with probability  $q$  and  $p_L = f_w(r_L + \theta, e)$  with probability  $(1 - q)$ . In the example, we have  $p_H = f_w(r_H + \theta, e) = \lambda(r_H + \theta)^{1-\lambda} e^\lambda$  and  $p_L = f_w(r_L + \theta, e) = \lambda(r_L + \theta)^{1-\lambda} e^\lambda$ .

Here, I am implicitly assuming that farmers can make a credible commitment that they will pay for the water they buy with the food they produce. Remember that the price of the food is normalized to 1. One can also think that farmers have a “big pocket” so that they have food stored from previous years and they can pay the water “in cash”.<sup>4</sup>

Since rainfall and irrigation water are perfect substitutes, and markets are complete and perfect, we can think about the allocation of property rights  $\theta_i$  as income shifters. In other words, the final allocation of water among farmers  $w_{it}$  is independent of the distribution of allocation rights  $\theta_i$ . This result makes the analysis much easier because we can focus on the final allocation of water when solving for the efficient allocation. Whether the water rights are owned entirely by the farmers, entirely by others than the farmers or partially by the farmers, the equilibrium allocation will be the same.

We can think in the simplest situation to implement this mechanism: there is only one Waterlord that owns all the water rights. Moreover, this player will act as the Walrasian auctioneer, he will receive (truthful) messages from all players and will set a price that clears the market. If we do not have a single Waterlord but a few Waterlords, or net sellers of water in a given period, we will have the same result if they can form a coalition (cartel) and sell the water in a centralized market. For the result to hold we do not even need the sellers to be the same every period. Farmers whose water rights are close to the average will be sellers in some periods and buyers in others, depending on their idiosyncratic rain  $r_{it}$ .<sup>5</sup>

In an environment with no idiosyncratic shocks, i.e.  $\sigma^2 = 0$ , full efficiency can be achieved without markets if the allocation of water property rights is egalitarian, i.e.  $\theta_i = \theta, \forall i$ . Since there are only aggregate shocks, at every period every farmer will receive the same amount of water. They also own the same amount of water rights. Hence, the initial (before trading) amount of water that every farmer has is the same and is equal to  $w_{it} = r_t + \theta$ , which is the efficient allocation. In this situation, even in the presence of markets, farmers will decide not to trade.

If, at every period  $t$ , a farmer is hit with a liquidity shock with probability  $\pi \neq 0$ , the previous analysis no longer hold. Constrained farmers can only use a limited amount of water, i.e.  $w_{it} \leq r_{it} + \theta_i$ . If we are in a situation in which there are no idiosyncratic shocks and the allocation of property rights is egalitarian, this restriction is not important, because the initial allocation  $w_{it} = r_t + \theta$  is already efficient. In other words, if there is no trading in equilibrium, a restriction on trading will not affect the equilibrium outcome. Moreover, and this is important, if there are idiosyncratic shocks or the initial allocation of property rights is not egalitarian, there will be inefficiencies associated with the liquidity shocks. Let now discuss the implications of this.

**Effort level:** In this case all farmers will be facing the same problem because all of them will have the same production function and will consume the same amount of water  $r_t + \theta$ . Each farmer has to solve:

$$\underset{e_i}{Max} \{E_w [f(\theta + r_t, e_i) - e_i - p_t]\}$$

<sup>4</sup>Of course, this is not literal since the only good in this economy is food. But the “big pocket” assumption implies that there is no liquidity concerns.

<sup>5</sup>This was precisely the case in Mula for many farmers, for centuries.

The solution to this problem is the same as in the Planner's problem. Hence, the level of effort is efficient,  $e_i = e^{FB}$ .

### 2.3.2 Liquidity Constraints, $\pi > 0$

First I will compute the equilibrium when there are no idiosyncratic shocks, but the distribution of water rights is not egalitarian. The initial distribution of water rights  $\theta_i$  has probability density function  $g(\theta_i) > 0$ , cumulative density function  $G(\theta_i)$ , mean equal to  $\theta$  and finite variance  $\sigma_\theta^2$ . When  $\sigma_\theta^2 = 0$  the distribution of property rights is degenerate, i.e.  $\theta_i = \theta, \forall i$ . In this case I say that the distribution of water rights is *egalitarian*.

Let  $\pi > 0$  be the probability that a given farmer is facing a liquidity constraint. A constrained farmer cannot buy any amount of water in the market. This probability is independent of  $\theta_i$ . The equilibrium in this case is fully characterized by a price  $p_t$  and an neutral farmer  $\tilde{\theta}(\pi)$  such that:

- $p_t(\pi) = f_w(r_t + \tilde{\theta}(\pi), e^*)$
- All (constrained or not) farmers with  $\theta_i > \tilde{\theta}(\pi)$  will sell water and all non-constrained farmers with  $\theta_i < \tilde{\theta}(\pi)$  will buy water. The farmer with  $\theta_i = \tilde{\theta}(\pi)$  will not buy nor sell water. Moreover, the final allocation of water is the same among all farmers that are not constrained and constrained farmers with  $\theta_i > \tilde{\theta}(\pi)$ . Constrained farmers with  $\theta_i < \tilde{\theta}(\pi)$  will not buy nor sell water.

**Proposition 1.** *The equilibrium in this case is fully characterized by  $\tilde{\theta}(\pi) = G^{-1}\left(\frac{1}{2-\pi}\right)$ .*

*Proof: See Appendix.*

Notice that without liquidity constraints ( $\pi = 0$ ) we have  $\tilde{\theta}(0) = G^{-1}\left(\frac{1}{2}\right)$ : the indifferent farmer is the average farmer. When there is a ban on trading ( $\pi = 1$ ) we have  $\tilde{\theta}(1) = G^{-1}(1) = 1$ : the indifferent farmer is the richest farmer. With  $\pi > 0$  there is a mass of farmers equal to  $\pi G\left(\tilde{\theta}\right) = \frac{\pi}{2-\pi}$  that will not trade although they would like to buy water. Since  $\tilde{\theta}(\pi)$  is increasing in  $\pi$ , the price that clears the market is decreasing in  $\pi$ . A greater value of  $\pi$  means that there are more people that cannot buy water and, hence, the indifferent farmer has a greater endowment of water rights. The price is determined by the indifferent farmer, thus, decreasing returns of water implies that the equilibrium price is decreasing in  $\pi$ . Notice also that the inefficiency is increasing in  $\pi$ . The case with  $\pi = 1$  coincides also with the case in which trading water is forbidden, hence, the inefficiency is maximal.<sup>6</sup>

**Lemma.** *When  $\pi > 0$ , reducing inequality (reducing  $\sigma_\theta^2$ ) will increase efficiency.*

This result is a direct consequence of the concavity of the production function. Reducing  $\sigma_\theta^2$  implies that there are fewer farmers in the lower tail, i.e. with very few water rights, and those are the farmers that would suffer the most from a liquidity shock.

**Lemma.** *When the allocation of water rights is not egalitarian, i.e.  $\theta_i \neq \theta$  for some  $i$ , there are idiosyncratic shocks to farmers, i.e.  $\sigma^2 \neq 0$  and farmers face financial constraints, i.e.  $\pi > 0$ , allowing for water markets will increase efficiency.*

Even though allowing for water markets will increase efficiency (with respect to the no-trade situation), the planner will do better (actually, he will do best) by expropriating the irrigation rights of the farmers and imposing the egalitarian distribution of water.<sup>7</sup> The expropriation of property rights with no monetary compensation is, however, not realistic and would introduce legal insecurity.

<sup>6</sup>For further details about the inefficiencies see Appendix.

<sup>7</sup>This was the solution adopted in Lorca and Mula in times of extreme drought, the water owners were later partially compensated with money coming from taxes.

**Effort level:** In this case all farmers without financial constraints and all farmers with  $\theta_i > \tilde{\theta}(\pi)$  will be facing the same problem because all of them will have the same production function and will consume the same amount of water  $r_t + \tilde{\theta}(\pi)$ . Each farmer has to solve:

$$Max_{e_i} \left\{ E_w \left[ f \left( r_t + \tilde{\theta}(\pi), e_i \right) - e_i - p_t \right] \right\}$$

The solution to this problem is different than in the Planner's problem. The First Order Condition implies  $1 = E_w \left[ f_e \left( r_t + \tilde{\theta}(\pi), e^* \right) \right]$ . Here the level of effort is inefficient,  $e^* \neq e^{FB}$ . Since the amount of water available to these farmers is greater than optimal the amount of effort they will exert will be inefficiently high if water and effort are complements in the production function ( $f_{we} > 0$ ) or inefficiently low if water and effort are substitutes in the production function ( $f_{we} < 0$ ).

For farmers that are both financially constrained and have small property ( $\theta_i < \tilde{\theta}(\pi)$ ) the production function and thus the effort level will be different, and will depend on  $\theta_i$ :

$$Max_{e_i} \left\{ E_w \left[ f \left( r_t + \theta_i, e_t \right) - e_i - p_t \right] \right\}$$

The FOC implies  $1 = E_w \left[ f_e \left( r_t + \theta_i, e^* \right) \right]$ . The level of effort is also inefficient. Financially constrained farmers with  $\tilde{\theta}(\pi) > \theta_i > \theta$  will not sell their water rights, since  $\tilde{\theta}(\pi) > \theta_i$ , but will be using an inefficiently high amount of water, since  $\theta_i > \theta$ . Farmers with  $\theta_i < \tilde{\theta}(\pi)$  will be using an inefficiently low amount of water.

**Definition.** The total value of the water, in each period, when  $\pi > 0$  is:

$$I \equiv I(\pi) = qp_H(\pi) + (1-q)p_L(\pi) = qf_w \left( r_H + G^{-1} \left( \frac{1}{2-\pi} \right), e^* \right) + (1-q)f_w \left( r_L + G^{-1} \left( \frac{1}{2-\pi} \right), e^* \right)$$

In the example, we have  $I \equiv I(\pi) = q\lambda \left[ r_H + G^{-1} \left( \frac{1}{2-\pi} \right) \right]^{1-\lambda} (e^*)^\lambda + (1-q)\lambda \left[ r_L + G^{-1} \left( \frac{1}{2-\pi} \right) \right]^{1-\lambda} (e^*)^\lambda$ . This definition will be important later when we compare the value of the water for the Waterlords under auctions and under quotas.

## 2.4 Non-Market Mechanism: Quotas

In this section I present some results that I have already sketch in the previous section. I show under which circumstances it will be more efficient to have a Quotas system than an auction system and under which circumstances a quotas system will achieve full efficiency.

A Quotas system is just a mechanism in which there is a ban on trading both water and water property rights. Hence, in every period, each farmer can only use the water that comes from rain and from her property rights,  $w_{it} = r_{it} + \theta_i$ . The ban on trading water property rights is needed to ensure that in every period the "initial" distribution of property rights is always egalitarian. The following result is useful to understand the specific role of each element in the present analysis.

**Proposition 2.** *The Quotas system is strictly more efficient than the Auctions system if  $\pi > 0$ ,  $\sigma^2 = 0$  and  $\sigma_\theta^2 = 0$ .*

*Proof: See Appendix.*

Although the proposition requires no idiosyncratic shocks, i.e.  $\sigma^2 = 0$ , since the result is strict, one can see that when the idiosyncratic shocks are small, i.e.  $\sigma^2 \simeq 0$ , the result is still true. Hence, it is a matter of the relative size of  $\sigma^2$  and  $\pi$  which system will be more efficient, provided that the distribution of property rights is egalitarian.

I do not need to show that a Quotas system will achieve full efficiency under any parameter set. For the argument to go through I only need to show that, under some parameters, the Quotas system is more efficient than the Auction system. However, in order to explain why the quota system has been present in most towns in the region until 1960s, and it is present in all of them until now, here I show that, indeed, the quotas system can achieve full efficiency under some parameter set.

**Proposition 3.** *The Quotas system achieves full efficiency if  $\sigma^2 = 0$  and  $\sigma_\theta^2 = 0$ .*

*Proof: See Appendix.*

It should be note the previous result does not make reference to the liquidity shocks. As I have argued before, conditional on the initial distribution of property rights, the presence of a (cheap) market for water will increase efficiency. This means that the only way to overcome the inefficiencies created by the liquidity shocks is by reducing inequality in the distribution of property rights. Of course, this will only be efficient if the idiosyncratic shocks are negligible. If idiosyncratic shocks are important, it might still be more efficient to have a non-perfect market than a non-market institution.

### 3 Institutional Change

The previous section was intended to build the tools needed to understand why each of two institutions could achieve efficiency under different environments. This is the approach taken by most economists. This section is concern with the problems that societies face when they try to change institutions in response to a change in technology and/or environment. When the allocation of property rights affects the total production of the economy, i.e. welfare, an given initial allocation of property rights may cause inefficiencies if the market for property rights is not perfect. In this section, I will show that this is the case if the farmer cannot fully commit to payback in the future.

If each farmer own the plot he is working on, he will receive all the output from it. The problem of the farmer is then:

$$\text{Max}_{e_i} [E_w [f(w, e_i)] - e_i]$$

Notice that this problem corresponds to the first best because there are no distortions in the decision of the farmer. The first order condition of this problem implies:  $\frac{\delta E_w [f(w, e)]}{\delta e} \Big|_{e=e^{FB}} = 1$ . I will use this result as a benchmark. In the example this is equivalent to:  $q((\theta + r_H) e^{FB})^\lambda + (1 - q)((\theta + r_L) e^{FB})^\lambda = \frac{e^{FB}}{\lambda}$ .

Lets now consider the case in which the Waterlord owns the land. The problem that the Waterlord will be facing will be identical for each farmer. Thus, we can focus on solving the problem of the Waterlord with just one farmer. The Waterlord will act as the principal and will offer a contract  $\Gamma$  to the farmer. The contract should be base on observables.<sup>8</sup>

If the effort was also observable the analysis will be simpler. The Waterlord will ask the farmer to exert  $e = e^{FB}$  and pays him  $e^{FB}$ . This situation, however, is unlikely to happen in the real world, hence, I assume that the effort is only observable by the farmer.

Through this section I assume that  $\sigma^2 = 0$ . Hence, from Proposition 5, a sufficient condition to achieve full efficiency is  $\sigma_\theta^2 = 0$ . In the case with one farmer with no water ownership and one Waterlord this condition is equivalent to the farmer to owning all the water rights.

In the real world, financial markets may not work so well. Moreover, financial institutions may have not access to relevant information about the output generated. One can go even further and ask whether the Waterlord could act as a financial institution. After all, the Waterlord is also interested in selling

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<sup>8</sup>Through the paper I refer to observable or contractible as the same concept. I will not consider here situations in which some variables are observable but not contractible. Hence, we are in a complete contracts setting.

the water rights to the farmer because the farmer has a greater valuation of the water rights than the Waterlord.

In this case, the farmer is suffering lack of commitment. The Waterlord could offer a contract  $\Gamma$  such that the farmer has to pay a fix amount of output after production has taken place. This contract is a debt contract and it is optimal in the present setting: it maximizes the set of parameters under which the sale will occur.<sup>9</sup> I normalize the value of the land to zero and assume that the farmer has some wealth  $C_i$  that she can use as collateral. Let  $I$  the value that a Waterlord assigns to the ownership of water rights which is equal to the market value of the water under the auction system. I consider the 2-stage game here. For details about the algebra as well as for the infinite-period game see the Appendix.

I am not considering here the possibility that the Waterlord sells only a fraction of the water to the farmer. The Waterlord will ask the farmer for a payment  $B$  after the (observable) output has occur. Since the Waterlord is incurring a risk because the farmer may not be able to pay the full amount  $B$ , in equilibrium we have  $B \geq I$ . I am concern with the biggest set of parameters under which the sale will occur. Thus I assume that the Waterlord will sell the water rights as soon as he get a profit from doing so. This means that the expected value for the Waterlord equals the market price of the water.

The game played here is the same displayed in Sub-section 2.1. The game is sequential. In the first stage, the Waterlord (*decision-maker*) decides whether to sell the water rights to the farmer and the amount to be paid  $B$ . In the second stage, the farmer (*stakeholder*) decides the transfer. Since this is a world with perfect observability of the output and perfect contracting, the Waterlord could force the farmer to pay up to  $B$ , provided that the farmer has any wealth. The farmer decides the level of effort to exert as a function of  $B$ ,  $\tilde{e}(B)$ . The amount that the Waterlord will get is a direct (increasing) function of the level of effort exerted by the farmer. Hence, the farmer is implicitly choosing the transfer. The rest of this section solves for the equilibrium of this game. I consider first the case in which the farmer has no wealth to use as collateral and then the more general case in which the farmer has some wealth to use as collateral  $C_i \geq 0$ .

The situation here might be an EPPI. Since the new allocation of property rights achieves full efficiency but the former did not, there is scope for a transfer between the farmer and the Waterlord so that both might be better off. However, it will not produce IPI, because the Warlord is worse-off after giving the property rights to the farmer and before the payment (transfer) is made. Hence, this corresponds with the framework I presented in Sub-section 2.1.

### 3.1 Benchmark: No collateral

The Waterlord sells the farmer the water rights  $\theta$  and will ask for a fix amount  $B$  to be re-paid after production occurs. The problem of the farmer is then:

$$\begin{aligned} \tilde{V}(B) &\equiv \underset{e_i}{Max} \{q [Max \{f(\theta + r_H, e_i) - B, 0\}] + (1 - q) [Max \{f(\theta + r_L, e_i) - B, 0\} - e_i]\} \\ \tilde{V}(B) &\geq 0 \end{aligned}$$

The farmer should choose a level of effort as a function of  $B$ ,  $\tilde{e}(B)$ . Because of the structure of the problem we need to define the equilibrium in three regions:

- If  $B > f(\theta + r_H, \tilde{e}(B))$ , the farmer will always default, and will get nothing. In this case, the farmer will not exert any effort and the profits for both (the farmer and the Waterlord) will be zero. Hence,

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<sup>9</sup>The proof in the appendix. This is a general result in the Finance literature as well as in the Mechanism Design literature. For a detailed discussion on optimal contract, when the asset is the land, and the effect of wealth as collateral see Hoffman (1996), Chapter 3.



there will be no sale.

- If  $B \leq f(\theta + r_L, \tilde{e}(B))$  the problem is simple. In this case, the farmer can always pay the loan, hence there is no moral hazard problem. There will always be sale.
- If  $f(\theta + r_H, \tilde{e}(B)) \geq B > f(\theta + r_L, \tilde{e}(B))$ , the farmer can only repay the output when the state is high. If the state of the world is high, the Waterlord will get  $B$  and the farmer will get the remaining output. If the state of the world is low the farmer can not paid  $B$  and the Waterlord will take over the remaining output. In this case, we have:

$$\tilde{V}(B) \equiv \underset{e_i}{Max} \{q[f(\theta + r_H, e_i) - B] - e_i\}$$

$$\tilde{V}(B) \geq 0$$

The first order condition in this case is  $[qf_e(\theta + r_H, \tilde{e})] = 1$ . In the example, this condition is:  $q(l(\theta + r_H)\tilde{e})^\lambda = \frac{\tilde{e}}{\lambda}$ . Since  $q < 1$  we have  $\tilde{e} < e^{FB}$ . Notice that even if the Waterlord sells the water rights to the farmer, the effort level is still sub-optimal. The effort level is independent of  $B$  when  $f(\theta + r_H, \tilde{e}(B)) \geq B > f(\theta + r_L, \tilde{e}(B))$ .

The market clearing condition is in this case:

$$qB + (1 - q)f(\theta + r_L, \tilde{e}) = I$$

The farmer will default with probability  $(1 - q)$ , hence  $B \geq I$ . Notice that there is no guarantee that this equation will have a solution for  $B$ . If the risk is too high the Waterlord will ask for a high  $B$ . This high  $B$  may make the farmer not willing to participate in the trade, i.e.  $B > f(\theta + r_H, \tilde{e}(B))$ .

In particular, when  $r_H$  is very high and  $r_L$  is very low, or when  $q$  is low, the Waterlord will find it optimal not to sell the water rights to the farmer but to write a sharecropping contract. Hence, when the aggregate rainfall is very volatile, the Waterlord will not sell the water rights to a penniless ( $C_i = 0$ ) farmer and, thus, efficiency cannot be achieved.

### 3.2 Collateral

“The pound of flesh which I demand of him is dearly bought. ‘Tis mine, and I will have it.”,  
William Shakespeare, *The Merchant of Venice* (IV.i.89–99).

If the farmer has some wealth that the Waterlord can appropriate in case of low rain, then the problem is less severe than before. If  $C_i \geq I$ , then the problem is trivial, because the farmer will always be able to payback. Moreover,  $C_i \geq f(\theta + r_L, \tilde{e})$  is sufficient to ensure that the farmer will payback. In this case the Waterlord knows that he will always be repaid, hence  $B = I$ . In this case, the problem of the farmer becomes:

$$\hat{V}(B) \equiv \underset{e_i}{Max} \{qf(\theta + r_H, e_i) + (1 - q)f(\theta + r_L, e_i) - I - e_i\}$$

$$\hat{V}(B) \geq 0$$

The effort here is optimal,  $\hat{e} = e^{FB}$ .

However, it could be the case that the farmer does not have enough wealth, i.e.  $C_i < f(\theta + r_L, \tilde{e})$ . In this case, the problem is the same as before. The farmer will get nothing in case of a bad shock and will get the output minus  $B$  in case of a good shock. The farmer will exert effort equal to  $\tilde{e}$ . But now the problem is alleviated because in the bad state the Waterlord can take over the collateral. The market clearing condition,  $W = I$ , is in this case:

$$qB + (1 - q) [f(\theta + r_L, \tilde{e}) + C_i] = I$$

The solution to this problem  $B^*(C_i)$  is decreasing in  $C_i$ . In particular,  $B^*(0) > B^*(C_i)$  for any  $C_i > 0$ . Depending on the value of  $C_i$  the solution of the problem is:

- If  $C_i + f(\theta + r_L, \tilde{e}) \geq I$ , then the farmer will exert the first best level of effort and will never default:  $\tilde{e} = e^{FB}$  and  $B = I$ . The Waterlord will sell the water rights to the farmer. Efficiency will increase and the contract will achieve full efficiency.
- If  $\frac{1}{1-q} \{2I - [qf(\theta + r_H, \tilde{e}) + (1 - q)f(\theta + r_L, \tilde{e})]\} \leq C_i < I - f(\theta + r_L, \tilde{e})$ , then the farmer will exert a suboptimal level of effort, i.e.  $\tilde{e} < e^{FB}$ , and will default with probability  $(1 - q)$ , thus  $B > I$ . The Waterlord will sell the water rights to the farmer. Efficiency will increase but the contract will not achieve full efficiency. This is the second-best possible outcome in this case.
- $C_i < \frac{1}{1-q} \{2I - [qf(\theta + r_H, \tilde{e}) + (1 - q)f(\theta + r_L, \tilde{e})]\}$ , the farmer will not accept the best contract that the Waterlord can offer. The Waterlord will sell the water rights to the farmer although it could increase efficiency with respect to the auction system. Thus, there will be no Institutional Change. In this case, it is better for the Waterlord to remain with the auctions system.

The last inequality comes from the fact that the farmer will always default if the rain is low. In this situation, the farmer will not accept the contract if:

$$q(f(\theta + r_H, \tilde{e}) - B) < I$$

Hence, a necessary condition for a transition to happen is:

$$[qf(\theta + r_H, \tilde{e}) + (1 - q)f(\theta + r_L, \tilde{e})] + (1 - q)C_i > 2I \quad (1)$$

Notice that this condition is necessary but not sufficient. As we have seen before, when  $\pi = 0$  and  $\sigma^2 > 0$  auctions are efficient but quotas are not. One can see that it is possible that the previous condition holds while  $\pi = 0$  and  $\sigma^2 > 0$ . This can happen because the left hand side includes all the output generated from all sources: water, land and effort; while the left hand side only includes the part of the output corresponding to water. It is also worth noticing that the effort in both side is suboptimal, but there is no reason *a priori* to think that one would be greater than the other. Finally one should have in mind that this is a static simplification. In reality one should compare the both sides of the equation using the net present discounted value, rather than the one-period value. This is not a problem because both sides will be updated in the same direction.

### 3.3 Institutional Inertia

I have just shown that, even in a world with perfect contracting and perfect observability, a mutually beneficial arrangement will not be attained if there are commitment issues. These issues could be generated by limited liability. In other words, the punishment that the Waterlord can use against the farmer in case of default is limited, because the farmer is penniless and the law, moral or monitoring technology prevents the Waterlord to impose a greater punishment than confiscating all the farmer's wealth. I have also show that this problem is not relevant if the farmer has some wealth that he can use as collateral.

Institutional Inertia is then a situation in which a new (more efficient) distribution of property rights cannot emerge due to lack of commitment from the *stake-holder* (farmer). It is call *inertia* because the reason why the more new definition of property rights does not emerge is precisely because of the structure

of the old institution. Efficiency requires the distribution of property rights to be egalitarian. If the new distribution cannot be attained due to contractual problems, it will not emerge. Moreover, since auctions can be run under any distribution of property rights, the inverse transition (from *quotas* to *auctions*) could always be achieved, without inertia. The Institutional Inertia is asymmetric.

Imagine a situation with several towns. Initially, in each town both the allocations of property rights ( $G(\theta)$ ) and the original institution (*quotas* or *auctions*) is established arbitrarily. Notice that quotas requires  $\sigma_\theta^2 = 0$  so the initial allocation of property rights is egalitarian. Farmers start with no wealth but they can save some money over time. If *auctions* are more efficient than *quotas* in all towns, i.e.  $\pi = 0$  and  $\sigma^2 > 0$ , then the towns in which the original institution was *quotas* will immediately change to *auctions*. In this case there is no Institutional Inertia because as soon as the new is more efficient (in this case *auctions*) the more efficient institution is implemented.

However, if *quotas* are more efficient than *auctions*, i.e.  $\pi > 0$  and  $\sigma^2 = 0$ , then the situation is different. Towns where the original institution is *quotas* will not change. This was indeed the case for most towns in Murcia. Towns where the original institution is an *auction* will not change to either. Farmers can save some money over time. Thus each town will change to *quotas* when the wealth of their peasants, relative to the initial allocation of property rights in this town, is sufficiently high. Hence, this is supportive with the evidence that some small towns settled mainly by farmers and thus had a more equal distribution of property rights will change to *quotas* soon. This was the case of small towns like Totana and Librilla that did change to *quotas* by the 16th century. However, big cities like Lorca and Mula, where the original institution was *auctions* and had an unequal distribution of property rights, will take it longer to change to a new institution.

### 3.4 Empirical Predictions

An institutional change is more likely to happen if:

- A more equal distribution of property rights (lower  $\sigma_\theta^2$ ) implies a lower equilibrium price of water and, hence, the transition is more likely to happen.
- A change in  $f(x)$  can be interpreted as a change in output prices. Moreover, when we re-scale up the production function, i.e. the new production function is  $f'(x) = \alpha f(x)$  with  $\alpha > 1$ , the right hand side of the equation grows faster than the left hand side, because the Collateral is not affected by the increase in output price. Hence, an increase in the output prices means that the transition is less likely.
- The effect of a change in climate conditions  $\{q, r_H, r_L\}$  is ambiguous.
- The Savings/Collateral of farmers is greater. Implicitly in 1 is the fact that bankruptcy costs are zero and banks earn zero profits in expectation. The more developed the financial system and the easier the access to credit will also favor institutional change.

## 4 Case Study

*“A majoribus tradita, et apud nos deposita”* - “Recibida de nuestros mayores y conservada entre nosotros”, (“Received from our elders, and kept among us”), Epigraph of the Preamble of the Ordinances of Mula, 1853.

In this section, I discuss the situation in Mula and the particular characteristics of the situation before, during and after its transition from a market institution to a non-market institution for water allocation.

Geographical, historical and social conditions at the time the Christians conquered the Kingdom of Murcia, may have had an important impact on the way these institutions were originally set up. There is evidence of experimentation with other systems and some towns did, indeed, switch back and forth from an *auctions* system to a *quotas* system before the 15<sup>th</sup> century (see Melgarejo-Moreno (2005)).

There are two plausible hypothesis that can explain why Lorca and Mula switch to an institution in which land and water ownership are independent (auctions), even if this was not efficient. The first explanation has to do with an epidemic disease (the black death or other). After the epidemic disease, and due to the decrease in population, the community faces a situation in which some of the land (and the water tied to it) are not being used. In such a situation and during a drought, it will always be optimal to make use of the water tied to the unused land. One way to make use of this land is by public auction by the city hall, and use the revenues to improve the channel system. Once it is agreed and understood that the city hall is using these water rights, the new settlers will only receive land, without water rights. In this situation, some of the owners of water and land might want to sell part of their water rights and some of the new settlers might want to buy them. This trade of water rights might be efficient because it increases equality. Once the city hall accepts private trading in water property rights, it might also decide to sell the water rights that it initially claimed and let the private owners run their own auctions. With free trade of water property rights, there is no reason to think that equality will remain constant. Moreover, Gonzalez-Castaño shows that inequality in water ownership increased during the 16<sup>th</sup> – 19<sup>th</sup> centuries.

The second explanation has a more economic taste. Before 1492 the Muslim Kingdom of Granada was the main port for silk in Europe. It also had a big industry for silk fabrics. After 1492 with the conquest of Granada by the Catholic Kings and the expulsion of the Muslims afterwards there was an excess of demand for silk in Spain and Europe. The artisans in the neighbor region of Murcia rapidly took over. They build new factories and demanded white mulberry leaves from the local farmers. The farmers uprooted the vines, olive and fruit trees that have been there for years (centuries) and planted white mulberry trees to satisfy the increasing demand. Then, by 1570-1580, a crisis emerged in Europe, due to the Wars of Religion. Since silk is a luxury good and is of little use both in war or in famine, the demand for silk plummeted. The consequences were disastrous for the Region (see Perez-Picazo and Lemeunier (1984)). Farmers now have to uproot the useless white mulberry trees and plant vines, olive and fruit trees, or just wheat to survive. Some of these trees take 5 or more years to become productive, hence the farmers were in a real desperate situation. In such a situation is sensible to think that the farmers agreed to untied the ownership of land and water, sell their water rights and keep their land. With the cash received in exchange for their water rights they could feed their families while the new trees grew up. Although inefficient, this new system was far better than die starving. Since Mula and Lorca were both big cities, each the capital of their county and both in the border with Granada, it is plausible that these cities were more specialized in the silk industry and, hence, they suffered most from the silk crisis. Hence, only in these full-specialized cities did the system change, and not in other places. By the late 16<sup>th</sup> century there was no more change in institutions until the 20<sup>th</sup> century.

If a new economic institution could substantially increase the output of a given society, there would exist some way to allocate the increase in output so as to satisfy the elites (*decision-makers*). However, it is not so clear that the elites can credibly benefit from that. One problem that can arise is lack of commitment. The Waterlords could sell their rights to the farmers. Farmers would then make better (non-distorted) decisions and, thus, increase output. This result is standard in moral hazard problems (“sell” the firm to the agent). However, farmers are penniless and could only buy the water rights (not the water) with a promise of future repayment.

Figure 1: Offer made by the government for the full ownership of the water. Pages 10-11.

— 10 —

<b>Cuadro de precios de los diferentes cuartos de agua</b>									
	VALOR		%	Preferencia		Valor con Preferencia		TOTAL GENERAL	
	Pesetas	C.		Pesetas	C.	Pesetas	C.	Pesetas	C.
<b>De las cuatro</b>									
Hilas de arriba	7	19,023	14	2,800	21,823	152,761			
Treses " "	2	14,267	12	1,800	16,067	25	32,134	50	
Doses " "	13	9,511	10	1,000	10,511	50	136,649	50	
Unos " "	4				4,755	75	19,023		
Doses de abajo	10	9,511	14	400	9,911	50	99,115		
Unos " "	76				4,755	75	361,437		
<b>De las cinco</b>									
Hilas de arriba	27	19,023	14	2,800	21,823	589,221			
Treses " "	5	14,267	12	1,800	16,067	25	80,336	25	
Doses " "	55	9,511	10	1,000	10,511	50	578,132	50	
Unos " "	23				4,755	75	109,382	25	
Hilas de abajo	1	19,023	8	1,600	20,623	20,623			
Doses " "	35	9,511	4	400	9,911	50	346,902	50	
Unos " "	310				4,755	75	1,474,282	50	
<b>De las Seis. - 3.º Sta. Maria</b>									
Hilas de arriba	2	15,736	14	2,333	18,069	34	36,138	88	
Treses " "	1	11,802	12	1,499	13,302	08	13,302	08	
Doses " "	2	7,868	10	833	8,701	39	17,402	78	
Unos " "	1				3,934	03	3,934	03	
Doses de abajo	10	7,868	4	333	8,201	39	82,013	90	
Unos " "	4				3,934	03	15,736	12	
Unos " "	8				3,934	03	31,472	24	
							4,200,000	03	

One option would be to use the land as collateral. However, the farmers might be reluctant to do so. On one hand this would imply that farmers should carry a lot of risk, since they can lose “everything” during a drought. On the other hand, it would be hard for the Waterlord to take over the land and it would also be hard for him to sell it so someone else since maybe most farmers are in the same financial situation. Finally, the Waterlord is not a farmer, just a financial speculator, hence, it would be even harder for him to grow the land by himself. In the data, 97.35% of the parcels are cultivated by their owner, which reinforces the idea that the production function is intensive in labor and requires a lot of “know-how”. In any case, due to the scarcity of water, the value of a plot of land is much lower than the value of the water rights needed to irrigate it properly, so even if the farmers are willing to use the land as collateral it will not cover 100% of the purchase.

As I showed in Section 2, this debt contract will create inefficiencies in production, due to the risk that the farmer is bearing, even if the farmer is risk-neutral. Hence, contractual/commitment problems can delay or make impossible an institutional transition. In such situation, the “only” way to achieve full efficiency is to “give” the water rights to the farmers (“give” the firm to the agent).<sup>10</sup>

Not surprisingly, this was the proposition of the government in 1931 when the new Dam was build (see 1). The government made an offer of 4.2 million *pesetas*. After the purchase, the government will allocate water rights to the farmers in proportion to their land, for free, and the water will be tied to the land.

<sup>10</sup>This is exactly the same policy followed after the American civil war. The one-mule-and-40-acres policy established explicitly that the former slave owners should “give” one mule and 40 acres of land to their freed slaves, not that they should “sell” a mule and 40 acres for the slaves. Of course the latter policy would have been meaningless.

Hence, the commitment problem would be solved and the more efficient institution will be adopted. The Waterlords took the offer very seriously. They printed a small book with the details of the offer and the opinion of the president and other members as well and some of the conclusions during previous meetings, before the voting in the general assembly. The opinion of the water owners was divided in three groups. The group of small owners (1 or 2 shares) were in favor of the sell, at any price. Since all of them were farmers with a small amount of water shares they will benefit greatly from the change. Not only they will receive money from their shares, but they will also be awarded more water rights than they have before. The group of middle owners (3 or 4 shares) were also in favor, they will received the same amount of water rights that they have now, but they would be paid for the water they own. The group of big owners (5 or more shares) were in favor of the offer only if the price offered was sufficiently high and the payment was made in cash. The offer of 4.2 was a “fair” price according to most of the big owners, the offer was accepted as adequate by the Waterlords. However, the sale was not finished because the Waterlords wanted the payment to be in cash, but the government (the new established 2<sup>nd</sup> Republic of Spain) could not afford to make the payment in cash. The government was unable to make a credible promise of future payment. The concerns of the Waterlords were justified since in 1936 a civil war erupted. The civil war ended with the defeat of the supporters of the Republic and the establishment of a 40-year long dictatorship. Have the Waterlords accepted the offer from the government, they will have not been repaid.

This was quite an unfortunate course of events. Before 1895, when a new book of “Ordenanzas” (civil law) was approved and printed, the system established a democratic (rather than corporatist) voting rule: one man one vote, regardless of the number of shares each member owns. After 1895, the rule established that a man with 1-4 shares will have 1 vote, a man with 5-8 shares will have 2 votes and so on. Had the old “Ordenanzas” been in place in 1931 the outcome might have been different.

During the 1950s and 1960s the foreign policy of the government begin to change. Borders were open and trade contracts were made with EU and US. This situation produced an unprecedented boost in the Spanish economy. This boost was specially important for the farmers in southeastern Spain because they take advantage of it and exports of fruit and dry fruit<sup>11</sup> grow exponentially. For the first time in their history, the farmers of Mula could produce enough output to create a surplus that can be storage. Improvements in the financial sector and a state policy concern with increasing local savings and provide easy access to credit for small business created the perfect environment for savings. By 1966 the savings accumulated by the farmers in Mula were enough to provide the local financial institutions and the Waterlords with a credible promise of future payments. After several centuries of history the auction mechanism came to an end.

## 4.1 Environment

In this area, the exploitation of the farm is made at the individual or family level (more than 90% of the parcels are smaller than 1ha). None of the exploitation are big farms (all owners have less than 5ha). The first explanation that comes to mind is that the technology/environment here makes the moral hazard problem so important that a bigger exploitation scale would not be profitable, even though it would alleviate the problems derive with the water scarcity. The same argument appears in Hoffman (1996).

### 4.1.1 Geography and weather

The coastal strip of southeast Spain is the most arid region of all continental Europe due to the “Foehn Effect”<sup>12</sup>. It is located right to the west of the mountain chain Prebaetic System, which includes the

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<sup>11</sup>See Critz, Olmstead and Rhode (1999).

<sup>12</sup>A Foehn wind is a type of dry down-slope wind which occurs in the lee downwind side of a mountain range. It is a rain shadow wind which results from the subsequent adiabatic warming of air which has dropped most of its moisture on

Mulhacen (the second highest mountain in Europe). The annual rainfall is less than 300 mm. The rainfall frequency distributions is skewed. The majority of years are dryer than the yearly average. The summer are dry with a secondary winter minimum appearing; Autumn is the only relatively wet season. However, in rainy days, in 70% of the cases, less than 1 mm falls and in 90%, less than 10 mm. The number of torrential rain days is not very high but when they occur, they can reach high intensity (for examples, 681 mm of water fell in Mula on one day, 10th October 1943, while the yearly average is 320 mm). Insolation is very high, more than 3000 hours of solar exposure per year, the highest figure in Europe. Arid conditions are found in relation to the marginal situation of southeast Spain to the circulating air movements found in the occidental Mediterranean area and to the Atlantic-origin storms.

#### 4.1.2 History and Origins

After the fall of the Caliphate of Cordoba in 1031, the Kingdom of Murcia passed under the successive rules of the powers seated variously at Almería, Toledo and Seville. In 1172 it was taken by the Almohades, and from 1223 to 1243 it briefly served as the capital of an independent kingdom.

The Castilians, with forces led by King Alfonso X, took the city at the end of this period of autonomy, whereupon large numbers of immigrants from north northern Spain resettled the town. As with much of the Spanish Reconquest, these Christian populations were brought to the area with the goal of establishing a Christian base here, one that would be loyal to the Crown of Castile and whose culture would supplant that of the subjugated Moorish peoples. In 1296, control over Murcia and the surrounding region was transferred to the Kingdom of Aragon and, in 1304, was finally incorporated into Castile under the Treaty of Torrellas.

Every king since Alfonso X has respected the customs that farmers have in Murcia and in every town of the region. He also gave them the right to self-govern as “farmers communities”. It is worth noticing that the ruler opinion, for this particular situation, was that it is better to let the people make their own economic decisions and charge a (somewhat) low distorting tax, rather than appropriate the rights of exploitation and create a monopoly.

After the capital city (Murcia) surrendered to the Christians there were still three fortress in the kingdom to be considered: Mula, Lorca and Cartagena. The leaders of these cities claimed rebellion and did not accept the terms of surrender agreed in the capital. Soon the Christian army was at the gates of Mula (the closest city to Murcia among the three) and the place was taken by force. After this victory the remaining cities of Lorca and Cartagena surrendered without resistance. This event had as a consequence stronger reprisals were taken against the (mostly Muslims) citizens of Mula, which increased the local demand for new Christians colons. The Muslims were then exiled to the adjacent village of La Puebla. Hence, the new Christian settlers in Mula had to start *tabula rasa* and made new institutional arrangements.

The need for more Christians, induced families from other parts of the peninsula, mainly from the kingdoms of Castile and Aragon to migrate to Mula. The *Concejo* (city council) would give every family a piece of land (*parcela*) and a quota on the water of the river (*tanda*). After some years due to war, illness and other reasons, some of the *parcelas* were abandoned. The *Concejo* claimed property rights over those lands and the water associated with them. The drought increased the demand for irrigation. The demand for land does not vary with rainfall. Since this was still a land-surplus economy, a drought would create a great demand for water but not for land (since population was already below-average).

In other circumstances, the solution would be to increase the time given in the *tandas*. However, Mula was a frontier-city between a Christian kingdom and a Muslim kingdom. Although the general

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windward slopes see orographic lift . As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes.

Table 1: Spain’s Political History

- 14<sup>th</sup> century until 1492: Crown of Castille
- 1492 century until 1701: Habsburg Monarchy
- 1701 until 1808: Bourbon Monarchy
- 1808-1813: Napoleonic war
- 1813-1867: Bourbon Monarchy
- 1868-69: Revolution
- 1870-1873: Savoy Monarchy
- 1873-1874: 1<sup>st</sup> Republic
- 1874-1923: Bourbon Restoration
- 1923-1930: Primo de Rivera’s Dictatorship
- 1931-1936: 2<sup>th</sup> Republic
- 1936-1939: Civil war
- 1939-1975: Franco’s Dictatorship
- 1978-... : Democracy

situation was of relatively peace, the documents from this age (centuries 13<sup>th</sup> to 15<sup>th</sup>) indicate repeated small skirmishes between frontier militias and raids intended to capture slaves or to steal cattle. All of this meant that the city hall was always in need of money. The solution adopted was to “sell” the water and earn some cash.<sup>13</sup> After a while, and responding to the demand of the farmers, the *Concejo* permitted the separation of ownership of water and land and eliminated the ban imposed on water rights’s trading. There is not a exact date for this process for the city of Mula, although this probably happened during the middle third of the 13<sup>th</sup> century, since the first document that talk explicitly about auctions dates from this time.

After that, the Waterlords (Waterlords) were clearly different persons than the land-owners (farmers). A well functioning cartel was established. The Waterlords themselves began to run the auctions. In the 19<sup>th</sup> century this cartel was made formal and legal and received the name “*Heredamiento de Aguas*”. The land-owners were small proprietors with family-size *parcelas* who created their own association, “*Sindicato de Regantes*”. The aim of this association was, for one side, to regulate themselves and settle disputes that arose between neighbors. Also, this association was created to keep balance the power in the market for water. Since the Waterlords were organized in a cartel, the market for water would, in practice, look as a monopoly. With the creation of the “*Sindicato de Regantes*” the market looked more like a two-sided bargaining problem. However, due to the need for water and the large number of farmers, the market ended up looking more like a monopoly with certain, implicit or explicit, restrictions.

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<sup>13</sup>In economic terms, the trade-off between cash today and cash in the future (or consumption vs. investment) faced by the citizens of Mula was biased toward more cash today. In this situation, the best response is not the same as in times of peace, i.e. in times of peace we will expect greater investment/savings than in times of war. Hence, the original institutions in every town will be different, since it will be the best response to a different environment.



### 4.1.3 The production system

I refer here to the traditional production system, present in the southeast of Spain from 13<sup>th</sup> century until the last third of the 20<sup>th</sup> century. As reported by Anderson and Maass (1978), in each of the two systems for allocating the water (*quotas* and *auctions*), the production structure is based on small (family-size) units. Since the land is owned individually but the water irrigation system (the river, the dam and the channels) have to be managed jointly, these farmers had to create an institution to manager the common resource.

However, in neighboring areas the structure is radically different. Powerful landowners hire seasonal workers to work in large estates and pay them wages just above their survival needs. These large estates are used to grow cereals and are not irrigated. The production function is different: scale effects are important (hence the big estates), the crop is homogeneous (cereals) and, thus, there is no need for specific human capital investment or proper incentives for effort: quantity is easy to verify and contract, quality not so much. The argument for the optimality of the contract on land is consistent with Hoffman (1996).

The goods produced in the *huertas* are also different than in the large estates. *Huertas* produce mainly vegetables and fruits. They were also the main producers of white mulberry leaves during the silk boom in the 19<sup>th</sup> (and 16<sup>th</sup>) century as well as saffron and other high quality products. However, large estates produce mostly grain and fodder. Olives and grapes (wine) are produced in both systems, with different qualities, due to their (chemical) complementarities for the soil.

The first thing to remark is that *huertas* produce goods that are heterogeneous in quality, while large estates produce homogeneous goods that bring low profit per acre. The former products (citrus, peaches, etc) are very sensitive to weather conditions and require constant and close attention. Also, products cultivated in *huertas* required a high level of specific human capital. Things like pruning, fertilizing, selective harvesting (and seeding) or animal caring require a level of specific human capital higher than average. This accumulation of human capital will take several years and is transmitted mainly from father to son. However, things like reaping are easily learned and poorly paid.

All the attributes mentioned in the previous paragraphs are determined by technological constraints. What about the economic structure? Goods that are heterogeneous in quality, for which production a high level of specific human capital is needed and which are subject to shocks and specific needs only observed by the farmer, have a severe moral-hazard problem in a principal-agent setting. Monitoring cost are prohibitively high. Critz, Olmstead and Rhode (1999) showed that “whereas wheat required about 9 man-hours of labor per acre in 1939, lemons required 286”. The optimal mechanism in this environment will be to “sell” the firm to the agent. Garrido (2011a) and Garrido and Calatayud (2011) show that this is indeed the case in eastern Spain. They also show that all the contracts in this type of environment require that the farmer owns the land or that the farmer has a long-term contract with the Landowner with compensation for all the improvements, which is roughly equivalent to the farmer owning the land.

In a static environment, the wage-worker will not pay much attention in taking care of the crop. He will have incentives to report bad weather and will not work as much as needed in some circumstances. All those problems could be solved by some incentives mechanisms, such as a piece wage instead of an hourly wage, adjusting the payment to some quality measure if needed. However, any of those mechanisms is unlikely to solve the problem of investment in specific human capital or the selective harvesting (and seeding) issue. Moreover, any other specific investments will only be carried out if the farmer can get all the surplus produced by the investment, such as experimenting with new crops/methods or irrigating at night.

#### 4.1.4 Market and Non-Market Institutions

In this sub-section, I will describe two different institutions/mechanisms used in South-Eastern Spain to allocate water from the river, among farmers. Each of them is used in several cities of South-Eastern Spain.

**Tandas (Quotas)** This institution is the one that contemporaries considered the fairest. Every *tanda* will last three weeks. Water ownership is tied to land ownership. Every plot of land has assigned some amount of time of irrigation during each *tanda*. The amount of time allocated to every farmer depends on the plots he owns. The time allocated is roughly proportional to the area of the plot. However, plots with better quality receive more irrigation time (they also contribute a greater share to the cost of the channel maintenance). Parcels placed in elevated lands also get some more irrigation time, because they will receive less water when irrigating during the same time, due to the differences in the pressure of the water flow.

This system has the advantage that every farmer gets some “fair” amount of water once in a while, so it is especially desirable during a drought. Another important feature is that because of the *insurance* property of this institution, farmers have security enough to carry out risky investment... like trees. A tree will take several years to be fully productive, but it can die if it does not get enough water in a given year. Vegetables grow faster, and need no waiting time. Other crops like corn last three months to grow and be harvested, while the farmer will incur no losses (besides the seeds) in case of a drought. Hence, a farmer with a secure supply of water is more likely to plant trees, and get a higher expected profit from them.

However, without such security, a farmer may not make the investment. I will argue that a market system, like auctions, might not achieve social optimum because of this. Credit constrained farmers will not be able to pay (in cash) for the water they need in case of drought. Imperfect financial institutions will make such investment non-viable.

**Subastas (Auctions)** Technically, the units sold in the auction refer to the right to use the water flowing through the river at a specific date and time. The property rights of water and land are independent: some people are the Waterlords (that is, they own the right to use the water flowing through the channel) and some people are the land-owners. The Waterlords form a (legal) cartel. They will meet once a week and decide how many units of water are going to be sold.

In Mula, water property rights were well established and were divided into 832 shares. The functioning of the cartel was very similar to a modern corporation: votes were proportional to shares and these shares were marketable.

## 4.2 Liquidity shocks

“[The auction] system is, in my opinion, highly unmoral and shameful for the [owners]: they seem here as a miser that keep the water stagnant to sell it part by part, during the critic moments when the crops are at risk, speculating in some sense over the public calamity, and over the desperate and distressing position of the farmer, willing to make the highest sacrifices in such times in order to get a drop of water”

Juan Subercase, Director of the Engineering School at Lorca, late XIXth century, cited by Muñoz, J. (2001).

The findings of Garrido (2011a) and (2011b) and especially those about the paradox of Maas and Anderson (1973) data are also consistent with the existence of liquidity shocks. In 1964 the crop which provided

the highest “full production net return/ha” in Alicante was the tomato, which allowed farmers to obtain 60,000 pesetas per year per hectare. So why were tomatoes only planted on 4.5 per cent of the *huerta*? (Maass and Anderson 1978, 144-145). If wheat and almonds only yielded 15,000 and 28,800 pesetas per hectare, respectively, why did they take up 20.5 and 24.6 per cent of the irrigated area? In eastern Spain as a whole, the crop with the highest net return was the orange (80,000 pesetas per hectare, p. 99), which was the monoculture of most of the huertas without a water market (Garrido 2011b).

### 4.3 Transition

In 1966, the auction mechanism ended. The farmers’ association (*Sindicato de Regantes*) reached an agreement with the cartel (*Heredamiento de Aguas*) and the auction was substituted by a bargaining process. They agreed on a fix price for all the water flowing through the river. The price will be revised every six months. The *Sindicato the Regantes* allocated then the water among the farmers using *Tandas* (quotas). Moreover, from 1966 the farmers’ association starts buying each of the shares from the original owners. By 1981 the association owned all the shares and formally changed the legal status of the water. Since then, the water of the Mula river is also tied to the land, in the same way as it is in other towns in Murcia.

This fact, and other anecdotal evidence show that the cartel, although a private (and arguably profit-maximizing) firm, usually took into consideration the effects that its actions may have on the farmers. In the late 17<sup>th</sup> century, and right after a plague, the Dam of Mula was broken due to a big flood. Most of the members of the cartel were dead or bankrupt. The citizens of Mula agreed that the Town Hall should paid for the Dam to be re-built, with tax collected money. They understand that, even though it was a private endeavor, it was essential for the survival of the city. In any case, the Town Hall reserved the right to use 5% of the water for public usage.

In 1868, Spain suffered one of the most severe droughts of modern history. The Waterlords in Lorca, after listening to the complaints of the farmers, decided to sell any amount of water demanded by farmers, at the minimum price paid in the last auction. After two days they had to stop this direct sale, since the dam was virtually empty. However, this shows that (myopic/static) non-profit-maximizing actions intended to help the farmers are not so uncommon. These actions could just be the responses to a concern that farmers will lose their crops and their trees (even their lives), and this will in turn reduce future demand for water. One could argue that this is a desperate measure when facing the threat of a (violent) revolution. In any case, this flexibility is, in my opinion, one of the keys to the success and survival of the system.

These examples of non-profit-maximizing actions together with the evidence found in Espin-Sanchez (2012) suggest that even if the market mechanism is inefficient due the existence of liquidity shocks, in the real world, both the farmers and the Waterlords took action to alleviate these effects, specially during severe droughts or floods. Even if the cartel was a private enterprise whose aim was to maximize profit, its survival depended on its role of insurance of last resort.

## 5 Data

The data in this paper comes from all water-auctions in Mula from March 1803 through August 1966, when the last auction was run.<sup>14</sup> Figure # shows the oldest sheet in our sample. On August 1st, 1966 the allocation system was modified from being an auction allocation system to quota system in which each farmer will get a fix proportion of the water available in the dam every year.

<sup>14</sup>The archive data might be partially incomplete from 1803 until 1850s.

Although the process of allocating water in Murcia has varied slightly over the years, its basic structure has remained, essentially, unchanged since the 13<sup>th</sup> century. Land in Murcia is divided into *regadio* (irrigated land) and *secano* (dry land). Irrigation is only permitted in the former. A channel system allows water from the river to reach all *regadio* lands.<sup>15</sup> The fundamental reason for this division is that *regadio* 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 the farmers that own a piece of *regadio* land in Murcia are allowed to buy water.

## 5.1 Agricultural Census and Economic data

I use data from different sources for the analysis.<sup>16</sup> Most of the economic data comes from INE (*Instituto Nacional de Estadística*). The data includes prices of agricultural products. Production and area cultivated of each product at a national and at regional level. I also collect financial data about deposits in public savings banks (*Cajas de Ahorros*) and rural loans provided by the government.

I use the price index computed by Ballesteros and Rehox (1993) because it covers the whole period considered here (1803-1991). It follows closely the Sarda (1998) for the 19<sup>th</sup> century, but the former is more volatile.

I augment the data with individual characteristics of the farmers' land, which I obtain from the 1954/55 agricultural census.<sup>17</sup> This census was conducted by the Spanish government to enumerate all cultivating soil, producing crops and agricultural assets available in the country. Individual characteristics for the farmers' land (potential bidders which are matched with the names in the auctions data) include the type of land and location, area, number of trees, production and the price at which this production was sold in the census year. Figure 2 shows a sample card for one farmer from the census data.<sup>18</sup> It can be seen in Table 2, that *Land Extension*, *Number of Trees* and *Kg sold* vary considerably across farmers. For the period 1954-1966, each farmer wins on average 22 units per year (an average of 792 thousand liters per year). This is consistent with the census data collected, where mean land extension is 5.5 ha. with an average of 33 trees per ha.<sup>19</sup>

## 5.2 Auction Data

Auction data, the primary source of data for this study, is obtained from the historical archive of Mula.<sup>20</sup> Based on bidding behavior and water availability, auction data can be divided into three categories: (i) Regular periods, where for each transaction the name of the winner, price paid, date and time of the irrigation for each auction is registered, (ii) No-supply periods, where due to water shortage in the river

<sup>15</sup>The channel system was expanded from the 13<sup>th</sup> to 15<sup>th</sup> century, as a response to the greater demand for land due to the increase in population. The *regadio* land's structure has not virtually change since the 16<sup>th</sup> century.

<sup>16</sup>These descriptive statistics are obtained from *Population and Agricultural Census* from the *National Statistics Institute* of Spain (INE) (available online at <http://www.ine.es/inebaseweb/treeNavigation.do?tn=201299&tns=199923#199923>).

<sup>17</sup>Detailed census data is also obtained from the section *Heredamiento de Aguas* in the historical archive of Mula, box No. 1,210.

<sup>18</sup>One nice feature of this data is that every individual record (card) contains information on any plot owned by the farmer, both in the *huertas* and in other places. Information on whether a farmer owns another plot of land not allowed for irrigation is important as it is the farmer's outside option (for other sources of income) in case he does not buy water at a given auction during a specific period.

<sup>19</sup>Average annual rainfall during the period is 320 mm. Recent irrigation studies on young citrus plantings have shown a water use of 2-5 megalitres per hectare annually. Water savings are possible if the irrigation can be allocated to similar units of production such as young trees or reworked sections of a property. In arid regions like Murcia water requirements could be around 20% less and, naturally, they are lower for grown up trees. Note that, as mentioned above, some farmers that are part of water-owner holding use their own water instead of selling it through auctions. Although water stress during droughts affects considerably the quality of production, trees would hardly die as a result. During a normal year without droughts trees could survive the whole year from rainfall. Finally, note that although the average number of trees per farmer is 161 (see Table 2), the average number of trees per hectare in our sample is 33 (this number is relatively lower than the conventional spacing for citrus trees of 100 trees per hectare).

<sup>20</sup>From the section *Heredamiento de Aguas*, boxes No.: HA 167, HA 168, HA 169 and HA 170.

Figure 2: Sample of individual data obtained from the Agricultural Census

DECLARACION NUM. 123

## DIPUTACION PROVINCIAL DE MURCIA

### ARBITRIO SOBRE RIQUEZA PROVINCIAL

Declaración que presenta D. Hernando Cristóbal Espeta Sánchez como propietario (1), con domicilio en Mula,  
C/ta Ortega y Rubio, de los productos sujetos al Arbitrio, obtenidos durante el 1º, 2º y 3º trimestre  
del año actual, en la finca denominada del término municipal de Mula.

Esp. (2)	Pago o paraje	Extensión	Núm. de árboles	Clase del fruto	Kilogramos obtenidos	Nombre del comprador	Precio de venta por sitio	Ingreso en pesetas	Impuestos		Observaciones	
									Pagos	Dia		
S.	Cogitan	100F.	800	Almendre	4.125	Hecaras	2'50	12.150				
P.	Palma	7 T	200	Naranja		Mauroano Gallego Lopez	2'00	7.000				
P.	Tysecastillo	8 T	240	id		id id id	3'0	10.000				
P.	Carrasquilla	2 T	75	Mandarina		Juan Gonzalez Fernandez	1'0	4.000				
P.	Alboaleja	10 T		Uva Negra	10.000	José Yelo Martínez	2'70	27.000				
P.	Carrasquilla	2T	40	Melocoton	400	Constantino Herrera	4'00	1.600				
P.	id	3 T	80	Naranja	8.000	Fernando	2'00	16.000				
S.	Cogitan y Rincón	300F		Trigo	13.272	Servicio Nacional	3'92	52.026				
Total												
10% amortización empréstitos												0'25
Timbre móvil												
Suma												

Mula, 5 de Noviembre de 1954  
P.O. *[Firma]*

(1) Táchese el que no sea.  
(2) P=Perilla; M=Motor; S=Secano.

Table 2: Summary Statistics of Selected Variables

Variable	Mean	SD	Min	Max	Obs
Rain	8.53	46.33	.00	980.00	3,834
Price	271.61	374	.05	4,830	13,872
Land Extension	5.54	32.24	.25	900	819
Selling Price	15.07	222.52	.02	5,700	964
Kg sold	5,569.70	10,003.76	0	110,000	1,000
Number of Trees	161.49	493.45	1	12,300	946

Source: Own elaboration from the data from the Municipal Archive in Mula, "Hereditario de Aguas".

or dam/channels damages (usually because of intense rain), no auction is carried out, and finally (iii) No-demand periods refer to auctions where no one bids and the registration auction sheet is blank. As we mentioned above, the sample for this study includes more than 150 years of auction data spanning from 1803 until 1966. Every week, 40 units (corresponding to 40 *cuartas*) are sold, with the exception being when no auction is run (no-supply) or no bids are observed (no-demand).<sup>21</sup>

### 5.3 Water Ownership data

I collected from the historical archive of Mula a series of ownership books for the years that were available. Each book contains the name of each owner and the amount of shares (*cuartas*) she owns. The total amount of shares is 832. This information is useful because I can use these names to match the names that appear in the auction data and see which of the buyers is also an owner (and whether is a big owner or a small one). I can also use this match to see how many of the owners never buy water in the auction. These owners might have not buy water because they could irrigate their land with the water they own or because they have no land and, thus, are no farmer but investors that collect the money from the auction. Since we have the census for 1954/55 I can use this third data base to match again the names and (for 1954/55) see which of the owners that never buy water are also landless.

### 5.4 Rainfall data

The auctions data is complemented with daily rainfall data for Mula from the *Agencia Estatal de Meteorología*, AEMET (Spanish National Meteorological Agency).<sup>22</sup> Mediterranean climate rainfall occurs mainly in spring and autumn. Peak water requirements for the products cultivated in the region are reached in spring and summer, between April and August. During this period more frequent irrigation is advisable because it is in this period where citrus trees are more sensitive (in terms of quality of production) to water deficits. The coastal strip of southeast Spain is the most arid region of all continental Europe due to the *Foehn Effect*<sup>23</sup> and because of its location: right to the west of the mountain chain *Sistema Penibético*, which includes the *Mulhacén* (the second highest mountain in Europe). Although annual average rainfall is 320 mm., rainfall frequency distribution is skewed, making the majority of years dryer than this yearly average. Aridity during the summer is especially acute. Autumn is the only relatively humid season. The number of days when torrential rain occurs is not particularly high, but when such rain occurs it is substantial.<sup>24</sup> Potential evaporation is four or five times higher than rainfall and the number of arid months vary from 7 to 11 in our sample. These arid conditions found in southeast Spain are related to the circular air movement in the occidental Mediterranean area and to the Atlantic-origin storms.

## 6 Empirical Study

In this section I address each of the empirical predictions made by the model. I will show that:

- The institutional change cannot be attributed to changes in technology or payoffs. I will do so by looking at the data from the auction as well as other micro indicators as the distribution of water ownership, price of the water, prices of the output and (aggregate) GDP. I will show that with the

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<sup>21</sup>For more details about the auction see Donna and Espin-Sanchez (2011).

<sup>22</sup>We thanks the AEMET for support for this project.

<sup>23</sup>A *Foehn* wind is “a type of dry down-slope wind that occurs in the lee (downwind side) of a mountain range. It is a rain shadow wind that results from the subsequent adiabatic warming of air that has dropped most of its moisture on windward slopes. As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes” (obtained from: [http://en.wikipedia.org/wiki/Foehn\\_wind](http://en.wikipedia.org/wiki/Foehn_wind)).

<sup>24</sup>As an example, on October 10th 1943, 681 mm. of rain water were measured in Mula, more than twice the yearly average for our sample.

Figure 3: Sample of Auction Sheet

D. Diego Melgarejo Leonés,  
 Melgarejo, Leonés

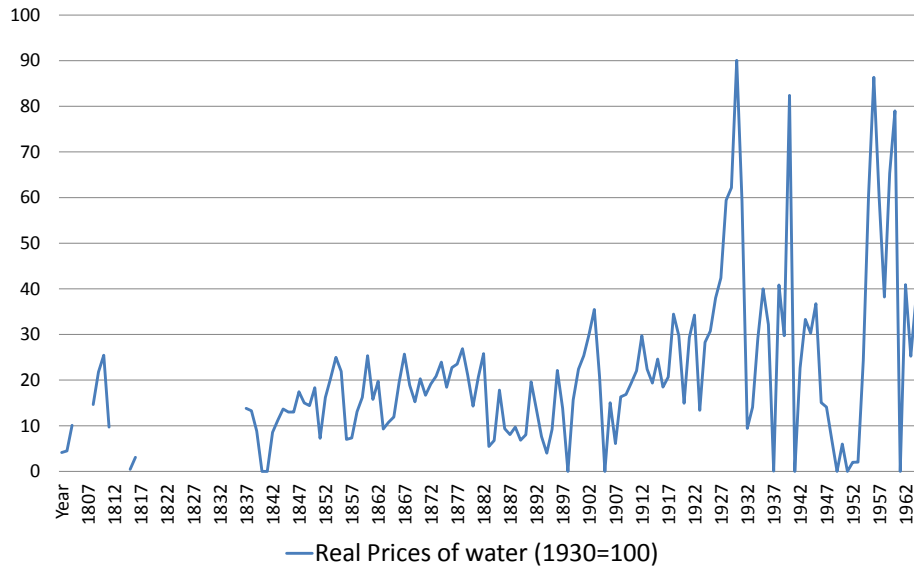
Diligencia de venta de un día y noche de agua en la Villa de Mula en ocho días del mes de Mayo mil ochocientos tres al Sr. D. Pedro Martín Fernández Alcalde Ordinario de ella por su cargo en su Estado, D. Diego María de Blaya Comisario del Excmo. Sr. de aguas con asistencia de D. Diego Melgarejo Leonés su Tesorero de procedo de la venta de un día y noche de agua en la forma siguiente:

Salvador Perez un quarto de agua en veinte y dos rs	8022.
D. Luis Perez otro en veinte y dos rs	8022.
Fran.º Lopez otro en veinte	8020.
Diego Voluda otro en Idem	8020.
El Dho otro en veinte y dos rs	8022.
Luis del Fero otro en veinte y dos rs	8024.
El Dho otro en Idem	8024.
Mattholome Lopez otro en Idem	8024.
Leonardo Fernandez otro en Idem	8024.
Pedro Ruiz otro en Idem	8022.
Martin Perez otro en veinte y dos	8022.
Damian Mañer otro en Idem	8022.
D. Luis Perez otro en Idem	8023.
Christobal de Moya otro en veinte y tres rs	8023.
El Dho otro en Idem	8022.
Martin Perez otro en veinte y dos rs	8020.
Pascual Perez otro en veinte rs	8020.
El Dho otro Idem	8022.
Mannel el Page otro en veinte y dos	8022.
Simón Ruiz otro en Idem	8020.
Juan Matias un quarto en diez y seis rs	8022.

Noche

“In the city of Mula the 8th of May of 1803, Mr. Pedro Martinez Fernandez, Mayor of the city, [...], Mr. Diego Maria de Blaya, Commissioner of the *Heredamiento de Aguas*, Mr. Diego Melgarejo Leonés, Treasurer, the sale of one day and one night of water began, with the following result:”

Figure 4: Real Prices of water (1803-1966), Pesetas (1930=100)



*Source:* Own elaboration from the data from the Municipal Archive in Mula, “Heredamiento de Aguas”. Some years are missing.

data we can not predict a structural change in 1966 and that most of the improvements in production happened one or several decades before.

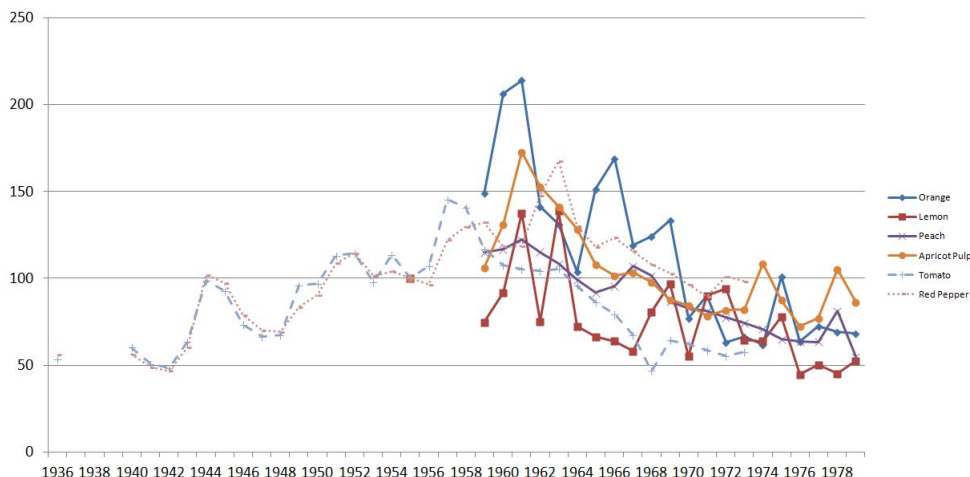
- The structure of power or ownership within the organization shows no particular trend during the years preceding the change. If what produced the change was a increase in the inefficiency gap we would observe a decrease in the concentration of water ownership.
- The financial revolution occur in Spain in the late 1950s and the early 1960s. The Bank of Spain was nationalized in 1962 unlike the Bank of England (1946) or the Bank of France (1945). An efficient financial market is not a necessary condition for an institutional change but it expands the set of parameters under which the change can occur.
- The increase in savings during the previous decade (specially since 1957) has no precedent in the history of Spain. A sufficiently high amount of savings to use as collateral is a necessary condition for a change in institution to occur.

## 6.1 Changes in Technology or Payoffs

NIE would predict that a new institution, with more precise definition of property rights, will emerge when the inefficiency gap grows big enough. The inefficiency gap is the difference in total surplus under the new (more efficient) institution minus the total surplus under the old (less efficient) institution. As I have argued above, in this case the transition goes from an institution with better defined property rights (auction) to an institution with more diffuse property rights (quota). The quota institution implies a reduction in property rights in at least two dimensions. Trading water rights are forbidden, hence ownership is not transferable. Selling the water is also forbidden, hence usage of water is restricted.



Figure 5: Real Prices of Agricultural Products (1955=100)



*Source:* Own elaboration with data from INE (Fondo documental del Instituto Nacional de Estadística). Price Index for a the most common agricultural products harvested in Mula (Base 1955).

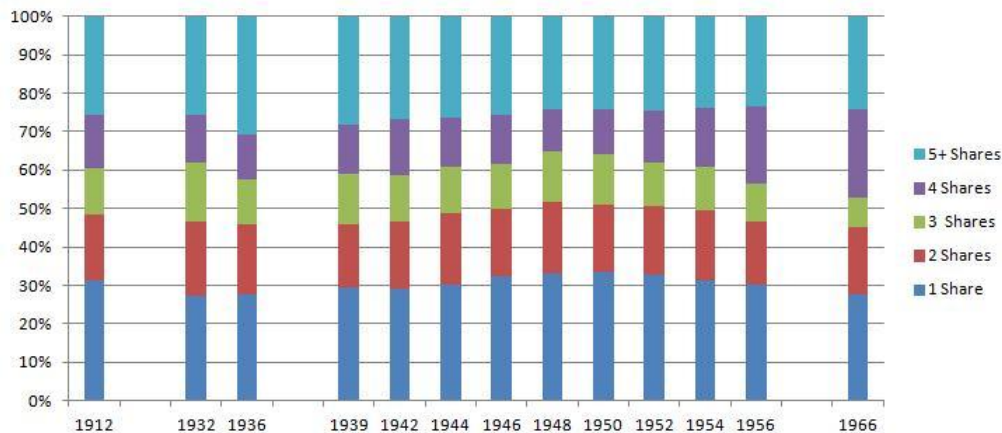
NIE makes no prediction about a case in which the new institution implies a reduction in the precision of the definition of property rights, because it implicitly assumes that more precise property rights unambiguously increase efficiency. Once we agree that, as the model suggests, an institution with restricted property rights (quota) can be more efficient than an institution with more precise property rights (auction) we can also compute the inefficiency gap. Then, the inefficiency gap is the difference in total surplus under the quota mechanism minus the total surplus under the auction mechanism.

If the parameters of the model change in such a way that the inefficiency gap increases, then the model predicts that the new institution (quota) is more likely to emerge. However, it is not clear how to measure the inefficiency gap. If the technology improves or the demand for the output increases, the total surplus will increase under both institutions. That is the value of the water for the farmers, under the quota, and the value of the water for the Waterlords, under the auction. Hence, the sign of the change of the inefficiency gap after an increase in the demand of the output is ambiguous. The sign of the change of the inefficiency gap will depend on the shape of the production function. If the production function is just “scaled up”, that is preserving its shape, the inefficiency gap will remain unchanged. This will be the case, for example, after an increase in output prices.

Thus, according to NIE, a change in output prices will have no effect on the emergence of the new institution. However, 1 predicts that a change is more likely to happen when the output prices decline. The value of the collateral (cash) is not affected by a change in output prices, but all the other terms are. A decline in output prices is equivalent to an increase in the collateral because all that matter is the relative size of the collateral with respect to the other terms. As we can see in Figure 5, there was a decline in real output prices starting in 1961. Prices grew in the early 1950s, peaked in 1961 and have been declining since. The pattern observed is that prices first increase, due to the increase in international demand, and then decrease as more firms are entering the market and increasing output. Hence, the shock in demand is transitory, not permanent. This implies that in the long run the value of the water does not change, but the profits that the farmers made in the short run are enough to provide the collateral needed to change the institution.

Figure 4 also shows that the real prices of water, that is the marginal productivity of water did not change much during the period considered here. It did not change at all during the 19<sup>th</sup> century, maybe with the exception of the 1898 crisis. There might be a slow upward trend at the beginning of the 20<sup>th</sup>

Figure 6: Composition of Water Ownership during the 20<sup>th</sup> century.



*Source:* Own elaboration from the data from the Municipal Archive in Mula, “Heredamiento de Aguas”. Some years are missing.

century. In 1923 there was announce the construction of the new dam. The dam was finished by 1930. This explains the high peak of the prices in 1930 and the drop in 1931. The farmers, anticipating the increase in supply, increased their demand for water since 1923 to grow more trees and increase their production capacity. The sooner the increase in supply (1930) the greater the incentives to increase the capacity, thus the peak. When the dam is opened in 1931 the supply increases and, hence, the price plummeted. The volatility during the 1930s and 1940s is due to the Spanish civil war (1936-1939) and WWII and their post-war period together with the autarky of the dictatorship (1939-1950s). Starting in 1952 with the new foreign policy of openness and boost of exports the prices rise dramatically. However, what happens with output prices is also true with the input prices: this rise is temporary, until the supply increase to adapt to the new (international) demand. By 1962 the price is already similar to historical standards and will be falling during the 1960s and 1970s. Although temporary, the farmers in Mula take advantage of this demand shock and use it to accumulate savings and capital (water ownership being the most remarkable) for the first time in History.

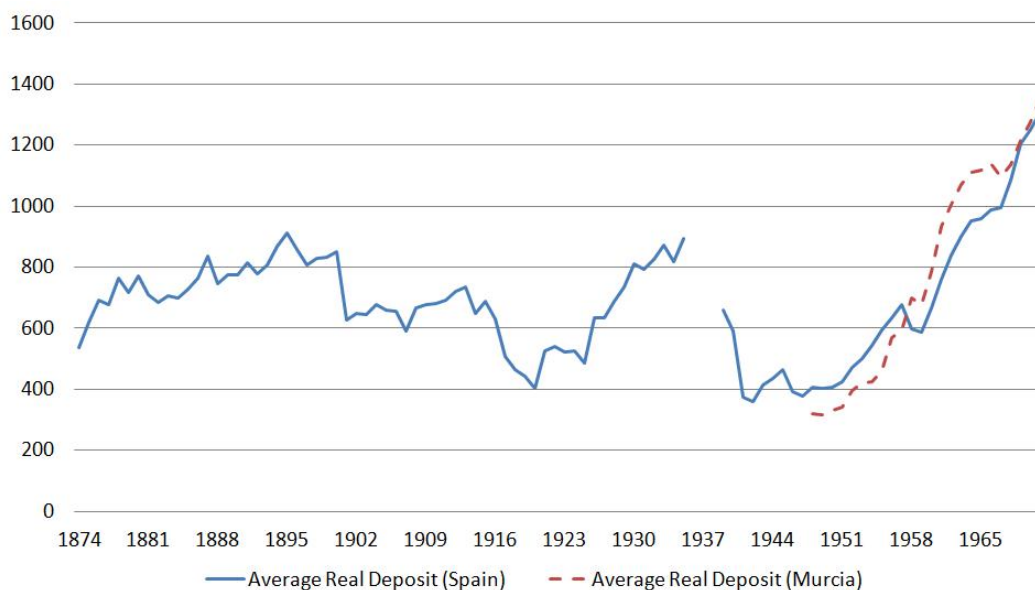
## 6.2 Ownership Distribution $G(\theta)$

One puzzling issue arises here. Why did each farmer not just buy water rights and solve his own problem? According to the intuition and the model buyers should have not wait until everyone have enough collateral. Richer farmers could afford to buy some water rights earlier than poorer farmers. Hence, the transition should have been gradual and not sudden. However, as Figure 6 shows that this is not what happened. The proportion of owners with just one share of the water, which is not sufficient to irrigate an average plot (there are 832 shares and about 500 farmers), is constant across time at about 30%. Of course, there are also some farmers that owned no water at all that are not in this sample. The other categories also remained unchanged over time. Several facts could help explain this puzzle.

First, the richer farmers might as well keep some cash and eliminate their liquidity issues without having to buy water rights. Moreover, as Theorem # shows, the more severe is the liquidity problem among farmers the cheaper will be the equilibrium price. Since farmers are competing for water with each other in the auction, farmers with deep pocket need not buy water rights to have security: they already have.

Second, some of the gains with the quotas system actually come from internalizing externalities. Since the farmers and the water owners are now the same people conflicts about improving channels and rules

Figure 7: Average Real Deposits in Murcia and Spain



*Source:* Own elaboration with data from INE (Fondo documental del Instituto Nacional de Estadística). Average value of deposits in pesetas (Base 1930).

of rationing during extreme drought will be easier to solve. Moreover, and related to the third point, a transition is easier to occur when it is sudden because the lender (whether it is a Waterlord or a financial institution) can use the law of large numbers and eliminate the idiosyncratic risk associated with each farmer. By pooling all the claims into a single claim the lender still have to bear the aggregate risk, but not the idiosyncratic risk. This means that the risk premium that the lender is asking will be lower.

Third, and more important, since the farmers are asking collectively for the loan through the “Sindicato de Regantes”, this organization has better monitoring technology than a single Waterlord or a financial institution. The farmers are member of this organization and are jointly responsible for the loan. With better monitoring technology it can encourage each farmer to pay their share but also to prevent some farmers from “cheating”.

### 6.3 Savings and Living Conditions

In Figure 7 we can see that the evolution of real deposits follow an erratic path during the 19<sup>th</sup> century. Slowly growing until it peaks during the crisis of 1898 and then declining until the inter-wars period. During Primo de Rivera’s dictatorship (1927-1930) they seem to recover until the civil war (1936-1939). The deposits did not grow during the post-war and autarky period and it is not until the 1950s that we see the deposits growing again, this time more sharply and steadily.

The graph makes clear that, however erratic and dependent of the macro-environment were the deposits, the tendency that begin in the fifties of uniform grows is something without precedent. Living conditions and the savings of the lower and middle class (the target audience of the public savings banks) increase during the 1950s and by 1960 they were greater that they have ever been. This tendency is specially important in Murcia, which began at a lower level than the average, but by 1957 is already ahead and continue this way.

This tendency, and the fact that real deposits in 1966 were higher than they have ever been is consistent with the model. In order to solve the commitment problems the farmers had to be able to put a collateral sufficiently big as to show a credible commitment to pay back.

In 1931, when the new Dam was completed, the government made an offer to the Waterlords. The government would buy all the shares of the water, hence becoming the sole owner, for a price of 4.2 Million of pesetas. The goal of the government was to give the water for free to the owner of the land and let them establish a system of quotas, the same that they did in 1966. The offer was discussed among the owners and, according to the report they gave and the records of the general meetings, the opinion of owners were divided in three groups. The first group, made of small owners (1 or 2 shares each), mostly farmers, were in favor of accepting the offer. Not surprisingly, since they were mostly farmers they were actually gaining more water than they have after the re-distribution promised by the government. The second group, made of middle-size owners (4 to 8 shares each) were in favor of the offer, if the quantity offered was big enough. A third group, made of the big owners, were in favor of the offer, only if the payment was made in cash. The owners get together in the general meetings and decided that 4.2M was a good offer, if paid in cash. They were worried that once they give away the ownership of the water the government will not be willing or able to pay the promised amount. The government in question was the 2<sup>nd</sup> Republic in Spain, established just 6 months away and very unstable. So unstable that a few years later a civil war ended with a long-live dictatorship.

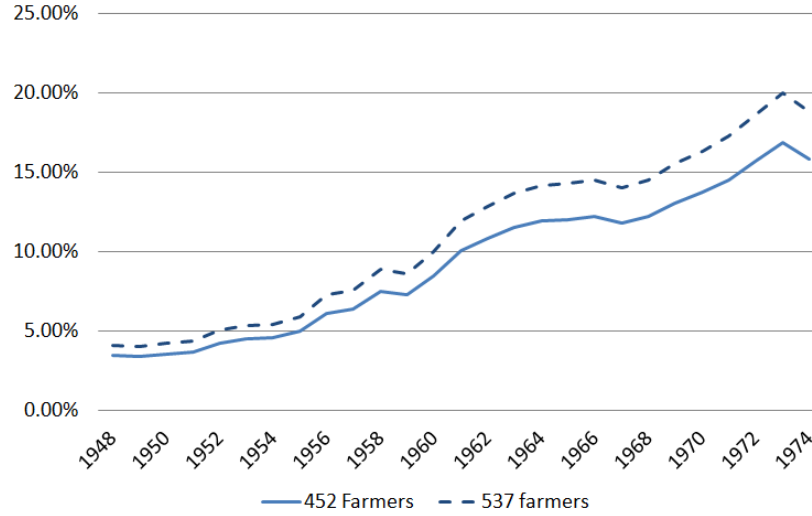
What this story tells us is that the Waterlords were economic agents, and willing to sell their water rights for the good price. Hence, they were not so much concerned with power and controlling the peasants as with making profit out of their property. They were also aware that a promise payment is different than a bird-in-the-hand, and they will only sell if they have confidence on being paid at the end. This is precisely what happened in 1966: the farmers have enough collateral as to convince the Waterlords that they will be eventually paid.

In 1, we can see that the water has different valuation depending on the season and that the total amount offered was 4.2 Million pesetas in 1931. If we knew how many farmers were there to divide the water we could know how much each farmer had to pay. If we look at the census data we see that there were 452 cultivating in 1954. This is a lower bound because there might be small farmers that did not appear in the census. If we look at the auction data we see that between 1954 and 1966 there were 537 farmers buying water in the auction. This is an upper bound because in 12 years some farmer could have sold his plot to another farmer or to his own son, hence we will be observing two different names/farmers that are using the same plot. In Figure 8 we can see what percentage of the water could have the farmer afford each year. The percentage goes from less than 5% to about 15% in 1966 and more beyond. Although 15% seems a small amount it is much greater than 3-4%. Also, the deposit is a lower bound measure for the collateral. Surely the farmers wanting to buy the water had been saving at a greater-than-average rate. Hence, their deposits would had been greater than the average deposit. Also they could have ask for money to their relatives and friends. Asking money to their relatives is something that was not likely before the increase in living conditions that began in the 1950s, so it was not an option before.

## 6.4 The Financial Revolution 1957-1962

The last empirical prediction of the static model is that more efficient financial markets will help to solve the commitment problem that the Waterlords and the farmers are facing. The work by Francisco Comin (Comin (2005) and (2007)) shows the role that the government and government agencies played in the 1950s and 1960s to promote economic development. The goals of the government were to increase the industrial sector, to modernize the agriculture and to provide cheap credit to small businesses and households. The main instrument used were the “*Cajas de Ahorros*” (Public Savings Banks). “[...] things begin to change for [the Savings Banks] in 1957 when they exchanged the oversight of the Ministry of Labor for that of the Ministry of Finance. Thereafter, they were treated more as financial institutions than as charitable

Figure 8: Percentage of the value of water that could be cover with collateral.



organizations”.<sup>25</sup>

The economic growth that followed the openness of Spain to international trade, specially in western Europe and the US, together with the ease access to credit and an efficient financial sector reinforced each other in a virtue circle. Economic growth in the 1960 enabled Savings Banks to expand their operations thanks to growing deposits, and to diversify them through the new regulations established in the “Development Plans” set in motion starting in 1964.

The role of the Savings Banks in fostering economic growth was specially important among the middle and lower classes. “Indeed, the savings banks carried out an essential function in fostering and attracting savings, in a specialized manner, among the middle and lower classes by means of strategies normally associated with what came to be known as ‘retail banking’”.<sup>26</sup>

During the Franco’s dictatorship (1939-1975) Saving Banks were forced by law to invest most of their resources in public debt issues and bonds of private companies selected by the National Institute of Industry (INI). Before 1951 the amount required by law was 30% of their resources. In 1951 the requirement changed to 60% and then to 80% in 1964.

In 1962 the Bank of Spain was nationalized and new legislation concerning banking regulation was passed in Spain. The new legislation changed dramatically the banking system. It changed the role that the Savings Banks were to play in the financial sector and increase the importance of the ICCA, a national agency whose main role was to coordinate the macro-decisions of the local Saving Banks. The new law also fostered banking specialization and long and medium term stability.

Figure 9 shows how both the number and the total amount of rural loans began to increase in 1951 at an exponential rate. However, the change in the institution did not occur in 1951, nor during the 1960s. In Figure 10 we can see that the average real value of the loans did not change much during this period.

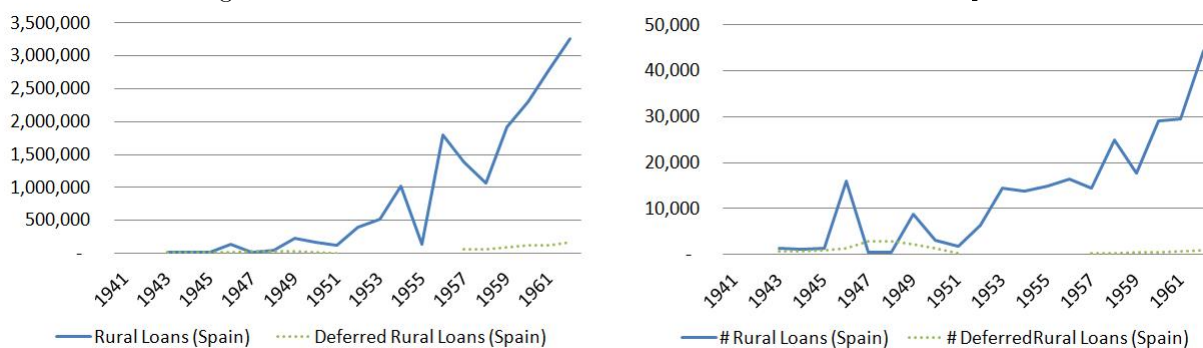
## 7 Conclusions

In this paper, I have shown the problems that arise when the farmer (the owner of the effort) and the Waterlord (the owner of the water) are not the same person. I have also shown that, in the environment assumed here, full efficiency can only be achieve if the farmer is the owner of all three inputs: land,

<sup>25</sup>Comin (2007), page 6.

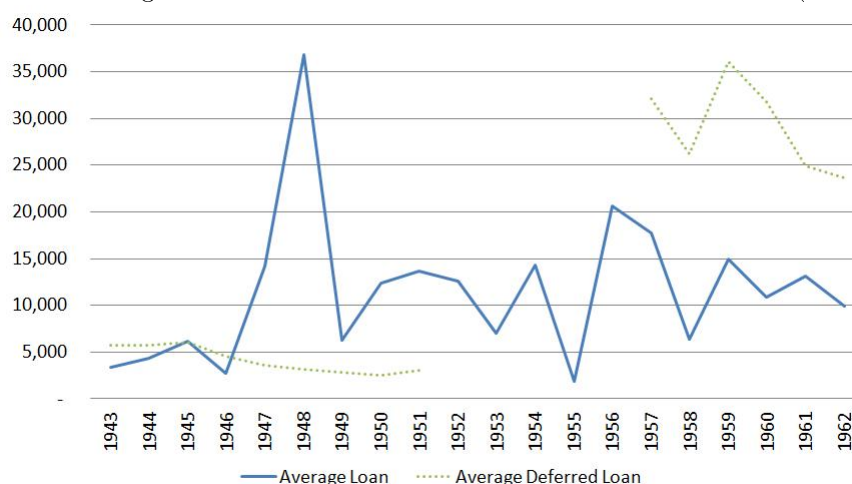
<sup>26</sup>Comin (2007), page 10.

Figure 9: Evolution of Rural Loans and Deferred Rural Loans in Spain



*Source:* Own elaboration with data from INE (Fondo documental del Instituto Nacional de Estadística). Data for Deferred Rural Loans for the years 1952-1956 is missing. The left graph shows the nominal volume of loans in 1,000 pesetas for Spain.

Figure 10: Average Rural Loans and Deferred Rural Loans in real terms (Base 1930)



*Source:* Own elaboration with data from INE (Fondo documental del Instituto Nacional de Estadística). Data for Deferred Rural Loans for the years 1952-1956 is missing. Average value of loans in 1,000 pesetas (Base 1930) for Spain.

water and effort. I have also shown that some common classes of contracts to alleviate this problem, sharecropping and debt, are not sufficient to solve the problem. Moreover, it can be shown, that the debt contract achieve the highest level of efficiency in this environment.

Summarizing, since the production function is very labor intensive, the maximum level of output could only be achieved when the farmer owns the water. However, under the auction mechanism the farmer does not owns the water. The Waterlord is willing to sell the water rights to the farmer for its market price, but the farmer has not enough money to pay in cash. The Waterlord will give the water rights to the farmer in exchange for the promise of a future payment. This contract will mitigate the problem but will create incentives if the farmer does not work hard and default in the loan. This problem can only be solved if the agent has enough cash to use as collateral or upfront payment for the loan.

There are other factors that will increase or decrease the probability of transition to the new institution. In particular, the new institution increases equality for the society and reduce the risk that farmers bear. Hence, in a democratic society or in the (very likely) situation in which farmers are risk-averse, the transition will happen sooner.

There are also other factors that push in the other directions. The ownership of water will increase

the local power of the Waterlords. Hence, their utility might be convex and not linear in the amount of rights they own. In this case, we will expect to see a few big Waterlords, that are reluctant to change the system and are not willing to sell their rights at market prices. Moreover, in a non-democratic regime, these Waterlords will have more political power and will make the transition less likely.

I have shown that an old institution may persist even though it is both less efficient and less egalitarian than a new institution. This situation can be sustained indefinitely regardless of the efficiency gap if there are severe commitment problems. This is a new way of looking at institutions, and institutional persistence, and the way of reasoning here can be applied to other fields such as Corporate Governance, Political Economy and Law and Economics.

As it turns out, what triggered the change was not that they had something to gain, but that they had something to lose.

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## A Mathematical Appendix

**Proposition 4.** *The equilibrium in this case is fully characterized by  $\tilde{\theta}(\pi) = G^{-1}\left(\frac{1}{2-\pi}\right)$ .*

*Proof:*

Given the conditions for an equilibrium in this case, we have a mass of farmers that do not trade of  $\pi G(\tilde{\theta})$  and a mass of trading farmers of  $[1 - \pi G(\tilde{\theta})]$ . Among the traders we have a mass of  $(1 - \pi)G(\tilde{\theta})$  of buyers and a mass of  $[1 - G(\tilde{\theta})]$  of sellers. Hence,  $\tilde{\theta}$  is the unique value that solves:

$$(1 - \pi)G(\tilde{\theta}) = [1 - G(\tilde{\theta})]$$

after some algebra and provided that  $G(\cdot)$  is invertible we get:  $\tilde{\theta}(\pi) = G^{-1}\left(\frac{1}{2-\pi}\right)$ . QED

We have two types of inefficiencies here. On one hand, there is mass of farmers  $\left(\frac{\pi}{2-\pi}\right)$  that cannot buy water but would be willing to buy water at the current price. On the other hand, we have a mass of farmers  $\left(\frac{2-2\pi}{2-\pi}\right)$  that are using "too much" water. This "too much" refers to a situation in which markets are efficient ( $\pi = 0$ ). The inefficiency will then be the difference in output when  $\pi = 0$  and when  $\pi > 0$ :

$$\int_0^1 f(r_t + \tilde{\theta}(0)) di - \left[ \int_0^{\tilde{\theta}(\pi)} f(r_t + \theta_i) di + [1 - \pi G(\tilde{\theta}(\pi))] f(r_t + \tilde{\theta}(\pi)) \right]$$

This inefficiency can also be decomposed in:

$$\int_0^{\tilde{\theta}(\pi)} [f(r_t + \tilde{\theta}(0)) - f(r_t + \theta_i)] di + [1 - \pi G(\tilde{\theta}(\pi))] [f(r_t + \tilde{\theta}(0)) - f(r_t + \tilde{\theta}(\pi))]$$

The sign of the first term is ambiguous. Since  $\tilde{\theta}(\pi) > \tilde{\theta}(0)$ , the second term is negative. We know that this amount is positive, because the liquidity constraints introduce inefficiencies, thus the first term must be positive. The second term being negative is a consequence that the farmers with a greater endowment are producing using an inefficiently high amount of water. Even though the production is inefficient, their production is greater than it would be with the (smaller) efficient amount of water. The first term is positive and big (at least bigger than the second term in absolute value) and it accounts for the lack of production suffered by the low-endowed farmers that cannot "afford" to pay for the water.

**Lemma 5.** *When  $\pi > 0$ , reducing inequality (reducing  $\sigma_\theta^2$ ) will increase efficiency.*

*Proof:*

Lets take the definition of efficiency above.

**Lemma 6.** *When the allocation of water rights is no egalitarian, i.e.  $\theta_i \neq \theta$  for some  $i$ , there are idiosyncratic shocks to farmers, i.e.  $\sigma^2 \neq 0$  and farmers face financial constraints, i.e.  $\pi > 0$ , allowing for water markets will increase efficiency.*

*Proof:*

The proof is simple.

## B Discussion

### B.1 Market for water and Market for water rights

It is interesting to look at the relation between the market for water and the market for water rights. As we have seen before, if the allocation is egalitarian and there are no idiosyncratic shocks, there will be no role for a market for water. If trading of water rights is forbidden, thus, there will never be a role for market for water. This implies that a ban in the market for water rights will also prevent the emergence of a market for water: no heterogeneity among farmers means no benefit from trade, thus, no incentives to trade.

If the allocation of water rights is not egalitarian, and there is a ban in trading water rights, efficiency will increase if we allow for trading water, even if there are not idiosyncratic shocks. This is because farmers with greater-than-average water rights have a lower marginal value for water than farmers with lower-than-average water rights. In this case, trading (of water) is efficient and will not create any long-run inefficiencies.

This is not, however, the whole story. If markets for water exist, due to some small differences on the initial allocation of water rights, this will create incentives for farmers to accumulate water rights (speculation). In other words, if trading of water is forbidden, the incentives of farmers to speculate are smaller than if there is a market for water. If there is a market for water, and  $\pi = 0$ , the owner of (excess) water rights can always get the market price for the water rights she owns. If there is no market for water, the owner of (excess) water rights will get her own marginal utility of water, which is decreasing in  $\theta_i$ . When  $\pi > 0$ , this is still the case, but the difference between the two scenarios (market vs. no-market) will be smaller. When  $\pi = 1$ , all farmers have liquidity shocks and there is no trading, hence both scenarios will give the same revenue to the speculator.

With a ban on trading of water farmers with greater-than-average rights have incentives to sell their rights (their marginal valuation is lower than  $p_t = f'(r + \theta)$ ) and farmers with lower-than-average rights have incentives to buy (their marginal valuation is greater than  $p_t = f'(r + \theta)$ ). Finally, remember that when  $\pi = 0$  (and assuming that markets can be established costless) the optimal mechanism is to have market for water (for any small value of idiosyncratic shocks) and the restriction on water rights trading will have no impact in the equilibrium outcome.

### B.2 Liquidity shocks and Paternalistic Planner: Ban on trading.

In this section, I will show how a paternalistic planner or a planner interested in the long run sustainability of the system will impose a ban on the trading of water ownership. The situation is the same as the one we just discussed: there are important aggregate shocks but mild (or none) idiosyncratic shocks. The egalitarian allocation of property rights is efficient,  $\theta = \theta_i$ . Hence, the efficient mechanism involves no trading of water. But this does not imply anything about trading of water rights.

In the environment that we are using, allocation of water property rights plays no role. Regardless of the initial (at the beginning of period  $t$ ) allocation of property rights  $\{\theta_i\}_{i=0}^{i=1}$  the market will always clear and the marginal utility of water for all farmers will be the same. It is implicitly assumed that farmer can buy the water before production takes place and will pay for it after the harvest or that farmer has enough savings to pay the water before the harvest. In any case, the market is efficient and there are no issues about commitment or liquidity constraints.

At every period  $t$  a farmer is hit with a liquidity shock with probability  $\pi$ . If a farmer is hit with a liquidity shock, she can not buy any water during this period. She could still sell some water. That means that farmers that are constraint the amount of water they can use is also limited, i.e.  $w_{it} \leq r_{it} + \theta_i$ . If we are in a situation in which there are no idiosyncratic shocks and the allocation of property rights is egalitarian, this restriction is not important, since  $w_{it}^* = r_t + \theta = r_{it} + \theta_i$ . In other words, if there is no trading in equilibrium, a restriction on trading will not affect the equilibrium outcome. Moreover, and this is important, if there are idiosyncratic shocks or the initial allocation of property rights is not egalitarian, there will be inefficiencies associated with the liquidity shocks. Let now discuss the implications of this.

[...]

We have already discuss the importance that idiosyncratic shocks have in determining the optimal allocation mechanism. Here, the existence of liquidity shocks can be though as one of the “transaction costs” that makes the market mechanism not efficient, even when there are some (mild) idiosyncratic shocks. If idiosyncratic shocks are not important and  $\pi$  is high, the optimal mechanism will require  $\theta_i = \theta$  at all times. A high value of  $\pi$  will not imply that markets are not efficient, but rather that they are useless, since most people can not bid in the auction.

Egalitarian property rights has deeper implications. For any value of  $\pi > 0$  a non egalitarian distribution of property rights will create inefficiencies. Hence, a paternalistic planner will impose a ban on water rights trading. Notice that this ban is binding, in the sense that at some point of time  $t$  a farmer would like to sell some of his water rights (future water) in exchange for water (present water).<sup>27</sup>

Such an exchange will create inefficiencies (for the whole economy) in the future but is mutually beneficial for both farmers. The planner might be against this (mutually beneficial) exchange for several reasons:

- The planner might have a different discount rate than the seller. They both understand the trade-off between production today and production in the future, but they assigns different weights to each part.
- The planner also acts as an ultimate life insurer. In the case that a farmer have sold all her water rights, the farmer have to feed the farmer according to the law or to the custom of the place, hence the farmer has perverse incentives on selling the water today, and then take advantage of the insurance. A smaller discount factor will also exacerbate this effect.
- The planner is worry about a catastrophe: with some very small probability the community will enter into a war, or a drought, or famine, or ... In such extraordinary situation the probability of survival of the community depends on the total output it can produce. Hence, the egalitarian distribution must be enforce.
- Of course, any other reasons not concerning with efficiency will also make the planner reluctant to water rights trade.

There are many other reasons why the planner will like to act in such a conservative way. All of them will involve some sort of externalities that the trading of water rights is creating in the efficiency of the economy and, hence, the planner will put a different weight in the outcome than the farmers themselves.

### B.3 Dynamics

“Even if the Prince distribute the Land equally among all the Inhabitants it will ultimately be divided among a small number. One man will have several Children and cannot leave to

<sup>27</sup>More interestingly, if there are no idiosyncratic shocks, such a farmer will be a farmer with  $\theta_i < \theta$ , that means that a small difference in initial allocation of property rights will create increasing inequality over time.

each of them a portion of Land equal to his own; another will die without Children, and will leave his portion to some one who has Land already rather than to one who has none; a third will be lazy, prodigal, or sickly, and be obliged to sell his portion to another who is frugal and industrious, who will continually add to his Estate by new purchases and will employ upon it the Labour of those who having no Land of their own are compelled to offer him their Labour in order to live.”, Cantillon, *Essai sur la Nature du Commerce*, I.II.4.

It is also interesting to simulate what will happen in a world in which water and water rights are marketable and there is a small idiosyncratic shock. For simplicity let's think about the case with only two farmers, no aggregate shocks and the idiosyncratic shock is perfectly negatively correlated among the two farmers and will occur only once. The rain is then:

$$r_{i1} = -r_{-i1} = \begin{cases} \epsilon & \text{with prob. } \gamma \\ -\epsilon & \text{with prob. } 1 - \gamma \end{cases}$$

where  $\gamma \in [0, 1]$  and  $\frac{1}{2} > \epsilon > 0$ . For the remaining periods we have  $r_{it} = r_{-it} = 0$ .

At  $t = 1$ , the allocation of water rights is egalitarian:  $\theta_1 = \theta_2 = \frac{1}{2}$ . At  $t = 1$ , the rain will occur and one of the farmers will have excess water while the other farmer will be in need of water. Without loss assume that  $r_{11} = -r_{21} = \epsilon$ . The total amount of water is 1. If  $\pi = 0$ , efficiency dictates that  $w_1 = w_2 = \frac{1}{2}$  and the market will clear at  $p_1 = f'(\frac{1}{2})$ .

When  $\pi > 0$ , player two might be facing a liquidity constraint. In this case player 2 will have to give water rights in exchange for water. It is easy to see that in this case we might have not efficient allocation of water:  $w_1 \geq \frac{1}{2} \geq w_2$ .

Then, at  $t = 2$ , the initial allocation of water rights is not egalitarian:  $\theta_1 > \frac{1}{2} > \theta_2$ . There are no more shocks, hence, player 2 will have to buy water from player 1. Actually, player 2 will have to buy water from player 2 in all remaining periods and in some periods player 2 will have to pay back with water rights because she is suffering a liquidity shock.

When  $t \rightarrow \infty$ , we have  $\theta_1 \rightarrow 1$  and  $\theta_2 \rightarrow 0$ . Player 1 has become the Waterlord of the water and player 2 a simple farmer. Player 1 is enjoying so much her rent that he might decide to sell her land to another player (Player 3) and sell water to both players and enjoy the rents generated.

This analysis is a little tricky, it could be the case that after production occurs, player 2 would like to exchange some output for water rights. In this case, player 2 may buy back all water rights from player 1, depending on the sizes values of  $\epsilon$  and  $\pi$ . The greater  $\epsilon$ , the bigger the gap that player 2 has to close. The greater  $\pi$ , the more periods in which the gap will increase.

Without more restrictive assumptions on the bargaining process and the concept of equilibrium is hard to obtain more precise conclusions from this exercise. However, this is sufficient to show how the existence of liquidity shocks will create perverse effects in the market for water rights, even when all the exchanges are perfectly rational and mutually beneficial.

## B.4 The “Tree” Hypothesis

“There is tale of Cyrus, the most famous prince, I need not tell you, who ever wore a crown. [...] Not one man, it is said, deserted from Cyrus to the king, but from the king to Cyrus tens of thousands. [...] His friends not only fought their battles side by side with him while he lived, but when he died battling around his dead body. [...] But there is another tale of the same Cyrus:

-Lysander: ‘All this beauty is marvelous enough’.

-Cyrus: 'Know then, Lysander, it is I who measured and arranged it all. Some of the trees I planted with my own hands'. [...]

All this I relate to you (continued Socrates) to show you that quite high and mighty people find it hard to hold aloof from agriculture",

Xerophon, 431 BC-350? BC, *The Economist*.

The analysis will be a Diff in Diff in a ratio. The ratio is between the production of fruits (trees-related products) and the production of vegetables (non-trees related production). The first difference is the difference in Mula (or Lorca) before and after the institutional change, i.e. the difference of the ratio under auctions less the ratio under quotas. The second difference is between Mula (or Lorca) and some comparable town like Pliego (or Totana) or the average of the region.

In the trees production we include: Lemons, Oranges, Peaches and Apricots. In the non-trees production we include: tomatoes and onions. The variables used to compute the production are: Area cultivated, production and value (production X price). With some robustness checks:

- Include mandarin trees in the trees.
- Include vines and/or olives in the trees.
- Include potatoes and/or peppers in the non-trees.
- Use the "Ensenada" data as the first observation.
- Include all the area or only the regadio area (especially important for the data from 1974 onwards).
- Make the same comparison but instead of fruits vs vegetables, fruits vs cereals?

## B.5 Optimal Contracts and Sharecropping

A common way to provide incentives is to implement sharecropping. The farmer will receive a proportion  $\alpha$  of the output and the Waterlord will receive a proportion  $(1 - \alpha)$ . The problem for the farmer under sharecropping is then:

$$V(\alpha) \equiv \underset{e_i}{Max} \{ \alpha E_w [f(l, w, e_i)] - e_i \}$$

Here, the first order condition is:  $\frac{\delta E_w [f(l, w, e)]}{\delta e} \Big|_{e=e(\alpha)} = \frac{1}{\alpha}$ . In the example this is:  $q(lw_H e)^\lambda + (1 - q)(lw_L e)^\lambda = \frac{e}{\alpha \lambda}$ . Obviously  $e(\alpha) < e(1) = e^{FB}$  whenever  $\alpha < 1$  because the left hand side of the equation is decreasing in  $e$ . The problem of the Waterlord is now:

$$W \equiv \underset{\alpha}{Max} \{ (1 - \alpha) E_w [f(l, w, e(\alpha))] \}$$

s.t.  $\frac{\delta E_w [f(l, w, e)]}{\delta e} \Big|_{e=e(\alpha)} = \frac{1}{\alpha}$

It is obvious that the optimal  $\alpha^*$  from the Waterlord's point of view is smaller than 1. Hence, the effort will be inefficiently low and so will be the output. Notice that if the farmer is the owner of the land, then she will get 100% of the output, i.e.  $\alpha = 1$ . In this case we have  $e(1) = e^{FB}$ . Hence, the production is efficient.

In this situation the Waterlord will like to sell the land to the farmer. Since  $V(1) = E_w [f(l, w, e^{FB})] - e^{FB} > E_w [f(l, w, e(\alpha))] - e(\alpha) = V(\alpha^*) + W$ , by the definition of  $e^{FB}$ , There are gains from trading. The Waterlord will be willing to accept a price greater than  $W$  and the farmer will be willing to pay a price lower than  $V(1) - V(\alpha^*)$ . The difference between these quantities is precisely the efficiency loss:

$E_w [f(l, w, e^{FB})] - e^{FB} - E_w [f(l, w, e(\alpha))] - e(\alpha) > 0$ . The final price will depend on the bargaining process between the farmer and the Waterlord. It could be that there are many potential Waterlords willing to sell their land, which will drive the price  $I$  to the lower bound, i.e.  $I = W$ , and make the Waterlord indifferent between selling the land or not. On the other hand, a more reasonable way to think about this problem is to assume that there is only one Waterlord and many farmers willing to buy the land, pushing the price upwards to the upper bound,  $I = V(1) - V(\alpha^*)$ .<sup>28</sup> In general, if they do Nash bargaining the price will be  $I \in [W, V(1) - V(\alpha^*)]$ .

In Murcia, sharecropping is used for small plots and small water fountains, or when the owner of the land cannot work the land but does not want to sell it, for some non-economic reasons. In this case, the custom establishes three types of sharecropping:

- $1 - \alpha = \frac{1}{3}$ , for products homogeneous in quality (and low labor intensive) such as potatoes and corn.
- $1 - \alpha = \frac{1}{4}$ , for products heterogeneous in quality such as peppers, tomatoes, cucumber, etc.
- $1 - \alpha = \frac{1}{5}$ , for products heterogeneous in quality and high labor intensive such as saffron.<sup>29</sup>

If the conditions posted above do not hold in the real world, we might expect a different ownership structure. If the production function has some fix costs and it is linear in effort, for example harvesting cereal, then it might be optimal that the Waterlord owns all the land. He will be the only one paying the fix cost and will pay the workers linearly according to production. This could explain why we see both types of ownership structures in Murcia and why the products differ between them. We see huge states of cereals and smalls family-size plots with fruit trees. We only see small cereal plots as a complement or hedging (self-insurance) for families whose main activity is to grow vegetables and fruit trees. We never see huge states of fruit trees until the late XXth century after mechanization and other technological changes occur.

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<sup>28</sup>I am implicitly assuming that any farmer can reject the price and go and work for another Waterlord with the power incentives. Hence, the farmer outside option is  $V(\alpha^*)$ . Taking the outside option equal to zero will not change the results.

<sup>29</sup>Moreover, saffron was grew in small quantities by most of the farmers as a way to insure themselves against bad weather. Since it is very labor intensive, families could rely on get some money from it if the weather was bad, since they will have more free time to harvest saffron.