The Fruits of Revolution;

Property Rights, Litigation and French Agriculture 1700-1860

Thesis by

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Abstract

This research, unlike other studies, examines the French Revolution, not through a debate on its economic, social or political causes, but through its economic consequences. The research shows that the lack of investment in agriculture prior to the French Revolution was due to institutional constraints inherent to the Old Regime. Reforms, undertaken during the Revolution of 1789, were responsible for most of the nineteenth century successes.

The argument is carried out through an examination of the political economy of drainage and irrigation. Drainage and irrigation were two types of investment in agriculture that increased the productivity of land and extended the area under cultivation. Both were important means of achieving growth in agriculture. The research shows that transaction costs involved with such activities were very high during the Old Regime but were substantially reduced after 1789.

Chapter One introduces the issues and makes the necessary definition for the study. Chapter Two is an empirical study of drainage in Normandy from 1700 to 1860. The chapter shows that drainage would have been profitable in the absence of transaction costs during the period 1700-1789 yet no drainage occurred. The problems of transaction costs lay with endless litigation over property rights and the inability of property rights owners to write binding contracts. Resources were, thus, expended to redistribute property rights rather than to make improvements. The Revolutionary reforms removed all causes for litigation and gave the state the authority to enforce contracts between landowners. As a result of the reforms of the Revolution, most of the marshes in Normandy were drained from 1820 to 1850.

Chapter Three examines irrigation supply in Provence from 1700 to 1860. As in Chapter Two, quantitative evidence suggests that, in the absence of transaction costs, irrigation should have been very profitable in the eighteenth century when it was carried out only in a

very limited way. The market failure is ascribed to the Old-Regime division of authority over eminent domain and water rights as well as to the inability of developers to commit to announced prices for irrigation water. The extreme division of authority that prevailed before 1789 gave many individuals and groups the opportunity to hold irrigation projects up and claim part of the profits. The Revolutionary reforms centralized all authority over water rights and eminent domain in the hands of the national government. Furthermore, the state took on the task of enforcing announced prices for developers, thereby solving an important revenue problem. From 1820 to 1860 the irrigated area in Provence nearly doubled. The research on Provence, thus, also points to the dramatic consequences of the decline in transaction costs as a result of the Revolution's reforms.

Chapter Four is a theoretical analysis of litigation and settlement that bears directly on the questions raised in Chapter Two. The model features a developer who has rights to the property of the plaintiff. The object of the game is to set the level of compensation for the property. The plaintiff can either accept a settlement offer made by the developer, or sue. If the plaintiff sues, both parties may search for evidence. The court will make a decision based on the evidence that plaintiff and defendant bring to court. The chapter shows that a sequential equilibrium generically exists. Modeling expenditure decision endogenously allows an examination of the issues of burden of proof in litigation. It is shown that burden of proof has substantial impact on the probability of litigation and the magnitude of the settlement offer. The conclusions of the theoretical research suggest why drainage proposal were so frequently litigated in eighteenth century Normandy.

Chapter Five extends the results of Chapters Two and Three beyond the specific regions of Normandy and Provence. Moreover, the results of Chapter Four are applied to the history of peasant property in Britain and France. The chapter then offers a general conclusion.

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Chapter 1

Introduction

In the most influential book written on the French Revolution since World War II, the late Alfred Cobban reflected that:

> Whether...France was capitalist before the Revolution has been a subject of some debate. Jaures, Levasseur, Germain Martin, des Cilleuls, Picard, Ardachev, said it was; Kovalesky, Tarle, Petrov, Loutchitsky argued that France remained a "pays agricole." This is mainly a matter of terminology. The essential point is to decide if the revolution does in fact represent an important stage in the economic history of France.[1]

This study meets Alfred Cobban's challenge by examining the political economy of drainage and irrigation in France from 1700 to 1860.

The literature on the French Revolution has focused either on its causes or on its distributional consequences.[2] Some historians have been greatly concerned with questions such as the relative importance of social groups in achieving the overthrow of the monarchy in 1789, while others have made efforts to show that the Revolution was the result of the complete decay of Old-Regime society.[3] The issues of redistribution and social change, while significant, cannot allow us to answer Cobban's question, because redistribution and social change had a limited impact on the French economy. To be sure, the redistribution of Church wealth made some individuals better off, but mostly those Frenchmen who bought Church assets at three-fifths of the market value were already part of the local elites.[4] Furthermore, it is far from obvious what impact the land redistribution of the Revoution had on productivity,

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1) Alfred Cobban, *The Social Interpretation of the French Revolution*. Cambridge: Cambridge University Press, 1964, pp. 66-67.

2) William Doyle, *Origins of the French Revolution*. New York: Oxford University Press, 1980; Michel Vovelle, *La Chute de la Monarchie 1787-1792*. Paris: Editions du Seuil, 1972; Francois Furet and Denis Richet, *The French Revolution*, New York: The Macmillan Co., 1970, and D.M.G. Sutherland, *France 1789-1815, Revolution and Counterrevolution*. New York: Oxford University Press, 1986.

3) On the topic of social groups in the Revolution, see William Doyle, *Origins of the French Revolution*, pp. 116-138; on the decay hypothesis, D.M.G. Sutherland, *France 1789-1815, Revolution and Counterrevolution*, pp. 49-62.

4) Michel Vovele, *La Chute de la Monarchie 1787-1792*, p. 192.

unless we assume that the Church was a poor manager of its resources and there is no evidence to that effect.

Yet the true measure of the impact of the French Revolution lies beyond redistribution or causation. The Revolution was an important event because it dramatically altered the institutional costs associated with many economic activities. Settling the question of whether the Revolution occurred because of fiscal problems, or because of the need for deeper social and political change, is less important than understanding how much social, institutional change the Revolution achieved and the impact of that change on France. While the causes of the French Revolution may give us clues to the problems that needed to be addressed in 1789, they cannot measure the success of the Revolution at addressing those problems or its overall impact. In contrast, research on the institutional change brought about by the Revolution will answer Cobban's question. Although institutional reforms such as the end of feudal privileges had some redistributional consequences, these reforms also dramatically altered the returns to many forms of private investment.

This study shows how the private returns to investment in agricultural improvements changed as a consequence of the French Revolution. The argument is developed through an examination of investment in water control. Two types of water control are considered: drainage of marshy areas, which extended the cultivated acreage, and irrigation, which raised the productivity of areas already under the plow. Both were important means of achieving growth in agriculture. The bargaining costs involved with such activities were very high during the Old Regime but, I argue, were substantially reduced after 1789. This study focuses on drainage in Normandy and irrigation in Provence. In both cases the eighteenth-century institutional structure featured uncertain property rights, veto players and a rent-seeking judiciary. These aspects of the institutional structure significantly raised transaction costs and prevented a

Coasian resolution of externality problems.

The Revolution swept away most of the obstacles to investment in drainage and irrigation. Economic progress was a central issue during the Revolution, and in agriculture, at least, the policies of the revolutionary governments were not merely redistributive but increased economic efficiency as well. Curiously, the institutional changes brought about after 1789 realized rather than destroyed the goals of the Old-Regime bureaucracy. Indeed, in the face of high transaction costs in most sectors of the economy, the need for reform had been evident for a long time. In agriculture, in particular, French officials, in the latter part of the eighteenth century, were very concerned--but not very successful--with increasing output. I show that their failures were due to institutional constraints inherent to Old-Regime France. Reforms, which eliminated the ability of local groups to oppose projects and decreased the costs of bargaining and arbitration, were undertaken during Revolution. The Revolutionary reforms were responsible for most of the nineteenth century successes.

Institutions and Economic History

The subject I have taken up here has an importance that transcends French history for it makes explicit the link between institutional change and economic growth. All too often economic history, though acknowledging the importance of institutions, fails to make claims about institutions testable or ignores institutions in order to focus on technological change as the prime motor of economic growth. Douglas North and others have long argued that institutions--defined as humanly devised constraints on economic activity--play an important role in economic activity.[5] The very breadth of North's definition makes testing claims about institutions difficult, and we thus remain ignorant of the true contribution that institutional

5) Douglas North, *Structure and Change in Economic History*. New York: Norton, 1981, chapter 15.

change makes to sustained economic growth. Other economic historians, such as David Landes have focused on technological change.[6] For them economies grow at the rate at which they adopt new technologies, but their argument fails to account for the fact that many countries adopt new technologies slowly or not at all. Thus any comparative research on economic development must have an institutional component.

One such comparative question permeates the entire study: why did French agriculture lag so far behind that of England in the eighteenth and nineteenth centuries? Issues of technology and environment cannot alone carry the burden of explaning the lag of France because the same technologies were available at roughly the same time on both sides of the English Channel. In some regions, mostly in the north, a few French landowners adopted the same techniques that made England more productive.[7] In fact there would have been no need for France to seek technology abroad in the adoption of enclosure, consolidation, and drainage improvements, nor was mixed husbandry unknown in France. Yet the improvements associated with mixed husbandry were adopted only locally and by very few landowners. In many areas, however, the French environment should have made adopting the English innovations at least as profitable as in England. Indeed, many areas in eighteenth-century France suffered from a shortage of pasture as well as poor drainage. Hence if the innovations associated with the agricultural revolution were not adopted in France it may well be because of institutions. This investigation suggests that uncertain property rights and the extremely high cost of judicial and legal reform were an important factor in France's lag in agriculture.

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6) David Landes, *The Unbound Prometheus*. Cambridge: Cambridge University Press, 1969. Introduction. In later chapters Landes does hint that institutions may explain why France and Germany lagged behind Britain (see pp. 134-152).

7) See Jean Meuvret, *Le Probleme des Subsistences a l'Epoque Louis XIV*, part II, Paris: E.H.E.S.S., 1987, pp. 193-199; Michel Morineau, *Les Faux Semblants d'un Démarrage Economique. Agriculture et Démographie en France au XVIII^{eme} Siecle*. Cahier des Annales #30, Paris: Armand Colin 1970; and Philip Hoffman "Institutions and Agriculture in Old-Regime France", Caltech mimeo, March 1988, forthcoming, *Politics and Society*, 1988.

Irrigation and drainage are ideal activities for an investigation of institutional change, because institutions were very important in determining the costs and revenues accruing to developers in irrigation and drainage. Because both drainage and irrigation demand specific property rights and feature extensive externalities, institutions will dictate to what extent the entrepreneur's costs and revenues will approximate the social costs and revenues of his project. At best institutions will allow bargaining between owners of property rights at low cost and the level of drainage and irrigation will be efficient in a Coasian sense.[8] At worst transaction costs will be so high that no development will occur independent of the social value of irrigation and drainage.

Another important reason to investigate drainage and irrigation is the abundance of archival material. The state was always heavily involved with drainage and irrigation projects, during both the planning stages and the realization phase. Developers of drainage and irrigation always had to secure permits from the state, and the permit records contain detailed descriptions of the costs and the technology both for projects that failed and for those that succeeded. Furthermore, because eighteenth-century developers were often involved in litigation even before the project started, judicial archives contain abundant information on projects. Finally, in the late eighteenth century the state began to monitor the performance of drainage and irrigation projects by keeping a file for each project, whether it was carried out or not, in the records of the Roads and Bridges Administration. Thus drainage and irrigation are good activities to investigate if one wants to test hypotheses about institutional change.

Definitions

For any economic activity, three sets of parameters are important: the environment, the

8) Ronald Coase, "The Problem of Social Cost," *Journal of Law and Economics*. 3 (1960), pp. 1-44.

technology, and institutions. The environment is best defined as the physical state of the world. For this study, concerned as it is with agriculture, the most important parameters of the environment are geography and population. Obviously in a general equilibrium framework the prices of inputs and outputs, as well as the level of output--and perhaps even the size of the population--are determined by the physical environment, by the technology and by institutions. In this study, however, I only consider activities that were small relative to the total economy, and I thus assume that the institutional changes under consideration affected only drainage and irrigation. In other words, the effect of institutional change on prices should be negligible. For simplicity I will then take input and output prices as fixed and assume they are part of the environment.

A technology is the set of methods that can be used to produce a set of goods. A technology is therefore the knowledge necessary to gather all the inputs--including plant, equipment, capital, and labor at the appropriate skill levels--to produce a given set of outputs. Because a technology is a method for transforming a set of inputs into a set of outputs, technological change can take a number of forms. A different set of inputs can be used to produce the same output, or the same inputs can be used differently to produce the same output. In the case of irrigation and drainage, the empirical chapters will show that technology changed little between 1700 and 1850, and that fact makes the examination of institutional change easier.

Institutions can be defined as the rules governing economic activity and the means of enforcing them. Such a definition is broad, and here we shall restrict ourselves to legal institutions--in other words, to the law governing economic activity. Clearly there are other, non-legal, constraints on economic activity--informal rules are but one example--but testing their economic impact would be extraordinarily difficult. Limiting ourselves to legal institutions is, in any case, hardly restrictive. Indeed, since my concern is how legal and political

changes during the French Revolution affected property rights, legal institutions, which are far better documented than less formal institutions are the obvious candidates for investigation.

One final term used throughout the study demands definition: veto player. A veto player is an individual or a group of individuals who can either stop an activity altogether or raise its cost so high as to make it unprofitable regardless of its social value. Through strategic behavior a veto player can threaten all the surplus created by an activity, lay claim to a portion of it or even seize it entirely.

Tools and Methods

This study is distinguished not only by its novel focus on institutional change but by its use of game theory as a tool for historical investigation. Game theory has been somewhat ignored by economic historians.[9] Game theory, however, is fundamental to any investigation of institutional change by economic historians because it offers a set of hypotheses to guide their data gathering.

Game theory offers the means of modeling the impact of specific institutions on transaction costs and the responses of investors to changes in transaction costs. Institutions serve both economic and political goals, as a result they are often inefficient in terms of economic growth. The inefficiency of institutions gives individuals and groups incentives to avoid institutional constraints. Because of the incentives to shirk, enforcement is an important aspect of institutional constraints. Clearly, enforcement, institutional constraints and economic costs are interrelated. Game theory offers a method to analyze the relationship between institutional change and economic costs because it focuses explicitly on the incentives and decisions of individuals. For historians there exists, however, yet another problem: the game theoretic

9) See however, John Umbeck, *A Theory of Property Rights with Application to the California Gold Rush.* Ames: University of Iowa Press, 1981.

models must bear directly on the set of institutions that constrain the economic activities under consideration, otherwise the conclusions may be quite difficult to test or irrelevant.

Game theory is a natural tool to model the environment, technology, and institutions of drainage and irrigation, and to understand why development did not occur before the Revolution. Indeed, the study will show that drainage and irrigation could have been profitably carried out long before the French Revolution. Moreover, eighteenth-century commentators, public servants and developers all agreed that drainage and irrigation were socially profitable, and in the interest of landowners. The oft observed lack of investment in improvement leads to an apparent dilemma.[10] Either eighteenth-century sources were lying and drainage and irrigation were in fact unprofitable, or developers and landowners were behaving inoptimally and more development of drainage and irrigation should have occurred. In fact the study shows that neither of these propositions explains the lack of development of irrigation and drainage in the eighteenth century. To explain the failure of improvements, institutions must be modeled. Game theory allows us to do so and explicitly consider the impact of institutional change.

This study focuses directly on two regions in France, Provence in the southeast and Normandy in the northwest. I chose to focus on a selected set of regions because although the different regions of eighteenth-century France all recognized the same central authority, they each had a different institutional structure,[11] which led to different amounts of institutional change in the eighteenth century and different levels of development. For example, there existed two basic types of local institutional structures, the *pays d'états*, and the *pays*

10) See AN F^{10} 261, 314-324, 627, 628 and 6391 for drainage and H^1 1260, 1303, 1494-1499, 1512, for irrigation, also H^1 1487 for improvements in general. Throughout the study AN will stand for *Archives Nationales* the central archives of France while AD will stand for *Archives Departementales* or regional archives, and AC will stand for *Archives Communales* or municipal archives. AD and AC will always be followed by the origin of the archive, the *serie*, and the call number, e.g. AD Calvados, C 451 for the departmental archives of the Calvados, *serie* C, box 451.

11) Pierre Goubert, *L'Ancien Régime*, Paris: Armand Colin, 1973, Chapters 1 and 2.

d'élection. The *pays d'état* enjoyed considerably more independence in fiscal and economic issues, than the *pays d'élection*. Provence, a *pays d'état*, was far more autonomous than Normandy, which as a *pays d'élection* was directly under the rule of the French king. The autonomy of Provence was embodied in a set of mediating institutions that often opposed the king but also helped achieve some institutional change and some irrigation development before the Revolution. In the directly administered province of Normandy such change proved impossible because local custom ruled property rights, and in the absence of mediating insitutions, the costs of amending local custom proved enormous. Because of the great institutional diversity of France, only local studies would capture the details of the institutions that mattered in water control before 1789. Of course Revolutionary reforms removed most of the institutional regionalism, but to judge the impact of such a reform it is important to clearly understand the prior institutional structure.

Another set of issues made local studies unavoidable. France in the eighteenth century was not only an institutional quilt but also a collection of different markets and different agrarian economies. The most important difference can be distinguished between the North with its three field system and heavy plows, and the South, an area with few communal constraints on farming and with light plows. Investigating a large number of other regions would have demanded arduous archival research to gather the necessary information on the different institutional structures of eighteenth-century France and to7 collect the quantitative data necessary to test the hypothesis that improvements would have been profitable before the Revolution. The quantitative data alone would be difficult to gather. Consider price series: very few price series span 1700-1860 because most historians and economic historians have seen the French Revolution as such a dramatic break, and they have kept their studies focused on only one side of 1789. The gathering of such data is slow. For example, gathering enough data to

construct the wage and land price series for Provence for a total of only 128 data points required the better part of two months' archival research. Duplicating this procedure for a large number of areas in France would take a number of years. Yet this was not necessary to show the importance of institutional change during the French Revolution to investment in agriculture, which was the goal of this study. Moreover, the conclusion of this study will show it is possible to apply a number of the results of the local research to all of France.

An Outline

After the introduction, two case studies are presented, one covering drainage in Normandy (Chapter 2) and the other irrigation in Provence (Chapter 3). The fourth chapter is a theoretical investigation of property rights litigation under asymmetric information. It is followed by a general conclusion.

Chapter 2 investigates the political economy of marsh drainage in Normandy. After investigating issues of technology and relative prices I show that drainage of marshes was actually profitable in the eighteenth century--when no drainage occurred. I then investigate the institutional causes for such a market failure. By the eighteenth century most marshes were owned both by communities and by feudal lords, but the rules of marsh division between community and lord were based on uncertain property rights. The uncertain rights over marsh property led to a first round of litigation between community and lord. Then, because there existed no rule to divide the share of the community between villagers, this issue was also litigated. Finally I show that the institutional changes associated with the Revolution were responsible for the drainage that occurred between 1820 and 1848.

Chapter 3 analyzes the development of irrigation in southeastern France. As early as 1700, developers attempted to promote irrigation in Provence yet no development took place until after 1760. I first examine the questions of credit and technology to show that these

factors alone cannot explain the lack of irrigation before 1760. Then using data from canals built after 1760, I compute the hypothetical rates of return for canal projects. The rates of return lead to the conclusion that irrigation could have been profitably developed under the Old Regime in the absence of institutional obstacles. The obstacles lay with uncertain property rights. After these property rights were clarified and a number of veto players were eliminated, some development occurred. Eighteenth-century institutions also led to severe revenue shortfalls. Developers could not commit to announced prices for irrigation rights, and because irrigation rights are durable goods, developers competed against themselves over time. As a result, in the planning phase of the project, they could not sell contigent contracts for irrigation rights to secure credit. Similar problems occured after the project was built because of the very low marginal cost of irrigation. As a result many developers were faced with great losses. It was not until after the reforms of the French Revolution that the state was able to intervene to resolve revenue problems for irrigation canals. After 1815, the irrigation networks of Provence grew to the extent that all of the water available for irrigation was in use by 1860.

Chapter 4 analyzes a game theoretic model of property rights litigation. The analysis of litigation was motivated by the important role played by the judiciary in the resolution of conflicts over property rights. The judiciary was called upon to resolve conflicts over uncertain property rights to land and water, and rights of eminent domain. Institutions also gave many individuals and groups veto power over projects. Veto power was exercised through strategic behavior and took the form of a judicial appeal against the drainage or irrigation developer's permit. Therefore the impact of litigation on the cost of projects were modeled. Chapter 4 presents the results of the theoretical effort.

The theoretical research was also motivated by the prevalence of litigation in drainage projects in Normandy. Nor was the problem peculiar to Normandy, developers throughout

France complained that litigation costs were so high that they threatened the profitability of the project. Clearly out-of-court settlements would have been preferred by all parties. Curiously, they were rare in the eighteenth century. One explanation regarding this issue was offered by Lawrence Stone for England in the sixteenth century.

> Sixteenth century litigation combined the qualities of tedium, hardship, brutality and injustice that tested character and endurance, with the element of pure chance that appealed to the gambler, the fear of defeat and ruin, and the hope of victory and the humiliation of the enemy. It had everything that war can offer save the delight of shedding blood. It gave shape and purpose to many otherwise empty lives.
>
> Litigation, therefore, remained the most popular of indoor sports despite unanimous agreement upon the folly of such behavior and the rapacity of lawyers. No noblemen of the day was without a string of suits against tenants or rivals, mostly about property.[12]

One could easily replace sixteenth century with eighteenth century and noblemen with Frenchmen for a possible explanation of litigation in Old-Regime France.

Lawrence Stone's claim that litigation was nothing short of a sport suggests that litigation occurred under the Old Regime because people liked it. The essays that follow suggest otherwise. Litigation was prevalent in the eighteenth century because pervasive uncertainty in property rights made litigation attractive. Uncertain property rights allowed individuals to increase their wealth at the expense of others. Therefore owners of assets were also forced to defend them via litigation in the face of a giant prisoners' dilemma. Such litigation was naturally unproductive because the redistribution it induced did not necessarily transfer assets from the hands of poor managers into the hands of superior ones. Furthermore, all the resources consumed by litigation were wasted.

Uncertain property rights also led to a second type of litigation. As technology and

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12) Lawrence Stone, *The Crisis of the Aristocracy 1558-1641*. New York: Oxford, 1965, p. 242.

relative prices changed in the Old Regime it became profitable to reassign assets from old production schemes (marshes for example) to new ones (drained pasture). As long as the marsh remained undrained, property rights were irrelevant because access and use were clearly defined. To effect the transition from marsh to drained pasture required clarifying property rights because the costs and benefits had to be assigned to owners not users. Since drainage increased productivity, the clarification of property rights, in this case, was socially useful, it was also achieved through judicial procedures. If court costs were not too high to preclude the transition from marsh to pasture altogether, and litigation could clarify property rights, judicial procedure would achieve productive ends.

The empirical chapters show that the institutional costs induced by eighteenth century institutions blocked the development of drainage and irrigation. The study also shows that the reforms of the Revolutionary period were important to the supply of irrigation and drainage in the nineteenth century. The Revolution, in a few years, achieved far more in terms of institutional change than the Old Regime had been able to in a century. Simplification of property rights, judicial reform, and the increases in administrative authority all decreased the costs of promoting drainage and irrigation, and in the long run fostered growth.

Chapter 2

Drainage in the Pays d'Auge 1700-1848:

The Weight of Uncertain Property Rights

Set in a particular geographical area, this paper provides a striking example of the economic impact of institutions; it demonstrates how the institutions governing property rights affected the development of drainage in northern France. The paper begins with a description of the geographical area studied: the basin of the Dives, better known as the Pays d'Auge in the French Calvados, where drainage problems were severe. After describing drainage technology and proposing an operational definition of institutions, the paper analyzes the reasons for a market failure in the Dives area and provides data to show that, between 1715 and the French Revolution, the equilibrium level of drainage was not responsive to changes in demand. After the Revolution, however, institutions did succeed in providing drainage and, it is argued, a new regime in property rights, not a change in technology or demand, was responsible for this evolution.

Geography, Technology and Institutions

The Dives basin lies on the coast of the English Channel in Normandy, only a few miles east of Caen in the French *departement* of the Calvados (see map). It corresponds roughly to the present canton of Troarn and is a very flat plain with small hills. Hydrologically the basin of the Dives can be divided between the areas south of the town of Troarn and the areas north of it. North of the town, the river Dives runs in a flat basin where the surface of the plain is roughly at the level of the highest tides. The Dives has a difficult exit into the English Channel, and without human intervention it would periodically flood a large area north of Troarn. In addition, south of Troarn there are a number of marshes that also drain into the Dives.

All these areas would have witnessed some economic activity without any drainage. A significant portion of the land is composed of small hills, which did not require drainage. The wet marshes themselves were the locus of productive activities. Nonetheless, by the 1700s the

owners of marshes had become convinced that draining marshes would be a profitable operation.[13] They wanted to convert the marshes to year-round pasture, which they considered the most profitable way to exploit them. Year-round pasturing, though, required control of the entry and exit of water. During most of the year a farmer wanted to drain his pasture fields, but after mowing the pasture or in a particularly dry year he might want to flood it. Such water control required the construction of a set of levees and ditches.

In the nineteenth century the marshes in the Dives belonged either to the state or to local communities. Individual peasants simply did not own marshes and rarely owned any pasture. Before 1789, ownership was even more concentrated: although some marshes lay in the hands of the king, communities or various seigneurs, most of the marshes--and a considerable amount of pastures as well--were owned by the area's largest seigneurial landlord, the abbey of Troarn. Only near the sea, in the communities of Varaville and Cabourg, did the abbey fail to dominate the ownership of pastures and marshes.[14]

For the *conseil du Roi* (the king's council), a committee that adjudicated property rights and issued drainage permits, the marshes in the area seemed, at least at first glance, to be devoid of economic value.[15] The truth was in fact quite different. Seigneurial owners derived small seigneurial rents from their marshes and also sold fishing rights, which were often economically significant. Moreover, because marshes were the water reservoirs of local mills, the drainage of marsh could, by lowering the water level, have a significant impact on the productivity of a mill. Mills were the property of the seigneurial lord and a significant source of revenue.

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13) See AD Calvados, C 4240-55. Between 1700 and 1789, it was proposed to drain almost every marsh in the area.

14) Most pastures in the Dives area were marshes that had been drained in the Middle Ages. The provincial adminstration used ownership rolls to tax landowners for upkeep costs. See AD Calvados, C 4073-4078.

15) See AN H^1 1495 for the opinions of staffers at the king's council and of the provincial administration.

Marshes were also of economic value to peasant communities because they provided mediocre but cheap pastures. The pasture they furnished was mediocre because of the lack of drainage, but it was cheap since the rent that the communities paid the seigneurial lords for the pasture rights had been frozen since the Middle Ages. In some cases the right to pasture had become customary, and the communities paid the seigneur nothing for their use. Even such free pasture, though, did not mean that the community owned the marsh. Typically the seigneurial lord retained certain rights to the marsh. The overlapping claims of the community and the seigneurial lord could be separated, however, if both parties accepted what was known as *triage*. The *triage* rule was a legal rule for dividing seigneurial property between community and lord. In the case of marsh pasture for which the community paid no seigneurial dues, the community received two-thirds of the marsh, while the lord retained one-third. In the case where the community did pay seigneurial rent for pasture rights to the marsh, *triage* (at least in Normandy) gave the lord two-thirds of the marshland and the community one-third.[16] In any event, it is clear that for the community and the lord, settling questions of *triage* could raise obstacles to drainage. Conflicts over which rule of division applied to a marsh frequently provoked litigation and added significantly to the cost of drainage. These conflicts would of course disappear with the abolition of seigneurial property rights during the French Revolution.

In order to argue that it was the Revolution that removed obstacles to drainage, it is necessary to assume that the technology of drainage did not change between the eighteenth and the nineteenth centuries. Fortunately, between 1715 and 1850 drainage technology was nearly static. In 1850, as in 1715, the task was still a matter of digging ditches and putting up levees. Both of these tasked were accomplished by hand and demanded mostly unskilled labor. Flood

16) See AD Calvados, C 4271.

gates did require skilled carpenters and masons and small amounts of wood and building materials, but the major input involved was still labor, and there is no evidence of changing techniques in masonry or carpentry.[17]

Only after 1850 was the French industrial base sufficient to provide a new drainage technology based on concrete and steam power.[18] Before 1850, nearly all the work was accomplished by men, particularly unskilled men, with shovels. Although there was certainly some learning by doing in drainage projects, the basic techniques remained the same. In the basin of the Dives nearly every supervising civil engineer formulated some proposal aimed at improving drainage. Over the course of the eighteenth and the first half of the nineteenth centuries, there was little change in what they proposed. From Remi Marquart in 1699 to Olivier, his counterpart of 1858, all the engineers in charge of the area offered essentially the same solution to the water control problem. Even in 1858, practically none of the ideas were new. Perhaps the only unique feature of Olivier's proposal was that it considered the area as a whole, and proposed both to increase drainage and to monitor how the increased flow of water in the river affected the rest of the area. Otherwise nothing had changed. The peripheral drainage canals that Olivier proposed in 1858 had first been proposed in the 1760s. Similarly his plan to straighten the bed of the Dives dated back to the 1770s.[19]

The solutions to the problem of drainage that were proposed in the eighteenth century were thus little different than those proposed after 1800. It was, therefore, not inadequate tech-

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17) Although the financing methods vary from project to project, nearly all the expense of drainage was for laborers and for masons. In the two cases where separate accounts were kept for flood gate construction and ditch digging, the cost of flood gates, including the labor to built them, was no more than a sixth of the total cost of the drainage network. See AD Calvados, C 4262 and 6671, S 1269-1272.

18) See Gabriel Desert, *Une Societé Rurale au XIX^{eme} siecle: Les Paysans du Calvados*. New York: Arno Press Inc., 1977, p. 304.

19) Olivier and Sallembert, *Projet de Déssechement des Marais de la Dives*, Caen, 1856. See AD Calvados, C 6771 and S 1004a and 1004b for earlier projects.

nology that was responsible for the lack of drainage before the Revolution. To be sure, drainage projects were expensive investments, but again the problem, as we shall see, was not their cost. Nor was it their revenues, for the evidence will indicate that drainage projects would have been profitable (had it not been for the cost of litigation) long before the Revolution. Rather it was the lack of institutions that would govern the distribution of the costs of a project among property rights holders.

Those institutions can be thought of as constraints, or more precisely as rules that restrict economic activity and define the distribution of the profits from drainage. For simplicity these rules can be divided into three categories: those rules that (1) concern the exchange of property rights, (2) concern the resolution of conflicts over property rights of uncertain value and legitimacy, and (3) enforce the exchanges and the settlement of conflicts.[20]

In the case of drainage in the Pays d'Auge, the first set of institutions did not change significantly between 1700 and 1850. In other words, the rules that governed the sale of land or water rights did not change: there was always a market for privately owned land or water rights. The third set of institutions--enforcement institutions--did not play a very important role in the development of drainage either, for the power to enforce contracts of sale and resolution of disputes was available throughout the period. The primary institutional change concerned the second type of institutions--the rules of litigation--and it was this change that brought about drainage in the nineteenth century.

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20) Cf. Douglas North and Lance Davis, *Institutional Change and American Economic Growth*. Cambridge: Cambridge University Press, 1971, which stresses the importance of institutions in economic development. However, the authors pay more attention to institutional arrangements that foster growth than to symptoms of institutional failure such as litigation. Underlying any institutional arrangement for production is a structure that enforces property rights. In the case of uncertain and overlapping property rights, as in Normandy, the courts are very important, perhaps more than in the American setting discussed by North and Davis.

A Simple Model of Drainage Production

In a universe where populations are widely spread out, externalities are rare and public goods problems are almost nonexistent. This was not the case for Normandy--and as a matter of fact for most of Old-Regime Europe. The central argument of this paper is that the externalities and public goods problems of the Old Regime (and the lack of institutions to deal with them) were the main impediment to drainage. To test this crucial point we need a model of a null universe where these problems do not occur.

The null universe is easiest to describe in a single period model. Assume that the global production function for drained land has only two arguments, marshland and labor, and that it is strictly concave. Denote the production function of drained land $H(m,l)$, where m is marshland and l is labor. Let the price of arable land be p_a, the opportunity cost of marshes p_m, and the wage p_l. Then we can write the profit function of drainage as :

$$\Pi = p_a H(m,l) - p_l l - p_m m.$$

Denote the supply of drained land by d. Because ditches and canals must be built, the usable acreage of a drained marsh ($d=H(m,l)$) tends to be less than the marsh itself (m). Then if m^*, l^* solve the maximization problem, and d^* is the quantity of land drained, then the comparative static results yield:

$$\frac{\partial d^*}{\partial p_a} > 0 \text{ and } \frac{\partial d^*}{\partial p_l} < 0.$$

Thus, in an efficient market the supply of drained land depends on the price of arable land (p_a) and the price of labor (p_l). In that case an increase in the price of arable land should lead to an increase in drainage, while an increase in the price of labor should lead to less drainage.

This model, of course, treats drainage as an instantaneous process, when in fact it is an investment. Supply therefore depends on rates of return. Moreover drainage is a discrete

good. To consider this more complex problem, let us index all the marshes by i. Assume that a fixed quantity of labor l_i will drain marsh i, which when drained yields d_i units of arable land and has opportunity cost m_i. Assume that it takes T years to drain the marsh, that the labor invested in each year is $\frac{l_i}{T}$, and that at time T the drained land is sold at a price of p_i. The price of drained land equals the price of arable land (p_a) minus the discounted present value of maintenance costs per unit of surface. Then the internal rate of return is δ_i such that

$$\frac{d_i p_i}{(1+\delta_i)^T} - \left(\frac{l_i p_d}{T}\right)\left[\frac{\frac{1}{(1+\delta_i)^T}-1}{\frac{1}{1+\delta_i}-1}\right] - m_i = 0$$

All projects with an internal rate of return higher than the interest rate will be carried out. To look at the impact of changes in relative prices, let us order the projects by their internal rates of return, for a given set of prices. It is easy to check that the internal rate of return rises as the price of arable rises and falls as the price of labor increases. Thus, if the price of land rises sufficiently, a project whose rate of return was initially less than the rate of interest will become profitable. A rise in the interest rate has three effects on the supply of drainage: higher interest rates demand a higher rate of return for a project to be profitable, decrease the price of land and also decrease the opportunity cost of the marsh. The second effect must be larger than the first because drained land carries a higher price than marshland. Therefore the net effect is to make projects less attractive.[21]

21) Choosing an appropriate rate of interest for comparisons proved to be more difficult than anticipated. Rental prices for land, from the notarial data I collected, ran at 5% of the sale prices throughout the period 1702-1870. This points to a real interest rate of 5% if we ignore appreciation in the value of land. Mortgages point to the same stable rate of 5%. At the same time, however French interest rates in various capital markets fluctuated between 4.75 and 8.25% in the nineteenth century. Unfortunately there are no comparable rates of interest for the eighteenth century except for *rentes* (personal loans) which ranged between 3 and 5%. All of this suggest that 5% was a reasonable upper bound for French interest rates in the eighteenth century and something closer to a lower bound in the nineteenth century. Choosing a 5% interest rate for the entire period 1700-1848 seems a reasonable assumption, which will bias my test against the profitability of drainage projects before 1800. This can only strengthen my findings.

The lack of supply of drainage in Normandy in the eighteenth century could have been the result of an unfavorable price of land relative to labor. A change in that relative price would then explain the abundance of projects that were carried out in the nineteenth century. However, the price ratio of land to labor, displayed in Figure 1 at the end of the chapter, suggests this was not the case. The small rise in the price ratio between 1700 and 1870 did make the price ratio more favorable in the nineteenth century. But the change is not sufficient to explain the dramatic increase in the supply of drainage after 1800. Conceivably, a significantly higher interest rate in the eighteenth century than in the nineteenth century could also explain why the development of drainage had to wait until after 1800. However as Figure 2 (at the end of the chapter) indicates, the data rejects such a hypothesis. Interest rates, except for the Revolution, are comparable across centuries.[22] Despite this evidence, we can accept the hypothesis of a market failure only if it can be shown that some drainage could have earned positive economic

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As an alternative, I estimated French interest rates from British data by running a linear regression of nineteenth century French rates on British interest rates for consols and a constant. I then used the British rates (which are available throughout the eighteenth century) to extrapolate French rates. When available, actual French rates are always about 1% higher than the British rates. However when British interest rates are very low as in the middle of the eighteenth century the extrapolation yields French rates which are too close to British rates and probably unreliable. When calculating rates of return to drainage projects, I used both the 5% rate of interest and the rate estimated from British data for my comparisons.

The French interest rate estimated from British data was computed as the predicted value of the regression of nineteenth-century French interest rates on British interest rates for consols (ruk) and a constant (one=1). The regression results were:

Independent Variable	Estimated Coefficient	Standard Error
one	-9.41189	2.30089
ruk	4.17690	0.59752

N = 73 R^2= 0.40767 $\overline{R^2}$=0.39933. The interest rate data comes from S. Homer, *A History of Interest Rates*. New Brunswick: Rutgers University Press, 1977, pp. 156-157, 172, 195-196, and 222-223. Data on R *rentes* is available in Emmanuel Le Roy Ladurie, *Les Paysans du Languedoc*, Paris: S.E.V.P.E.N., 1966, pp. 1024-1025.

22) The price data comes from a variety of sources: H. Hauser, *Recherches et Documents sur l'Histoire des Prix en France.*, Paris: Les Presses Modernes, 1936, pp. 160-194; G. Perrot, *Caen: La Génese d'une Ville Moderne*. Paris: Mouton, 1975, pp. 1026-1038; G. Desert, *Une Societé Rurale au XIX Siecle*, pp. 753-778. Figure 2 depicts French interest rates estimated from British data, but none of the direct French evidence points to higher interest rates in the nineteenth century either. On this point, see note 21 above.

profits if undertaken in the eighteenth century. We will therefore examine drainage projects that were carried out in the eighteenth and the nineteenth century and determine when, if ever, these projects would have been profitable in the absence of court costs.

Profitability

The argument that changes in institutions facilitated the drainage of marshes carries with it the implicit assumption that, in the absence of institutional barriers, drainage projects would have been carried out in the eighteenth century. In particular, more marshes would have been drained if the cost of resolving conflicts over property rights had been lowered. In other words, the validity of the hypothesis of institutional failure depends on whether or not the relative prices of land and labor would have made drainage of marshes a profitable operation in the absence of litigation. Estimated rates of return for drainage projects in the eighteenth century demonstrate that this was the case.

To estimate the rates of return, a set of price series is necessary. I constructed a wage series from published sources. The necessary land price series was more difficult to collect. Although historians of Normandy had published some land price data for the second half of the nineteenth century, there were no published land price series prior to 1850. To fill this gap I collected a sample of land sales and rental prices and constructed a price series from the notarial archives--the only source for land sale prices in the eighteenth and nineteenth centuries.[23] I used the archives of the notary in Troarn to collect data on all the land sales and leases

23) The French *notaires* have no proper equivalent in the U.S. The *étude de notaire* was a recording office that was neither truly private nor truly public. The private nature of the office comes from the fact that public officials cannot request notarial records. The public nature of *notaires* comes from the fact that offices are sold by the state. To be enforceable in court, private contracts must be signed in front of, and deposited with, a *notaire*. In the rural world, both in the eighteenth and nineteenth centuries, *notaires* took down all sort of contracts that transferred property rights between individuals. Loans, mortgages, land sales and rentals, wills, estate inventories, public auctions and marriage contracts run one after the other in the minutes that only rarely offer much in the way of tables. The collection of land sale and rental data is therefore painfully slow. To convert Old-Regime surface measures to metric units I relied upon Henri Navel "Recherches sure les Anciennes Mesures Agraires Normandes, Acres, Vergées, Perches," *Bulletin de la Societé des Antiquaires de Normandie*, Caen, 1932; and Gabriel Desert

for every fourth year, from 1702 to 1870. The data set represents 1241 contracts over 41 sample years (the notarial archives are missing for 1778 and 1798. There were unfortunately not enough contracts to allow the construction of separate arable land and pasture time series. Nor could a time series be constructed for Norman marshland, because marshes were neither sold nor rented in a market context between 1700 and 1870. Although separate series for arable land and marshes would have been preferable, there is sufficient data to estimate the opportunity cost of specific marshes, and the average land price series can be used as a lower bound for the price of pasture, because pasture always commanded a higher price than arable land. The land price series then allows me to construct a conservative estimate for the revenues associated with drainage--the sale of the drained land as pasture. The estimated revenue is conservative because contemporaries agreed that drained marshland was the most productive kind of land, so in all likelihood revenues from drained land were actually higher.

The issue of costs is more complex. An entrepreneur considering a drainage project in year (t) would confront three types of cost. First, the opportunity costs of the marsh (m_t); second, the cost of labor required to dig trenches and raise levees ($p_{lt} L_i$) where L_i is the number of man-days needed in each year while the network is being built. Third, upkeep costs $p_{lt} l$, where l is the expected number of man-days needed to maintain the network. Both construction and upkeep costs will be assumed to be only labor costs.

The revenue R depends on the price of land (p_{at}), and the surface area drained (n):

$$R = np_{at}$$

The estimated rate of return if the project is started at t, and finished at T, can be defined as Δ_t such that:

"Mesures Agraires Anciennes et Nouvelles dans le Calvados," *Annales de Normandie*, 1962.

$$\frac{np_{at}}{(1+\Delta_t)^T} - m_t - \sum_{i=0}^{T} \frac{p_{lt}L_i}{(1+\Delta_t)^i} - \sum_{i=T+1}^{\infty} \frac{p_{lt}l}{(1+\Delta_t)^i} = 0.$$

We can test the profitability of drainage by estimating changes in Δ_t over time as a result of changes in relative prices.

To be sure, drainage of marshland did contain an element of risk, and we would expect the rate of return on risky investments to be higher than on riskless assets. We must keep this in mind when we compare Δ_t to available interest rates for the period, such as those of the mortgage market. Except for the revolutionary period, the mortgage rates remained stable at 5% and although they were not without risk, they were the safest form of investment available to eighteenth-century Frenchmen. I also calculate rates of return using an estimated rate of interest constructed from French nineteenth-century data and British interest rates.

The first test of profitability uses the drainage project of the Marais des Terriers, a marsh that was drained between 1714 and 1717. The test relies on a series of assumptions. First we assume that the only input used was unskilled labor. Although there were skilled workers on all drainage projects, their wages are highly correlated with those of unskilled workers so this assumption will not carry too great a risk of error. The assumption that unskilled labor was the only input allows us to convert the cost of the drainage network as well its upkeep into man-days by dividing the 1714 cost of drainage by the 1714 wage for laborers. The estimated wage bill in other years is then computed by multiplying this number of man-days by the wage rate in the year in question.

During the four years of the Marais des Terriers project, the developers spent 44,000 livres.[24] I will assume they spent equal amounts each year, or 11,000 livres in each year. With wages for an unskilled laborer in the decade 1710-1720 at 0.4 livres per day, the developers

24) AD Calvados, C 4073.

used 27,500 man-days per year to build the drainage network. After 1718, the upkeep of the project ran at 2,000 livres a year, and since upkeep primarily involved maintaining the ditches and the main canal, it can also be regarded as a labor cost and converted into man-days. At the same 0.4 livres per man-day, 2,000 livres is equivalent to 5,000 man-days.

The second set of assumptions for the project concerns the opportunity cost of the marsh that was drained. It belonged to the abbey of Troarn and was drained under the technical direction of Remi Maquart, a royal engineer. After drainage it was divided among the abbey, as seigneur; the developers of the drainage project, who were Maquart and four Parisian nobles; and the communities with rights to the marsh.[25] The abbey received one-third of the marsh, while the developers received half as payment for draining it. The communities with rights to the marsh got one-sixth of the drained surface as compensation for their customary rights. I will assume that the one-sixth of the drained marsh that the communities received left them better off than their use right to the whole undrained marsh, and that the communities thus gained from drainage (after all they did accept, without a legal challenge, the whole drainage project). There is good evidence that the communities were indeed better off after drainage. Though smaller, their pasture was greatly improved, for the undrained marshland had been flooded too often to offer pasture except for the summer months.[26]

Draining the marsh also involved a decline in the value of fishing rights and of a mill.

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25) See AD Calvados, C 4295 for the original contract between all the parties of the drainage of the Marais des Terriers in 1699.

26) According to AD Calvados, S 1270, the imputed change in the value of private pastures from increased drainage was never less than 50%. The original drainage contract states that " the land of the marsh has never produced anything but reeds and bad grass" (AD Calvados, C 4295). Although the assumption that drained land was three times as productive in terms of pasture as marshland is reasonable, the estimation does not depend on it. Because I wanted to calculate *the rate of return to the project for the developers*, I did not count in the revenue calculation some 300 arpents (150 hectares) that were the abbey's share (even though their drainage costs were counted) but I used the cost of draining the whole marsh as my cost estimate. In effect, half the land drained was set aside to compensate for lost pasture, thus clearly biasing revenues downward.

Fishing must have greatly declined, although it is clear that commercial fishing continued in the drainage ditches. The mill suffered a 50% loss of power. Although neither milling nor fishing completely disappeared, I make the assumption that drainage resulted in an end to both activities. That assumption should bias the estimated rate of return downward. In fact, the rental value of the mill was 1,000 livres a year and remained so throughout the period 1650-1766 despite the completion of the drainage project in 1717. Hence, although the rental price did not increase in a period of general inflation, it did not decline, a clear indication that damage was limited. The fishing rights seem to have generated about the same revenue, but there is no certainty that the archives of the abbey of Troarn contain the full set of rental contracts for any year. The best estimate is that those rights represented another 1,000 livres of yearly revenue. At worst then, the loss of fishing and milling rights would have amounted to 2,000 livres per year. Typically, assets like the milling and fishing rights could have been purchased for a price very close to the capitalized value of the rent they earned. This can be estimated using the rate of interest--either the 5% mortgage rate or the rate estimated from British data. In the 5% case 40,000 livres is the estimated opportunity cost for the marsh from the capitalized value of the rents earned by the abbey from milling and fishing.[27]

Although Maquart's widow and three of his associates sold their shares in the Marais des Terriers to the remaining developer, Oursin, the sales contracts were impossible to trace. We thus do not know how much the drained marsh was worth but we do know the surface area of the developers' share. Revenue estimates are computed assuming that the developers' 45,000 ares (the are was the standard unit of surface measurement in nineteenth-century France

27) Most of the data on mills comes from the AD Calvados, H 8160-8166 (Abbaye de Troarn). The abbey has a complete list of the rental contracts for the mill from 1665 to 1760. The rental price remained stable at 1,000 livres per year even in the contracts for 1710-1730 when the abbot sued the developers arguing his mill had lost some of its power.

and is equal to 1/100 of an hectare or 0.0247 acre) were sold at the prevailing average price for naturally drained land minus the present discounted value of future maintenance costs. Again, the use of such an average price for land understates the revenues since drained marshland was reputed to be the best in Normandy.

To estimate the discounted value of the future maintenance costs, I will assume that having drained the marsh in four years the developers sell the land and create a sinking fund to deal with maintenance costs. The sinking fund is composed of bonds (*rentes*) with a yield equal to the interest rate. With these assumptions, the capital cost of future upkeep will equal the wage costs for 5,000 man-days of labor divided by the interest rate (in the case of the fixed interest rate it will be 100,000 times the wage). The expected rate of return Δ_t on the project if it had been started in year t thus solves:

$$(45000p_t - \frac{1}{r_t}5{,}000w_t)\frac{1}{(1+\Delta_t)^4} - 27{,}500w_t\sum_0^3\frac{1}{(1+\Delta_t)^i} - 2{,}000\frac{1}{r_t} = 0,$$

where p_t, w_t ,r_t are the price of land, wages, and the interest rate in year t.

Table 1, Columns 2 and 5 give the hypothetical rates of return for the Marais des Terriers broken down by periods.[28] Despite the conservative assumptions, all of which should bias the estimates downward, the project returned at least 20% per annum, assuming that the project was completed in four years. There are three years--1734, 1794 and 1806-- when rates of return are extreme, the result most likely of poor estimates of land prices in years when only a small number of land transactions were recorded by the notary of Troarn. With these years excepted, between 1718 and the French Revolution, the project's internal rate of return was never less than six times the rate of return on mortgages. If instead of 5% mortgage rates, we use interest rates derived from British data, then the rates of return are smaller but they remain

28) Table 2, at the end of the chapter, gives the complete series of estimated rates of return.

very substantial: through the eighteenth century the project would have returned on average at least four times the estimated rate of return. Thus, regardless of what interest rates are used, significant profits could have been earned from this project, all the more so since the conservative assumptions probably lead to an underestimate of the rates of return. Moreover, although all the estimates for the eighteenth century are lower than in those for the nineteenth they leave us with the same conclusion: if the Marais des Terriers is any evidence, drainage ought to have been profitable as early on as the 1720s.

	5% Model			Estimated Rate Model		
	Return Terriers	Return Troam	Interest Rate	Return Terriers	Return Troam	Interest Rate
1702-1750	37	21	05	26	09	07
1754-1786	52	25	05	40	12	05
1790-1814	83	40	05	80	38	09
1818-1850	69	31	05	73	34	08
1854-1870	64	24	05	59	18	04

Table 1: Average Rates of Return for Drainage Projects by Period

(in percent per annum)

A more convincing test of the market failure hypothesis involves computing the hypothetical rates of return to drainage projects that occurred in the nineteenth century. In the 1830s, the government provided an institutional mechanism for the division of common lands that ultimately facilitated the drainage of marshes. The measure affected marshes because the Revolution transformed the marshes, which had been seigneurial property, into common lands owned by villages. Like other common land, marshes were divided equally between each household in the village. The entire operation was supervised by the government, and before the marshes were divided, a basic drainage system was put in. Households in the village had to pay for the share they received, and the price they paid was set to compensate the community

for revenues it had collected from the marsh and to pay for the drainage network. Sufficient data is available from one such division of a common marsh--in Troarn in the 1840s--to estimate a crude rate of return.[29]

In the division of the common marsh in Troarn, villagers received an average parcel of 30.1 ares for the price of 100 francs. I will assume that the entire 100 francs went to pay for the drainage network. This assumption no doubt exaggerates the cost of the network because some of the money paid by the villagers reimbursed the village for lost revenue from the marsh. In Troarn these revenues came from pasture rights (there was no mill on the marsh), but we will use other evidence to estimate their magnitude. I shall also assume that yearly upkeep costs amounted to 5% of the cost of the drainage network. Actual upkeep costs for Troarn were not available in the archives, but account books of other drainage projects suggests this is an appropriate figure.[30] Both the cost of the drainage network and of its upkeep were estimated as labor costs.

The most difficult cost to estimate is the opportunity cost of the pasture foregone by the villagers. Since undrained marshes were never sold, one cannot use sale prices. However, contemporary sources (the tax service, the state, and dividing communities) did estimate the value of marshes from their revenues before division. These estimates average eleven francs per are or 46% of the average price of land between 1838 and 1850. We will assume that the marsh in Troarn was worth slightly more than this--50% of the average price of land . Again this is a conservative assumption, for the Troarn marsh had no mill, and some of the value of the pasture foregone was actually part of the 100 francs per parcel that we assumed paid for the

29) In the seventeenth century, the seigneurial owners of the marsh at Troarn had attempted to exercise *triage* and drain the marsh. In the eighteenth century, the communities who then owned the marsh also attempted to have the marsh drained. Yet, as we shall see later, litigation prevented the realization of any drainage. AN H^1 1692

30) See AD Calvados, S 1269 (*syndicat de la Dives*).

drainage network. Once again we have biased the rate of return downward.[31]

The project was carried out in only one year, a fact that makes the calculation of rates of return very easy. As the third and sixth columns of Table 1 indicate, this project also would have earned significant profits independently of the time it was carried out. Like the Terrier project, the Troarn project would have been profitable in the eighteenth century. The average rate of return for the eighteenth century (1702-1789) was 23%, more than four times the rate of return on mortgages. For the period 1750-1786, when drainage became an important policy issue, the rate of return is near 25% or five times the mortgage rate. With interest rates estimated from British sources, profits are much smaller. However in the second half of the eighteenth century, the project would have been quite profitable (it returned two and a half times the rate of interest). Clearly some marshes that were not drained before the nineteenth century could have been profitably drained 50 or 100 years before.

Both estimated rate-of-return series (displayed in Figures 3 and 4 at the end of the text) were calculated in a conservative fashion, yet both lead to the same conclusion: without litigation costs drainage projects would have given an entrepreneur sizable profits. With the exception of one year, the estimated rates of return for both projects in the eighteenth century exceeded 5%--the mortgage rate--by a wide margin (Table 2). With the interest rates estimated from British sources, the rates of return were almost always favorable except in the 1740s when the British interest rates fall below 4% a year and the linear form of the estimated French rates may make them unreliable. Of course, one could imagine that even higher rates of return would have been necessary to compensate eighteenth century entrepreneurs for the risks they took. Yet risks were actually limited, for the marsh retained its value in case of failure.

31) One problem with using such drainage projects as measures of profitability is that commercial exploitation only started after drainage took place.

Furthermore, the technology involved with drainage was simple. Typically a drainage network failed, as did the one in the Marais des Terriers, not because the network failed to drain the marsh, but because of lack of upkeep.[32] If the developer sold the land, he would not face that risk. In any event, the estimated rates of return for drainage projects in the eighteenth century seem high even for risky ventures. They were almost always well above 15%, a figure that compares very favorably with the estimated 18% rate of return for contemporary French slave trade ventures, which were notoriously risky.[33] Finally, because these rates of return were constructed in a conservative fashion--one that would produce high costs and low returns--it seems safe to assume that the true rate of return would in all likelihood have been even higher in the eighteenth century. The conclusion that the market for drainage was very inefficient in the eighteenth century thus seems inescapable. The fact that a great deal of attention was focused on drainage in the later eighteenth century (as we shall see in the last two Sections) suggests that the problem was not due to the lack of economic acumen of Norman landowners. Rather, marshes remained undrained because of a market failure.

Market Failure

For the student of eighteenth-century French agriculture, the presence of externalities and public good provision problems is no surprise. One might even argue that since they persisted into the nineteenth century, the supply of drainage was far from optimal even then. However, I will concentrate on the eighteenth-century situation. This focus will be a first step in evaluating whether or not the Revolution improved the institutional structure for the provision of drainage.

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32) AD Calvados, H 8163.

33) Cf. Robert Forster, *Merchants, Landords and Magistrates, The Depont Family in the Eighteenth Century*, Baltimore: The Johns Hopkins University Press, 1980, p. 5 and note 7. Robert Stein, *The French Slave Trade*. Maidson: The University of Wisconsin Press, 1979, suggests that average profits in the slave trade were in fact much lower, at least in the 1780s.

Eighteenth-century administrators and investors were well aware of the potential for high returns to drainage and the relative lack of drainage. The most important administrators in drainage affairs were the *intendants*, the king's special representatives in a particular area called a *généralité*. The *intendant* not only had executive power over taxes, military matters, and roads and bridges, but he was also the judge for extraordinary affairs. The *intendants'* support for drainage schemes was very strong and tempered only by their knowledge of the difficulty of carrying drainage projects through. In 1770, the *intendant* of Caen, Esmangard, remarked in connection with marshes not far from the Dives:

> These marshes have, in their present state [undrained], produced nearly no revenue, even though the soil is good and could become through drainage one of the most fertile of the region...There is no kind of obstacle a portion of the village has not created to prevent the division of the marshes and their drainage... The Count of Langeron and the Marquee of Lambert [the promoters of a project to drain the marshes in question] have been progressing only step by step because everything has been done under duress and the different legal procedures that have become indispensable have brought about considerable delays.[34]

Esmangard's attitude exemplifies the interest that *intendants* had in drainage and also their inability to accelerate judicial procedures. Developers shared their belief in the potential high return to and high social value of drainage. A would-be developer concluded in 1765:

> An operation conducted with such generosity should necessarily return precious land to agriculture. The important affair is to drain some land, an operation deeply desired in a province such as lower Normandy, where the inhabitants suffer much from stagnant water.[35]

He went on to discuss the problems that he had faced in finding land that could be drained

34)AN H^1 1496 (62), September 17, 1770. A similar example comes from the South of France, where the *intendant* of Montpellier in 1760 discussed the drainage of a marsh. After approving the project from an economic and a technical point of view, the *intendant* came to the issue of property rights. He discussed the demands made by the developers for eminent domain privileges, but concluded that the privileges requested by the developers were probably too weak to insure realization of the project.(AN F^{10}318.)

35) A. D. Calvados, C 4200 (62), 1780; C 4203, June 1765. That local communities or landowners were often opposed to drainage has surprised a number of historians. Staunch opposition, though, could result in higher

without litigation.

Intendants and developers worried about litigation over drainage not only because drainage would be difficult to provide in any market, but also because the distribution of property rights under the Old Regime exacerbated the problems associated with drainage. The difficulties that drainage would pose in any market, even those where property rights are certain and litigation not an issue, are obvious, for drainage enjoys very significant positive externalities and economies of scale: it would have been impossible to drain part of the Marais des Terriers without draining it all. Furthermore, drainage also imposes negative externalities on all lower lands, for each new drainage project forces owners of lower lands to raise their levees. If the drainage of a whole hydrographic basin is contemplated, this latter issue is largely irrelevant, because the developers will have to take into account the costs associated with the negative externalities. In France, however, the scale of suggested projects remained much smaller than a whole hydrographic basin. In such a situation the institution that allocates the costs of the externalities among landowners is crucial for the successful development of any drainage project. In eighteenth-century France, conflicts between developers and owners of land affected by drainage were handled by the courts, and there was no clear precedent to lead the courts to rule that developers were liable, say, for downstream damages due to increased water flow. Thus the downstream landowners were often opposed to projects from the start, and their opposition significantly raised the cost of drainage.

When there are many participants to a project, the costs of drainage also depend on the institution that resolves conflicts between participants over the distribution of cost and benefits. If marsh ownership is sufficiently dispersed, no drainage can occur without an rule to allocate

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levels of compensation. In many cases the developers attempted to avoid compensating communities for customary rights. For example, see Robert Forster, *Merchants, Landlords, Magistrates*, pp. 77-78.

costs among owners. Moreover, whether the development is undertaken by someone exterior to the group of landowners, by some subset of the landowners, or by the landowners collectively, a rule of profit division is necessary. An entrepreneur who undertakes the project will have to be paid and the landowners will have to divide the remaining benefits. Clearly, the rule that transfers a portion of the benefits from the landowners to the entrepreneur will determine the profitability of the projects for the entrepreneur. Division rules thus become important parameters in the equilibrium quantity of land drained, even though they do not affect the social value of the project because they address purely redistributive issues.

In the case of well-defined property rights and certain rent valuations, a simple institutional structure (having the state set the rule for sharing costs and benefits, for instance), would presumably avoid litigation. In the case of property rights over a marsh, though, litigation is almost inevitable because of informational asymmetries. The price of the property right in question--pasture rights over a marsh slated for drainage, for example--is in fact private information to the owner because he, better than anyone else, knows the nature of the marsh, the quality of its pasture, the problems of flooding, and thus the profits it can be expected to generate. None of this information is truly private, but clearly it is expensive to acquire, especially in the case of marshes that were generally not sold. The landowner obtains this information readily because he observes the returns of using or renting out his property rights to the marsh, but the state or an entrepreneur trying to reimburse a landowner for the loss of the property right would have difficulty estimating what the undrained marsh is worth. Even if the entrepreneur used unbiased methods to estimate the costs and benefits to improvement it would be difficult to devise a compensation rule that would leave all property rights owners Pareto indifferent. When property rights owners are improperly compensated, they could appeal the contract in court. Hence, costly litigation is also likely when there are significant informational

asymmetries between the developers and the owners of property rights to a marsh.

The asymmetric information problem also effects the case of the negative externalities associated with drainage. For example, the value of damages to a mill suffered from drainage is better known to the owner of the mill than to the entrepreneur. The mill's rental contracts are private information, hence any damage suffered is private information. Thus the uncertainty in the value of damages or benefits is yet another cause for litigation, adding to the cost of supplying drainage.

Another source of litigation is overlapping or uncertain property rights. When property rights are overlapping or uncertain the entrepreneur will face yet another problem: whom to compensate for damages. When property rights are uncertain litigation is often the only way to determine who owns the right to compensation. Under the Old Regime, a large number of individuals often had some title to the same piece of land. The list could include landowners, farmers, religious institutions, seigneurial lords or the state. In Normandy, where marshes were most often common lands, claims to the property were often divided between the lord, the king, and the community. In a world where property rights were uncertain, projects could not start until they had been attributed, and the attribution of property rights over marshes was the source of numerous suits.

The supply of drainage thus depends not only on such normal market forces as the relative prices of land and labor or the interest rate, but also on institutions. Because it is a public good, drainage requires rules for the division of costs and benefits, and when asymmetric information or uncertain property rights pose problems, drainage is likely to give rise to litigation. Only when institutions resolve these difficulties is drainage likely to proceed, but in Old-Regime France institutions failed to do so. As we shall see, it was not until after the Revolution, when institutions had completely changed, that drainage could be successfully pursued.

1715-1789: The Failures of the Old-Regime Institutions

France in the eighteenth century experienced significant economic growth as well as general inflation in agricultural prices. After 1750, state agents, intellectuals and agronomists became concerned with improving French agriculture.[36] They focused partly on improving productivity per acre and partly on increasing the cultivated area. One way to increase the cultivated area was to drain marshes, and in the second half of the eighteenth century, government officials enacted a set of reforms that they believed would promote drainage. In order to explain the failure of these reforms, I will first describe the institutions of drainage in the last days of the reign of Louis XIV. Then, to illustrate the importance of litigation, I will analyze the history of three marshes and the attempts to drain them between 1700 and 1789. Finally, I will examine belated efforts by the royal government to reduce litigation and thereby encourage drainage.

The institutional structure that governed drainage in the eighteenth century was primarily judicial. Conflicts were resolved in court. Two types of institutions governed litigation over property rights. The first were regional rules about the distribution of common or seigneurial lands.[37] The second were royal laws. Conflicts over either regional rules or royal laws, as well as over royal permits to drain, were handled in royal courts, and because all marshes were in fact common lands, the rules of *triage*, that I described earlier, generally prevailed. The only exception concerned royal land. While technically royal marshes could not be sold, rights to them could be leased in perpetuity. Although in theory, at least, individuals would have had weaker claims to land drained if it was royal land, this land was particularly attractive

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36) See, for example, state attempts to promote enclosures, division of the commons and drainage AN H^1 1482-1492.

37) A good introduction to the institutional rules of eighteenth-century France is Pierre Goubert, *L'Ancien Régime*, vol. 1, Chapters 1-3. A more detailed presentation of the issues appears in Roland Mousnier, *The Institutions of France under the Absolute Monarchy*, 2 vols., Chicago: University of Chicago Press, 1979.

to developers, because the property rights in question concerned only the king.

The primary cause of litigation over marshes in the eighteenth century was conflict over property rights. By 1700, communities and seigneurial lords had accumulated overlapping property rights to most marshes. Drainage, though, required that marshes be divided and that the overlapping property rights be sorted out for the allocation of costs and benefits. Uncertainty in property rights led to three sorts of litigation. The first pitted king against seigneur over the determination of seigneurial property. At issue was who held the seigneurial rights to the marsh. In Normandy the seigneur almost always won these suits, because, as we saw earlier, most marshes were not part of the royal domain. The second type of suits involved seigneurs and communities and focused on the form of *triage* rule that should be used for division.[38] The third type of litigation was due to conflicts over division of the surplus when the communities had strong use rights to the marsh.

It was only the last set of suits that prevented drainage in eighteenth-century Normandy. In communities with strong use rights access to the marsh was determined by local custom. Changing the way the marsh was used in effect required changing customary law. Because the marsh was ruled by customary law individual villagers had standing before the courts if they wished to appeal drainage projects. Because drainage changed access to the marsh by dividing the drained land into parcels for private rather than communal use, villagers could credibly argue that their customary rights were violated. Because customary law was part of *privileges*, a complex set of personal and group franchises granted by the king, royal courts were unable to dictate reform of customary law. Theroretically the king could have

38) The Abbey of Troarn presents a telling example of the complexity of suits. In the case of the Marais des Terriers, the abbey was seigneurial lord and owner and thus had two-thirds of the marsh. In the case of the marsh of Troarn, it was seigneur of Troarn but not the owner of the marsh. The abbey would therefore receive only a third of the marsh under *triage* AN H^1 1496 and AD Calvados, C 4293. For a contemporary view of the issue , see AN H^1 1496, Marais de Chaumont.

modified customary law but such action would have involved great cost as it would have faced the opposition of judicial officers. As a result if communities had strong use rights the unanimous consent of all villagers involved was necessary. Many landowners attempted to use their effective veto power to appeal the drainage projects and demand larger shares of the drained land. Faced with appeals by landowners, royal courts neither enforced the drainage grants nor decided on a new allocation of the drained land. As a result there was no judicial finality in conflicts over drainage grants.

The suits almost inevitably ended up in the king's council, the highest royal court. Drainage projects were involved in the high court even in the absence of suits because they changed the flow of water, and all projects that changed the flow of water required a royal grant from the council. The royal grants were, at least in theory, contracts that divided costs and benefits between the different parties in drainage projects. They also awarded the monopoly right to carry out projects to a specific individual called the developer. Except for legal costs, these grants were supposed to be free; however, entrepreneurs were well aware of the need for political influence in order to obtain a speedy and favorable verdict from the council. In the case of the Marais des Terriers, for example, Maquart, who was the originator of the drainage project, found four Parisian nobles who became his associates and who presumably had some influence in the king's council.[39] The abbot of Troarn, the seigneurial lord of the Marais des Terriers and the opponent of Maquart in nearly every suit, wielded considerable influence himself.

Anyone dissatisfied with a proposed royal grant could oppose it by filing a brief with a royal court. Although technically an appeal of a royal decision, the brief took the form of a suit

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39) AC Vimont (Saint-Pierre Oursin), 9E 761/75.

against the developers. The suit could be pursued before the *baillage* (the local court) or the *Parlement* (the regional royal court of appeals) in Rouen and then go back to the king's council for another appeal. If the opponent found the prospects of the regular court system unsatisfactory, he could file with the *Eaux et Forets* (Water and Forestry) courts because in the case of marshes the jurisdiction of the regular court system overlapped with the jurisdiction of the *Eaux et Forets*. Here, too, final appeals could always be sent to the council. Any court that accepted the appeal would automatically grant a staying order, thus preventing the realization of any drainage network until all suits had been resolved. The process of court enforcement of drainage grants was very complex, lengthy and expensive, and it could delay a drainage project for a long time.

The royal governments in the eighteenth century were well aware of the severe economic costs associated with court delays. A number of ministers attempted to centralize judicial authority not only to reinforce royal power but also to reduce delays. Beginning in the 1740s, some new drainage grants issued by the king's council contained a clause that stated that they could be reviewed only by the *intendant* or the council itself. Unfortunately, because such direct appeal clauses were not automatically included in all new drainage grants the effects of this reform were limited. Developers had to request the privilege of such a direct appeal clause in their grant. Soon though, almost all developers began to seek direct appeal clauses. As de Blossac, the *intendant* in Poitier, remarked,

> Such an edict [that only allowed appeals directly to the council for a particular drainage project] would not be unique in its kind, and all those who have started drainage projects have obtained similar ones so they could avoid the length and formalities of the procedures that are nefarious to enterprises of this nature.[40]

The result was that the king's council became overloaded with appeals, and they took longer

40) AN H^1 1497, (1776).

and longer to process. For Normandy in particular, this reform meant longer rather than shorter litigation time. Unlike other provinces where the *Parlements* and other local institutions played important economic and judicial roles, Normandy was the domain of direct royal power, at least insofar as drainage was concerned. Indeed, as early as 1711, court cases over marshes were going directly to the king's council.[41] The centralization of judicial authority into the council did not facilitate drainage in Normandy. After 1740, litigation before the king's council took four or more years to settle. The delays affected all the drainage projects of which we have records, for all were in some way involved in litigation before the council. It is no wonder then, that of the numerous drainage projects proposed in the eighteenth century, most were failures.

Three examples illustrate the problems with litigation that thwarted many eighteenth-century drainage projects. The first example is the marsh of Troarn and all the unsuccessful attempts to divide it and drain it. The legal battle over property rights to this marsh started in the seventeenth century and it was still in the courts a hundred years later when the Revolution finally brought the litigation to an end. In a first phase, the Abbey attempted to drain the marsh, no doubt in order to convert it to pasture and arable land.[42] The four communities (Troarn, Saint-Samson, Saint-Ouen-de-Bures and Barneville) that enjoyed use rights over the marsh sued the abbey, arguing that their rights were customary and that the abbey had no right to drain the marsh. The communities won their suit against the abbey in the king's council in 1667. As a result, the abbey's claims of ownership were invalidated and the abbey was forced to destroy whatever drainage it had begun. The four communities with rights to the marsh also

41) AD Calvados, C 4293.

42) The attempts to drain the marsh are documented in the archives of the central government (AN $H^1$1492), the *intendant* (AD Calvados, C 4263, 4293), and the communities (AC Bures, Marais).

won *possession*, a form of property that gave them two-thirds of the marsh in the case of *triage*, as well as veto power over any future division.

A second phase of litigation erupted in 1711 when the same communities attempted to divide the land among themselves and to drain the marsh. Although the king's council was solicited twice for a division edict, no cost sharing rule could be agreed upon. The *intendant* was either unwilling or unable to enforce the decision of the council. The project was once again abandoned. In the 1770s the issue of drainage surfaced again, and the battle over which method should be used to divide the marsh was renewed. The three smaller communities demanded equal shares, whereas the larger community of Troarn stuck by the 1711 proposal. Although Troarn later abandoned its position, the case was still in the courts at the Revolution. Clearly what kept this marsh from being drained was not a question of profits or of technology but rather the absence of any precedent or other rule to divide the land between the different title holders. In fact, after the Revolution when institutional structure had changed, the marsh was divided between the communities, drained and then split up among the villagers.

The second example involves the Marais des Terriers.[43] Although it was ultimately drained, the project provides a telling example of the length and extent of litigation. The original contract between the entrepreneur Maquart and the abbey of Troarn dates from 1699, but the royal grant permitting drainage was not enacted until 1711. By 1711, Maquart had formed a partnership with four Parisian nobles who provided capital and political influence while he offered technical expertise. Despite a legal contract reinforced by a royal grant, Maquart and his associates became involved in suits with the abbot of Troarn. By 1717, the king's council

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43) AD Calvados, H 8163-8166 and C 4293 and AC Vimont, 9E 761/75. There were actually a number of suits over the question of maintenance. It is unclear whether the network of ditches and canals was improperly maintained or whether the abbot attempted to renege on his financial obligations.

was examining two different suits brought by the abbot. In the first, the abbot sued Maquart and his associates claiming his mill was less productive as result of the drainage they had undertaken. The abbot claimed that both the royal grant and the original contract between himself and Maquart had promised to leave the waterfall of the mill intact. The second suit, also between the abbot and Maquart, concerned the quality of the drainage. The abbot won the first suit and was awarded 1,000 livres as damages. He was also given the opportunity to sell his mill to Maquart and his associates at the capitalized value of the rent before drainage affected the water flow. He lost the second suit over the quality of drainage, and work on the drainage network continued. In 1723 the network was declared complete, and, as in the grant of 1711, each landowner was to be taxed for upkeep costs according to the surface he owned. A new contract that provided for the distribution of future maintenance costs was written between all the owners of drained land and Maquart and his associates.

The legality of this new contract was tested in 1726 when the abbot was back in court arguing that the developers (Maquart and his associates) had broken both the 1711 and the 1723 contracts because they so poorly maintained the drainage network. The *intendant* agreed with the abbot that work had to be done, but he also forced the abbot to pay his share of the costs, which the abbot had hitherto resisted. Despite the customary appeal by the abbot, this issue was one of the rare occasions when the king's council refused to review the *intendant's* decision. Litigation, however, was not over. In 1740 one of Marquart's associates who had bought all the other developers' land, a Monsieur Oursin, brought suit against the abbot. Oursin appealed to the council because the abbot had raised the floor of the drainage canal to increase the fall at his mill. Again the abbot lost, but the developers of the marsh faced other suits from seigneurs who claimed rights to the marsh and who attempted to impose seigneurial dues or exercise *triage*. Although Oursin managed to win all these trials, the legal costs

were quite large, and there is only one mention of reparatory damages.

The final case comes from the village of Ranville, a parish that spent 645 livres between 1747 and 1748 to defend their lease on a marsh.[44] The marsh was part of the royal domain (the property of the king), and the domain officials attempted to lease it at a higher rent to an individual. The villagers won their suit only to face a renewed threat in 1765 from a developer named d'Avenel, who had received a royal grant of the marsh for drainage. The village opposed the grant on the basis that their tenure had become customary, but it lost on appeal to the king's council. The council wanted to encourage drainage and leased the marsh to d'Avenel. He promised to drain the marsh, while the village wanted to use it at as common pasture. D'Avenel, however, never even began to drain the marsh. In a final suit waged during the Revolution, the villagers argued that the corruption of an *intendant's* delegate had allowed such an injustice to take place. This case dramatically demonstrates that not even royal property rights were sufficiently well established to avoid litigation.

The complication, length, and dates of the lawsuits, make it clear that the Old Regime had failed utterly to limit lawsuits over the property and administration of marshes. The problem worsened in the 1760s when fiscal difficulties forced the monarchy to increase the revenue from the king's domain. As a result, leases on royal possessions, including marshes, were revised upward. This revision led to renewed attempts to auction leases to royal possessions instead of renewing the old contracts. D'Avenel was able to rent the marsh at Ranville in such an auction. Royal officials were particularly fond of schemes like d'Avenel's, because they would raise the value of the royal domain without any royal investment. In the long run drainage would increase the value the marsh and increase the rent the state could earn. The

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44) AD Calvados, C 4288 and AC Ranville, Marais.

fiscal difficulties of the 1760s also led to an effort to recapture parts of the domain that had been appropriated by other seigneurial lords. In fact, because of increased fiscal needs, the central government became more concerned with economic prosperity. In order to increase the cultivated acreage, the government enacted a series of reforms that aimed to promote drainage. These included reforms of the judicial system, subsidies, and a streamlining of the process of granting out marshes to developers. All of these measures should have lowered the cost of drainage, but the economic record of the reforms was mixed, at best.

Consider, for example, the judicial reforms. As we have seen, the attempts at judicial centralization did not reduce--and perhaps increased--the delays associated with litigation over drainage. The delays, of course, had a significant impact on the profitability of the ventures. Moreover, the amount of litigation over edicts from the king's council suggests that the real problem lay with the state's inability to make contracts binding. More radical attempts at judicial centralization like Maupeou's (the minister of justice) in the 1770s were short-lived. Their only effect was to increase the uncertainty of the judicial process, and they brought no gains for drainage entrepreneurs.[45]

Ministers concerned with agricultural development also attempted to subsidize drainage and other agricultural improvements. The subsidy laws were enacted in 1765 and 1766 and received the nearly unanimous support of all *intendants*.[46] According to entrepreneurs, the subsidies were in fact valuable for agricultural improvements that did not lead to externalities and did not involve public goods problems. For drainage, though, profitability was not the issue. The problem was litigation, and it could not be resolved by the

45) See D.M.G. Sutherland, *France 1789-1815, Revolution and Counterrevolution*, p. 23. Sutherland in fact argues that the judicial reforms brought no gains for anyone whether entrepreneurs (because the reforms failed), judicial officials, or agents of the state (because the prestige of all civil servants was badly damaged).

46) Edit de Compiegne, August 13 1766 (in AN H^1 1499). See also AN H^1 1496-1497.

sort of subsidies the reformers had in mind--chiefly tax rebates.[47] Subsidies could not reduce the time needed to resolve property rights conflicts, and since the subsidies only became effective after the project was carried out their impact was minimal. Even as powerful a figure as Bertin, the minister of finance and a staunch supporter of agricultural development, could not use the subsidies to avoid litigation. Bertin spent 150,000 livres on litigation in the 1780s on a marsh that would have been worth little over a million livres drained. Furthermore, he spent the money over a space of ten years. It is clear that the 150,000 was probably not the total sum he would have spent on legal fees to drain his marsh because his suits were still in court in 1789. The subsidies Bertin was eligible for would have increased Bertin's profits had he been able to drain his marsh, but they had no impact on the delays that prevented him from draining it.[48] As Bertin no doubt found out himself, in the absence of a clear rule for compensating customary right, lawsuits were almost inevitable, and the subsidies were worth very little.

A final set of reforms undertaken to raise royal revenue actually increased the number of lawsuits. Liberal interpretations of a point of medieval law known as the *vacance* rule led nearly every community in Normandy into lawsuits.[49] The *vacance* rule was a medieval law that gave all abandoned (*vaine et vague*) land to the king. It had been used by the medieval kings to repopulate deserted areas, but in the modern period little land was sufficiently devoid of activity to be legally recognized as abandoned. Entrepreneurs could, however, attempt to have a marsh or a fen recognized as abandoned in order to secure their property rights. Indeed, once land had been recognized as abandoned, the king could grant it out again. If a piece of land could be found that was vacant, the subsidies offered to developers became very attrac-

47) See AN H^1 1487-1490.
48) Cf. R. Forster, *Merchants, Landlords, Magistrates*, p. 77.
49) The suits over the vacance rule left a mass of archives in AD Calvados, C 4190-4203.

tive, because only a small purchase price would be paid and no taxes were due for the first 20 years. Several individuals attempted to use this clause to secure marshes that were in fact the common lands of villages. They argued that the lands were not under cultivation, but lack of cultivation did not mean lack of use, for village communities owned strong customary use rights to most marshes. As the *intendant's* delegate in Caen remarked:

> there is not one foot of commons, fen or marsh in the hand of the King due to lack of cultivation. These lands are not abandoned, nor deserted. Since time immemorial all the communities enjoy their communal property privately and pasture them each year without interruption.[50]

One of the most extreme attempts to liberally interpret the *vacance* rule was launched in 1761 by M. de Boullonmoranges, a refugee from Turkey who had converted to Catholicism and was the protege of high court nobles. Under the *vacance* rule Boullonmoranges was able to secure a royal grant of 12,240 hectares of land. Of that 1,600 were marshes, in over a hundred parishes in the *généralité* of Caen. The royal grant gave him the rights to all the 12,400 hectares unless other individuals could prove ownership. Not surprisingly the grant gave rise to scores of lawsuits, as all the concerned (parishes and their lords) marshaled evidence on behalf of their title to the land claimed by M. de Boullonmoranges.[51] This was litigation on a scale previously unthought of. Bures, a parish whose only interest was a small share of 500 hectares of fens and marshes, spent over 3,000 livres in just four years over the Boullonmoranges affair. And during the same four years, Bures actually paid a total of 4,571 livres defending its rights to the marsh in other suits. The total amount of money expended by Bures against Boullonmoranges is not available because the accounts of the community are incomplete, however, because litigation lasted over 22 years it is safe to assume that Bures spent significantly more

50) AD Calvados, C 4203 (June 1765).
51) AD Calvados, C 4195-4203.

than the 3,000 livres it went through in the four years for which there is data. Boullonmoranges himself spent an enormous sum on litigation. Precisely how much is difficult to evaluate, but Boullonmoranges suggested that his cost had run to more than 300,000 livres. And one can only guess how much the other parishes in the *généralité* spent.[52]

The trials over the *vacance* rule lasted until 1783 when an edict was published forbidding concessions of the sort given to Boullonmoranges.[53] But for 20 years the validity of property rights over marshes had been so shaken that no one would have dared to drain a marsh. And while by 1783 the litigation over the Boullonmoranges affair had finally clarified property rights to marshes, the Revolution intervened before anyone could take advantage of the legal calm.

The Old-Regime reforms had thus failed to reduce litigation costs, and no changes were made to the institutional structure to facilitate private ventures in drainage. So many overlapping property rights over marshes existed that no development could take place without litigation. The reform attempts of the second half of the eighteenth century were thus doomed to failure because they failed to address the central issues: overlapping property rights and endless litigation. As I shall argue later, the Old-Regime monarchy simply could not resolve these central issues. The simplification of the property rights structure would have demanded deep social change, for much of the economic and political power of the Church, the nobility, and other elite groups came from seigneurial rights. The Coase "theorem" would suggest that they could have sold their seigneurial rights to individuals but transaction costs made this process impossible. Alternatively the state could have bought these seigneurial rights, but the process would have raised up insurmountable political obstacles because of the distributional

52) See AC Bures, 563 EDT/15. For Boullomoranges' expenditures, see AD Cavaldos, C 4200.
53) AD Calvados, C 4200 (62).

consequences. Only a revolutionary government could have effected institutional change of such magnitude.

The fiasco of the Boullonmoranges episode did not deter the government from the promotion of drainage. But because private enterprise had failed, in the last years of the Old Regime the *intendants* resorted to using a Royal agency: the *Ponts et Chaussées*. It drew up plans for the Divette canal, which improved drainage in about a fifth of the basin.[54] The *Ponts et Chaussées* then built the canal and administered it between 1783 and the Revolution. To pay for the cost of the canal, landowners were taxed on the basis of acreage. Communities, near the canal, did sue to reduce their share of the burden, but the amount of litigation was far less than it had been with the Marais des Terriers. Suits were rare because the project demanded no redistribution of land, and because the entrepreneur was the state, and the state clearly had a strong hand against plaintiffs. A public agency had thus replaced private enterprise. In nineteenth-century Normandy, even stronger public institutions would play the dominant role in dividing and draining the common lands, and administrative decision would replace litigation.

1789-1850: After the Revolution, Continuity and Contrast

The French Revolution and the Napoleonic regime left France with a strong central authority, reduced uncertainty about property rights, and a strengthened administrative agency (*Ponts et Chaussées*) capable of handling all the technical aspects of drainage. As a result, drainage flourished with two types of projects undertaken in the first half of the nineteenth century. First, common lands were drained and sold to local landowners. Second, the *Ponts et Chaussées* worked to increase the flow of the Dives, for as more and more drainage took place,

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54) AD Calvados, C 6771 and S 1004 a.

more and more water had to be moved out to sea. The institutional challenge was to allocate the costs of both of types of projects among landowners.

None of these projects took place during the revolutionary period (1790-1814). These were slack years for drainage despite the fact that the estimated rates of return were higher than either before or after: between 40% and 38% for Troarn, 83% and 80% for the Marais des Terriers. During the same period no drainage occurred, and there is significant evidence suggesting that existing networks fell into disrepair. The lack of development and upkeep suggests that despite the marked demand for drainage as evidenced by the high rates of return, the institutional structure had failed. The absence of drainage is not surprising, for the period of the French Revolution was a time of widespread uncertainty in property rights. The Napoleonic period that followed replaced the uncertainties of institutional reform with those of war. Thus, it was not until after 1815 that the supply of drainage in Normandy could adjust to the new institutional structure.

While the period between 1789 and 1815 was a period of inactivity in drainage, the Revolution did recast the institutional constraints on the supply of drainage. Foremost among the reforms was the creation of a powerful executive that wielded far more power than even the absolute monarchy. The Revolution, in fact, achieved the centralization of power that the monarchy desired but could never obtain. The new power of the executive meant that its decisions about drainage matters would carry far more weight because there could be little doubt about their legality. At the same time, the judicial system was completely reformed. The Revolution ended the tensions between judicial authorities and the executive, and the likelihood of winning a judicial appeal of an administrative decision declined dramatically.[55] The judiciary

55) A basic introduction to the Napoleonic administration can also be found in R. Holtman, *The Napoleonic Revolution*, Baton Rouge: Louisiana State University Press, 1967, chapter 4. A more elaborate description of the administrative power of post-Revolutionary governments can be found in F. Ponteil, *Les Institutions de la*

also lost jurisdiction over a host of economic matters; henceforth these matters were attributed to the prefects--the nineteenth century counterparts to the *intendants*--and to the Ministry of Interior. Such reforms alone would have been enough to reduce the institutional costs of drainage significantly, but the revolutionary governments also gave greater coherence to village government. Municipal councils became executive and legislative bodies whose decisions were subject to the approval of the prefect. Once the administration had approved municipal council resolutions, they could not be opposed by villagers. Hence, developers after 1815 found a state that was more cooperative than the Old Regime and able to wield much greater power.[56]

Beyond the institutional reforms, the Revolution also rewrote property rights. All seigneurial property rights were destroyed. Church property was nationalized and what land was under cultivation--either arable or pasture--was sold to the public. The sale of *biens nationaux* (land that was confiscated from the Church or from nobles who fled France during the Revolution) put on the market large amounts of property and completely redrew the distribution of landownership. Before the Revolution the abbey of Troarn had been the largest landowner in the area. After the sale of the *biens nationaux* large secular landowners took its place. The nationalization of Church property and the end of seigneurial privileges also gave the state and local communities exclusive ownership of the marshes that had once belonged to seigneurs. Where customary rights existed, as in the Dives basin, the municipalities received all the undrained marshland. In effect, the end of "feudal privileges" as well as the sale of Church

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France de 1814 à 1870, Paris: P.U.F. 1965, part 1, chapter 3, and part 2, chapter 2. The regimes of the Restoration never relinquished this authority.

56) Cf. D.M.G. Sutherland *France 1789-1815, Revolution and Counterrevolution*, pp. 344-347; and Jean Petot, *Histoire de l'Administration des Ponts et Chaussées de 1599 a 1815*. Paris: Marcel Rivièesre et Cie., 1958. Petot, among other historians stresses the centralization and administrative logic achieved by the Revolution and the Napoleonic era.

property swept away all overlapping property rights and secured the villages' title to the marshes they used for pasture. The Revolution had eliminated one of the major parties to Old-Regime litigation--the seigneurial lord. Once he was gone litigation subsided.

The Revolution also facilitated the division of village commons, including marshes. Subject to the approval of the prefect, a favorable vote in the municipal council was now enough to divide and drain a common marsh. Projects were subject to the review of both the prefect and the Ministry of the Interior, but once the central government agreed to a scheme, individuals had little power to resist drainage. The state could enforce whatever rule it chose for allocating costs and benefits while offering few avenues for judicial appeal by property rights owners. The effect was to eliminate much of the uncertainty that had hung over drainage projects.

One problem remained: finding a set of rules that would promote drainage and preserve the new structure of property rights. It is clear that prefects and ministers alike saw the division of the commons not only as a an economic task--a means of increasing the cultivated acreage--but also as a political one--as a mean of increasing the number of grateful and conservative landowners. Furthermore, just as the *intendant* had controlled the budgets of communities, so prefects controlled the budgets of municipalities and they did so with political goals in mind. They exercised the same control over the *syndicats*, the associations of landowners that administered drainage projects. The Restoration governments of Louis XVIII and Charles X had created these associations, which resembled Old-Regime associations charged with the care of levees.[57] One key difference between the *syndicats* and their Old-Regime predecessors was that the decisions reached by the *syndicat* could not be appealed once

57) If the projects were very large it required the approval of the ministry of interior. See AD Calvados, S 1269 for the role of the *Ponts et Chaussées* and the municipalities in the administration of the syndicats.

authorized by the prefect.[58] This applied in particular to decisions about allocating costs and it allowed the *syndicats* to divide up the cost and benefits without the risk of paralyzing opposition.

The laws governing the division of common lands and the creation of *syndicats* were enacted between 1800 and 1823. They had a substantial impact in Normandy. Between 1820 and 1848, most villages in the Dives basin secured royal edicts authorizing the division of their commons, including marshes, which now belonged to the villages. The marshes and other commons were to be sold in equal portions to village households, and the edicts allowed households to mortgage their portions to the village at 5% for 20 years.[59] Drainage of the marshes was accomplished at the time of the division. The engineers of the *Ponts et Chaussées* drew up plans, and the prefect made sure that they were carried out. A *syndicat* was also created to insure upkeep of the drainage network.

The creation of a larger, supra-village *syndicat* contributed to the solution of the perennial problems with the Dives' exit into the English Channel and with maintaining levees on its banks. Created in 1821 by a decision of the central government, the *syndicat de la Dives* oversaw all drainage in the basin.[60] Each village had a least one representative on the *syndicat's* council, but the real power lay with the prefect and the engineer of the *Ponts et Chaussées*. The engineer proposed improvements and the prefect approved the budgets. This *syndicat* provided, for the first time, an institution that collected funds from all concerned parties (landowners and

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58) See AC Janville, 9 E 344/46 for an interesting exchange between the village council and the prefect over division rules for the village marsh. The prefect forces the village concil to accept the rules laid down by the central government within a year and without litigation. Moreover he alone decides whether individuals are eligible to receive a share of the marsh or not. (1831-1832)

59) All the localities in the Dives area that owned some marshland seem to have divided their commons between 1820 and 1848. One cannot be completely sure, however, because of the loss of village archives during the fighting in 1944.

60) AD Calvados, S 1269 "Reflexions de M. Pfistre-Duvant Ancien President du Syndicat" (1829).

communities) for the maintenance of levees through out the Dives. Although the *syndicat* was unable to raise funding for a general drainage project, it did reduce flooding in the Dives area because now levees were built and maintained by a single agency.[61]

The achievements of the first half of the nineteenth century may well appear limited: a couple thousand hectares' worth of drainage in Calvados and only a few hundred in the Dives. But if we discount the period between 1789 and 1820 as too tormented politically for long-term investments, the new institutional structure was able to achieve in three decades what the eighteenth-century regime had failed to do in a hundred. The governments which succeeded the Old Regime demonstrated remarkable continuity where drainage was concerned. They all promoted drainage, and they did so effectively. Their effectiveness resulted from a new distribution of property rights and a new set of political and judicial institutions, and the institutions that mattered were the product of revolutionary reform. Thus drainage in Normandy stresses the institutional and economic importance of the Revolution of 1789.

Conclusion

Throughout the eighteenth century, administrators and investors had tried to increase agricultural output by promoting drainage. The record shows the extent of their failure: between 1714 and 1783 no significant drainage projects were realized in the *généralité* of Caen. Yet drainage would have been profitable if the market failures had not intervened. In this situation, recourse to an administrative solution of the sort adopted after 1789 would have been more efficient than the existing legal process. The problem lay with litigation over overlapping property rights and the inability of property rights owners to write binding contracts. In theory, property rights owners could have bargained among themselves to resolve the externalities, but

61) AD Calvados, S 1270-1271.

any agreement that brought their bargaining to a close could be attacked in court. Because of the lack of finality of judicial decisions over customary, law resources were expended on repeated attempts to redistribute property rights rather than on making improvements.

In eighteenth-century Normandy resources were effectively expended on litigation that did not foster economic growth. Everyone--except the lawyers of course--was made worse off. The Old-Regime government could not resolve the problem, for the government itself could not write binding contracts, because drainage concessions could be appealed by private individuals. Simplifying the property rights that had accumulated since the Middle Ages was politically impossible within the institutional structure of the Old Regime. Thus the reforms that the Old-Regime government undertook to promote drainage simply failed, even though many of the problems associated with drainage were well known. Only after 1789 was the resolution of the problem within the government's grasp, and then only because of the Revolution's institutional change.

Appendix 1

Maps, Tables and Figures for Chapter 2

Date	Mortgage Rate Model		Estimated Rate Model		Wages	Land Price	Number of Land Contracts	Estimated Interest Rate
	Return Terriers	Return Troarn	Return Terriers	Return Troarn				
1702	0.21	0.08	.	.	0.40	4.45	27	.
1706	0.31	0.18	.	.	0.40	5.55	30	.
1710	0.33	0.21	0.53	0.39	0.40	5.86	13	0.252
1714	0.29	0.17	0.47	0.27	0.40	5.34	16	0.177
1718	0.41	0.29	0.46	0.30	0.40	6.94	51	0.093
1722	0.59	0.40	0.36	0.21	0.50	11.31	10	0.031
1726	0.44	0.27	0.19	0.04	0.50	8.38	12	0.031
1730	0.46	0.29	0.32	0.15	0.50	8.63	50	0.043
1734	0.04	-0.14	-0.13	-0.29	0.50	3.55	7	0.039
1738	0.38	0.21	0.06	-0.09	0.50	7.38	32	0.025
1742	0.60	0.41	0.32	0.17	0.50	11.50	29	0.031
1746	0.34	0.17	0.17	-0.01	0.50	6.72	36	0.048
1750	0.36	0.14	0.17	-0.01	0.66	8.35	28	0.031
1754	0.39	0.14	0.08	-0.13	0.75	9.61	36	0.027
1758	0.51	0.25	0.32	0.08	0.75	11.99	17	0.039
1762	0.56	0.30	0.40	0.15	0.75	13.39	25	0.043
1766	0.40	0.14	0.33	0.08	0.78	9.99	10	0.047
1770	0.56	0.27	0.44	0.17	0.87	14.67	10	0.057
1774	0.61	0.30	0.43	0.14	0.94	16.80	24	0.049
1782	0.66	0.33	0.68	0.36	1.01	19.40	6	0.125
1786	0.64	0.31	0.51	0.21	1.06	19.35	17	0.075
1790	0.78	0.42	0.67	0.34	1.06	25.03	5	0.068
1794	1.22	0.78	1.57	0.72	1.10	40.17	7	0.089
1802	0.76	0.39	0.77	0.41	1.19	26.10	14	0.082
1806	0.23	-0.07	0.39	0.08	1.23	10.04	12	0.109
1810	0.91	0.48	1.05	0.58	1.27	35.40	12	0.092
1814	0.74	0.36	0.89	0.49	1.32	26.69	2	0.111
1818	0.56	0.21	0.63	0.28	1.36	19.98	7	0.067

Table 2: Hypothetical Annual Rates of Return for Drainage Projects, Wage and Land Price Series

Date	Mortgage Rate Model		Estimated Rate Model		Wages	Land Price	Number of Land Contracts	Estimated Interest Rate
	Return Terriers	Return Troarn	Return Terriers	Return Troarn				
1822	0.88	0.45	0.94	0.50	1.37	35.05	13	0.064
1826	0.72	0.33	0.77	0.39	1.40	26.80	24	0.064
1830	0.84	0.42	0.85	0.43	1.40	33.21	18	0.051
1834	0.73	0.34	0.70	0.31	1.40	27.36	29	0.044
1838	0.62	0.25	0.57	0.20	1.41	22.75	43	0.040
1842	0.74	0.35	0.70	0.31	1.42	28.15	41	0.042
1846	0.55	0.18	0.50	0.13	1.58	21.99	135	0.036
1850	0.58	0.22	0.48	0.11	1.44	21.47	32	0.036
1854	0.75	0.35	0.73	0.32	1.58	31.19	46	0.042
1858	0.72	0.30	0.66	0.24	1.83	32.75	79	0.035
1862	0.65	0.23	0.62	0.20	2.15	32.87	36	0.040
1866	0.63	0.22	0.63	0.21	2.19	32.60	41	0.048
1870	0.50	0.11	0.42	0.23	2.08	24.82	35	0.041

Table 2 (Continued)

SOURCES AND UNITS FOR TABLE 2

The price of labor is one day's wage for an unfed, unskilled laborer in francs.

The price of land is in francs per acre (100 square meters). The number of contracts is the number of contracts in the notarial records that were used to construct the price average. These contracts contained both price and surface data, while others only contained price or suface data.

Footnote 21 explains the construction of the interest rates.

The price data comes from a variety of sources:

H. Hauser, *Recherches et Documents sur l'Histoire des Prix en France*, pp. 160-194. For wages from 1700 to 1750.

G. Perrot, *Caen: La Génese d'une Ville Moderne*, pp. 1026-1038, for wages from 1750 to 1789.

G. Desert, *Une Societé Rurale au XIX Siecle*, pp. 753-778, for wages from 1805 to 1870.

Map 1

The Pays d'Auge

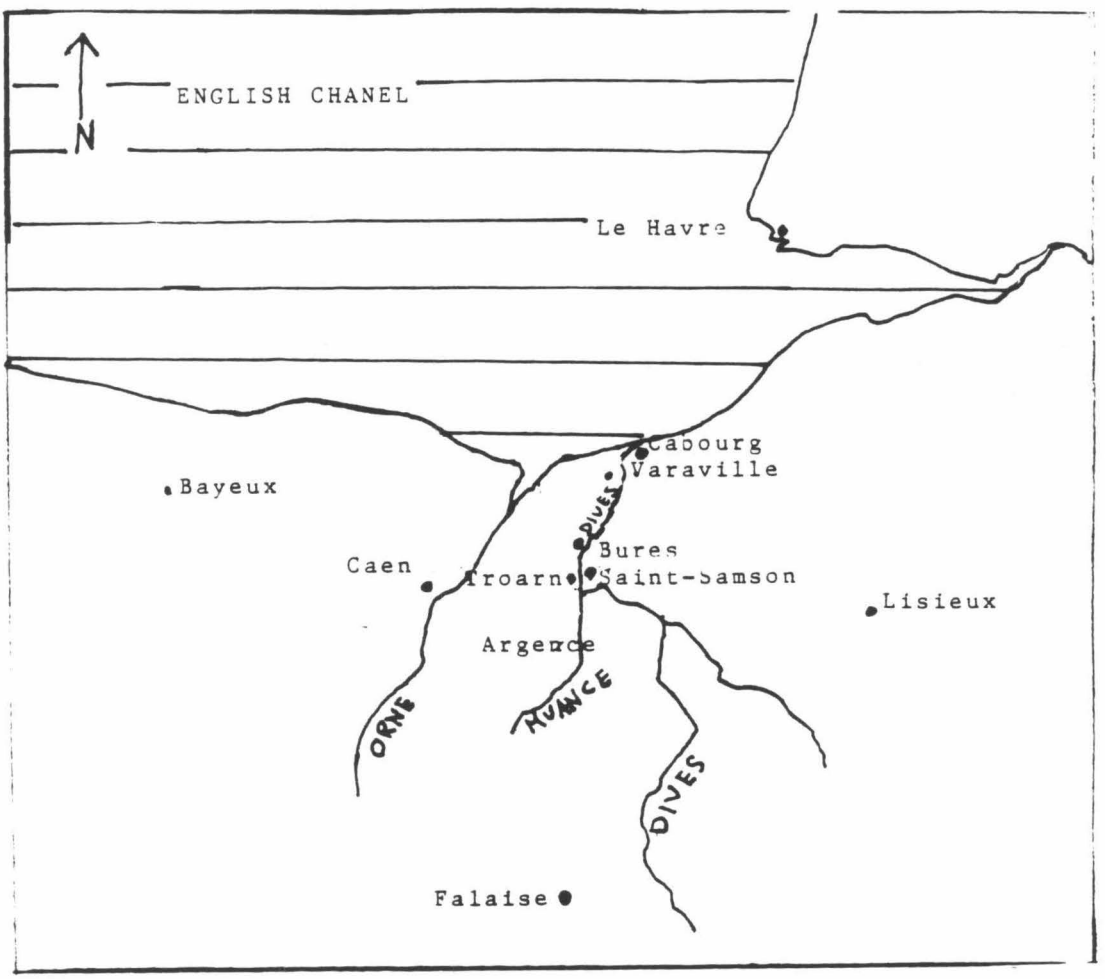


Figure 1

Land Labor Price Ratio, 1702-1870

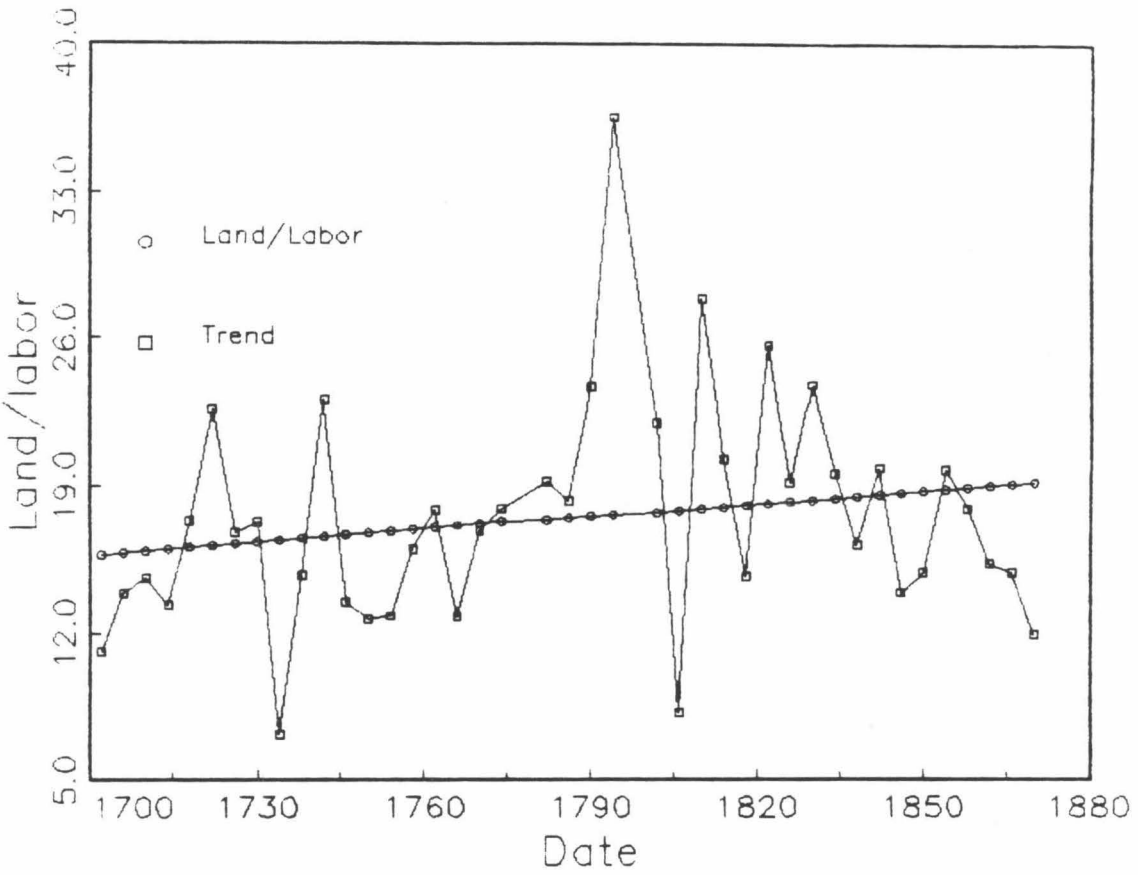


Figure 2

Estimated French Interest Rates, 1710-1870,

in % per year

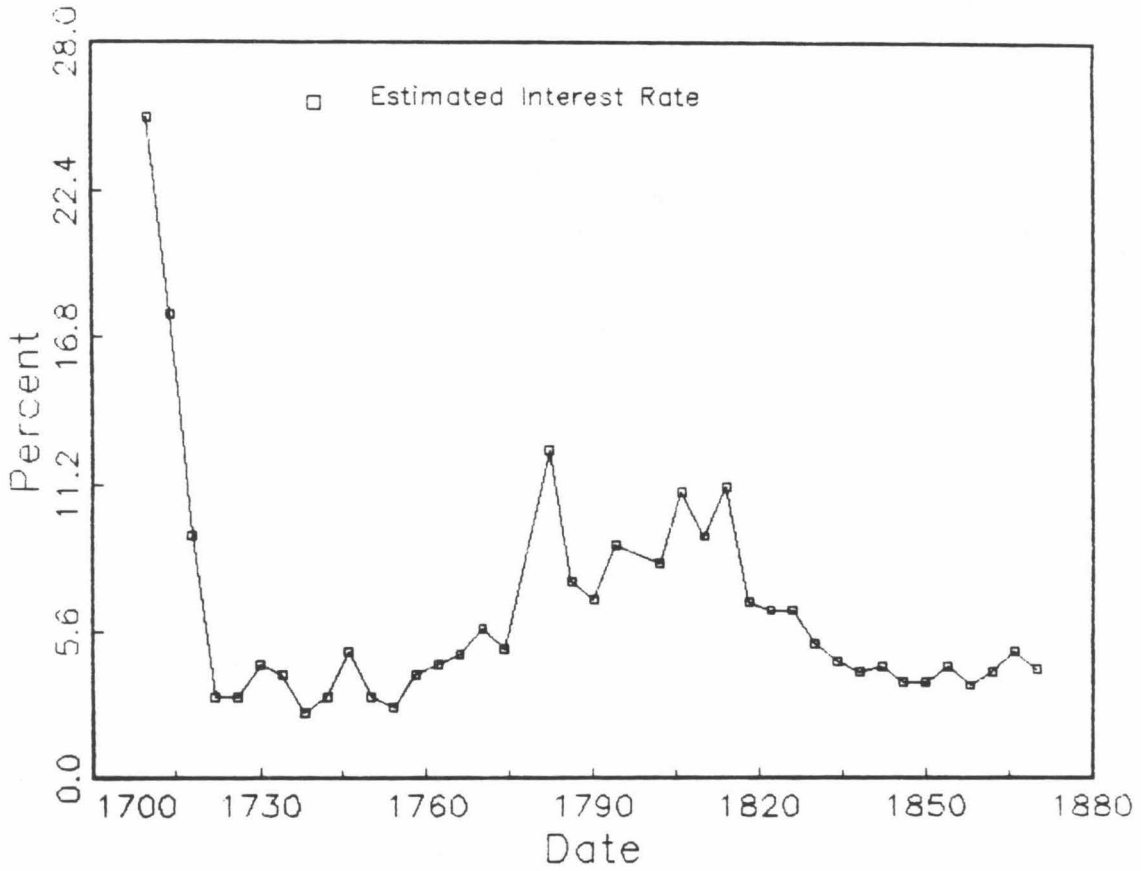
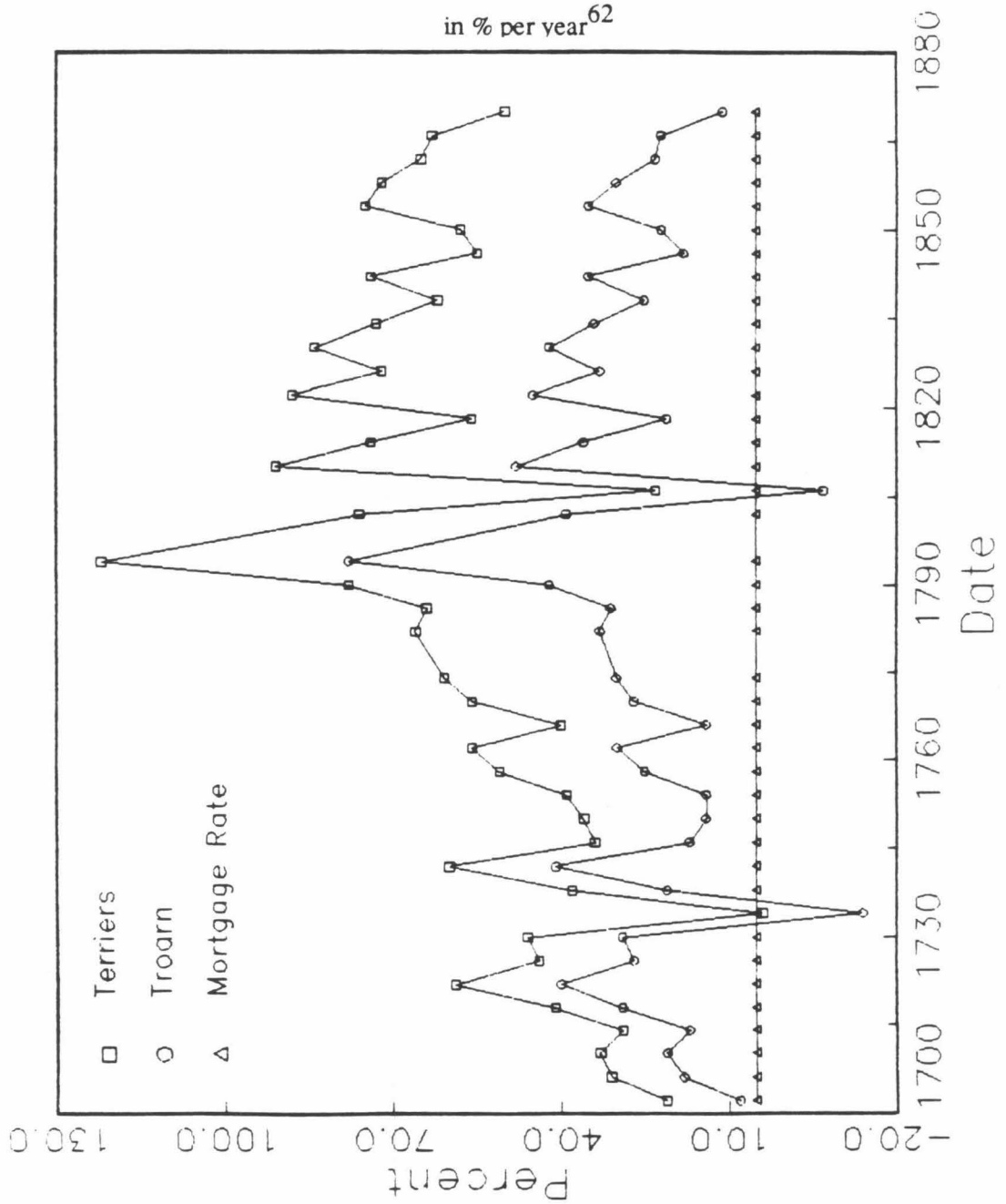


Figure 3

Rates of Return in the 5% Mortgage Rate Model, 1702-1870,

in % per year[62]

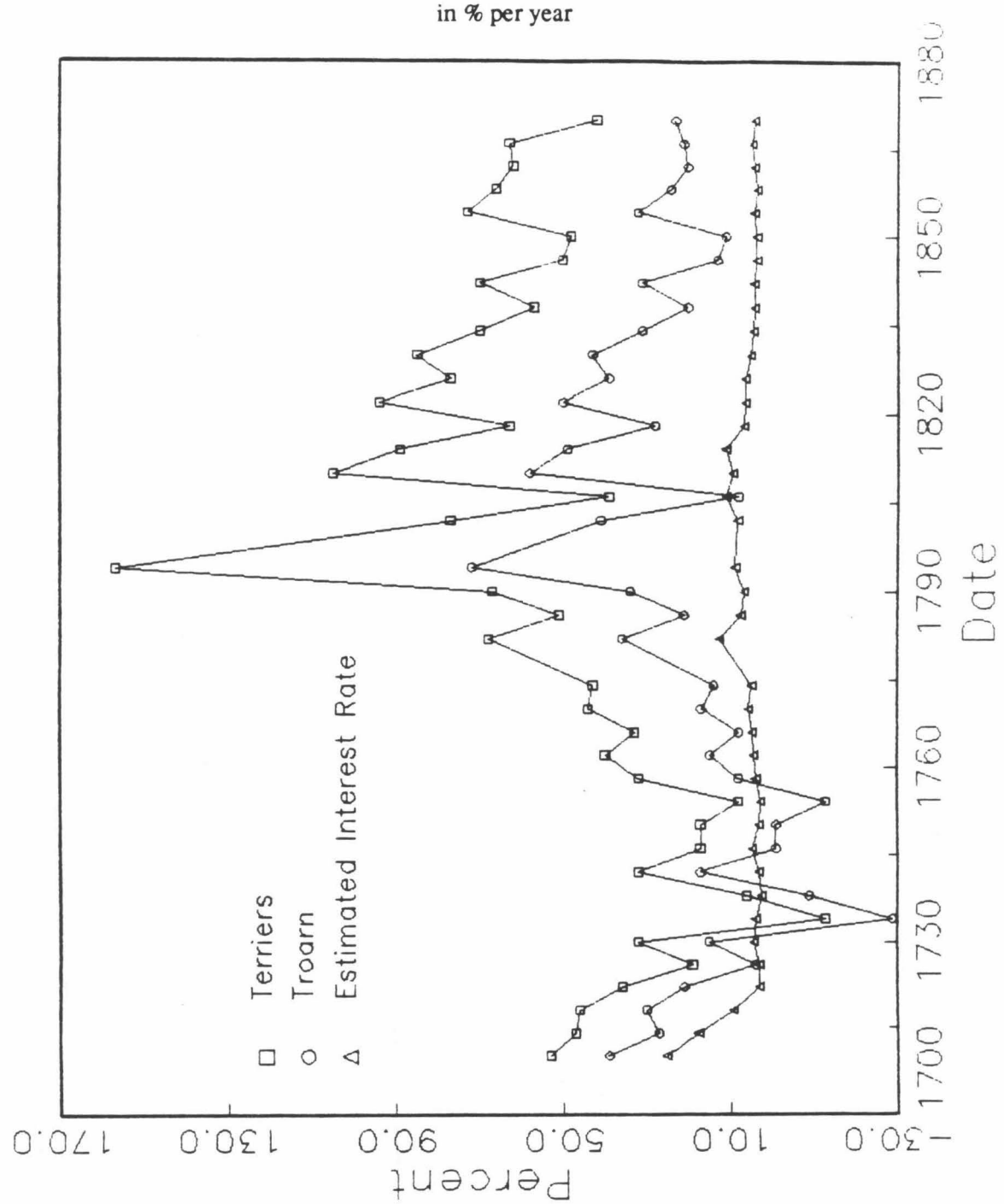


62) The interest rates were estimated from British data. For details see footnote 21.

Figure 4

Rates of Return in the Estimated Interest Rate Model, 1710-1870,

in % per year



Chapter 3

Irrigation in Provence 1700-1860:

The Costs of Divided Authority

Introduction

In this chapter I argue that institutions rather than technology or relative prices blocked the development of agriculture in southeastern France, and I show how specific political and judicial institutions throttled economic growth. Institutions were important to irrigation for two reasons. First, property rights were uncertain and the judicial system was responsible for resolving problems with overlapping or conflicting property rights. Second, irrigation projects faced severe revenue problems independent of their social profitability. These revenue problems were due to the inability of developers to commit to announced prices for irrigation rights and they are best modeled in terms of a durable goods monopolist problem.

The first section of the chapter presents the issue and argues that irrigation networks built after 1765 significantly raised agricultural output in southeastern France--specifically, in the area of Provence that is today the departments of the Vaucluse and the Bouches du Rhone. The second part confronts the question of technology and demonstrates that such irrigation networks could have been built profitably prior to 1765. the third part analyzes the market failure of the early eighteenth century, and the fourth traces institutional changes in the second half of the eighteenth century that permitted limited irrigation development before the French Revolution. The fifth part examines the institutional changes associated with the French Revolution and their consequences: the significant development of irrigation in the nineteenth century.

For the agriculture of southeastern France, irrigation may well have been the most important improvement of the eighteenth and nineteenth centuries.[63] Promoters, public

63) For other parts of France other improvements, such as drainage or enclosures, might have been more important. Even in Provence other productivity-increasing innovations may have been available, but irrigation was the one most often promoted in the eighteenth and in the nineteenth century.

officials, and commentators, both in the eighteenth and nineteenth centuries, agreed that the prosperity of southeastern France depended on irrigation. An eighteenth-century historian, Fornery, wrote:

> There is in Cavaillon [a small town in southeastern France] considerable commerce in artichokes, green peas, garlic and very beautiful fruits. The water of the Durance is responsible for this rich produce. This water, as we said above, admirably enriches the soil and the inhabitants [of Cavaillon] make a great profit from it. . . If the river itself [the Durance] is dangerous, its water by contrast is excellent. It carries silt so rich that it makes the most meager lands fertile. The canal of Oppede, which distributes water [from the Durance] to a good share of the territory of Cavaillon, is responsible for the best produce in the region, and this justifies what I said about the extreme utility of building a great irrigation canal across the province.[64]

In fact, the example of Cavaillon was frequently used to argue for further irrigation development both in the eighteenth and nineteenth centuries. Fornery's praise of irrigation was echoed by Villeneuve, the prefect of the Bouches du Rhone in the early nineteenth century:

> The advantageous results of this operation [the building of an irrigation canal] can not be doubted. The fact that the territory of eighteen communities has been fertilized to such an extent that the value of their land has doubled is a striking proof of its value. . . Under a burning climate where sometimes nine months go by without rain, where the northwest winds blow so frequently, where the limestone or sandy soils are made even dryer by the deforestation of the mountains, irrigation is a necessity. This is something one cannot repeat enough: all the efforts of farmers tend toward irrigation and it should be the goal of every improvement in Provence.[65]

Irrigation increased agricultural productivity by allowing farmers to abandon the traditional one year-crop, one year-fallow rotation. With irrigation farmers could grow crops every year because the silt carried in the irrigation canals is a natural fertilizer. Alternatively, if the

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64) Joseph Fornery, *Histoire du Comtat Venaissin*, vol. III, Dictionaire Géographique. Avignon: Seguin et Roumanille, 1903, pp. 501-502. Fornery's words were echoed in the regional assembly when a new irrigation canal was proposed, cf. AC Vaucluse, C 48.

65) Villeneuve, *Encyclopédie des Bouches du Rhone*. vol. III, Marseille: Ricard, 1825-1829, p. 714.

fallow is abandoned and fertilizer increases, one can have two crops a year instead of one. Furthermore there is a greater choice of crops that can be grown when irrigation is available than when it is not. Thus productivity per acre should double. The land price series also bear this out--the price ratio of improved land to unimproved land averages 1.8 between 1815 and 1855.[66]

When land becomes irrigated total factor productivity increases less than productivity per acre, for farming methods do not change substantially and as a result inputs other than land also double to produce two crops a year. Using sharecropping contracts we can get an estimate of the factor shares of all inputs.[67] Sharecropping contracts, for both irrigated and unimproved land assigned half of the output to the renter, who provided the labor, and the other half to the owner of the land. In these contracts the shares of the other variable inputs (capital) provided by renter and landowner is uncertain. If we assume that the renter provided all the capital, we can get an upper bound on total factor productivity change. If the renter provided all the capital, even split share contracts imply that the value of all other inputs is equal to the value of land. The proportions of output assigned to renter and owner were the same whether land was improved or not suggest that inputs other than land increased by the same proportion as output.

Total factor productivity can be calculated using different formulas corresponding to different assumptions about the production function under study.[68] Here I report the result for

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66) The land price ratio was calculated from a sample of data from rental and sale contracts for land that I collected. The sample will be discussed further in the second section. One should note that eighteenth- and nineteenth-century supporters of increased irrigation estimated the rent increase to be 100%. Biases in the sampling method lead to a low estimate of the price ratio for two reasons. First, the prices were collected from land sale records and sorted according to location, an imperfect measure of irrigation, thus some unirrigated land appears in the irrigated series and vice versa. Second, irrigated land prices are gross of capitalized maintenance fees (10% of the value of land historically). Thus the actual price of irrigated land was higher than it appears, for more details cf. Part 2.

67) Data from a small sample of share contracts was collected along with the land price data. This sample as well as the cash rental contracts give much information on agricultural practices, if when land was not irrigated the rule was to fallow every other year, when was irrigated (*ferrage*), it was cultivated continuously.

68) See Robert Allen, "Recent Developments in Production Cost and Index Number Theory, with an Application to International Differences in the Cost and Efficiency of Steel Making in 1907/9," *Historish Sozialwissen-*

two such assumptions. If we assume that the production function for agricultural output is Leontief then the total factor productivity change due to irrigation was 33%. If we assume that the production function for agricultural output is Cobb-Douglas, and that the factor shares were one-half for variable inputs and one-half for land, then the total factor productivity change due to irrigation was 41%. Clearly in agriculture land is a substitute for labor, a fact that gives weight to the second estimate. Therefore the total factor productivity change due to irrigation was probably above 33%, a very substantial figure.

To understand the effect irrigation had on total output we must look at the geography of what is today the two departments of the Vaucluse and the Bouches du Rhone in southeastern France (see Map 1 in Appendix 3). The river Durance flows between the two departments with the Vaucluse to its north and the Bouches du Rhone to its south. The southern and western parts of both departments are composed of alluvial plains which are easily irrigable. In the middle of this area and on the northern bank of the Durance is the town of Cavaillon, from which much of the data--in particular, the land price series--are drawn.

The single most important source of water in the area for irrigation was, and remains, the Durance river. Although the much larger Rhone rivers flows through the area, it cuts below too much of Provence to provide affordable irrigation. That leaves the Durance, which provided roughly 92 cubic meters per second at its lowest point in the summer and often flooded in the winter. In the twentieth century the French electrical utility built a large number of dams that regularized the flow of water, and increased capacity during the dry months. Such modern investments have allowed further development of the irrigated area, but while they were available before 1900, they were not used in the nineteenth century because they were too

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schaftliche Forchungen des Zentrum fur Historische Sozialforschungen. Baud 15, Stuttgart: Klett-Cotta, 1983, pp. 90-99.

expensive. As a result, the area irrigated in the 1860s was close to the maximum.[69]

Barral's studies of irrigation in the Vaucluse and the Bouches du Rhone, published in 1876 and 1878 respectively, offer good data to analyze the chronology of irrigation in the eighteenth and nineteenth centuries. In 1875, the total area irrigated for both departments was estimated at at least 57,000 hectares, or 16% of the total cultivated area.[70] In 1760, the Vaucluse had less than 12,000 hectares of irrigated land and this area had been irrigated since the late Middle Ages. However, by 1789, irrigated land had increased to 14,600 hectares and by 1870, to over 20,500 hectares. Nearly all these increases were achieved by drawing from the Durance. Thus the area irrigated from the Durance more than doubled between 1760 to 1850, going from under 4,000 hectares to 12,400 hectares.[71] The data on the Durance is reliable because at the Revolution the canals were all organized into *associations*. In case of drought, the priority of claims on water from the Durance was based on the date of construction of the canals, with the oldest receiving his allocation first.[72] The standard allocation was a liter of water per minute per hectare, thus both date of construction and area of irrigation were carefully recorded.

The data allows us to estimate the change in agricultural output as a result of the

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69) After the Revolution, the French government began to closely monitor water use through the *Ponts et Chausseés* administration. Barral used their data to compile his two books on irrigation in the region in the 1870s. See Jean Auguste Barral, *Les Irrigations dans le Département de Vaucluse*, 2 vols, Paris: Imprimerie Nationale, 1877-1878 and, idem, *Les Irrigations dans le Département des Bouches du Rhone*. Paris: Imprimerie Nationale, 1876. See also Villeneuve, *Encyclopédie*, vol. III, and AD Vaucluse, I Doc., 121. Dams were first built in the South of France for the canal of Languedoc in the late seventeenth century and in Provence for an urban canal between 1857 and 1860 (see Paul Masson, "Le Canal de Provence," in *Revue Historique de Provence* 1, 1901, pp. 350-359 and 421-437; and André Maistre, *Le Canal Des Deux Mers, Canal Royal du Languedoc, 1666-1810*. Toulouse: Privat, 1968), but they were not used for irrigation until the twentieth century.

70) 140,000 American acres. Total cultivated area in the Bouches du Rhone and the Vaucluse was 356,000 hectares or 880,000 American acres. Barral, *Les Irrigations dans le Vaucluse*, pp. 323-334, idem, *Les Irrigations dans les Bouches du Rhone*, pp. 83-87, 511-512.

71) The irrigated areas for 1789, and 1760, were calculated by subtracting from the known 1870 totals, the area irrigated from canals built between 1789 and 1870, and again from those built from 1760 to 1789.

72) AD Vaucluse, I doc. 221.

development of irrigation after 1760. To evaluate total output changes we must know the increase in area irrigated, not only for the Durance in the Vaucluse (a figure that is available), but also from other sources, and in the Bouches du Rhone. The increase in irrigation from other sources is not known precisely, but it can be estimated. I did so under three different hypotheses, the first being the most conservative and the last the most optimistic. The conservative estimate assumes that increases in irrigation other than from the Durance in the Vaucluse were negligible. This scenario is unduly pessimistic--it underestimates the increases in irrigation because a number of other projects did occur. The second assumes that the Durance was the only source of increases in irrigation and that the Bouches du Rhone's increases were of the same proportion as those in the Vaucluse. This hypothesis is still conservative because most of the irrigation development in the Bouches du Rhone, except for the canal of Craponne, occurred after 1760, but it is no doubt closest to the truth. The final estimate assumes that the ratio of irrigation from the Durance developed after 1760 to all irrigation from the Durance in the Vaucluse is the true measure of the growth in irrigated area in the whole area. This last estimate is optimistic because other sources of water, such as the Sorgues, were already well used in the early eighteenth century. The other necessary data are the increases in output per hectare due to irrigation, they can be taken to be either 80% (using land price ratio estimates) or 100% (from eighteenth- and nineteenth-century sources). Table 3 below displays the output change calculated as the change in output per hectare times the ratio of increases in irrigated area to total cultivated area.

			Total output Change	
Hypothesis	Acreage Change In Hectares	Acreage Change In Percent	Irrigation Output/Hectare Increase=80%	Irrigation Output/Hectare Increase=100%
Total Increase Equal to Known Increase	14,500	4.0%	3.2%	4.0%
Total Increase in Proportion to Increase in the Vaucluse	23,630	6.5%	5.2%	6.5%
Total Increase in Proportion to Increase in Durance use	38,850	10.8%	8.7%	10.8%

Table 3
Estimates of Output Increases due to Irrigation

Output over all the cultivated area of the region thus seems to have increased from 5% to 7% as a result of the extension of irrigation between 1760 and 1860. Qualitatively it is important to note that land improved as well, for irrigation allowed farmers a wider variety of crops. Most important of all, in the eighteenth and nineteenth centuries, irrigation was the only improvement that eliminated the biennial fallow in southern France. It is no wonder that the productivity increases that came in irrigation's wake were quite significant.

The benefits of irrigation were well known long before 1765, when the development of irrigation began to accelerate. Indeed, some of the canals of southeastern France dated back to the Middle Ages.[73] Ignorance could not have been the obstacle to irrigation in the early eighteenth century, and we thus must look elsewhere to explain why it developed so slowly before 1765. One simple answer is it was simply not profitable to carry out irrigation schemes before 1765. To examine this hypothesis, we must turn to the issue of hypothetical rates of return.

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73) The canals of Saint-Julien in Cavaillon and l'Hopital in Avignon were built in the thirteenth and fourteenth centuries. See Map 2 in Appendix 3.

Relative Prices and Profitability

The most plausible explanation to the lack of irrigation in the early eighteenth century was that the returns to irrigation were low before 1760 and rose thereafter because of relative price changes or institutional reform. Using data from projects built both in the eighteenth and nineteenth centuries, we shall see that relative price changes were not the determining factor in the timing of irrigation development, but before doing so, we must first examine the issues of technological change and credit.

Technology

The technology of irrigation raises three important issues. First, we must define what were the important inputs in canal construction. Second, we must determine whether the techniques of irrigation canal building changed between 1700 and 1860. If there were significant changes in canal construction techniques, then the effects of that change on costs would have to be taken into account when estimating hypothetical rates of return. Third, we must examine the risks involved in canal building. If risks were high, premiums might be necessary to attract investors to the development of irrigation networks

The level of technological sophistication of irrigation projects in use today varies greatly, but in the eighteenth and early nineteenth centuries the technology of irrigation was quite simple. Throughout the period, the primary inputs to canal construction were land, unskilled labor, and skilled labor. Although after 1880, dams and lined main canals (to avoid seepage losses) were increasingly used in water projects in southeastern France, before this date canals were unlined, and all water flowed by gravity. It also seems that the technology used to build irrigation canals was very simple, and had little to do with the sophisticated techniques that evolved with the rise of transportation canals. Indeed by the middle of the eighteenth century transportation canals in France involved locks, dams, bridges and complex

water management.[74] None of these techniques affected irrigation, even in the nineteenth century. One reason was that as late as 1870, much more land could have been irrigated using such simple technologies, had there been water in the Durance to draw. Thus, except for a few bridges where skilled labor and other inputs were required for stone masonry, irrigation projects thus required mostly unskilled labor for digging ditches.

As one might gather from the simplicity of the inputs, technical change in irrigation canal construction was insignificant. For irrigation canals, construction techniques changed very little until late in the nineteenth century. Other techniques were available, but they were not used in irrigation construction because they were too costly. The technological stasis in canal construction may well have extended back well before the eighteenth century. The techniques used in the eighteenth and nineteenth centuries were, from a technological perspective, similar to those used to build the canals of Saint-Julien and l'Hopital, both constructed in the thirteenth century, or the canal of Craponne built in the sixteenth century.[75] From the thirteenth to the nineteenth century, all these canals were unlined dirt ditches, where water flowed by gravity alone. The only dams in use, which captured the water from the Durance river, were flimsy dirt levees, and they had be rebuilt frequently. These dams only diverted part of the flow of the river but made no attempt to retain water behind a reservoir. Stone masonry was used only for bridges.

Further proof of the absence of technical constraints on irrigation development is the canal of Boisgelin. Begun in 1773, it was to become over a fifty year span of intermittent construction the largest project in the Bouches du Rhone during the early nineteenth century.

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74) A valuable contemporary source on eighteenth-century canal technology is Delalande, *Des Canaux de Navigation.* Paris: Dessaint, 1777. See also Andre Maistre, *Le Canal des Deux Mers* chapter 3.

75) Jean Rigaud, *Le Canal de Crapone. Etude Historique et Juridique Relative aux Concessions Complexes des Arrosage Communaux d'Istre et Grans.* Aix en Provence, 1934; Roget Caillet, *Le Canal de Carpentras.* Carpentras: Imprimerie Batailler, 1925, chapters II and III.

Politics demanded that the canal go through the rock of Orgon in a long tunnel that took ten years to build and was extremely expensive.[76] By the French Revolution no significant amount of water had flowed beyond Orgon, although some irrigation did occur above the town. The architect and director of the project, Brun, resigned over the issue of the building of the tunnel. In the nineteenth century, promoters of further development ascribed the canal's disastrous financial situation to the ill-advised decision to continue digging through the rock of Orgon. Indeed, a slightly longer route would have allowed the canal to bypass Orgon and made the project much cheaper.[77] Until 1860, no other irrigation canal ever made use of tunnels or dams, in fact none were necessary as there was much land that could be irrigated without such expensive investments.

The returns to agricultural development could probably not have supported very expensive and innovative technologies. In contrast to the low levels of technological sophistication utilized in agricultural projects stands a set of urban projects that overlap both geographically and temporally with those under study. As urbanization progressed in the nineteenth century, the demands on the water supply outside agriculture increased and some projects had two functions: one agricultural and the other urban. The construction of the canal of Marseille (1840-1848), a joint urban and rural water supply project, offers a good example of the technologies that were available in the middle of the nineteenth century but that were not used in agriculture. The canal of Marseille featured a large dam and a permanent reservoir, many bridges, and was underground for 25% of its length. The project was financed by the city of Marseille, which attempted to sell excess water to landowners. The city also wanted the farmers to pay a

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76) The tunnel swallowed over 50% of all the expenditure on the canal prior to the French Revolution. BM Méjanes, Ms. 834(848) and AN H^1 1261

77) Villeneuve, *Encyclopédie*, vol. 3, pp. 714-718.

share of the building costs equivalent to their share of the water. This led to a price for water 15 times the cost of water on other agricultural projects. As a result, the scheme to retail excess water to farmers failed and the only buyers were produce growers who supplied the town market.[78]

The final issue concerns technological risk. Although irrigation technology did not change, it is possible that over time learning by doing led to smaller engineering errors. The resulting reduction in technological risk would affect investor's decisions because investors might have demanded premiums if the technological risks were high. Yet, if we define technological risk as the risks associated with the construction phase of the project, then that risk was very limited. Even in the eighteenth century, the relationship between technology and cost was well established. Engineering costs could be predicted with a good deal of confidence because of the experience gained from transportation canals, which were much more demanding technologically and thus riskier. Irrigation projects were by contrast quite simple, even when there were unanticipated delays and costs with projects,[79]

It thus appears that between 1700 and 1860 technological change in irrigation canal construction was limited, and the canals developed from 1760 to 1860 are all similar technologically. Technological risk did not threaten irrigation projects. Neither risk nor technology therefore constrained the supply of irrigation. Why then did water remain unused until past the 1850s? The answer clearly lies beyond the simple issue of technology.

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78) Paul Masson, *Encyclopédie des Bouches du Rhone*, Vol. 7, Paris: Honore Champion, 1929-1930, pp. 162-167. The total length of the canal was 100 kilometers and it was underground for over 25 kilometers. This canal ran through the most rugged part of eastern Provence to deliver water to Marseille.

79) The history of the canal de Boisgelin shows that risk was small. The canal of Boisgelin was the most ambitious canal realized prior to the Revolution. The engineer, Brun, had warned of the very large costs associated with the tunnel necessary to go through the rock of Orgon. He did not, however, doubt that the tunnel could be built. a later section will discuss the political and institutional factors that raised costs on the canal of Boisgelin, cf. BM Mejanes, Ms. 840(853).

Credit

Since the construction of irrigation canals involves significant outlays of capital, credit was very important for irrigation development. One reason for the lack of canal building in the eighteenth century might therefore be insufficiently developed capital markets. This argument appears plausible because Old-Regime France lacked a well-developed, centralized, government credit market, and there were nearly no banks.[80] The absence of a well-established government credit market raises questions out of the scope of this paper. Yet the absence of institutions commonly associated with credit markets suggests an institutional failure--in the case of the absence of a government bond market, the unreliability of state as a borrower--rather than the absence of capital. Furthermore, I want to argue that the credit problem is largely moot in the case of irrigation.

Although the French state found it increasingly difficult to borrow money in the late eighteenth century, some local institutions, such as estates and city councils, were successful in bonding themselves and they could borrow significant amounts of money. They could gather credit for the state and for public works projects, as the case of the canal of the Midi demonstrates.[81] Similar institutions existed in southeastern France in the eighteenth century, and they did play an important role in the financing of some irrigation canals.

In addition to public sources of capital, well-developed credit markets existed in rural

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80) See Pierre Goubert, *L'Ancien Régime*, vol. II, chapter 7 for an introduction to French finance in the eighteenth century. For a deeper investigation of eighteenth-century credit, see Guy Chaussinant-Nogaret, *Les Financiers du Languedoc au XVIII^{eme} Siecle*. Paris: S.E.V.P.E.N. 1976.

81) The canal of the Midi was primarily financed by the estates of Languedoc through loans. The project was promoted by the state, which negotiated with the estates for their support. The state did not have the capital to support the construction of the canal and its credit reputation was poor. The estates by contrast could easily borrow the money necessary to build the canal. See Robert Forster, *The Nobility of Toulouse in the Eighteenth Century: A Social and Economic Study*. Baltimore: Johns Hopkins University Press, 1960, pp. 66-74; William Beik, *Absolutism and Society in Seventeenth Century France, State Power and Provincial Aristocracy in Languedoc*. New York: Cambridge University Press, 1985, pp. 292-297; André Maistre, *Le Canal des Deux Mers*, Chapter 4.

France. These markets were based on mortgages of land and other immovables, which had low default risk. Furthermore, in the case of southeastern France, there were at least two other sources of funds for irrigation projects: Jews and the high nobility. There is evidence that Jews were directly involved in making loans to at least one developer. These loans did not have the collateral of land, and the developer paid an interest rate double that of the mortgage rate--10 to 11% as compared to 5%. The high nobility was also able to finance projects directly in the case of many of the smaller projects. The high nobility put its vast wealth resources at the disposal of canal developers in other instances as well, perhaps because irrigation development did not carry the stigma attached to many other forms of investment.[82]

Finally, in the case of agricultural improvements it is important to note that the single largest source of capital in France, landowners, could be mobilized outside any credit market. Indeed there existed a number of contract alternatives that avoided Old-Regime institutional problems such as state confiscation. The most obvious of these alternatives were joint stock arrangements that were attempted in the case of irrigation.[83] The reasons for the failure of these alternatives can not be ascribed directly to issues of credit availability and will thus be explored in the third part of this paper. Therefore, it appears reasonable to assume in the hypothetical profit calculations that there were sufficient sources of capital (though not necessarily market sources) to carry out the irrigation projects.

Data

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82) See Paul Masson, "Le Canal de Provence" pp. 423-425; Elie "La Spéculation sous la Régence: l'Affaire du Canal d'Avignon à la Mer," in *Provence Historique*. 3 (1953), pp. 112-113; Reboulet "Construction du Canal de Crillon," in *Mémoires de l'Académie du Vaucluse*. 1914, pp. 46-47 in the case of the canal of Crillon, 25% the construction costs were loaned by Jews and another 25% by nobles, bourgeois and landowners.

83) Landowners were the largest source of credit in France because they could borrow money through mortgages. Had developers been able to interest more than a small number of landowners ex ante, the credit problem would never have existed.

To establish that irrigation projects would have been profitable before 1760, I have estimated the level of hypothetical profits that projects, realized after 1760, would have earned had they been started earlier. The results will be presented under two forms: rates of return and cost benefit ratios. The calculations require two kinds of data--price series for the inputs and outputs of canal construction and factor shares for each canal. The data for factor shares is available from published sources on canal construction. These sources give sufficiently detailed accounts of the costs that it is unnecessary to go to the archival records, while the necessary wage and land price series were constructed from original archival data. The only other series necessary is one of interest rates. Unfortunately, time series of interest rates are lacking for the eighteenth and nineteenth century. One possible source of data is the mortgage market. Notarial records of land sales often contained mortgage rates. Since land sales were rarely paid in full, the seller would extend a mortgage to the buyer and the mortgage was often directly included in the sales contract. The mortgage rates from these land sales contracts remain stable at 5% through the period 1700-1855. An alternative method of estimating interest rates involves shadow interest rates constructed from nineteenth-century French data and from British consol rates that span the period.[84] I ran the calculations of rates of return and cost benefit ratios using both sets of interest rates, and the results do not depend on which series of interest rates is used in the calculations.

I was able to construct two different wage series for labor. The data is centered on Avignon, a town 15 miles from Cavaillon where the land price series was collected.[85] The labor data consists of wage bills from the account books of religious institutions and municipal

84) cf. Chapter 2, p. 22, footnote 21.

85) For any year the wages are identical across sources in the area. This correlation suggests a considerable labor mobility and allows me to use data from two different towns.

offices for unfed labor.[86] The data are relevant for this study because they are drawn from the very professions involved in canal construction and maintenance. Religious institutions, whose account books I used, were part owners of medieval canals and they hired some of the labor used for maintenance work on these canals. The data have been sorted into two series: skilled and unskilled workers (see Figure 5 and Table 7, at the end of the text). The first, unskilled labor, is composed of agricultural laborers, road gangs and levee maintenance workers. The second is composed of skilled workers: masons, carpenters, miners, and gang bosses.[87]

Because canal and other construction accounts do not break down the costs in a very detailed fashion (except in the case of labor where the accounts are more specific) it is difficult to get time series for such things as quarried stone, lime, wood and other material inputs. However the since material inputs other than labor were only used on bridges and other necessary buildings, land and labor composed nearly all the costs of canal construction. Therefore, wages will be our deflators of the input costs of canal construction other than land. Our deflator for the price of output (revenue) will be the difference between the price of irrigated land and the price of dry land. The series come from Cavaillon, the community with the largest amount of irrigated land in southeastern France both in the eighteenth and in the nineteenth century. The choice of Cavaillon allows us to ignore any local market effects on the price of improved land. If anything, the fact that Cavaillon had more land irrigated than other areas should lead to a

86) Most of the workers were employed by religious institutions that received food was paid not on a *per diem* basis, but on a monthly or yearly basis. Not knowing how many days a year's wages consisted of for any given year I did not use wage bills of workers who received food as part of their compensation.

87) The data also reflects partially at least the extraordinary levels of inflation associated with the French Revolution, unlike most series previously published. One excellent source for wage data is René Baehrel, *Une Croissance, La Basse Provence Rurale (1650-1789)*, Paris: S.E.V.P.E.N., 1962. Baehrel's data unfortunately stop in 1789. The sources used for wages were AC Avignon, CC 550 to CC 805; AD Vaucluse, H Bompas 182-185; H Cordeliers Avignon 62-64; E Ste Marthe E 103, BM Cecano, Ms 5659; and A. Chabert, *Essais sur le Mouvement des Revenus et de l'Activité Economique en France de 1789 à 1820*. Paris: De Medicis, 1930, pp. 250-260.

downward bias in the price of land irrigated and thus to an underestimate of potential canal revenues.[88]

The data for the land price series are taken from a sample of land-sale and land-lease contracts that were negotiated between 1700 and 1855. The sample comes from notarial archives. This kind of data has already been described in Chapter 2 but the series for irrigation are superior because the notarial archives are more plentiful in the Vaucluse than in Calvados. Indeed, although the area of Cavaillon is smaller than the area covered by the sample in Calvados, the local notary always had more contracts in every year than the one for Troarn.[89]

There were at least four active notarial *études* (practices) in Cavaillon between 1700 and 1855. However, gathering the complete set of land contracts for Cavaillon from 1700 to 1855 would have taken at least two years' research. Sampling was therefore necessary. The data is a complete sample of both land sale and land rental contracts from one *étude* once every five years from 1700 to 1855. From 1700 to 1720 I sampled two *études* because the first had too few land contracts. The total sample of observations contains 1781 contracts.

To obtain both an irrigated and a non-irrigated land price series, it was necessary to distinguish sales and rental of irrigated land. Until 1800, such sorting was relatively easy since the contracts all contained detailed information about the quality of the land. However, during the French Revolution, notaries ceased recording such information regularly. What I had to do therefore was to rely on location data to distinguish between irrigated and dry land after 1800.

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88)In eighteenth-century France transportation costs were high, if irrigation projects delivered water to areas that had none, goods that had to be imported at a high costs might become produced locally. These goods, such as fodder, might have commanded a very high price. At least 15% of the area of Cavaillon was irrigated before the eighteenth century. The large area irrigated suggests that most irrigation specific goods would have commanded only a competitive price.

89) The relative abundance of data in Provence can be ascribed to two factors. First, notarial activity was older and better established in the South than in the North of France. Second, the average field was smaller in the South (an area of diversified agriculture) than in the North (an area primarily devoted to cattle raising), and there were a series of large estate break ups in Cavaillon in the middle of the eighteenth century.

Such sorting by location is imperfect, making the irrigated series a downward estimate of irrigated land prices and the dry series an upward estimate of the price of dry land after 1800.

The land prices were estimated using a simple procedure that allowed to take into account data from both the rental contracts--that predominated in the eighteenth century--and the sales contracts--that predominated in the nineteenth century. For rental contracts the value of a transaction was computed by capitalizing the rent using the mortgage rate. For sales the value was simply the price. For each year and for each type of land (dry or irrigated), average prices were calculated as the sum of the value of all transactions divided by the sum of the number of ares (0.024 acres) sold for each type of land. Each of the 64 estimated prices rely on at least 15 contracts. The series are displayed in Figure 6.[90]

To calculate hypothetical profits I also needed data on the specific costs and revenues of the canals that were built in both the eighteenth and the nineteenth century. The costs include both the amount of labor expended and the amount of land used. The revenues associated with the supply of irrigation are equal to the increase in the value of all the newly irrigated parcels. The data is available for two eighteenth-century projects (Cabedan-Neuf and Crillon) and for two projects proposed in the eighteenth century but not realized until the nineteenth (Plan Oriental, Carpentras).[91] While there is insufficient data to estimate profit from most other eighteenth- and nineteenth-century projects, the canals for which data is available are representative of all canals built in the eighteenth and nineteenth century, in terms of size, location, and timing. The canal of Carpentras is as large as any other canal in Provence and the

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90) Figures and maps are displayed in Appendix 2, all the data appears also in tables in Appendix 2.

91) The canal of Cabedan-Neuf irrigated 600 hectares in and around Cavaillon and was built from 1764 to 1766; the canal of Crillon irrigated 1,000 hectares around Avignon and was completed in 1777. The canal of Plan Oriental was another canal in Cavaillon it watered 800 hectares to the north of Cavaillon, and was built in 1823. Carpentras was a very large canal built in the 1850s that irrigated more than 4,500 hectares.

smaller Cabedan, Crillon and Plan Oriental are representative of most other projects, all the canals are displayed in Maps 2 and 3, in Appendix 2.[92]

Actual cost figures were allocated, between construction, digging and land. Clearly, land and labor (skilled and unskilled) were not the only inputs of canal construction, however these three inputs were the most significant, and they were the only ones for which price series could be constructed. Moreover canal construction accounts rarely itemized costs beyond excavation (*terracement*) and skilled construction (*ouvrages d'arts*). As the former was done by unskilled labor, I divided the those costs by the wage for unskilled labor for the period in which the project was carried out to get an an estimate of the quantity of labor employed. Skilled construction involved the building of bridges for roads over the canals and aqueducts for the canal over small rivers and valley, such jobs were clearly the domain of skilled masons and stone cutters. I assigned all skilled construction and administrative costs to skilled labor, an assignment that greatly simplified the rates of return calculations. The simplification is acceptable--if we assume that there were no significant changes in the demand for stone--because the primary input of skilled construction other than labor was quarried stone. Quarrying was an extractive industry that required only skilled labor, and some transportation, thus the cost of quarried stone should closely follow the price of labor. An estimate for the quantity of skilled labor employed was derived in the same fashion as for unskilled labor except that the wages of skilled labor were used.

The amount of land required for canal construction was found by calculating the area covered by a band 15 meters wide and as long as the canal and its main branches. This procedure simplified our calculations, of the area occupied by canals. Canals decrease in width

92) The complete description of all the irrigation canals appears in J.A Barral's two works on irrigation in Provence: *Les Irrigations dans le Vaucluse* and *Les Irrigations dans les Bouches du Rhone.*

from beginning to end. The land occupied by a canal is the sum of the section of the canal plus the width of its banks. The choice of 15 meters as the width of the band occupied by canals biases profit estimates downward because even the main canal of Carpentras--the largest canal in my sample--was only 7.5 meters wide, and it occupied an area less than 17 meters across for the first quarter of its length. All the rest of the main canal was under five meters across, and occupied an area less than ten meters wide, and its branches were even smaller. All of the other canals were less than four meters at their widest and their branches were much smaller than that. The assumption that all canals were of the same width simplified calculations greatly. Moreover this simplifying assumption, by reducing the estimated profits, can only strengthen any finding that irrigation was indeed profitable before 1760.

			Canal Costs (in nominal terms)
Canal (date of completion)	Land Irrigated In Ares	Total Construction Costs	Capitalized Maintenance Costs
Cabedan Neuf (1767)	50,000	822,300	97,200
Cabedan Neuf (1767)	27,000	172,490	97,200
Crillon (1779)	100,000	400,000	400,000
Plan Oriental (1821)	59,000	138,595	100,000
Carpentras (1857)	500,000	5,297,011	100,000

Table 4
Canal Cost Data[93]

93) Sources for Table 3 are as follows. For the first estimate of the costs of Cabedan Neuf, J. A. Barral, *Les Irrigations dans le Vaucluse*, pp. 539-544. For the second estimate of the costs of Cabedan Neuf, Syndicat du Canal de Cabedan-Neuf, *Archives et Documents 1230-1883*, Cavaillon: Imprimerie Mistral, 1883 pp. 45-52. For the canal of Crillon, Reboulet, *Le Canal de Crillon* pp. 37-40; and J. A. Barral, *Les Irrigations dans le Vaucluse*, pp. 326-327. For Plan Oriental, André Martel, "Les Origines du Canal de Plan Oriental," in *Actes du Congres des Societés Savantes*. 1955, pp. 394-395; and J. A. Barral, *Les Irrigations dans le Vaucluse*, pp. 545-547. For Carpentras, R. Caillet, *Le Canal de Carpentras*, vol. 2, pp. 199-201; and J. A. Barral, *Les Irrigations dans le Vaucluse*, pp. 326.

		ITEMIZED COSTS		
Canal (date of completion)	Years Under Construction	Skilled Man-days per year	Unskilled Man-days per year	Land Requirements in Are
Cabedan Neuf (1767)	2	88,815	73,053	2,700
Cabedan Neuf (1767)	2	21,410	19,824	2,700
Crillon (1779)	3	35,088	41,190	4,950
Plan Oriental (1821)	2	63,561	46,631	975
Carpentras (1857)	6[94]	-	-	-
	first 3 years	61,341	224,242	9,666
	last 3 years	221,852	112,403	7,329

Table 5
Canal Construction Accounts

Tables 4 and 5 display in condensed form all the project specific data used in the construction of hypothetical profit streams. Although there are only four canals surveyed, they represent between 20% and 30% of the newly irrigated area.

Two more assumptions are necessary to simplify the calculation of profit rates. In the first place I disregarded certain revenues accruing to canals that are difficult to estimate. I also double-counted certain costs that are already partially taken into account in the price series. Both these assumptions bias the rates of return downward and make it more difficult to show that there was a market failure in irrigation and thus strengthen my findings.

The revenues I disregarded came from accruing from the sale of water power rights on the canal to mill owners. To be sure mills were an important source of revenues for some canals. They brought in revenues equal to one-sixth of maintenance costs on the canal of Crillon. Each large mill was itself worth above 20,000 livres in the eighteenth century or more than 5% of the cost of the canal.[95] The size and value of mills varied greatly and the value of a

94) Carpentras was a very large canal, for the first three years work was focused on the main canal and only in the next three years were branches built. Cf. R. Caillet, *Le Canal de Carpentras*, vol. 1, pp. 69-70.

96) AD Vaucluse, S *Usines et Cours d'Eau, Avignon*, canal de Crillon (1820). The series S was being classified and sorted at the time I looked through it thus no precise references can be given, however the canal of Crillon's archives in that series amounted to one box and Cavaillon's to six.

mill is only a partial indicator for the rent of the fall, which accrues to the canal owner. Therefore one would need not only the rental contracts of the mill but also their agreement with the canal, to know what they paid for the fall. The archival research effort to secure rental contracts would thus be very large for little gain. Obviously the omission will push my hypothetical rates of return downward.

The costs I double-counted were maintenance costs. Some maintenance costs already appear in the price of irrigated land. Indeed the price of a particular piece of irrigated land is equal to the discounted stream of profits from using that land minus the capitalized value of whatever maintenance costs are assessed on that land. If all canal organizations assessed all land uniformly there would be no need to double count maintenance costs. Such uniformity, though, was far from prevalent in Cavaillon, where each canal had a different organization dealing with maintenance. Each organization assessed landowners on a yearly basis for contributions, but they did not assess land uniformly, either over time or across parcels. Thus the land price series only reflect maintenance costs as assessed by the institutions governing canals in Cavaillon. It was clearly wrong to assume that the maintenance costs already affecting the irrigated price series are the correct ones for all projects. As a result it seemed best to assume that the price series reflected the discounted future revenues from land and account for maintenance costs explicitly. To do this and to simplify the calculation of internal rates of return I assumed that the developers created a sinking fund to pay for the future maintenance costs. One reason for this procedure is that it greatly simplifies the calculation of internal rates of return. The double counting of maintenance costs also created a downward bias in the rate of return estimates.

Hypothetical Cost-Benefit Calculations

The hypothetical cost-benefit calculations are displayed in Tables 8, 9, and 10 and in Figures 7, 8, and 9 in Appendix 2. I estimated both benefit-cost ratios and internal rates of return. The conclusions are identical and do not depend on which interest rate series was used for the calculations.

All projects were profitable during nearly the entire period under study. But, the projects were more profitable in the early eighteenth century when they were not carried out than in the nineteenth century when they were. Although some projects are always more profitable than others, changes in profit rates are similar over the entire period for each project so that the profitability of an irrigation canal did not seem to depend on the scale of the project. Because the hypothetical profits of projects built in the eighteenth century are similar to those of projects built in the nineteenth century, it is unlikely that changes in technology played a major role in irrigation development. Otherwise the later projects should have been much more profitable.

The highest profits come in the early eighteenth century (1700-1730). In fact, the projects were hypothetically more profitable during this period than during any subsequent one, as Table 6 below shows.

	Average Hypothetical Internal Rates of Return in Percent per Annum				
Period	1700-30	1735-55	1760-85	1790-1820	1820-55
Cabedan-Neuf (1767)	113.0	32.5	77.8	11.0	63.3
Cabedan Neuf (1767)	60.0	2.1	35.3	-16.0	24.2
Crillon (1779)	91.8	33.8	68.6	10.7	57.8
Plan Oriental (1821)	126.9	49.9	104.0	25.3	78.9
Carpentras (1857)	32.0	13.4	30.0	-1.4	25.0
Estimated Interest Rate	10.7	3.8	7.1	7.8	4.3

Table 6
Hypothetical Internal Rates of Return by Period

In the middle of the eighteenth century, (1735-1755) projects were less profitable than at any other time except for the Revolutionary period. Yet a number of projects built after 1760 were proposed during this period, suggesting that investors, at least, found it profitable to participate in irrigation development. The last decades of the Old Regime (1760-1785) show high internal rates of return and high benefit-cost ratios. The rates of the late eighteenth century were in fact on average higher than those of the nineteenth century when most of the development actually took place. After 1785, the rates of return dropped until 1820, no doubt because of the uncertainties provoked by the Revolution.

The hypothetical rates of return all suggest that a low level of profits cannot explain why more irrigation canals were not built before the late eighteenth century. The presence of significant profits through most of the eighteenth century, and in particular during the years 1700-1730 suggest that changes in relative prices were not responsible for the late development of irrigation in southeastern France. During most of the eighteenth century, rates of return were in fact higher than those of the nineteenth century. Yet irrigation development was much more limited from 1700 to 1789 than it was from 1820 to 1860. Some sort of a market failure in the supply of irrigation must have been at work in the eighteenth century. Indeed, despite the fact that hypothetical rates of return before 1760 were well above both the estimated interest rate and the mortgage rate, no project was undertaken before that date. The discrepancy is even greater before 1730. The market failure cannot be ascribed to a lack of acumen on the part of eighteenth-century French investors, for as we shall see, entrepreneurs, landowners and the wealthy elites proposed a number of irrigation projects in this period.

History and Institutions: the Early Eighteenth Century

The real obstacle to irrigation lay with gathering property rights and internalizing benefits. As with drainage in Normandy, irrigation required a very specific set of property rights. To gather these property rights, eighteenth-century developers needed to bargain with a large number of institutions and individuals. The absence of eminent domain made the task more difficult because organizations or individuals had effective veto power over their projects. The number of veto players led in turn to problems of strategic behavior and litigation. The problem with veto players was aggravated by the fact that both property rights and the authority of institutions were uncertain.

Nor were these the only problems. Irrigation is plagued by the durable goods monopolist problem, which makes it difficult to entice future beneficiaries (landowners) to bear construction risks. The problem lies in the difficulty of devising a time-consistent price path that gives landowners incentives to join an irrigation project before construction is finished. Irrigation developers thus faced a morass of institutional problems that the state was powerless to resolve.

Gathering Property Rights

Let us examine the problems one by one beginning with property rights. Obviously, the developer of an irrigation project has to have the right to draw a minimum amount of water from a specific location on a river for consumptive use. He also has to install the network of canals that will carry the water from the river to potential users, and building the network will require some form of right of eminent domain. One often assumes the existence of either a unique source of property rights to water or many competing sources for such property rights. In eighteenth-century France, however, property rights were highly dispersed, and a developer often had to bargain with several monopolists before he had a 'usable' property right.

In Provence, the problems of bargaining over water rights and eminent domain rights were severe. Let us first examine the question of water rights. In the eighteenth century, the primary source of water for irrigation in the region was the Durance river. The king of France had a monopoly right to grant new irrigation rights from the Durance. The king's right was limited by those of individuals and institutions who in the Middle Ages had acquired inheritable monopoly rights to draw water from various points on the river. In the seventeenth and eighteenth century the monopoly nature of these rights was challenged by new royal grants of water in the same area.[96] The validity and extent of grants was a legal question, and expensive suits were fought by owners of grants in the early eighteenth century. Significant transaction costs were involved with settling uncertain property rights in the rent-seeking court system of the eighteenth century. Until the issue was decided (in 1733) the validity of both medieval and more recent royal grants was uncertain.

A related set of transaction costs involved eminent domain rights. If the eminent domain rights belong to overlapping authorities--as was the case in eighteenth century Provence--each authority has a credible veto power, and each may attempt to appropriate the entire surplus generated by a potential irrigation project. This very thing occurred frequently in Old-Regime Provence and led to significant transaction costs. In such a setting the Coase "theorem" no longer holds and there is no guarantee that an efficient outcome will be reached. In fact the allocation of authority and property rights in eighteenth-century France prevented the efficient development of irrigation as the historical section will show.

Irrigation and Commitment

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96) On ownership of usable water see André Maistre, *Le Canal des Deux Mers*, pp. 51-52. On conflicts over monopoly rights see AC Cavaillon, BB 20, 21.

The second set of problems faced by potential suppliers of irrigation is inherent to the industry itself. To secure credit before a project occurs, a developer prefers to make landowners sign contingent contracts committing them to buying irrigation rights once the project goes through. Associated with this commitment contract is an announced price path that consists of a price charged for water bought before the project is built and another price--or set of prices--charged after the project is finished. Theoretically, however, there exist no credible price announcements that make it a dominant strategy for landowners to sign the commitment contract. Quite to the contrary, in the absence of institutions committing the developer to time-inconsistent price paths, the developer will sell no contracts before building his canal.[97] The problems faced by irrigation developers have been modeled in an extensive theoretical literature on time consistency, commitment. Models of the durable goods monopoly problem are closest to the problems faced by irrigation.[98]

Models of the durable goods monopolist are set in discrete time. At each period the monopolist must announce a vector of prices, which he claims will prevail from now until the end of the game. The question then is what vectors of prices are credible, if the game goes on for a large number of periods, and if the monopolist cannot commit to any announced price for any future period? The theoretical results are as follows, for a monopolist producing a durable good at constant marginal cost and who faces a downward sloping demand curve. If the

97) The developer's original announcement is a pair of prices. The first price will be charged to those who buy water before the canal is built and the second is promised to be the price of water rights after the canal is built. A pair of prices are time inconsistent; if landowners naively believe the prices announced and act accordingly the developer would not want to set the price of water rights after the canal is built at the second price of his original announcement.

98) See R. H. Coase, "Durability and Monopoly," *Journal of Law and Economics*. 15 (1972), pp. 143-149. More recent work in the field includes Charles Kahn, "The Durable Goods Monopolists and Consistency with Increasing Costs," *Econometrica*. 54 (1886), pp. 275-294; Faruk Gul, Hugo Sonnenschein and David Wilson, "Foundations of Dynamic Monopoly and the Coase Conjecture," *Journal of Economic Theory*. 39 (1986), pp. 155-190; Nancy Stokey, "Rational Expectations and Durable Goods Pricing," *Bell Journal of Economics*. 12 (1982), pp. 112-128.

monopolist has no institutional mechanism to commit to a price path, then prices will fall over time. Furthermore, under certain demand conditions--namely that there is at least one buyer with a reservation price equal to the marginal cost--the monopolist will in the long run charge marginal cost. Prices will converge to marginal cost faster as the length of each period falls or alternatively as the interest rate falls.

The models appear to fit irrigation rights in eighteenth- and nineteenth-century France. Such rights are clearly a durable good, since in the eighteenth and nineteenth century contracts were--and remain--one-shot sales of permanent access to water from a canal. The marginal cost of an irrigation right was either small or zero until the capacity of a main canal was reached. If we assume that by the second period the entire distribution network was built, then marginal cost was zero. If by the second period only the main part of the network was complete, then marginal cost was low because only a small ditch is needed to connect the canal to any particular field. Demand for irrigation rights was also (weakly) downward sloping, as some parcels derived greater benefits from irrigation than others because of the differential quality of land and some were located closer to the canal. In the absence of institutions that allow commitment in contracts, it is not credible to have an *ex ante* price that is lower than the *ex post* price.

This result can be made explicit in a simple two-period model. Let there be n landowners all indexed by the value of discounted profits accruing to them if they irrigated their plots for free, Π_j, so if $j>k$ then $\Pi_j>\Pi_k$. Assume further that all plots are of the same size and that irrigation rights are simply the right to as much water as one wants for a particular plot and that enforcement of these contracts is both costless and perfect. At the beginning of Period 1, the developer announces two prices p_1 and p_2 as the prices he will charge for irrigation rights in Periods 1 and 2. Let r be the interest rate. In Period 2, given that k landowners remain, the developer will maximize his profits when marginal cost equals marginal revenue. Let m be the

number of landowners who remain without irrigation rights at the end of the game. Then by the definition of m, $p_2=\Pi_{m-1}$. In this setting the monopolist cannot credibly announce a rising pair of prices, yet falling prices will lead all landowners to wait until after the canal is built.

Indeed, rising prices paths that lead to positive sales in Period 1 are not credible. Suppose that in Period 1 the developer announces a pair of prices such that $p_1 \leq \frac{p_2}{(1+r)}$. Then it is a dominant strategy for anyone willing to pay p_2 in Period 2 to buy the irrigation right in Period 1. Indeed, landowners who buy an irrigation right in Period 1 and borrow the money for one Period at the going rate of interest save over buying in Period 2. So all the landowners willing to buy irrigation rights in Period 2 do so in Period 1. Then at the beginning of Period 2, there remain m landowners who have no irrigation rights. Their profits are all t Π_m. By definition, $\Pi_m < P_2$, so if p_2 is actually announced again there will be no Period 2 sales of irrigation rights. This is clearly not optimal for the developer. A better strategy would be for the developer to charge Π_m or less, sell at least one irrigation right and earn positive profits in Period 2. Therefore a profit maximizing developer will not charge p_2 in Period 2. Rather, at the beginning of Period 2 time the developer will announce a new price which will be lower than p_2. Thus the original announcement is not credible.

The developers problems do not stop there. It turns out that there exists no credible prices that can induce landowners to buy in Period 2. Assume $p_1 > \frac{p_2}{(1+r)}$. Let us then look at the problem of landowner j in Period 1. He wants to maximize:

$$\max\left\{\frac{\Pi_j}{(1+r} - p_1, \frac{1}{(1+r)}\max\left[0, \Pi_j - p_2\right]\right\}.$$

He can either buy in Period 1 or wait to Period 2 when he will chose again whether or not to buy an irrigation right. Independent of when the irrigation right is bought, the benefits are only

enjoyed in Period 2, when the canal is complete, so benefits are always discounted. First assume that $\Pi_j - p_2 > 0$. Then landowner j would want to buy the irrigation right in Period 2 if he had not already purchased it in Period 1. He will buy in Period 1 if $\frac{\Pi_j}{(1+r)} - p_1 - \frac{\Pi_j - p_2}{(1+r)} > 0$. This condition is equivalent to $(1+r)p_1 < p_2$, which contradicts our assumption. Therefore landowner j will not buy any irrigation rights in Period 1.

Now assume that $\Pi_j - p_2 < 0$. Then landowner j will not buy the irrigation right in Period 2 under any circumstance. He will buy in Period 1 if and only if $\frac{\Pi_j}{(1+r)} - p_1 > 0$. However, because he does not buy in Period 2, $\Pi_j < p_2$ and $\frac{\Pi_j}{(1+r)} < \frac{p_2}{(1+r)}$, which in turn is less than p_1 by assumption. Thus the landowner will not buy an irrigation right in Period 1 either. More important there exists no credible price path that the developer can announce such that some landowners will buy irrigation rights in Period 1.

The simple model explored above suggests that without commitment, only price paths where no *ex ante* buying occurs are credible.[99] In the absence of commitment landowners will simply not buy irrigation rights *ex ante*. Furthermore, the argument outlined above does not make use of the fact that landowners have no incentive to bear the risks associated with buying *ex ante* contracts, since *ex post* contracts will always dominate them. For this reason too, they would rather wait until after the project is built to buy their contracts from the developer. But, because the construction costs are sunk after the project is built, marginal cost is always very

99) There are other types of contracts that get around part of the durable goods monopoly problem. For example, the monopolist could offer contracts that promise anyone that their price will be the lowest prices he charges at any time. Then in equilibrium the amount of rights sold is exactly that which would be sold if the market only opened for one Period. These contracts would however be quite costly to enforce, as each buyer must monitor prices forever. The same monitoring costs are encountered whenever the quantity of irrigation rights that maximizes the developer's one-shot profits is less than the total quantity available, because landowners know the developer has a long run incentive to sell everything. Not surprisingly, these contracts were never offered in the eighteenth century.

low, and even the monopolistic developer would find it nearly impossible to break even without the ability to commit to time inconsistent price paths.

Beyond the problem of commitment, the developer may face revenue problems after the canal has been built. Indeed, the overwhelming share of the costs lies in the construction and that *ex post* marginal cost is nearly zero. The low marginal cost may act against the developer in two ways. First, landowners know that marginal cost is the developer's reservation price and, in the context of bargaining, they may decide to wait to let the price fall. Second, once the canal is built the developer has not one but many periods in which to sell his water rights, and as a result, the problem of commitment plagues him over and over. In fact if he can reconsider his prices frequently--i.e. periods are short--the developer may set his prices very low soon after the project is built.

In such a situation lenders would not offer credit without other collateral, because the expected revenues after the canal is built may not be high enough to cover all the costs. If creditors are unable to estimate the relationship between expected revenues and total costs, they will prefer signed *ex ante* contingent contracts as sources of collateral. Thus we can conclude that, in the absence of institutional mechanisms to commit, the credit problem is less one of credit markets than a contracting problem between developers and landowners.

The importance of the theoretical exercise outlined above becomes obvious in light of the fact that most canal developers in the eighteenth century were unable to sell more than a few contingent contracts. Other developers whose personal wealth allowed them to proceed without outside source of credit never recouped more than a small amount of the construction costs from water sales. In fact, although the total profitability of irrigation was never doubted, it was always a problem to get landowners to pay for projects in the eighteenth and the nineteenth centuries. This difficulty was often explained by the lack of foresight and "the

backwardness," of peasants, however it seems that those backward peasants understood the nature of the game much better than the developers did.

Geography and Institutions

Given the lack of success of canal developers before 1765 when irrigation would have been highly profitable, it seems obvious there was an institutional failure. But did eighteenth-century institutions make any progress at providing developers with the property rights they needed? Did it become possible for eighteenth-century developers to commit to price paths that would have made credit possible? And was the state willing to provide the financial insurance necessary for the projects to get under way? The answer to the first question is that litigation during the early eighteenth century firmly established ownership of property rights and authority over these rights, and by 1765 most of the problems associated with property rights had been eliminated, at least for small projects. For larger projects, however, problems with veto players were not addressed until the French Revolution. The late eighteenth century also witnessed some limited progress in solving the credit problem associated with irrigation. The state was still unable or unwilling to force developers to commit to announced prices for irrigation rights and thereby constrain the problem of revenues. In the absence of national reforms, local institutions successfully stepped in and provided the insurance required if lenders were to make capital for irrigation projects available. Local involvement did lead to limited development of irrigation between 1765 and 1789, but large scale projects still faced credit problems until after the Revolution of 1789.

To understand this progress in the late eighteenth century, we must take a detailed look at the political and judicial geography of southeastern France under the Old Regime. In particular we must examine the institutions that blocked irrigation before 1765. We can then

understand the institutional change of the late eighteenth century and the relative success of irrigation in the period from 1765 to 1789.

The political and judicial authority in southeastern France in the eighteenth century can be best explained in terms of the medieval division of the region, known as Provence, and its subsequent partial appropriation by France. Provence in the early Middle Ages was part of the Holy Roman Empire, but by the fourteenth century it had become virtually independent. Medieval Provence was divided into three distinct areas that led to three different Old-Regime judicial and political systems: the *Comtat* Venaissin, the *Comté* of Provence, and the *Terres Adjacentes* (see Map 2 in the appendix). The Old-Regime *Comtat* Venaissin (hereafter the *Comtat*) is geographically equivalent to the present day Vaucluse. The western half of the *Comté* of Provence (hereafter the *Comté*) and the *Terres Adjacentes*, make up what is now the Bouches du Rhone. The existence of three different sets of institutions was a legacy of medieval state building. The most important phase of this process was the division of Provence between the Pope--whose share was the *Comtat*--and the counts of Provence who controlled the *Comté*. Subsequently the king of France inherited the *Comté*. The *Terres Adjacentes* were a set of administratively independent communities that included Marseille, Arles and a number of communities on the border of the *Comté* and the *Comtat*. These communities had never been directly incorporated into Provence. In fact, until they became part of France, the *Terres Adjacentes* only recognized the direct authority of the count of Provence.[100]

The geographic divisions outlined above corresponded to institutional divisions that determined the transaction costs of irrigation. Although the *Comtat* was an independent

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100) The best reference to the political divisions of Provence is Edouard Baratier, *Histoire de la Provence*. Toulouse: Privat, 1969. The issue is treated in more detail in Paul Masson, *Encyclopédie des Bouches du Rhone* and Villeneuve, *Encyclopédie des Bouches du Rhone*.

enclave inside France, the king of France controlled its water supply. Prior to the Revolution of 1789, the Comtat had a legislative body in charge of taxes: the Estates of the *Comtat*. Like most Estates in France it was composed of representatives of the nobility, the clergy and the leaders of each major community in the region. The approval of the Estates was necessary to secure the financial or legal support of any public institutions for irrigation projects, but the Pope and his local representative (the vice legate) had veto power over decisions by the Estates, a veto power they regularly exercised. The *Comtat* also had a more or less final court of appeals (the Apostolic Chamber), but some cases were ultimately argued in Rome. Those institutions were by and large poorly centralized, and any one of them could hold an irrigation project hostage.

Beyond the institutions specific to the *Comtat*, French institutions also had an impact on transaction costs in region because the *Comtat* was economically tied to the rest of southeastern France. Among the regions bordering France, the *Comtat* enjoyed a privileged status. The king of France had granted the inhabitants of the *Comtat* the status of *régnicoles*, which removed any French tariffs on goods produced in the *Comtat*. The status was very valuable to the *Comtat*'s agriculture and industry, because, it was a major exporter of grain and silk textiles. The preservation of this special economic relationship was contingent upon a good knowledge of Provencal institutions, as local powers in the *Comté* (such as the *assemblée* or village governments) often attempted to interfere with the royal privilege.[101] Because of the complex institutional history of the area, jurisdiction over civil suits that affected both *Comtat* and *Comté* was uncertain; however, most of these suits were fought in French royal courts. In

101) One should also note that the armies of the king of France occupied the *Comtat* twice in the eighteenth century in order to put pressure on the Pope over a larger set of issues. On the same issue it is also important to note that the elites of the *Comtat* had economic, political and familial ties with the elites of Provence and many had served the French crown for which they were sometimes rewarded with water rights for their *Comtat* estates. BM Cecano, Ms 2435-2436 on the litigation between *Comté* and *Comtat* on trade issues.

fact, officials of the *Comtat* had frequent recourse to the French judicial system to preserve the privileges of the region.

The *Comté* of Provence had institutions similar to those of the *Comtat*. In terms of eighteenth-century French political institutions, the *Comté* was a *Pays d'Etat*. As a *Pays d'Etat* it had a fiscal and legislative body--often known as an Estate--the *Assemblée du Pays*. The *Assemblée du Pays* had suffered a long eclipse between 1660 and 1760, due to its participation in the seventeenth-century rebellions. In the late 1770s the *Assemblée du Pays* became more active and helped the royal government promote irrigation. The importance of the *Assemblée du Pays* rests more in the fact that it provided a locus of bargaining for institutional change than its role as a motor of economic development. As far as the judicial system in the *Comté* was concerned, the final court of appeals was the *Parlement* of Aix. Whereas the *Assemblée du Pays* was dominated by the clergy, the *Parlement* was the realm of the Provencal nobility. Both the *Assemblée du Pays* and the *Parlement* often resisted royal reform, if only to bargain for better terms with the crown.[102]

The third and final area under study, the *Terres Adjacentes* were as set of communities that were classified as a *Pays d'Election*. These communities were directly under the authority of the king and had no Estate. Even here, however, the division of eminent domain authority between king and communities was ambiguous. Particularly ambiguous was the division of judicial authority between king, communities and the *Parlement* of Aix, which exercised certain judicial powers in the *Terres Adjacentes*. In practice, the uncertainty of authority gave both local institutions and the king veto power over irrigation projects.

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102) Paul Masson *Encyclopédie de la Provence*, vol. 3, and Rene Pillorget, *Les Mouvements Insurrectionels en Provence entre 1596 et 1715*. Paris: Editions A. Pedone, 1975, pp. 864-877.

Despite this confusion there were certain institutions that may have reduced the transaction costs associated with irrigation. The judicial system in southeastern France operated under Roman rather than customary law, and Roman law facilitated the enforcement of written contracts. For example, it recognized private property more clearly than did the customary law that prevailed in regions such as Normandy. Furthermore village and local organization were very well developed and not subject to the same unanimity rules as their counterparts in northern France. Each village or town had at its head a council headed by three consuls. The first consul was almost always a noble, and he effectively ran the town government. Because developers could write contracts with the consuls, this form of municipal organization made it easier for them to bargain with villagers. The same municipal organization, however, also made strategic behavior easier for villages in the south than in regions like Normandy. Despite the benefits of Roman law and village government, irrigation developers still faced a formidable array of obstacles. In particular, the tangle of different legal and political authorities and overlapping jurisdictions made it very costly to sort out conflicting property rights.

Property Rights Over Water

On both banks of the Durance river, communities, religious institutions, and individuals claimed monopoly rights to draw water from certain sites, but only seven sites were highly desirable, four on the *Comté's* bank of the Durance and three on the *Comtat*'s side.[103] To develop a new irrigation network one had either to find an unused site or to increase the draw

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103) One site on the *Comtat's* side of the river was occupied by the Medieval canal Saint-Julien in Cavaillon. Another was the future site of the canal of Cabedan-Neuf, this site would then also feed the canals of Carpentras, L'Isle, and Plan Oriental. Finally, one site was used for the medieval canal of l'Hopital in Avignon, the same site would also feed other canals in Avignon and the canal of Crillon. On the south bank of the river, one site was used for the canal of Craponne, another would used be for the canal of Boisgelin and the last two for smaller canals. Desirable sites were rare because the low technology of irrigation canals demanded rapid current in the river to avoid silting and hard rock on the banks to avoid erosion. On the issue of sites, see Villeneuve, *Encyclopédie*, pp. 697-698.

from a site already in use. In the early eighteenth century, three of the four desirable sites were already in use, and proprietary claims were made for all of them. Claims of ownership of sites were based on royal grants that dated back to the Middle Ages. The medieval grants tended to be monopolistic and perpetual grants of a site rather than of a certain amount of water. Owners of property rights over water drawn from a site argued that hereditary and transferable title to water rights had been granted to them by the king. They also claimed that the medieval titles also gave them monopoly rights over all water from their site, even beyond what they used. New and overlapping property rights were granted by the king in the seventeenth and eighteenth centuries to developers. In the eighteenth century developers with new royal grants to water from the Durance were challenged by the owners of medieval property rights in court. In fact, in the early eighteenth century, any developer who had secured new rights from the crown and wanted to build a new network invariably faced court challenges.[104]

The royal courts that handled the suits over water rights were faced with a dilemma. If they affirmed the medieval grants it would have been impossible for the king to grant any more water rights, and many of the water rights granted by the king in the eighteenth century would have been invalidated. The legitimacy of medieval water rights, however, was not really in doubt by the courts as the parchment rolls on which the grants were written were among the most prized possessions of religious institutions and cities. Both sides had received their grants from the king and had solid but conflicting legal rights.

At the same time, the crown had considerable incentive to invalidate the medieval grants. The medieval grants were old and to a large extent outdated, because they artificially limited irrigation development. The Crown recognized that economic growth depended on

104) See AC Cavaillon, BB 20-21, AD Vaucluse , B *Concessions d'Eau*. See also *Archives du Canal de Cabedan*, pp. 7-61 ; and René Caillet, *Le Canal de Carpentras*, Vol. 2.

wider usage of water than the medieval monopolists would allow. Moreover, it had become a standard practice for the king to default on monopoly grants. In every sector of the economy, from judicial offices to water rights, the sixteenth and seventeenth centuries witnessed royal sales of monopoly titles. Soon however, the king attempted to renege on these monopoly grants, in order to resell a part of the title to raise further revenue. In the case of water rights, the invalidation of medieval grants would have allowed the Crown to pay off favors it owed to the local nobility.

One legal case decided the issue: the lawsuit that pitted the bishop of Cavaillon and the community thereof against the Baron Forbin-Maynier d'Oppede. The Oppede[105] family owned considerable property in both the *Comtat* and the *Comté*. They were ardent speculators in water rights. The first water grant to the family dated to the early sixteenth century, and it had been given to a family member by the Pope for services as ambassador to Venice. In the mid-sixteenth century, they became royal servants and purchased an office of *président* (chief justice) at the *Parlement* of Aix. As a result additional water grants were acquired in the seventeenth century as recompense for their support during Provencal unrest.[106]

Litigation over water rights pitted the Oppede family against the bishop and the city of Cavaillon from the early seventeenth century to the middle of the eighteenth. The bishop's water rights dated back to 1180, when the count of Toulouse as count of Provence, and thereby owner of the Durance river, gave the bishop a monopoly to draw water from the river. In the thirteenth century, the bishop used his water rights to build both a canal--known as the canal Saint-Julien--and Cavaillon's first water mill. Both the city and the bishop quickly realized

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105) Oppede came from a long and distinguished Provencal line, who more than others straddled the border between *Comté* and *Comtat*. The Oppede family had become one of the most powerful families of the region. Their power was a recompense for their staunch support of the king in the civil wars of the seventeenth centuries. See René Pillorget, *Les Mouvements Insurrectionels en Provence*, pp. 759-770, 784-790, and 856-862.

106) Rene Caillet, *Le Canal de Carpentras*, part 1, pp. 30-66.

that the canal could be used for irrigation. The bishop gave the city the right to use the canal for irrigation in return for a significant participation to the building costs. Over the course of the thirteenth and fourteenth centuries, the bishop alienated most of the canal to Cavaillon in return for a greater participation in maintenance by the city, but he retained his monopoly water right to draw water from the Durance. Cavaillon only had rights to the water in the canal Saint-Julien. Until the seventeenth century this arrangement suited everyone involved, even the Maynier d'Oppede family, who, as the largest landowner in Cavaillon, greatly benefited from the canal.[107]

In the seventeenth century, however, the arrangement began to fall apart. in the 1620s a financially strapped bishop sold his mill twice, once to the Oppede family and once to the city. To determine which purchaser really did own the mill required a long suit apparently resolved late in the seventeenth century. Then, in the 1690s the Oppede family, allied with other important French nobles, attempted to build a canal through the *Comtat*, part of their project was to use a new royal grant to draw water from the Durance. The new royal grant allowed the Oppede to draw water from the site that was owned by the bishop; thus it conflicted with the bishop's monopoly property rights.

Although judicially long lived, the Oppedes' attempt to build what would eventually become the canal of Carpentras, never succeeded. The main problem was that the bishop had maintained complete ownership to his monopoly rights. Since the property rights of the bishop and those of the Oppede clearly overlapped, both parties headed to the courts. Yet there was a further problem: what court was to hear the case? Oppede wanted the suit resolved in the *Parlement* of Aix, where he sat on the court, while the bishop preferred the Apostolic

107) AC Cavaillon, BB 22 and BB 23.

Chamber, a court where religious institutions held sway.

The uncertainty over jurisdiction was compounded by uncertain authority. Although the Durance belonged to the king, the authority over water granted to individuals in the *Comtat* was unclear. No doubt unable to bear the high costs of litigation alone, the bishop sold his monopoly water right to the city along with complete ownership of the canal Saint-Julien. The city then laid claim to the mill and canal network that had been sold to Oppede in the seventeenth century. After over 30 years of court battles, the issue was finally resolved by arbitration in 1733. The bishop's right was upheld; however, it was no longer to be a strict monopoly water right. Owners of the bishop's water right had unlimited access to unused water in the Durance, but they could not prevent others from using Durance water. Second, the Oppede family was confirmed in all the property rights they had acquired in the seventeenth century. The family was freed to pursue their trans-*Comtat* canal, a canal that Cavaillon had decided to fight by other--political--means.[108]

The court challenges were costly not only because they consumed resources but also because for three decades it was unclear whether the new or the old rights would be upheld. Until the issue of the validity of property rights was decided no development could occur. From the point of view of water development, however, the event was important: medieval grants could no longer be interpreted as monopolies, they only secured high priority access to water in the case of scarcity. More importantly, owners of medieval grants could no longer hold projects up for ransom. Clearly, development was more likely to occur with one fewer veto player.

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108) The importance of political support for political projects can be underscored by a number of examples. The most striking of these is the Oppede canal project, where high court nobles were to get one-third of future profits in return for 'protection'. The baron of Oppede was also promised one-third of the profits for his water right and his local 'protection'. Investors would have to be content with the final third of the elusive future profits. BM Cecano, Ms 1632,1633 and Ms 2512 (circa 1710).

Property Rights Over Land

To build a canal one needed a right of eminent domain. In the *Comté* rights of eminent domain could be granted by the Estates or the king, but they had to be ratified by the *Parlement*. Each of the three organizations could thus veto, or threaten to veto, a canal. In the case of the *Comtat*, the Estates, the Apostolic Chamber, the Pope's representative (the vice legate) and the Pope himself all held effective veto power as well. Securing eminent domain rights was thus expensive and extremely difficult in the early eighteenth century, for there were a very large number of veto players.

Consider rights of eminent domain in the *Comté*. Since any canal on the southern side of the river would irrigate land mostly in Provence, the king, the Estates and the *Parlement* were also veto players; however, the need to cross the *Terres Adjacentes* added a further cost. In the *Comté*, the best site to draw water from the Durance were in the *Terres Adjacentes* or led into them, thus the organizations that regulated eminent domain in the *Terres Adjacentes* had the ability to veto projects. In the *Terres Adjacentes* the king of France had sole power over water grants, and at least in theory he decided all issues of eminent domain. In fact, each local community had effective veto power over eminent domain rights as well. In the Middle Ages the *Terres Adjacentes* had been very autonomous and had in fact decided issues of eminent domain alone.[109] Although the extent of local autonomy was uncertain and subject to continual disputes during the eighteenth century, the communities were well-organized, and they could credibly threaten to sue anyone who did not secure rights of eminent domain from them.

The credibility of their threat had been verified at least once in the sixteenth century when Adam de Craponne, a Provencal nobleman and an engineer who enjoyed the favor of the

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109) J.-B. Bertin and P. Audier, *Adam de Craponne et son Canal*. Paris: Honoré Champion, 1904, p. 113.

king and had solid political support from both the *Parlement* and the Estates, attempted to build a large irrigation canal in the *Comté*. He secured a grant from the king to draw water from the Durance, and a grant of eminent domain rights from the Estates. Both were registered in *Parlement*. His grant for water made it necessary for his canal to go through a number of *Terres Adjacentes* communities. They, however, did not come under the jurisdiction of the Estates as far as eminent domain was concerned; and they delayed the project until Craponne gave them what they wanted: free access to all the canal's water that they desired.[110]

Despite these outlandish concessions, Craponne not only proceeded to build his canal in 1520 but he also succeeded in selling a number of irrigation rights below the *Terres Adjacentes*. In dry years, however, the *Terres Adjacentes* communities used up most of the canal's capacity, and with no water, Craponne had to to renege on his other contracts. The resulting suits led Craponne to an early bankruptcy and discouraged other investors from pursuing irrigation projects. From the standpoint of the communities in the *Terres Adjacentes*, the whole affair was a free ride. Although Craponne's bankruptcy saddled them with part of the maintenance costs, they had gotten their irrigation water without having to pay any construction costs. The example of Craponne and his sixteenth-century canal underscore the costs of securing adequate rights of eminent domain in southeastern France.

The history of the canal of Boisgelin is another example of the costs of the division of authority. The canal of Boisgelin was a large-scale project that was built in the *Comté* under the financial authority of the *Assemblée du Pays* after a number of other attempts had failed to secure the approval of a sufficient coalition. The proposed canal had two possible routes, one

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110) On the canal of Craponne, J.-B. Bertin and P. Audier, *Adam de Craponne et son canal*, Jean Rigoud, *Le canal de Craponne*, Villeneuve, *Encyclopédie* vol. III, pp. 698-714. Paul Masson *Encyclopédie* vol. VII pp. 148-152.

through the *Comté* alone, while the other crossed the *Terres adjacentes*. While the latter would have been cheaper it involved bargaining with the *Terres Adjacentes* for rights of eminent domain. Rather than bargain with each community in the *Terres Adjacentes*, the *Assemblée du Pays* avoided the issue but at a very high cost. The *Assemblée* decided in favor of the much more expensive route that was completely in the *Comté* and involved tunneling through the rock of Orgon. Indeed, piercing the rock of Orgon allowed the developers to avoid the *Terres Adjacentes* communities of Senas and Salon, where the cheaper routes lay.[111] Once the tunnel was built, the *Assemblée* had the ability to exclude the *Terres Adjacentes* from the benefits of the new canal if they did not contribute to its cost. Not surprisingly, the *Terres Adjacentes* communities did purchase a significant amount of water from the canal just before the French Revolution.[112]

In short the institutions inherited from the Middle Ages significantly raised the cost of building canals in southeastern France. One either had to pay off the veto players, as Craponne did, or one had to bear much higher construction costs as did the developers of the canal through Orgon. The presence of active organizations like the Estates and the *Parlement* did allow for some institutional change. It was, after all, possible to build the canal of Boisgelin, but the sort of institutional change that would have substantially reduced costs lay outside the authority of these organizations, for neither the king, the *Parlement* nor the *Assemblée* could reform the status of the *Terres Adjacentes*. The peculiar status of the *Terres Adjacentes* was indeed a privilege, something only the Revolution would change.[113] The problems of eminent

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111) The issue of the costs associated with the tunnel at Orgon have already been discussed in the section on technology. One should also note that any challenge to the claims of the *Terres Adjacentes* would have taken the form of a suit, no doubt lengthy and expensive. Thus when the *Assemblée du Pays* decided to bear the costs of tunnelling at Orgon, it may well have chosen the cheaper of the two alternatives.

112) Villeneuve, *Encyclopédie*, vol. 3, pp. 714-721.

113)The *Terres Adjacentes* used their peculiar status to free ride on the rest of Provence for much more than irrigation: Villeneuve, *Encyclopédie*, Vol. 2, pp. 755-761.

domain were never clearly worked out before the French Revolution, and the lack of clear-cut eminent domain rights had a hampered the the development of irrigation.

Through the examination of the histories of a few projects it has become clear that the institutional environment blocked irrigation. The obstacles had their origins in the long-term development of the institutional structures in the *Comtat* and the *Comté*. At the basis of these institutions was a set of medieval political decisions that led to uncertain property rights and a large numbers of veto players.

The institutions of the eighteenth century led to high transaction costs both in the case of water rights and in the case of rights of eminent domain. These transaction costs were much higher than they would have been, had authority been centralized in the national government. Judicial proceedings threatened projects with extraordinary delays, in some cases over half a century, and they could result in the complete loss of one's property rights. Moreover, the ambiguous establishment of authority within the judicial structures led to an even higher level of uncertainty. Not only were contracts and property rights uncertain, but the weight that a court decision carried was uncertain as well. There was no institution capable of constraining the strategic play that is inherent to such a bargaining process. The next section explores why a number of irrigation projects failed (testimony of the limitations of institutional change) and a small number succeeded (testimony to its reality).

The Eighteenth Century: Failures, Change, and Success

The eighteenth century is distinguished from previous centuries because for the first time investors attempted to irrigate major parts of southeastern France. Some attempts failed, chiefly large ones and those undertaken at the beginning of the eighteenth century, other succeeded, chiefly at the end of the century. In this section I examine first failures, then successes.

The pattern of failures and successes is explained in terms of institutions.

Failures

A number of projects failed, and they all had one common characteristic--they were all very large even by nineteenth-century standards. They failed in a large measure because their scale gave too many individuals and groups a veto power. The large set of veto players responded to political necessity rather than to questions of profitability. The most interesting of these failures was the canal of Provence promoted by the Baron d'Oppede and an engineer named Cyprian. It would have crossed both the *Comtat* and the *Comté* from Donzere--north of Orange--to Marseille (see Map 3), and it would have been used both for transportation and for irrigation. As a transportation canal, it would have been a competitor of the Rhone river, which was full of tolls. It was one of many attempts to use the water rights of the Oppede family, all of which failed.

The failure of the canal of Provence, which would have been the match of Languedoc's canal of the Midi, has fascinated a number of historians.[114] It would have gone through the *Comtat* and the *Comté*, and it could have been vetoed by the Estates of either region, the Pope, or the king. In fact, because the canal was to be used for transportation, the king had final say both over both water grants and rights of eminent domain in the *Comté* and the *Terres Adjacentes*. His assent and backing was secured through lobbying by the highest nobles of France, the project still required the approval of the political and administrative powers of the *Comtat*, where veto lay with the vice legate (the papal representative in Avignon), the Apostolic Chamber, and the Estates of the *Comtat*. The communities and religious institutions represented in the Estates were divided on the question of the canal. Not

114) Hubert Elie, "Une Affaire de Spéculation"; Paul Masson, "Le Canal de Provence"; Roger Caillet, Le Canal de Carpentras, chapter 1.

surprisingly, those communities which would directly benefit from the canal were all in favor. Other communities, though, would lose if the canal were built and they opposed the project. Avignon, would be bypassed by the canal and its trade would thereby suffer. Cavaillon, a town that already had invested heavily in irrigation, faced a decline in the value of already irrigated land.[115] Many religious institutions also opposed the canal, although their publicly-stated reasons--the financial burden on the province and the fear of French invasion-- are difficult to believe. The real reason for their opposition was their fear that goods transported on the canal would escape the tolls on the Rhone river, tolls that they themselves owned. The private correspondence of between the Prior and the Abbot of a monastery near Avignon makes these fears explicit:

> They [the promoters of the canal of Provence] want to built a canal that, after crossing the *Comtat*, will go directly to the sea and will avoid all the dangers of the mouth of the Rhone. . . If this [project] succeeds we can forget about our toll at Tarrascon [on the Rhone]. . . Twenty two ecclesiastical communities or hospitals that own the salt toll [also on the Rhone] in Avignon have also protested [to the Pope], and if this canal occurs we alone would lose more than a 1,000 livres of annual income.[116]

Economic and political issues loomed large in the fate of the canal of Provence. The Pope made the final decision against the canal and his decision reflected the fears of religious institutions. The Pope was undoubtedly also concerned with the purely political issue of preserving the *Comtat*'s independence from France. Opponents of the project had claimed--somewhat disingenuously--that the canal would be an ideal route for invading French troops.[117] Of real

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115) See AD Vaucluse, C 43 folio 520.

116) AD Vaucluse, H Celestins d'Avignon, Correspondence Inutile, (February 4 and March 22, 1717). On the canal of Provence, see also Roget Caillet, *Le Canal of Carpentras*, vol. 2, *Pieces Justificatives*.

117) French soldiers had no need for such a route when they occupied the *Comtat* in the 1760s. The Comtat, which was surrounded by France, could be invaded by infantry from the North or the East where the were no major rivers. On the debate over the value of the canal, see Roger Caillet, *Le Canal de Carpentras*, vol. 1 chapter 1, and vol. 2, *Pieces Justificatives* 1-12. See also Hubert Elie, *La Spéculation sous la Régence*, pp. 117-118.

concern was the fact that the canal, while increasing the *Comtat*'s economic well-being, would have made the *Comtat* dangerously dependent on French water and French markets. The Pope's fear was undoubtedly that the loyalty of the *Comtat* would weaken in the face of increased dependence on French water.

In any event, the canal of Provence did not fail because of inadequate financing. To be sure it would have required expensive bridges and much more complex water management than a simple irrigation canal, but contemporaries believed the higher costs could be repaid because of it would be used for transportation. They pointed out that other transportation canals used similar expensive technologies and had fared well financially. It was not the lack of anticipated profits that stopped the canal of Provence, rather it was the political structure of southeastern France. Had Provence not been divided in the Middle Ages, the canal might well have been built.

The institutional structure favored decisions made for political rather than economic motives. Although the Pope was aware of the economic benefits of the canal, it was the political costs that decided the issue. Despite intense lobbying by the French government and by the promoters of the canal, the Pope went against the recommendation of both the Estates and the vice legate and vetoed the project. The fate of irrigation development in the eighteenth century was decided on the basis of a political calculus, which took little account of the benefits of increased economic activity.

Institutional Change and Irrigation Successes (1765-1789)

The years between 1765 and 1789 witnessed an increase in irrigation, and for the first time in the eighteenth century a number of projects were actually realized. The new projects were of two types: those that served local purposes, and those that aimed to irrigate larger

areas. The smaller projects were much more likely to succeed because they faced fewer institutional challenges. Larger canals did face higher transaction costs because they fell prey to the veto power of more groups.

At least four small projects were completed in the late eighteenth century. Three of the small canals were in the *Comtat* and the fourth was in the *Comté*. Each of the four project distributed water to at most a few communities. They did not cross any important institutional boundaries and remained small because larger projects were plagued by a variety of institutional problems, and even among the four projects, delays and transaction costs rose with size.

The two smallest canals, Janson and Cambis, were only a few kilometers long at most, and they faced only minor transaction costs. Both were entirely financed by the principal landowner in the area they irrigated. Both the Marquis of Janson and the Duke of Cambis, the two noblemen who built the canals, wanted to irrigate their estates, which were very large. They both maintained strong political ties to the French royal court, and they successfully lobbied for water grants. The size of their estates eliminated the free rider problem and allowed each nobleman to internalize most of the benefits of his irrigation canal. In his grant application, the Marquis of Janson argued that the benefits to his estates would more than suffice to cover the construction costs.[118] He did allow the neighboring community to use the canal for irrigation purposes--no doubt to facilitate his use of rights of eminent domain-- but there is no evidence exists to show that he or Cambis failed to make a profit from the canals. In any case, unlike other examples, these two small canals were completed swiftly and gave rise to little in the way of transaction costs.

The third project actually completed was the canal of Cabedan-Neuf built in 1765.

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118) AN H^1 1515 (March 1780).

Although it affected only Cavaillon and two neighboring communities (The Taillades and Merindol), it was large enough to create problems with the enforcement of contracts. The canal was built by an association of landowners under the tutelage of the city of Cavaillon. The association made use of Cavaillon's rights of eminent domain as well as the bishop's medieval water grant that had been validated in 1733. Because most of the land irrigated from the canal was in either the territory of Cavaillon or that of The Taillades, the costs of the canal were apportioned to each community according to the area irrigated, and the communities' debt responsibilities were calculated in the same way. Predictably, soon after the canal was completed The Taillades attempted to escape from its financial responsibilities. This maneuver forced Cavaillon, which had underwritten all the loans for the canal, to sign a new contract with The Taillades. In return for the complete repayment of outstanding debts by the village of The Taillades (a third of construction costs), Cavaillon agreed to assume a larger portion of the maintenance costs. The third community involved, Merindol, enjoyed an even more generous free ride. Much of the canal passed through Merindol, which, unlike Cavaillon, lay in the *Comté* not in the *Comtat*. Merindol undoubtedly derived benefits from the canal, but it did not contribute anything to the project.

Except for their redistributive implications, the free ridding by Merindol and the shirking by The Taillades were relatively unimportant. Neither stopped the project. In particular, the shirking by The Taillades only occurred after the project was built and the benefits were captured. Moreover litigation was avoided because Cavaillon alone could have paid for the entire canal and and still benefited from the project.[119] Yet the history of Cabedan-Neuf demonstrates that the involvement of a mere three communities was enough to drive institu-

119) *Archives de l'Association du Canal de Cabedan Neuf*, pp. 48-69.

tional costs higher than when only one community was involved. In addition to the costs incurred after the project was completed, there were significant delays associated with getting rights of way through Merindol since Merindol was in the *Comté* and thus not covered in the original grant of rights of eminent domain from the *Comtat* institutions. Once again these costs were associated with scale because of the extreme division of authority in the region.

The final canal, the canal of Crillon, delivered irrigation water to Avignon and surrounding communities. It was built by the Duke of Crillon, descendant of an old line of *Comtat* noblemen who led the French king's armies. Using his favor at court, Crillon secured a grant to draw water from the Durance and he then had the grant registered in the Aix *Parlement.* He negotiated with the *Comtat*'s institutions--the vice legate, the city of Avignon and the Apostolic Chamber--and secured rights of way from them. The canal, however, ran through several communities and challenged the water monopolies of a number of seigneurs and religious institutions, who all held the project up for ransom by attacking it in court. Two types of suits were fought. The first concerned Crillon's right to cross other canals, an absurd point of law in terms of economic growth but potentially a very profitable one for the owners of the other canals. The most important of these suits was brought by the Duke of Gadagne, Lord of Vedene, one of the communities traversed by the canal. Gadagne contested both the right to cross Vedene without his authorization and the right to cross his own irrigation canal in Vedene. The suit was temporarily settled out of court in 1777, and in the settlement Gadagne granted rights of way in return for water rights. The settlement was not fully executed by either party and the case was still being litigated long after the French Revolution.u120

The second set of suits were more serious. In 1778 fourteen ecclesiastical institutions

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120) BM Cecano, Ms. 2459.

and several communities charged that the canal increased the incidence of malaria, a disease endemic in the lower *Comtat*. The claim about malaria was hardly sincere and was probably no more than a strategic maneuver aimed at extracting profits from the canal builders. One sign that malaria was a mere pretext was the fact the religious institutions filling the suit themselves owned other irrigation canals, which presumably were just as likely to spread malaria. They and the other plaintiffs refused to settle the suit even after the Duke of Crillon offered a solution that offered better drainage of irrigated fields, and hence a smaller likelihood of malaria outbreaks.[121] In any event, although the opponents of the canal won the initial round of litigation in Avignon, their victory was overturned by a papal court in Rome in 1781. Yet the suits delayed the completion of the canal of Crillon, and even the powerful eminent domain rights Crillon had secured did not prevent litigation and delays.

Beyond the institutional costs associated with large canals, the developers of Cabedan-Neuf and Crillon faced revenue problems that did not exist for smaller projects. Since the smaller projects primarily irrigated the land of the promoters, the benefits were internalized, making the sale of water rights irrelevant. But such was not the case with Cabedan-Neuf and Crillon, which were designed to irrigate the land of several hundred landowners each: both the city of Cavaillon and the Duke of Crillon failed to recover their investments from landowners. For the canal of Crillon, revenues from the sale of water were only 8,000 livres in 1781. This did not suffice to pay for maintenance costs, let alone to provide a return on the more than 400,000 livres the Duke had spent building the canal. The meager revenues from the canal brought the Duke to the edge of bankruptcy and he was forced to sell a number of his other assets (in particular land).[122] Landowners refused to buy his irrigation rights because

121) BM Cecano, Ms. 1605, 2459, 4°6198; and Reboulet, "Le Canal de Crillon," pp. 41-43.
122) BM Cecano, Ms 4° 6824.

they were aware of the fact that once the canal was built Crillon's reservation price had to be very low. They were evidently waiting for the Duke to lower his price.

In addition to the four small irrigation projects, one large project was started before the French Revolution. The canal of Boisgelin, should have delivered water to the western half of the *Comté*; however, it was not completed until after the Revolution under the name of the canal of the Alpinnes. The *Assemblée du Pays*, a group of clerics and noblemen, was responsible for initiating the project. In the eighteenth century, there had been at least two previous attempts to develop a large irrigation canal in the *Comté*, both had been private attempts and both had failed, these failures had discouraged private investors from supplying irrigation.

In the absence of private investment there was only one institution in the *Comté* that had the credit sufficient to undertake such a project: the *Assemblée du Pays*. The other potential source was, of course, the royal government, but by the 1770s it faced such deep credit and revenue crises that it could not even consider direct financial participation to public works projects. Nonetheless the royal government had an indirect hand in the project. The king could not increase the fiscal burden on Provence without the approval of the *Assemblée du Pays*. On the other hand if the *Assemblée* wanted to raise revenue to spend in the *Comté*, it required the approval of the king. Obviously there existed significant gains from trade if the two parties could agree to share the resulting tax increases. Thus in 1772, during the negotiations on increasing the price of salt--a royal monopoly--the province received a direct subsidy of 200,000 livres, half specifically marked for public works projects. The archbishop of Aix, Boisgelin, persuaded the *Assemblée* that the money should be spent on an irrigation canal.[123]

The canal was designed by the builder of Cabedan-Neuf, and mostly, it was a simple

123) AN H^1 1510.

gravity flow network of unlined ditches. With simple technology, it should have been very profitable because at that time rates of return were estimated to be more than five times the rate of interest for all the projects for which we have data. However one important institutional constraint, discussed earlier, greatly increased the cost of the canal. To avoid bargaining with the *Terres Adjacentes* over rights of eminent domain, the *Assemblée du Pays* required that the canal go through the *Comté* only. That requirement implied that a tunnel had to be built to traverse the rock of Orgon, which meant tunneling through solid rock. Work on the tunnel started in 1777 and proceeded up to the Revolution, using over half of the funds available for the project.[124] Unlike all other irrigation projects, which involved little more than the digging of ditches, the canal of Boisgelin had to resort to an extraordinarily costly technology; a technology imposed by institutional constraints.

Given the distribution of authority the *Assemblée du Pays* could not have imposed its canal on the *Terres Adjacentes*. Once again the division of authority led to higher institutional costs than if only a small canal had been built. In the case of the canal of Boisgelin the institutional costs were indirect. the *Assemblée du Pays* did not pay off the veto player--the *Terres Adjacentes* communities that lay across the less expensive canal route. Rather it chose to bear the higher costs of digging a tunnel at Orgon.

The canal of Boisgelin seems to mark a change in the attitude of local institutions regarding economic development. Until this project, the primary role of the Assemblée and the *Parlement* seems to have been to protect the province's privileges--the politically written rules that were economically favorable to the province--against encroachment by the king. By funding the canal of Boisgelin, the *Assemblée* went beyond its position to get around a large

124) BM Mejanes, Ms. 834(848) and 840(853). For the decision of the *Assemblée du Pays* to build the canal of Bosigelin, AC Aix, AA 37,44,45,46.

number of the institutional problems of irrigation. Indeed ,in the *Comté* at least, the backing of the *Assemblée* greatly simplified the gathering of water eminent domain rights and provided the funding to get around the revenue problems of so many irrigation projects.

By promoting the canal of Boisgelin in 1777, the *Assemblée* was voting to provide the infrastructure for economic development, this action foreshadowed the role of the French state in the nineteenth century. The Old-Regime state, however, could not play that role because it lacked the resources. The failure of the national government to provide for irrigation development left that responsibility to local organizations, and in the eighteenth century irrigation was developed under the direction of local organizations. In two important cases (Cabedan-Neuf and Boisgelin) local organizations shouldered the financial risk associated with economic development. Cavaillon actually underwrote the loans of the canal of Cabedan-Neuf and thus provided an association of landowners with little legal identity the credit necessary to build the canal. The canal of Boisgelin was financed by the *Assemblée* directly.

The history of eighteenth century irrigation development shows how the ultimate barriers to irrigation were related to the division of authority. The lawsuits between Oppede and Cavaillon had settled the question of water rights, and the participation of local institutions had also reduced institutional costs. Together these changes allowed limited development of irrigation in the last half of the eighteenth century. Yet these changes were not enough. The example of the canals of Crillon and Boisgelin show that the eighteenth-century institutions did not change enough to lower the institutional costs of large projects. The extreme division of authority over rights of eminent domain continued to plague large projects, as numerous groups held authority over eminent domain and each could block certain canal routes. The authority of other groups was less certain, but litigation was sufficiently lengthy and costly that those groups were able to appropriate part of the developer's profit or impose high costs on the

canal. Despite its reforms, the Old Regime therefore failed to limit and simplify the problems associated with uncertain property rights, veto power and litigation. True fundamental institutional change would wait for the Revolution.

The Revolution and Irrigation

For 25 years after 1789 there was not increase in the irrigated area in Provence. Revolutionary turmoil and the Napoleonic wars suspended the development of irrigation. Yet at the very same time the Revolution was bringing about institutional reforms that would be prerequisites for future development even though during their effects were delayed by the wars. The reforms would reduce the number of veto players and simplify the state's procedures for granting water and rights of eminent domain. This section examines the institutional changes brought about by the Revolution and their consequences: the construction of a number of new irrigation canals after 1820.

Revolution (1789-1815)

Between 1789 and 1815, no new irrigation canals were constructed, and those networks already in use were very poorly maintained.[125] The Revolutionary turmoil during the years 1789-95 cast doubt on the strength of property rights and discouraged investment. Moreover, a number of other problems with the Revolutionary economy impeded further irrigation. Government induced inflation, price controls, and the war economy distorted the market. Most importantly the Revolutionary wars drained away manpower, and drove up the price of labor relative to land. The manpower drain continued and even worsened during the Napoleonic period (1795-1815). It is not surprising then that the estimated rates of return and benefit-cost

125) AD Vaucluse, S *Usines et Cours d'Eau* Cavaillon and L'Isle sur Sorgues.

ratios were at their lowest of the two centuries between 1789 and 1815 and that irrigation development came to a halt.

Nonetheless the Revolution and the Napoleonic era were important times for irrigation. Institutional reforms, initiated by the Revolutionary regime and continued by Napoleon, drastically cut the institutional costs of irrigation in the nineteenth century. The reforms consolidated all powers of eminent domain in the hands of the central government and gave that government the power to bind developers to announced price paths. They also eliminated the problems with certain veto groups and with the rent-seeking judiciary.

The most dramatic changes associated with the Revolution were the destruction of the old organizations and institutions that had protected each area from royal reforms. In Provence the annexation of the *Comtat*, and the abolition of the peculiar status of the *Terres Adjacentes* removed a major obstacle the development of irrigation, and for the first time since the early Middle Ages, a single authority could decide issues of property right in Provence.

Administrative Reforms

From the point of view of irrigation development, the most important single Revolutionary reform was the centralization of legal and political power. Although centralization had been one of the goals of the absolutist monarchy, and although the king held a veto power over virtually all economic activity, he had never been able to eliminate local veto players like the *Parlement*, the *Assemblée du Pays*, the Estates, or even city councils.[126] Centralization during

126) The limitations of Old-Regime royal power are demonstrated by the ability of the city of Marseille to resist reform over wine exports for over forty years. In 1719, a royal decision allowed wine to transit through the port of Marseille if it was to be exported. In order to protect their local monopoly--granted in the thirteenth century--wine growers in Marseille refused to allow any import of wine into the city, even for purposes of export. A suit in opposition to this decision was filed in 1750 but it was not until after 1767 that export was authorized again. See Georges Billioux, "Le Vignoble Marseillais, du XIII^{eme} Siecle à l'Aduction d'Eau de 1840," *Provence Historique*, Melanges Busquet, 6 (1956), pp. 166-185; and Georges Rambert, "Le Commerce de l'Eau de Vie a Toulon au XVIII^{eme} Siecle," *Provence Historique*. 13 (1963), pp. 31-53.

the Revolution eliminated these local organizations and replaced them with a single pyramidic administrative structure headed by the Ministry of Interior. And despite violent resistance in some provinces, centralization was achieved early on.

At the same time, the government appropriated all eminent domain and unused water rights. The appropriation of unused water rights to major rivers like the Durance was complete, and after 1790, all authority over water rights lay in Paris. In the case of rights of way, the agent of the government at the local level--the prefect--wasd charge with all the decisions, the government became the sole veto player for irrigation projects.[127] The destruction of all other veto players freed irrigation development from the shackles of strategic behavior.

Municipal government was also reformed. Unlike Normandy, municipal governments in Provence possessed considerable power under the Old-Regime. The Revolutionary reforms put an end to their independent authority and made it difficult for Provencal towns and villages to resist central government decisions. Authority that had previously rested with the municipal government was placed directly in the hands of the prefect, particularly authority over economic matters. Although the ability of prefects to directly coerce wayward village governments would vary between 1789 and 1860, the indirect means at their disposal were very significant. Prefects supervised town finances and closely controlled the management of village assets. Finally, villages no longer had the power to block projects approved by the central administration.[128]

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127)Jean Petot, *L'Administration des Pont et Chaussése*, pp. 383-87; Louis Bergeron, *L'Episode Napoleonien; Aspects Interieurs*. Paris: Editions du Seuil, 1972, pp. 33; D.M.G. Sutherland, *France 1789-1815* pp. 345; and AC Vaucluse, S (*Usines et Cours d'Eau*).

128) Fernand Ponteil, *Les Institutions de la France de 1814 a 1870*, pp 30-34; and Louis Bergeron, *L'Episode Napoleonien* pp. 32-39. The power of the prefect emerges from his day to day correspondence. He made the final decision over most changes in town budgets. In the case of canals he made the final decision over every new water wheel based on the recommendation of local officials and the engineer of the Roads and Bridges Administration: AD Vaucluse, S *Usines et Cours d'Eau*, Cavaillon. The new power of the French administration on village life during the Revolution is detailed in Anne Zinc *Azereix. La Vie d'une Communautée Rurale a la Fin du XVIII^{eme} Siecle*. Paris: S.E.V.P.E.N. 1969, pp. 221-234.

As a result of these reforms, towns and villages near a river could no longer refuse rights of way for new irrigation projects simply to protect the market value of their older irrigated land or, even worse, to syphon off part of the profits. The issue had been of great importance in the eighteenth century when towns that held authority over rights of way had argued they should be compensated for externalities imposed by the developers. The division of political power allowed towns to use their authority to demand compensation for losses in the value of older irrigated land as a result of expanded irrigation; as if these losses were negative externalities of the project.[129] This problem highlights the difference between the impact of economic development at the local level and at the national level. Cavaillon was pursuing the best interest of its inhabitants when it sought to prevent increased irrigation in the *Comtat.* Cavaillon and many other towns that behaved similarly, where simply trying to limit competition. If the property rights to irrigation expansion had been owned by a larger political body than Cavaillon, irrigation would have been more fully developed in the eighteenth century, and the economic growth associated with irrigation would have occurred before the Revolution. As a result of Revolutionary reforms, those property rights to increased irrigation all rested in the national government in the nineteenth century.

The national governments of the Revolution gave prefects complete authority over projects until they were built and those governments also removed the judiciary from the planing stages of irrigation, making it difficult for local groups to delay projects through litigation. Local groups could appeal a project before the prefect but they could no longer appeal an irrigation proposal in court. The approval of the prefect was thus sufficient to guarantee the success of an irrigation project, and litigation--when it occurred--did not start until after the canal

129) The modern equivalent would be if new entrants in the computer industry had to pay older firms for the lost profits associated with their entry.

was built and the social gains were realized. The ability of individuals and groups to litigate was further limited because conflicts over technical and engineering issues could no longer be litigated, they were instead decided by French administrators and the judiciary's potential interventions were limited to monetary (i.e. redistributive) questions. After the Revolution not only did the central administration have the power to provide developers of irrigation with the property rights they needed, it also had the power to enforce all the contracts itself.[130]

Meanwhile the judiciary itself was reformed, the venality of offices was abolished. The Old-Regime system, where judges bought their offices, was replaced by an administrative judiciary that was paid and monitored by the central government. The Revolution eliminated all rent-seeking because the judiciary could no longer prey on civil cases in hope of financial rewards. The Revolution also solved all the problems of overlapping judicial authority, by simplifying the geographical and legal jurisdictions of courts.

Restoration (1815-1860)

After the end of the Napoleonic Regime in 1815, and under a variety of different governments, irrigation in southeastern France flourished. The hypothetical rates of return and benefit-cost ratios suggest that irrigation entrepreneurs earned hefty profits (above 24% or five times the rate of interest). From 1815 to 1860 political leaders and governmental structures were in constant flux: Louis XVIII and Charles X, under the Restoration constitutional monarchy were succeeded by Louis-Philipe, under the Bourgeois constitutional monarchy, and he in turn, by Napoleon III, under both the Second Republic and the Second Empire. Despite the

130) The Old-Regime had attempted give the *intendants*--the equivalent of the prefect--the same authority that the Revolution and Napoleon gave to prefects. Despite much legislative maneuvering the Old Regime once again failed. For irrigation specifically the case of the canal of Toulon, a town in eastern Provence--and its irrigation canal is most instructive. Toulon had built a canal and had allowed landowners to use the water it did not yet need to irrigate their land. In the 1780s the city attempted to reclaim its water. The canal rental contracts were all supposed to be under the jurisdiction of the *intendant*; however, many courts were involved in the litigation. See AN, H^1 1307 (March 1782)

political changes in Paris, the various governments all promoted irrigation, as had the late eighteenth century monarchies. It was not government support that brought about irrigation, but rather the new set of institutions created during the Revolution. These new institutions allowed for the realization of some large projects, such as the canals of Carpentras, L'Isle, and Alpinnes, and many small ones, such as the canals of Plan Oriental, Vergers, and Lauris.[131]

Another post-Revolutionary change reduced the risk of investing in irrigation: the *associations syndicales*. The Restoration governments promoted these organizations of landowners who stood to benefit from a canal. The *associations* allowed them to share the costs of the canal and deal with collective problems. Each landowner was responsible for a share of the costs equal to his share of the land irrigated. *Associations* actually began during the Revolution but they did not become widespread until the 1820s, when new legislation simplified their creation. Although some projects (the canal of L'Isle, half of the canal of the Alpinnes, and the canal of Pierelatte) were developed by private companies, other by local or departmental organizations (the canal of the Alpinnes), most were built and administered by *associations*.[132] So successful were the *associations* that even some privately owned canals employed them to deal with revenue collection and water allocation in times of drought.[133]

Yet the great advantage of *associations* lay beyond the economies of scale in administration. *Associations* were organizations that solved all the price commitment problems

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131) Irrigation networks varied tremendously both in length and in area serviced. They could be as small as the network of the Vergers canal, which was less than a kilometer long and irrigated less than 80 hectares or as large a s the canal of Carpentras, which was over 100 kilometers long and irrigated over 5,000 hectares. In the eighteenth century the distinctions between small and large canals were primarily institutional: a project which ran through a large number of communities (more than two or three) qualified as large. For the nineteenth century, I adopted the rule that any project over 800 hectares was large.

132) See J. A. Barral, *Les Irrigations dans le Vaucluse* vol. 1, p. 326.

133) J. A. Barral, *Les Irrigations dans le Vaucluse* vol.1, pp 326-328. In 1870 there were 73 different canals in the Vaucluse, five were private properties three owned by the state, the others were owned by local administrations such as *associations* and towns council. Most canals were administered by *associations*, in fact more than 75% of all the water distributed in the Vaucluse was through *associations*.

because they were under the authority of the state. *Associations* could post a price for irrigation water before the project occurred and the state would enforce that price forever. The state was the only party to these agreements who could credibly claim to enforce any price path despite the fact that it never had the ability to commit. Although the state had no power of commitment, it was a repeat player in irrigation development, as it participated in all the projects. Repeated participation gave the state reputational incentives to enforce prices. In fact, the state alone had reputational incentives to enforce announced price paths because it alone was a repeat player in irrigation. Developers could benefit from state enforced prices by creating an *association*, which would announce rising prices for irrigation rights. In turn rising prices would enduce individual landowners to buy irrigation rights before the project occurred. Moreover, given the *association's* commitment to such prices, creditors were also willing to finance projects because revenue was no longer risky.

The impressive irrigation record of the period 1820-1860 is thus not surprising. The overall success of the nineteenth century is striking: in the Vaucluse well over half of the increase in irrigated area between 1700 and 1860 came after 1820, and in the Bouches du Rhone nearly all the increase occurred after 1820. In sum, more than 10,000 hectares (or a third of all the land that was ever irrigated) were supplied from canals completed between 1820 and 1860. Moreover, by 1870 the demand for Durance water from irrigation canals was greater than what was available in the river during the summer drought, and as a result some canals could not deliver water during the summer and fall of dry years.

Whether in the case of a small project such as Plan Oriental, or in the case of a large project such as the canal of Carpentras, state approval was swift and *associations* where created by the promoters to raise revenue. The canal of Plan Oriental involved only a small amount of land (less than 1,000 hectares) and delivered water only to fields in Cavaillon. The

project was quickly approved by the prefect and carried out less than four years after the project was initiated. In contrast because it involved very large amounts of land (more than 4,000 hectares were eventually irrigated), in many different communities the canal of Carpentras was a project that took decades to get off the ground. The small number of desirable drawing sites on the Durance required securing rights of way for the water of the canal of Carpentras through other canals (Cabedan-Neuf and L'Isle). The project was delayed until the creation an organization grouping all the canals that drew water from the site originally used by Cabedan-Neuf alone. Nonetheless, given the new rules, the promoters were able to rely on the support and authority of the national government and, within 20 years of its initiation, that canal, too, was completed.

Conclusion

In the early eighteenth century, uncertain property rights over water and and uncertain authority over eminent domain stifled the development of irrigation. The uncertainty in property rights over water was resolved in the middle eighteenth century, when owners of monopoly water rights were defeated in a set of lengthy legal battles. The veto power of owners of existing canals over new projects was abolished while their rights to the water they used were affirmed. Thus the institutional costs of irrigation fell and development proceeded, but the division of authority over rights of eminent domain still limited the scale of irrigation development. In Provence, the political division of authority--a legacy of the Middle Ages--gave ample opportunity to a variety of groups to hold a project up using their veto power. Veto players successfully used this position to extract rents from potential developers.[134]

134) The use of veto power to extract rents from developers was in fact widespread in Old-Regime Pro-

Only local irrigation projects could avoid the costs associated with divided authority over rights of eminent domain. As a result, the transaction costs associated with irrigation development increased dramatically when projects crossed authority boundaries. Irrigation developers were forced to face these transaction costs because the state proved incapable of reform, and the limited development of the late eighteenth century was plagued by very high costs imposed by institutions.

The nineteenth century witnessed the significant development of irrigation in southeastern France without significant litigation and with much shorter delays than had been customary in the previous century. The Revolutionary reforms lowered transaction costs in irrigation by eliminating all local veto players. Not surprisingly, between 1820 and 1865 the area irrigated in Provence more than doubled and all the water in the Durance was used.

Old-Regime institutions had made it impossible for developers to commit to announced prices for irrigation rights, and as a result irrigation projects were plagued by the durable goods monopolist problem. Starting during the Revolution a number of laws created *associations syndicales*, legal organizations that grouped landowners. Coupled with the increased power of the state, nineteenth-century *associations* successfully solved the durable goods monopolist problem. The law allowed *associations* to use the state to enforce announced and time-inconsistent prices for irrigation rights, and the state, because it was a repeat player, was willing to enforce the time-inconsistent price paths.

The problems of expanding the irrigation network in eighteenth-century France suggest that the state must play a fundamental role in economic development: it chooses the insti-

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vence, cf. Rene Baehrel, *La Basse Provence* pp. 450-456; Rene Pillorget, *les Mouvements Insurrectionels*, pp. 196-207; Maurice Alguhon *La Vie Sociale en Provence Interieure au Lendemain de la Révolution*. Paris: Societé des Etudes Robespierristes, 1970 pp. 43-59.

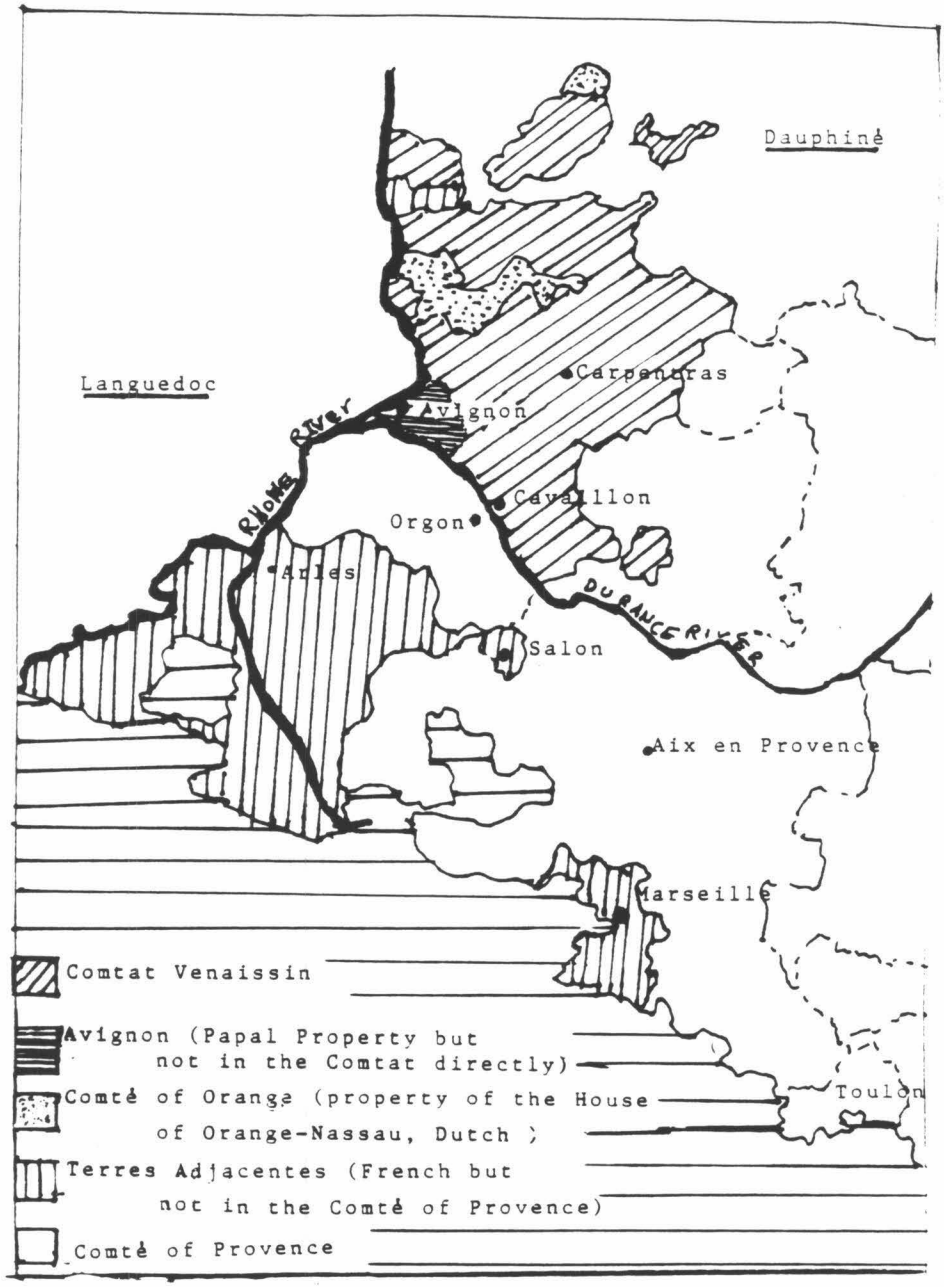
tutions that control economic activity. It defines property rights and the nature of the contracts by which they can be traded. In short the state defines the law and thereby the magnitude of institutional costs. Under the Old Regime there existed no organization--not even the state--with the power to make the changes necessary for for substantial irrigation development. Not even the absolutist state could realize fundamental reforms. The French Revolution achieved just that end through the creation of a strong central state.

Appendix 2

Maps, Tables, and Figures for Chapter 3

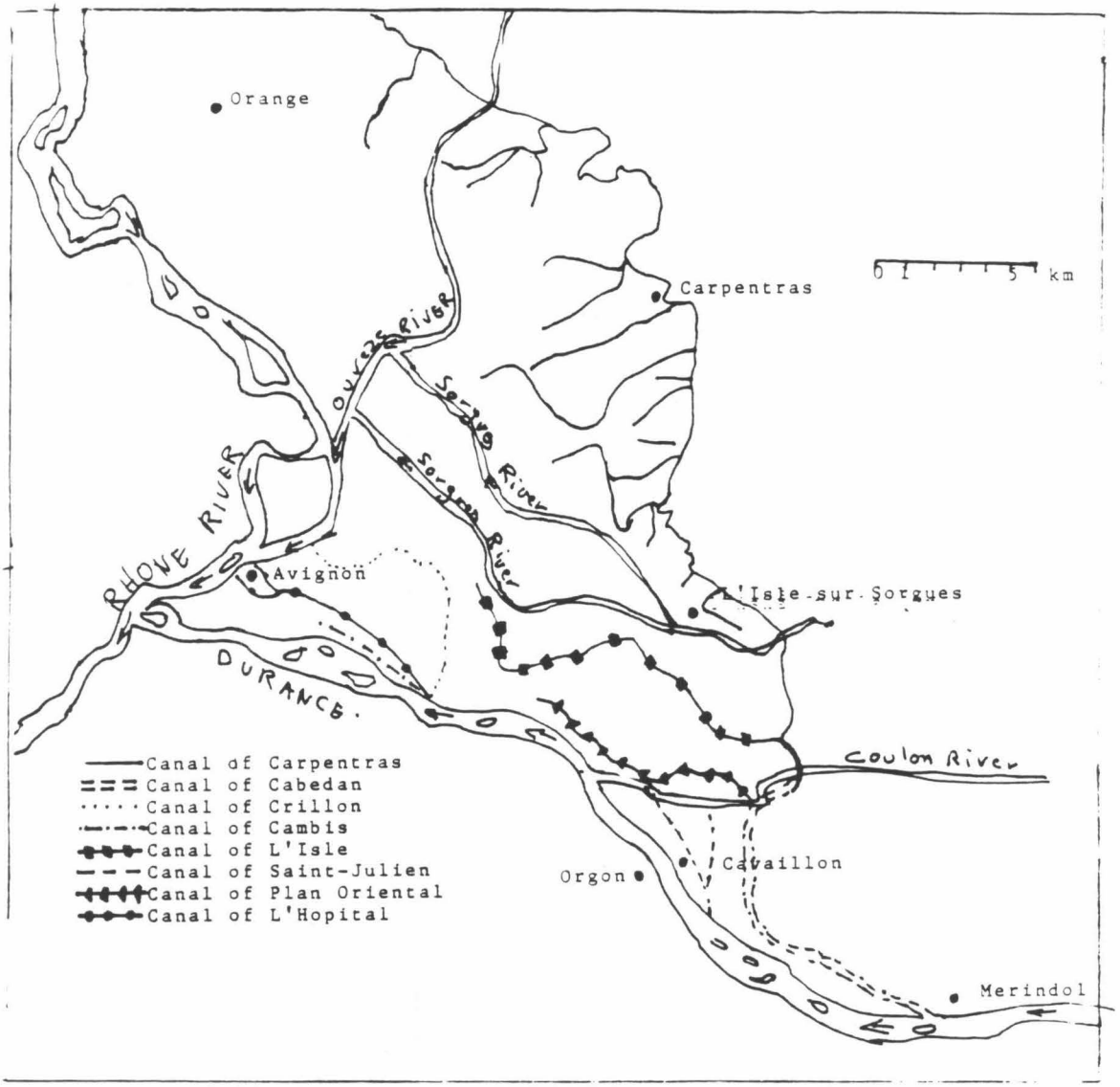
Map 2

Western Provence in the Eighteenth Century[135]



Map 3

Irrigation Canals in the Vaucluse[136]



Map 4

Irrigation Canals in the Bouches du Rhone[137]

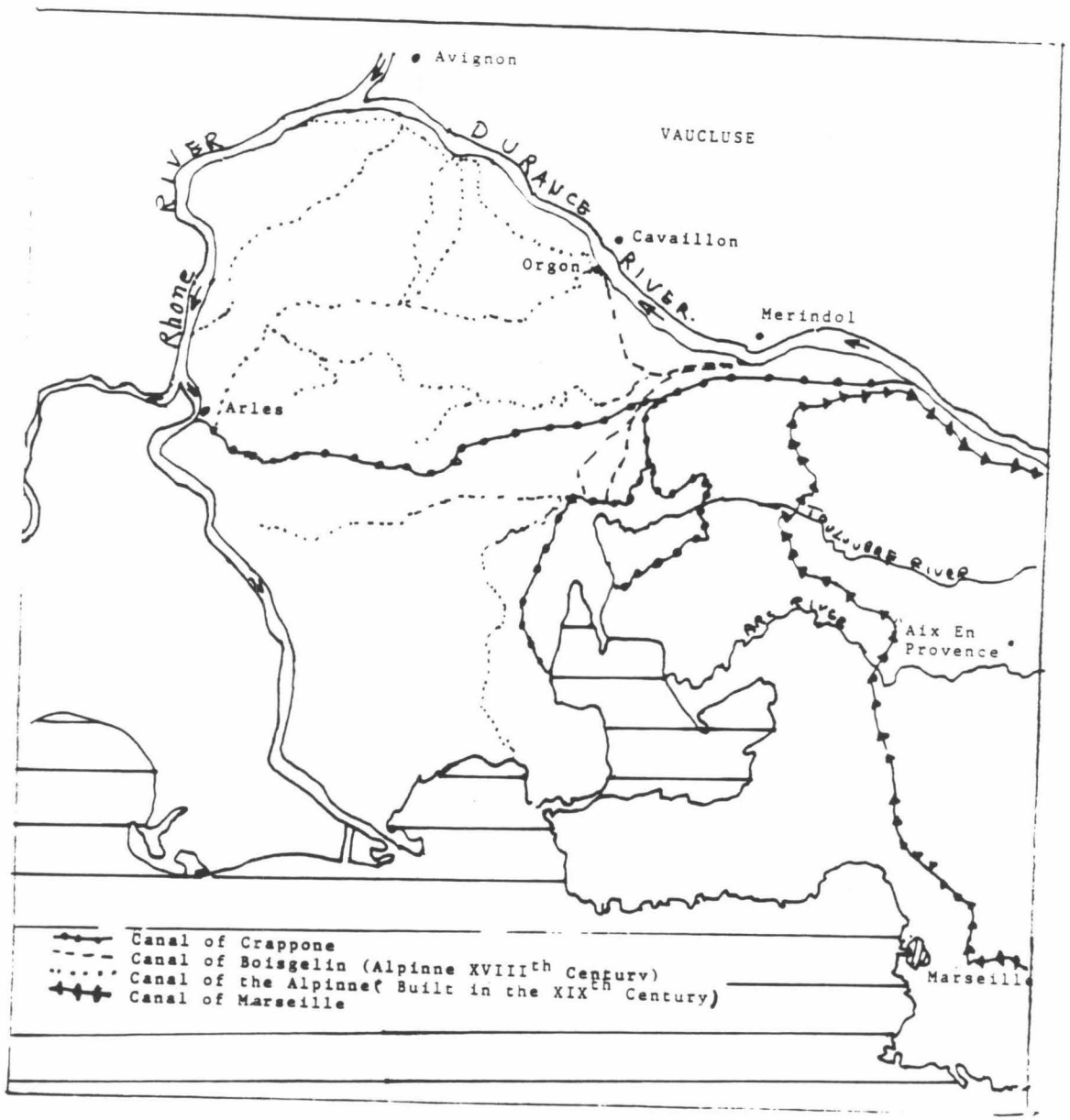


Figure 5: Wages in Avignon 1700-1855

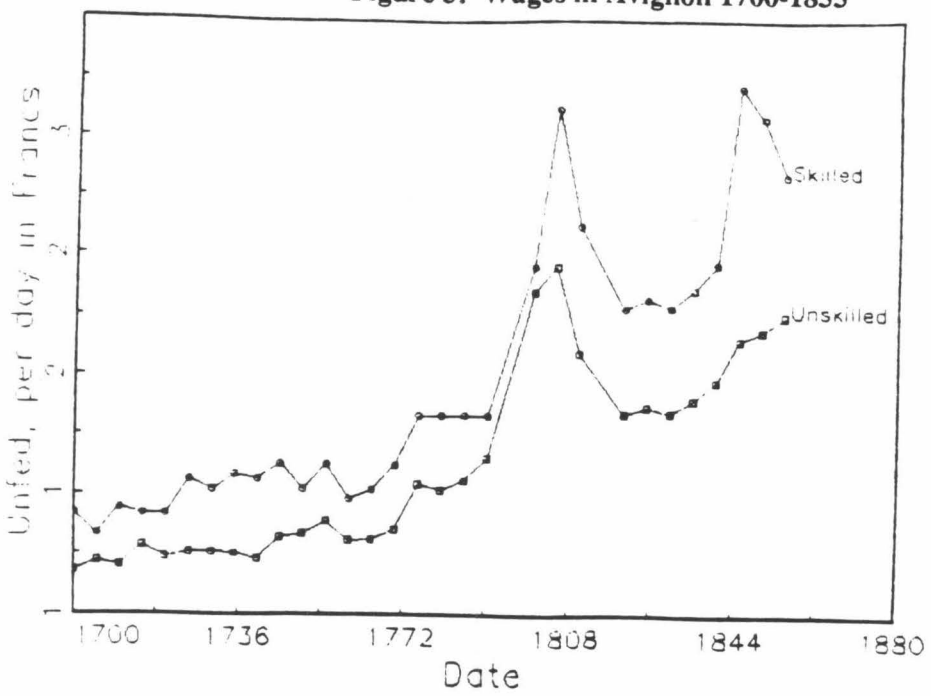


Figure 6: Land Prices in Cavaillon 1700-1855

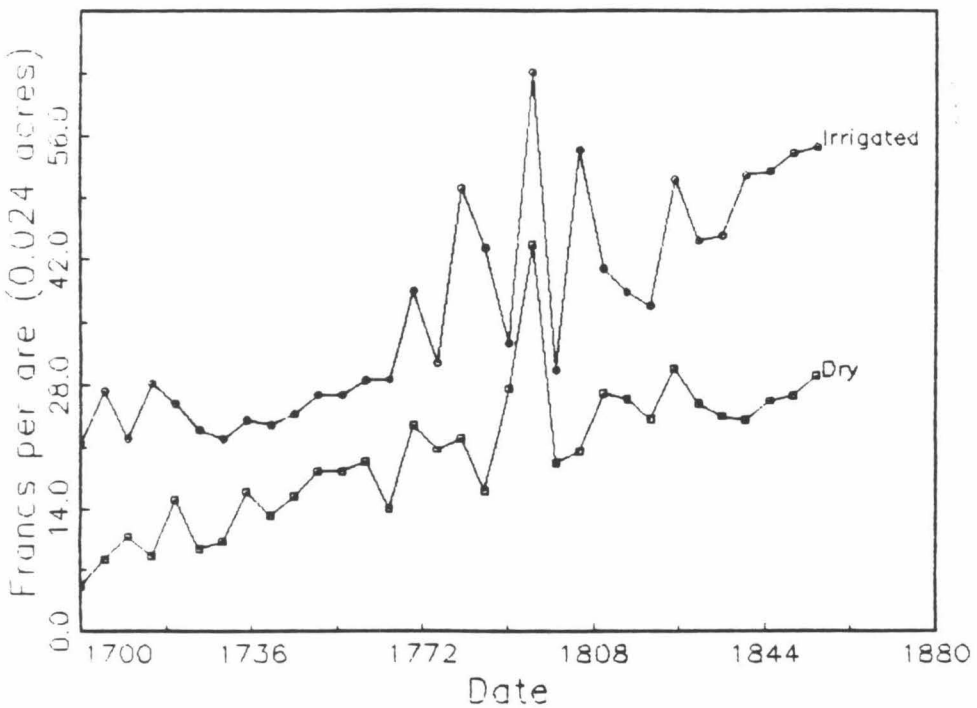


Table 7: Price Series For Provence 1700-1855

Date	Wages		Land Prices	
	Unskilled (Unfed in Francs per day)	Skilled	Dry (in Francs per Ares)	Irrigated
1700	0.71	1.00	5.11	21.53
1705	0.76	0.89	8.14	27.30
1710	0.73	1.02	10.8	22.01
1715	0.84	1.00	8.51	28.19
1720	0.78	1.00	15.10	25.90
1725	0.80	1.17	9.39	22.97
1730	0.80	1.12	10.31	22.02
1735	0.80	1.20	15.98	24.07
1740	0.77	1.17	13.20	23.55
1745	0.88	1.25	15.38	24.77
1750	0.89	1.12	18.27	26.94
1755	0.96	1.25	18.27	26.94
1760	0.86	1.07	19.34	28.57
1765	0.87	1.12	14.10	28.67
1770	0.92	1.25	23.61	38.54
1775	1.15	1.50	20.81	30.55
1780	1.12	1.50	22.03	50.03
1785	1.17	1.50	16.04	43.28
1790	1.28	1.50	27.56	32.71
1795	.	.	43.65	63.09
1800	2.12	2.25	19.10	29.63
1805	2.25	3.03	20.44	54.38
1810	1.81	2.45	26.98	40.97
1815	.	.	26.40	38.31
1820	1.51	2.03	24.20	36.77
1825	1.54	2.08	29.85	51.00
1830	1.51	2.03	25.90	44.11
1835	1.57	2.12	24.50	44.69
1840	1.67	2.25	23.99	51.49
1845	1.87	3.16	26.21	51.92
1850	1.92	3.00	26.79	54.00
1855	2.00	2.70	29.00	54.70

135)The present day department of the Vaucluse begins north of the Durance river while all the land south of the river is in the Bouches du Rhone. The map is inspired from Edouard Barratier, *Histoire de la Provence*, p. 369.

136) The Map is inspired from Rene Caillet, *Le Canal de Carpentras*.

137) The map is inspired from Paul Masson, *Encyclopédie*, vol. VII, p. 188.

Figure 7: Hypothetical Benefit-Cost Ratios for Irrigation Projects (estimated interest rate)

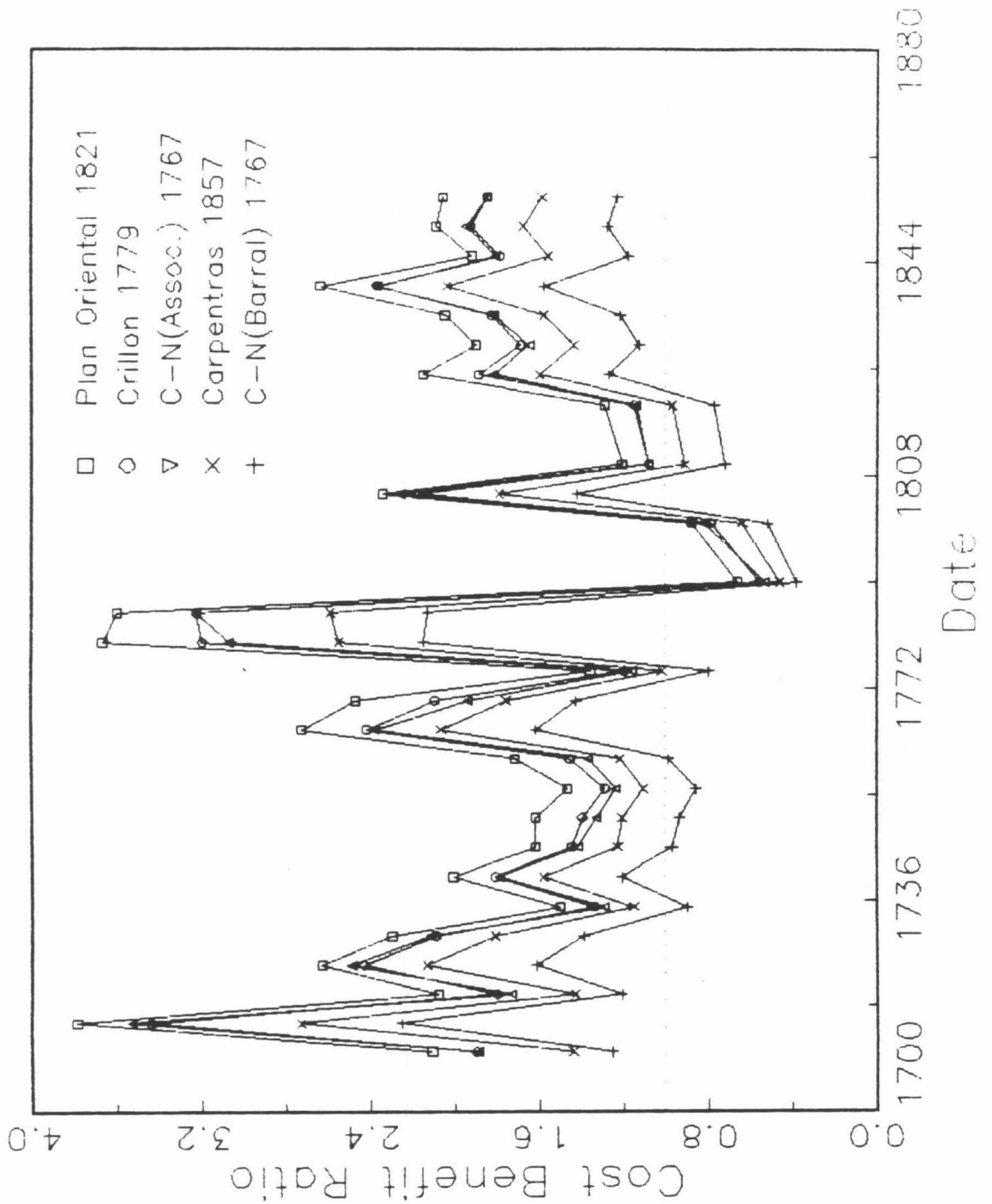


Table 8: Hypothetical Benefit-Cost Ratios for Irrigation Projects (estimated interest rate)

	Hypothetical Benefit-Cost Ratios				
Date	Plan Oriental	Crillon	Cabedan Neuf (Association)	Cabedan Neuf (Barral)	Carpentras
1700	-	-	-	-	-
1705	-	-	-	-	-
1710	2.11	1.90	1.89	1.25	1.44
1715	3.79	3.44	3.53	2.25	2.73
1720	2.08	1.80	1.73	1.21	1.43
1725	2.63	2.43	2.49	1.61	2.13
1730	2.30	2.09	2.12	1.39	1.81
1735	1.50	1.34	1.29	0.90	1.15
1740	2.01	1.81	1.79	1.21	1.58
1745	1.62	1.45	1.42	0.97	1.23
1750	1.62	1.40	1.33	0.94	1.21
1755	1.47	1.29	1.24	0.86	1.11
1760	1.72	1.46	1.37	0.99	1.22
1765	2.73	2.42	2.38	1.62	2.07
1770	2.47	2.10	1.94	1.43	1.76
1775	1.36	1.20	1.16	0.80	1.02
1780	3.67	3.20	3.07	2.15	2.55
1785	3.60	3.23	3.23	2.13	2.59
1790	0.66	0.56	0.53	0.38	0.46
1795	-	-	-	-	-
1800	0.88	0.79	0.82	0.52	0.64
1805	2.34	2.17	2.26	1.42	1.79
1810	1.21	1.08	1.08	0.72	0.91
1815	-	-	-	-	-
1820	1.29	1.15	1.14	0.77	0.97
1825	2.15	1.89	1.82	1.27	1.60
1830	1.90	1.69	1.65	1.13	1.44
1835	2.05	1.83	1.82	1.22	1.58
1840	2.64	2.37	2.37	1.58	2.04
1845	1.92	1.79	1.81	1.18	1.56
1850	2.09	1.93	1.95	1.28	1.68
1855	2.06	1.85	1.85	1.23	1.59

Figure 8: Hypothetical Benefit-Cost Ratios for Irrigation Projects (Mortgage rate)

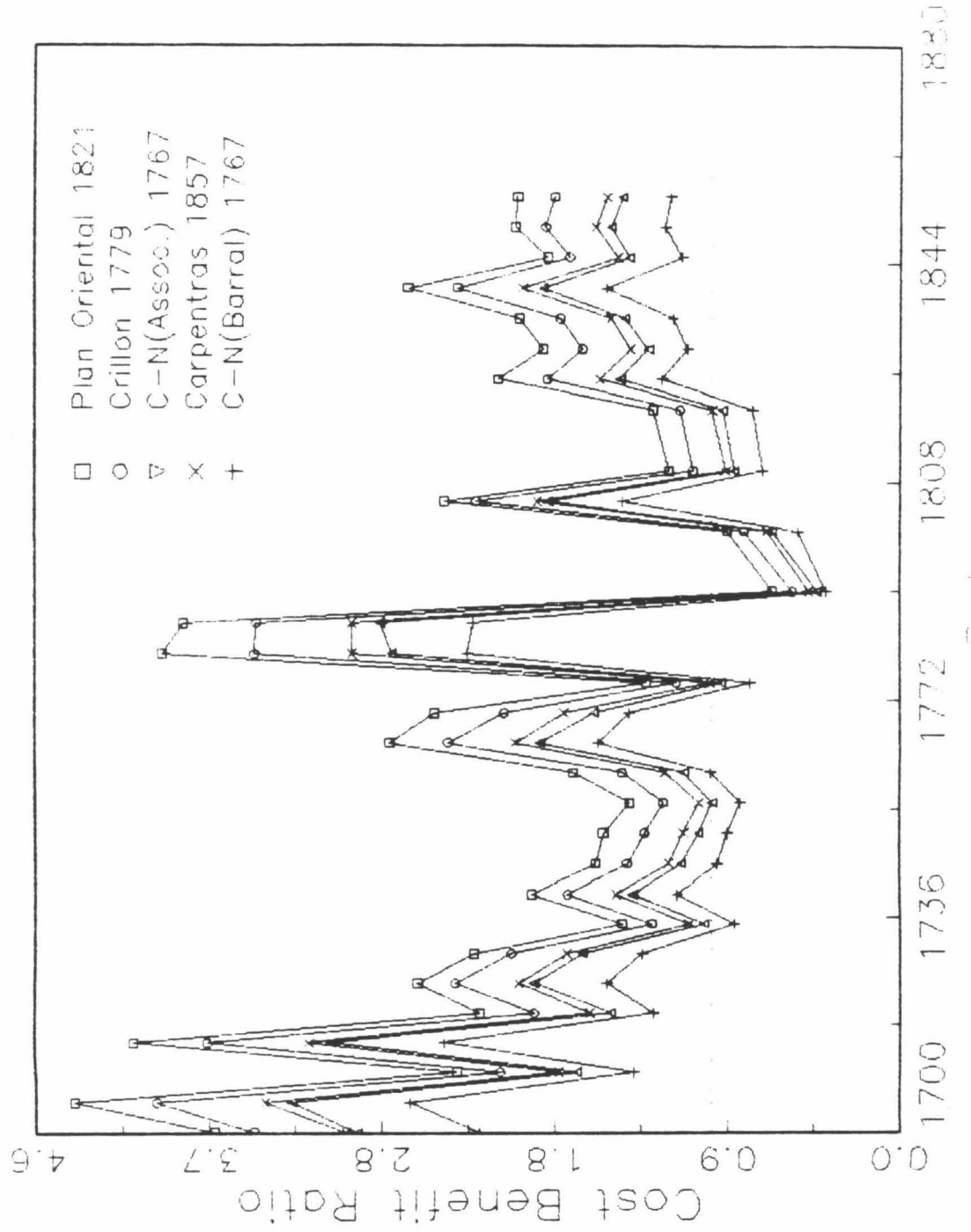


Table 9: Hypothetical Benefit-Cost Ratios for Irrigation Projects (Mortgage rate)

Hypothetical Benefit-cost Ratios					
Date	Plan Oriental	Crillon	Cabedan Neuf (Association)	Cabedan Neuf (Barral)	Carpentras
1700	3.65	3.44	2.89	2.24	2.95
1705	4.40	3.96	3.24	2.61	3.38
1710	2.36	2.13	1.72	1.42	1.82
1715	4.08	3.69	3.03	2.43	3.15
1720	2.24	1.95	1.54	1.31	1.65
1725	2.57	2.37	1.95	1.56	2.03
1730	2.27	2.07	1.69	1.37	1.77
1735	1.48	1.32	1.04	0.88	1.12
1740	1.96	1.77	1.42	1.18	1.51
1745	1.62	1.45	1.16	0.97	1.23
1750	1.58	1.36	1.07	0.92	1.15
1755	1.44	1.26	1.00	0.85	1.07
1760	1.74	1.48	1.15	1.01	1.25
1765	2.72	2.41	1.92	1.61	2.05
1770	2.48	2.11	1.63	1.44	1.79
1775	1.35	1.19	0.95	0.80	1.01
1780	3.93	3.44	2.71	2.31	2.92
1785	3.82	3.43	2.77	2.28	2.92
1790	0.68	0.57	0.44	0.39	0.48
1795	-	-	-	-	-
1800	0.92	0.83	0.68	0.54	0.71
1805	2.43	2.26	1.87	1.48	1.93
1810	1.23	1.10	0.88	0.73	0.93
1815	-	-	-	-	-
1820	1.31	1.17	0.94	0.78	1.00
1825	2.14	1.88	1.49	1.27	1.60
1830	1.90	1.69	1.34	1.13	1.43
1835	2.03	1.81	1.46	1.21	1.54
1840	2.62	2.36	1.90	1.56	2.01
1845	1.88	1.76	1.44	1.16	1.50
1850	2.05	1.89	1.54	1.25	1.62
1855	2.04	1.84	1.48	1.22	1.56

Figure 9: Hypothetical Internal Rates of Return for Irrigation Projects

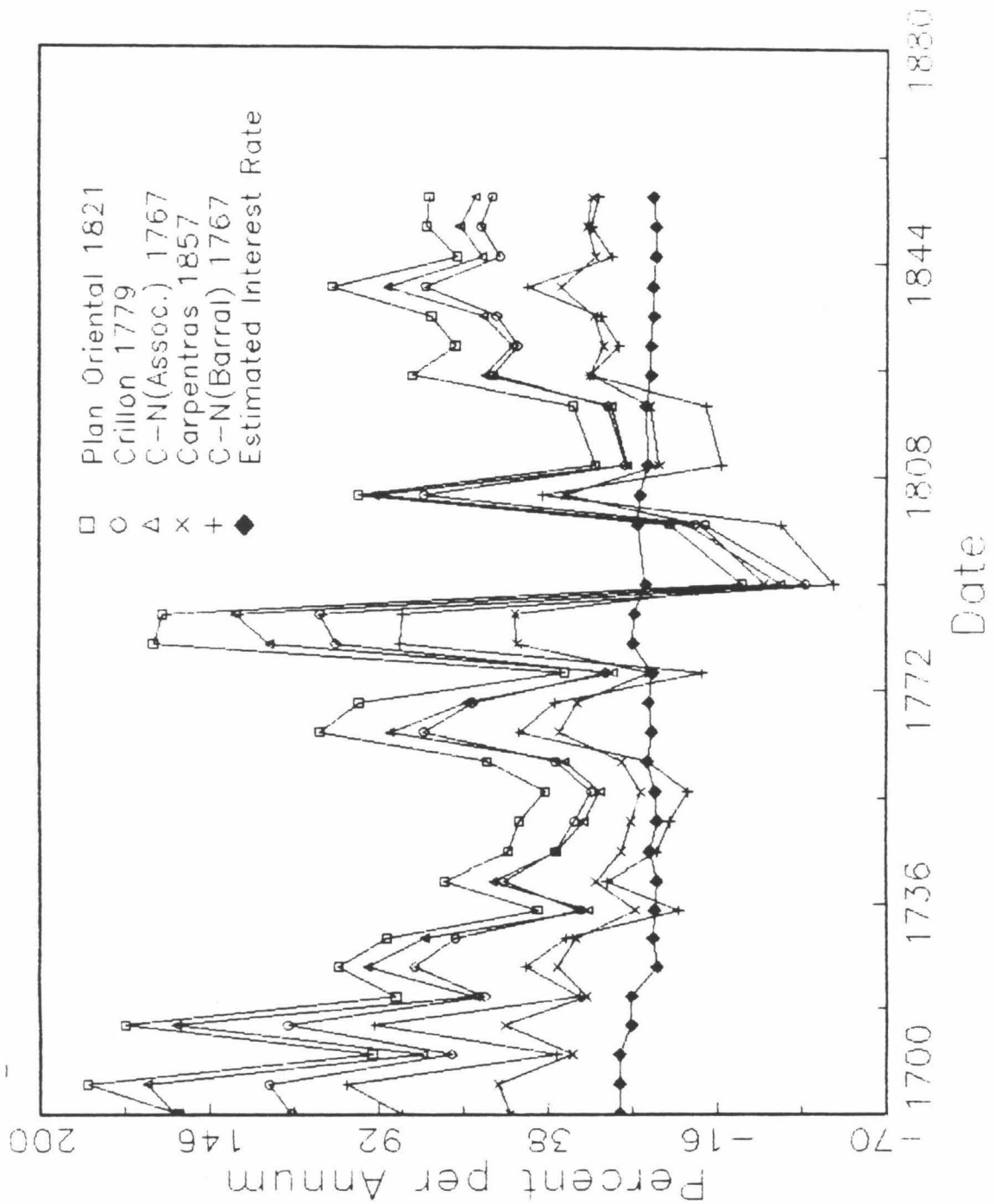


Table 10: Hypothetical Internal Rates of Return for Irrigation Projects

Hypothetical Internal Rates of Return (In percent per annum)						
Date	Plan Oriental	Crillon	Cabedan Neuf (association)	Cabedan Neuf (Barral)	Carpentras	Estimated Interest rate
1700	156.	120.	157.	84.6	50.1	15.0
1705	185.	127.	166.	102.	54.1	15.0
1710	94	68.8	77.9	35.4	30.1	15.
1715	173.	121.	157.	93.2	51.5	11.4
1720	86.5	58.2	61.3	27.9	25.8	11.4
1725	105.	80.5	95.5	45.0	34.8	3.11
1730	89.4	67.6	77.3	32.4	29.2	4.37
1735	41.3	27.6	25.3	-3.73	10.2	3.91
1740	71.3	52.3	55.6	19.0	22.7	3.11
1745	50.9	35.8	35.5	3.19	14.4	5.33
1750	47.5	29.6	26.7	-0.84	11.3	3.11
1755	38.8	24.1	21.4	-6.70	8.34	3.70
1760	57.5	35.7	32.6	5.99	14.7	6.33
1765	111.	77.6	88.5	47.1	34.4	4.83
1770	98.4	62.1	64.0	35.9	28.7	5.79
1775	32.6	19.6	17.1	-11.1	5.85	4.74
1780	164.	106.	127.	85.3	48.0	10.9
1785	161.	111.	138.	84.7	48.5	10.4
1790	-24.0	-44.2	-36.3	-53.4	-31.2	6.87
1795	-	-	-	-	-	9.4
1800	-0.97	-12.1	-6.86	-36.5	-10.8	9.30
1805	98.6	77.8	93.5	39.8	32.8	8.70
1810	23.1	13.4	12.7	-17.4	2.42	6.15
1815	-	-	-	-	-	7.40
1820	29.9	18.9	17.6	-12.5	5.38	6.70
1825	81.5	55.7	58.4	24.8	24.6	5.09
1830	67.8	47.9	49.7	15.2	20.4	5.16
1835	75.4	54.6	58.9	21.1	23.5	4.33
1840	107.	77.3	89.3	44.7	33.9	4.58
1845	67.4	53.6	59.2	17.7	22.9	3.62
1850	77.1	59.6	66.6	24.2	25.7	3.57
1855	76.2	56.1	61.4	21.9	24.1	4.41

Chapter 4

Settlement, Litigation and Eighteenth-Century Norman Drainage

Introduction

This chapter analyzes a game of litigation and settlement with endogenous court costs--a game with implications for economic history and for the impact of judicial institutions on economic activity. The chapter demonstrates the importance of information and evidence in litigation and settlement decisions and shows that rules of legal proof cannot be ignored when modeling settlement and litigation games. I begin by arguing that the way players gather and use information in a litigation game is crucial to an understanding of the judicial process. I then review the relevant literature in law and economics, and after describing the game and defining the equilibrium concept, I show that an equilibrium exists and that it is generically unique. I next examine the impact of specific legal rules on the equilibrium. Finally I use the model to analyze litigation over the drainage of marshes in eighteenth-century France, the goal being to uncover how particular institutional rules blocked drainage and technical change.

For our purposes litigation can be defined as a process whereby two parties who disagree on the value of a contract come to a binding resolution. This resolution is enforced by a third party--the court. Because court resolutions are costly, both parties would prefer to settle out of court. In this game I assume that the true value of the contract can be either high or low and that, at least initially, neither player knows its true value. The true value of the contract, though, is less important in this context than the difficulty each party has documenting its value before the court. If the parties fail to reach an out-of-court agreement, the court decides on the value of the contract based on the evidence brought before it by the players. The players must therefore expend resources trying to document the value of the contract. In this process they may or may not learn its true value. We examine the effect of their ability to learn the value of the contract under two assumptions: first, the information gained while they do their research is private; second, if neither player is able to document the true value, the court awards a convex

combination of the high and the low value of the contract.

The judicial game that is played when the parties fail to reach an out-of-court settlement is the driving force behind the magnitude of the settlement offer and the decision to accept the settlement or refuse it. The outcome of the court game depends on what each player can prove about the value of the contract, but the players only search for evidence if the settlement attempt fails. Because I ultimately want to model eighteenth-century French litigation, I assume that only the defendant can make a settlement offer; obviously in other institutional settings this may not be the case. I also assume that the plaintiff is better informed than the defendant, another assumption that I shall defend at the end of the chapter.

The game involves a four-step procedure. First, an uninformed defendant makes a settlement offer to a partially informed plaintiff. Second, the plaintiff either accepts or sues. Third, if the plaintiff sues, both players do research and present evidence to the court, and that body, in the fourth and final step, decides on the value of the contract.

In the first part of the chapter I characterize the unique perfect equilibrium of this game. The salient features of the equilibrium are as follows. First, if no plaintiff will accept a zero offer, it is a dominant strategy for the defendant to make a strictly positive settlement offer. Hence some settlement always occurs. Second, in keeping with the results of the literature,[138] higher plaintiff court costs weakly increase the probability that a settlement offer is accepted. Third, the model illuminates the importance of rules governing the burden of proof. They have, in the past, tended not to be analyzed.[139] If the burden of proof rests with the

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138) See for example Luce Bebchuk, "Litigation and Settlement under Imperfect Information," *Rand Journal of Economics*, 15 (1894), pp. 404-415.

139) See, however, Joel Sobel, "Disclosure of Evidence and Resolution of Disputes: Who Should Bear the Burden of Proof?" in A.E. Roth, *Game Theoretic Model of Bargaining*. Cambridge: Cambridge University Press, 1985, pp. 341-361; and David Rubinfeld and D.E.M. Sappington, "Efficient Awards and Standards of Proof in Judicial Proceedings," *Rand Journal of Economics*, vol. 18 (1987), pp. 308-315.

plaintiff, as in most civil cases, then in equilibrium defendants do no research, and plaintiffs are more likely to accept the settlement offer than under any other burden of proof rule. Finally, minor modifications of the model allow me to examine the issue of settlements when courts must either decide that the contract has a high value or let the settlement offer stand as the legal contract. It is this final model that most closely resembles the settlement and litigation process in eighteenth-century French contract appeals.

Bebchuk,[140] and Wilde and Reinganum[141] have analyzed models of litigation and settlement. The key difference between their models is that Bebchuk has the uninformed party, while Reinganum and Wilde have the informed party, make the settlement offer. Whether the informed or the uninformed party makes the offer affects the probability of settlement as well as the magnitude of the expected transfer between plaintiff and defendant. While Bebchuk's model is closest to mine, it suffers from underdetermination: unless the density of the distribution function of damages is single peaked, there is no guarantee that the equilibrium will be unique. The problem of multiple equilibria in fact plagues all models where the uninformed party makes the settlement offer because in these models the equilibrium settlement offer depends on the distribution function of damages.[142]

Both Bebchuk and Reinganum and Wilde were primarily concerned with the impact of different rules for allocating litigation costs between plaintiff and defendant on equilibrium trial probabilities. Thus they have little to say about the impact of judicial resolution of conflicts on economic activity. In contrast, Meurer analyzes the settlement and litigation of patents in a setting more directly relevant to mine.[143] In that model the players compete for

140) Luce Bebchuk, "Litigation and Settlement under Imperfect Information."

141) Jennifer Reinganum and Louis Wilde, "Settlement and Litigation Costs," *Rand Journal of Economics*, 1987.

142) Luce Bebchuk, "Litigation and Settlement under Imperfect Information," p. 408. Bebchuk simply assumes that the distribution has the right properties but does not investigate the implications of this assumption.

143) M.J. Meurer, " The Settlement of Patent Litigation," *Working Paper #21, Department of Economics,*

the surplus generated by a patent, but the value of those surpluses depend on the structure of the industry. The structure of the industry in turn depends on the impact of the litigation and settlement game. One problem with Meurer's model, though, is that he fails to consider the effect of endogenous expenditure decisions by plaintiffs and defendants. Therefore, in that model, trials remain lotteries.

In the law and economics literature, trials generally occur because of imperfect information. In preparation for a trial, plaintiffs and defendants expend resources documenting their respective cases. It is well established in the literature cited above that litigation costs tend to drive up the likelihood of out-of-court settlement. But litigation costs are also directly tied to the amount of evidence a plaintiff or a defendant will bring to bear on his case, and this evidence directly affects the decisions of judges and juries. Most of the literature ignores the issues of evidence and models the trial process as a lottery that depends only on the type of the defendant or of the plaintiff. Clearly litigation costs, judicial outcomes, and the likelihood of out-of-court settlement are all interrelated. It is thus essential to make court costs endogenous. Moreover, with endogenous court costs it is possible to address other questions including the effect of rules--for example, the burden of proof--on the whole process. The model analyzed below is an attempt to consider these issues.

The Model

The game I will analyze involves two players, a developer (the defendant) and a property right owner (hereafter the plaintiff). The developer has a license to carry out an activity that produces externalities. The plaintiff suffers from this activity. The object of the game is to set the level of compensation for the plaintiff's property right. Depending on the nature of his

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Duke University. November 1986.

property right he may suffer high damages and be entitled to high compensation (A) or he may suffer low damages and only be entitled to low compensation (B). There are two types of plaintiffs: strong plaintiffs and weak plaintiffs. The strong plaintiffs have a higher probability of having high damages then weak ones. Types are randomly distributed by nature, strong types occuring with probability $1-p$ and weak types with probability p.

In the first stage of the game, nature draws the plaintiff's type, and that is revealed to the plaintiff. The plaintiff, however, does not know his true level of damage but only which lottery he faces over high and low damages. The developer is uninformed about damages and types, but he knows the probability distribution of type of plaintiffs, and the probability distribution of damages given types. In the second stage, the uninformed developer offers a settlement offer (denoted S) to the plaintiff. The plaintiff either accepts the settlement offer or appeals in court. If he accepts, the game ends; if he goes to court, both parties simultaneously choose their level of legal expenditures. In the final stage, the court makes a decision about the case. If conclusive evidence of the level of damages is brought by either party then the court awards that level of damages as compensation. If no conclusive evidence is brought before the court, the court awards a convex combination $tA+(1-t)B$ of the damage levels denoted by D. Variations in t are equivalent to variations of the burden of proof rules. Indeed, burden of proof rules come into play only when no conclusive evidence is brought before the court. For example, if t is 0, then the burden of proof rests completely on the plaintiff. Figure 10, a the end of the text, provides a schematic diagram of the game.

Assumptions

Assumption 1: Plaintiffs can be two types: 1 (weak), or 2 (strong). Since there is only one kind of defendant, types will always refer to plaintiffs. A plaintiff is weak with probability p, and strong with probability $1-p$.

Assumption 2: A plaintiff of type i has high damages (A) with probability β_i and low damages (B) with probability $1-\beta_i$. We assume $\beta_1<\beta_2$: strong plaintiffs have higher probabilities of having high damages than weak ones.

Assumption 3: Plaintiffs do not know their true damages; they only know whether they are of type 1 or 2.

Types 1 or 2 can also be viewed as different probability distributions over evidence concerning high damages. Type 2 plaintiffs are more likely to be able to show that they suffered high damages, and are thus more likely to get a high award in court. Because I want to emphasize the distinction between the true level of damages (in this case A or B) and the ability to prove such a level of damage, I introduce the issue of evidence.

(1) For plaintiffs with low damages it is possible to obtain conclusive evidence that they are entitled only to low compensation but it is not possible to obtain conclusive evidence that they are entitled to high compensation. In short, it is only possible to document low compensation claims.

(2) For plaintiffs with high damages it is possible to obtain conclusive evidence that they are entitled to high compensation but it is not possible to obtain conclusive evidence that they are entitled only to low compensation (*i.e.*, only high compensation claims can be documented). The research process involved in documenting claims about damage levels is assumed to be both costly and probabilistic.

Assumption 4: For cases where damages are in fact low, the probability of finding conclusive evidence that damages are low, given expenditure c, is defined as a concave and differentiable function $g(c)$ from R^+ into the unit interval. The probability of finding conclusive evidence that damages are high is 0.

For cases where the damages are in fact high, the probability of documenting a claim that compensation should be high is defined as a concave and differentiable function $f(c)$ from R^+ into the unit interval where c is the amount spent on research. The probability of documenting low damages is 0.

Assumption 5:

$$\frac{\partial g(0)}{\partial c} > \frac{1}{\beta_2(A-B)} \text{ and } \frac{\partial f(0)}{\partial c} > \frac{1}{\beta_2(A-B)}$$

Assumption 5 is sufficient to avoid a corner solution with zero joint expenditure. In game theory terms, the assumption insures that neither party has zero spending as a dominant strategy.

In the case of litigation, both parties are able to hire lawyers to do research for them and to present evidence to the court. The court makes a decision about the plaintiff's damages based on the evidence brought to the trial. Lawyers may find either conclusive evidence or inconclusive evidence. Research findings are private information, so if the plaintiff's lawyer finds evidence that the plaintiff has low damages, he will only report inconclusive evidence. If the developer's lawyer finds evidence the plaintiff has high damages then he also will report only inconclusive evidence.

Going to court involves both fixed and endogenous costs. The fixed costs of the plaintiff are denoted F_p, those of the developer (or defendent) are denoted F_d. Fixed costs are intended to capture such things as the cost of delay and the fixed legal expenses associated with the case. The endogenous costs of plaintiffs of type i are denoted c_i, those of the developer c_d. These are the costs of research to document claims. The settlement offer is denoted S while $(1-k_i)$ is the probability that a type i plaintiff accepts the settlement offer. Thus the loss function of the developer is:

$$L_d=p\Big[[1-k_1]S+k_1\Big[\beta_1\Big[f(c_1)A+[1-f(c_1)]D\Big]+(1-\beta_1)\Big[g(c_d)B+[1-g(c_d)]D\Big]+c_d+F_d\Big]\Big]$$

$$+(1-p)\Big[[1-k_2]S+k_2\Big[\beta_2\Big[f(c_2)A+[1-f(c_2)]D\Big]+(1-\beta_2)\Big[g(c_e)B+[1-g(c_d)]D\Big]+c_d+F_d\Big]\Big].$$

The profit function of a plaintiff of type i is

$$\Pi_i=[1-k_i]S+k_i\Big[\beta_i\Big[f(c_i)A+[1-f(c_i)]D\Big]+(1-\beta_i)\Big[g(c_d)B+[1-g(c_d)]D\Big]-c_i-F_p\Big].$$

Strategies

A strategy for the developer is a pair $\{S,c_d(S,k)\}$ where S is a member of R^+, $c_d(S,k)$ is a function from $R^+ \times \{0,1\}$ into the positive reals, and k is the decision of the plaintiff (0 is acceptance, 1 is refusal of the offer). Although the plaintiff may randomize, the developer only observes the outcome (0 or 1) of his action.

A strategy for the plaintiff is also a pair: $\{k_i(S),c_i(S,k_i)\}$ where $k_i(S)$ is function from R^+ into the unit interval [0,1], $k_i(S)$ is a number indicating the probability of refusing the settlement, and $c_i(S,k_i)$ is function from $R^+ \times [0,1]$ into R^+.

Assumption 6:

$$S \in [0,A-F_d]$$

$$c_i \in [0,\beta_i(A-B)]$$

$$c_d \in [0,(1-\beta_1)(A-B)]$$

Strategy spaces are bounded below because the players cannot spend or offer negative amounts. They are also bounded above because of rationality. They will never spend more than is at stake in the game.

Equilibrium

Because research results are assumed to be private information, in equilibrium, individuals (plaintiffs or defendants) will never report information that does not help them. Inconclusive evidence is ignored by the court by assumption, and thus the court's decision will depend only on the developer's evidence if the plaintiff has low damages and only on the plaintiff's evidence if he has high damages.

Definition 1: A sequential equilibrium is defined as a vector $E^*=(S^*, c_1^*, c_2^*, c_d^*, k_1^*, k_2^*, q^*)$ such that:

1) c_i^* maximizes

(I) $$\beta_i\left[f(c_i)A+[1-f(c_i)]D\right]+(1-\beta_i)\left[g(c_d^*)B+[1-g(c_d^*)]D\right]-c_i-F_p,$$

subject to $c_i \in [0,\beta_i(A-B)]$;

2) c_d^* minimizes

(II) $$q^*\left[\beta_1\left[f(c_1^*)A+[1-f(c_1^*)]D\right]+(1-\beta_1)\left[g(c_e)B+[1-g(c_d)]D\right]\right]$$

$$+(1-q^*)\left[\beta_2\left[f(c_2^*)A+[1-f(c_2^*)]D\right]+(1-\beta_2)\left[g(c_d)B+[1-g(c_d)]D\right]\right]+c_d+F_d,$$

subject to $c_d \in [(1-\beta_1)(A-B)]$, where q^* is the developer's probability belief that i is of type 1;

3) k_i^* maximizes

(III) $$[1-k_i]S^*+k_i\left[\beta_i\left[f(c_i^*)A+[1-f(c_i^*)]D\right]+(1-\beta_i)\left[g(c_d^*)B+[1-g(c_d^*)]D\right]-c_i^*-F_p\right],$$

subject to $k_i \in [0,1]$;

4) S^* minimizes

(IV) $$L(S)=p[1-k_1^*]S+(1-p)[1-k_2^*]S+\left[pk_1^*+(1-p)k_2^*\right](c_e^*+F_d)$$

$$+pk_1^*\left[\beta_1\left[f(c_1^*)A+[1-f(c_1^*)]D\right]+(1-\beta_1)\left[g(c_e^*)B+[1-g(c_d^*)]D\right]\right]$$

$$+(1-p)k_2^*\left[\beta_2\left[f(c_2^*)A+[1-f(c_2^*)]D\right]+(1-\beta_2)\left[g(c_d^*)B+[1-g(c_d^*)]D\right]\right],$$

subject to $S\in[0, A-F_d]$; and

5) q^* satisfies Bayes' rule:

(V) $$q^*=\frac{pk_1^*}{pk_1^*+(1-p)k_2^*}.$$

Definition 2: A self-fulfilling equilibrium is a sequential equilibrium such that the probability that the court awards high damages when no conclusive evidence is presented by either party equals the true probability t^* that damages are high when there is no conclusive evidence.[144] In other words, t satisfies Bayes rule :

(VI) $t=t^*=$

$$\frac{pk_1^*\beta_1[1-f(c_1^*)]+(1-p)k_2^*\beta_2[1-f(c_2^*)]}{pk_1^*\left[\beta_1[1-f(c_1^*)]+(1-\beta_1)[1-g(c_d^*)]\right]+(1-p)k_2^*\left[\beta_2[1-f(c_2^*)]+(1-\beta_2)[1-g(c_d^*)]\right]}.$$

Notice that because of subgame perfection c_i^{x*} and c_e^* cannot depend on the randomness of the litigation rule. Furthermore, as I have defined them, neither sequential equilibria nor self-fulfilling equilibria are fully Bayesian because the players take the posterior beliefs of the court as fixed. This assumption makes the analysis simpler and seems in keeping with the notion that courts are bound by precedent.

144) A more intuitive way to state the property is: an equilibrium is self-fulfilling if, when no evidence is presented by either party, the probability of high awards (t), which is announced by the court at the begining of the game, equals the Bayesian probability that damages are high (t^*). One could assume that an outside observer computes t^* and compares it to t, to see if they match, if they do, then the equilibrium is self-fulfilling.

Theorem 1:

There exist at most two equilibria to this game, E_1 and E_2. In any equilibrium optimal levels of expenditures are c_1^*, c_2^*, c_d^* given by :

$$\frac{\partial f(c_i^*)}{\partial c}=\frac{1}{\beta_i(1-t)(A-B)}, \; i=1,2$$

$$\text{and } \frac{\partial f(c_d^*)}{\partial c}=\frac{1}{[q^*\beta_1+(1-q^*)\beta_2](1-t)(A-B)}.$$

Optimal settlement levels, S_1^*, S_2^* (corresponding to E_1, E_2) are defined by:

$$S_1^* \text{ minimizes}$$

$$[1-k_1^*]S+k_1^*\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]-c_e^*+F_d, \text{ and}$$

$$S_2^*=\beta_2\Big[f(c_2^*)A+[1-f(c_2^*)]D\Big]+(1-\beta_2)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big].$$

Optimal litigation probabilities for each equilibrium are as follows:

$$k_1^* \in [0,1] \text{ and } k_2^*=1 \text{ if } S^*=S_1^*,$$

$$k_1^*=0 \text{ and } k_2^*=0 \text{ if } S^* \geq S_2^*.$$

Proof

The proof is done by backwards induction. First, I solve for the optimal expenditures, c_1^*, c_2^* and c_e^*, given q and S. Second, I solve for the optimal litigation probabilities probabilities, k_1^* and k_2^* given S. Third, I solve for the optimal settlement offer S^* taking the previous optimizations into account at each step. Where proofs of lemmas are not given those proofs can be found in the appendix.

1. Legal Expenditures

Fix the settlement offer, S, and the post-settlement probability that the plaintiff is strong, q. Assume that the plaintiff has refused the offer. The players now face the

simultaneous decision of legal expenditures. The plaintiff must choose c_i to maximize (I) or,

(1) $$\beta_i\Big[f(c_i)A+[1-f(c_i)]D\Big]+(1-\beta_i)\Big[g(c_d^{\,*})B+[1-g(c_d^{\,*})]D\Big]-c_i-F_p.$$

Noting that $D=tA+(1-t)B$, the first order condition is

(2) $$\frac{\partial f(c_i)}{\partial c_i}(A-B)\beta_i(1-t)=1.$$

The developer must choose $c_d^{\,*}$ to minimize (II) or,

(3) $$q^*\left[\beta_1\Big[f(c_1^{\,*})A+[1-f(c_1^{\,*})]D\Big]+(1-\beta_1)\Big[g(c_d)B+[1-g(c_d)]D\Big]\right]$$

$$+(1-q^*)\left[\beta_2\Big[f(c_2^{\,*})A+[1-f(c_2^{\,*})]D\Big]+(1-\beta_2)\Big[g(c_d)B+[1-g(c_d)]D\Big]\right]+c_d+F_d.$$

The first order condition is

(4) $$\frac{\partial g(c_d)}{\partial c_d}(B-A)\Big[q(1-\beta_1)+(1-q)(1-\beta_2)\Big]t=-1.$$

The concavity of $f(.)$ and $g(.)$ as well as assumption 5 are sufficient to guarantee that a solution to both problems will exist. Assume that the rationality constraints do not bind. First order conditions will be necessary and sufficient because concavity insures that the second order conditions hold. Thus $c_i^{\,*}$ and $c_d^{\,*}$ are defined by

(2') $$\frac{\partial f(c_i^{\,*})}{\partial c}=\frac{1}{\beta_i(1-t)(A-B)}\text{ and,}$$

(4') $$\frac{\partial g(c_d^{\,*})}{\partial c}=\frac{1}{[q(1-\beta_1)+(1-q)(1-\beta_2)]t(A-B)}.$$

Corollary 1

The equilibrium expenditures of the plaintiff do not depend on the size of the settlement offer or on the probability that the plaintiff accepts it. The equilibrium expenditures of the developer, however, do depend on litigation probabilities since these affect his beliefs about the type of the plaintiff. The developer's legal expenditures rise with the probability that

weak plaintiffs sue and fall with the probability that strong plaintiffs sue.

2. Optimal Litigation Levels

Fix S. Let $\{c_d^*(k_1,k_2),c_1^*,c_2^*\}$ be the equilibrium expenditures. Plaintiffs of type i will want to choose k_i^* to maximize (III) or

$$(5) \quad \Pi_i=[1-k_i^*]S+k_i\left[\beta_i\left[f(c_i^*)A+[1-f(c_i^*)]D\right]+(1-\beta_i)\left[g(c_d^*(k_i))B+[1-g(c_d^*(k_i)]D\right]-c_i^*-F_p\right].$$

Lemma 1

For each S there exists at most one equilibrium pair $\{k_1^*(S),k_2^*(S)\}$ of litigation levels.

Definition 3: let x_j be the probability that plaintiffs of type j litigates. Then let $k_i^*(x_j)$ be the best response of plaintiffs of the other type to such a litigation probability. Since there are only two types of plaintiffs we can write simply $k_i^*(x)$

Lemma 2

$k_1^*(x)<k_2^*(x)$

Lemma 2 is enough to guarantee the existence of a unique pair of equilibrium litigation probabilities despite the fact that the best response function of strong plaintiffs (type 2) may not be continuous. Indeed, if it is continuous, it is either constant, at 0 or at 1; and then the fact that type 1's best response function is monotone guarantees that the equilibrium will be unique.

If the best response function of type 2 is discontinuous, then it is 1 when k_1 is low and 0 when k_1 is high. Noting that $k_1^*(x)\leq k_2^*(x)$ for any x in [0,1] and that $k_1^*(x)$ is weakly decreasing guarantees that $k_1^*=0$. The equilibrium will thus be $k_1^*=0$, $k_2^*=1$. Thus for any S, the equilibrium pair of litigation probabilities is unique. Furthermore strong plaintiffs always use pure strategies.

Definition 4: z_i is a reservation settlement for type i if and only if (1), $k_i^*=1$ for all $S>z_i$, and (2), $k_i^*=0$ for all $S<z_i$. z_i is a reservation like offer if only (1) or (2) hold.

Lemma 3

There exists one reservation settlement offer for strong plaintiffs (type 2) and two reservation like offers for weak plaintiffs (type 1).

The reservation offer of strong plaintiffs will be denoted z_2. Strong type plaintiffs reject any offer less than z_2 with probability one and accept any offer higher then z_2 with probability one. Reservation like offers of weak plaintiffs will be denoted $\underline{z_1}$ and $\overline{z_1}$. Settlement offers less than $\underline{z_1}$ are refused by weak plaintiffs with probability one, those offers between $\underline{z_1}$ and $\overline{z_1}$ are accepted with some probability less than one, and those offers above $\overline{z_1}$ are accepted with probability one.

Lemma 4

The reservation offer of strong types is accepted by weak types with probability one ($z_2>\overline{z_1}$).

Thus if strong plaintiffs accept the settlement offer, then weak plaintiffs accept the offer as well. For any settlement offer above $\overline{z_1}$ $q^*=0$, and the developer will spend the least documenting his claim. Define $\overline{c_d}$ to be his litigation expenditures in this case.

$$(6) \qquad z_2=\beta_2\Big[f(c_2^*)A+[1-f(c_2^*)]D\Big]+(1-\beta_2)\Big[g(\overline{c_d})B+[1-g(\overline{c_d})]D\Big]$$

Lemma 4 allows us to naturally define out-of-equilibrium beliefs for the developer. The natural extention of q^* above $\overline{z_2}$ when no trials should occur is clearly $q^*=0$.

To find $\underline{z_1}$ and $\overline{z_1}$ recall (III), the profit function for type 1 plaintiffs. Differentiating with respect to k_1, yields:

$$(VII) \quad \bar{S}=\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]$$

$$-c_1-F_p+k_1^*(1-\beta_1)\frac{\partial g(c_e^*)}{\partial c_d}\frac{\partial c_d^*}{\partial k_1}t(B-A)=0,$$

$\underline{z_1}$ is the S such that (VII) is verified when k_1=1 and k_2=1. $\overline{z_1}$ is the S that solves (VII) when k_1=0 and k_2=1.

To avoid the trivial equilibrium where the settlement offer is 0 and everyone accepts, I assume that strong plaintiffs would always sue if offered 0. However there is no guarantee that weak plaintiffs will not accept a zero offer with positive probability ($\overline{z_1}\leq 0$ or $\underline{z_1}\leq 0$). The reservation like offer of type 1 plaintiffs will be negative if the fixed court costs of the plaintiff are high enough. If either $\overline{z_1}\leq 0$ or $\underline{z_1}\leq 0$, we can redefine them without loss of generality to be 0. The possible equilibrium litigation levels are described in Table 11

	$S < \underline{z_1}$	$S \in [\underline{z_1}, \overline{z_1}]$	$S \in [\overline{z_1}, z_2]$	$S \geq z_2$
k_1^*	1	[0,1]	0	0
k_2^*	1	1	1	0

Table 11

Optimal Litigation Probabilities Given Plaintiff Type and Settlement Level

3. Optimal Settlement

Now that optimal expenditures and litigation probabilities have been determined let us consider the choice of settlement offers by the developer.

Claim: there are three potential settlement offers $0, \bar{S}, z_2$, where $\bar{S}$ minimizes

$$(7) \quad [1-k_1^*]S + k_1^*\beta_1\Big[f(c_1^*)A + [1-f(c_1^*)]D\Big] + (1-\beta_1)\Big[g(c_d^*)B + [1-g(c_d^*)]D\Big] - c_e^* + F_d$$

subject to $\bar{S} \in [\underline{z_1}, \overline{z_1}]$.

Proof:

Other potential equilibrium settlement offers are ruled out because they are dominated by those listed above. For example, settlement offers greater than $\overline{z_1}$ but less than z_2 are dominated by $\overline{z_1}$. If offered a settlement between $\overline{z_1}$ and z_2, type 1 plaintiffs still accept the offer with probability one but get higher settlement. Type 2 plaintiffs' behavior is also unchanged, they sue with probability one. So the developer pays strictly more and thus $\overline{z_1}$ dominates S.

The developer's loss function is:

$$(8)\quad L_d=p\Big[[1-k_1]S+k_1\Big[\beta_1\Big[f(c_1)A+[1-f(c_1)]D\Big]+(1-\beta_1)\Big[g(c_d)B+[1-g(c_d)]D\Big]+c_d+F_d\Big]\Big]$$
$$+(1-p)\Big[[1-k_2]S+k_2\Big[\beta_2\Big[f(c_2)A+[1-f(c_2)]D\Big]+(1-\beta_2)\Big[g(c_d)B+[1-g(c_d)]D\Big]+c_d+F_d\Big]\Big].$$

Now for $S \in [\,0,\underline{z_1}\,]$, 0 is a weak local minimum. For $S \in [\,\underline{z_1},\overline{z_1}\,]$ the developer's loss function is :

$$(9)\quad p\Big[[1-k_1^*]S+k_1^*\Big[\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d\Big]\Big]$$
$$+(1-p)\Big[\beta_2\Big[f(c_2^*)A+[1-f(c_2^*)]D\Big]+(1-\beta_2)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d\Big].$$

The first-order condition for the developer is

$$(10)\quad [1-k_1^*]-\frac{\partial k_1^*}{\partial S}\Big[\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_e^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_e-S\Big]=0.$$

The second-order condition always holds because $\frac{\partial^2 L_e}{\partial S^2}=-2\frac{\partial k_1^*}{\partial S}\geq 0$. The loss function, thus, has a unique minimum between $\underline{z_1}$ and $\overline{z_1}$. Call S_1 the settlement that minimizes the loss function between $\underline{z_1}$ and $\overline{z_1}$. Then the only possible equilibrium candidates for fixed t are

$$E_0=(0,k_1,1,c_d^*,c_1^*,c_2^*,p),$$

$$E_1=(\bar{S},k_1^*,1,c_d^*,c_1^*,c_2^*,\frac{pk_1^*}{pk_1^*+(1-p)k_2^*}),$$

$$E_2=(z_2,1,1,\overline{c_d},c_1^*,c_d^*,0).$$

Lemma 5

E_0 is never an equilibrium, because it either $\bar{S}$=0 or 0 is a setlement offer dominated by $\bar{S}$.

Proof:

We must look at two cases $0<\underline{Z}_1$ and $0>\underline{Z}_1$. Consider first $0<\underline{Z}_1$. Now let us compute the loss function of the developer if he offers 0:

$$(11)\qquad p\Big[\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d\Big]$$
$$+(1-p)\Big[\beta_2\Big[f(c_2^*)A+[1-f(c_2^*)]D\Big]+(1-\beta_2)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d\Big].$$

Because $0<\underline{z}_1$ all plaintiffs sue with probability one, now let us compute the loss function if the developers offers $\bar{S}$:

$$(12)\quad p\Big[[1-k_1^*]\bar{S}+k_1^*\Big[\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d\Big]\Big]$$
$$+(1-p)\Big[\beta_2\Big[f(c_2^*)A+[1-f(c_2^*)]D\Big]+(1-\beta_2)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d\Big];$$

now let us look at (11) -(12) or

$$(13)\quad k_1^*\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]+c_d^*+F_d-\bar{S}.$$

Then recall that $\bar{S}=\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_d^*)]D\Big]$

$$-c_1-F_p+k_1^*(1-\beta_1)\frac{\partial g(c_e^*)}{\partial c_d}\frac{\partial c_d^*}{\partial k_1}t(B-A).$$

Note that $k_1^*(1-\beta_1)\dfrac{\partial g(c_e^*)}{\partial c_d}\dfrac{\partial c_d^*}{\partial k_1}t(B-A)<0$.

So (11) -(12) > $(c_d+c_1+F_d+F_p)k_1^*>0$. Therefore 0 is dominated by $\bar{S}$.

Now suppose $0>\underline{Z}_1$, then 0 belongs by assumption to the interval $[\underline{Z}_1,0Z_2]$. On that interval the unique minimum of the loss function is $\bar{S}$ so 0 cannot be an equilibrium offer unless it is $\bar{S}$ and E_0=E_1.

Therfore there remain only possible equilibria:

$$E_1 = (\bar{S}, k_1^*, 1, c_d^*, c_1^*, c_2^*, \frac{pk_1^*}{pk_1^* + (1-p)k_2^*})$$

$$E_2 = (z_2, 0, 0, c_2^*, c_1^*, c_2^*, 0).^{145}$$

This completes the proof of theorem 1.

Corollary 2

The equilibrium is unique for almost all sets of parameter values $(t, A, B, F_d, F_p, \beta_1, \beta_2)$. Furthermore, as t increases compensation increases weakly, as the fixed court costs of the defendant increase compensation increases weakly, and as the fixed court costs of the plaintiff increase compensation decreases weakly.

Proof:

Suppose that the initial conditions lead to multiple equilibria. Then any δ rise in the fixed trial costs of the developer, F_d, will make him prefer the high-settlement equilibrium. Similarly any δ increase in the fixed court cost of plaintiffs, F_p, will raise the probability that type 1 accepts $\bar{S}$ which lowers the developer's cost in that equilibrium only and thus breaks the tie. So without loss of generality I will assume that the equilibrium is unique for every t. Comparative statics follow directly.

Self-Fulfilling Equilibria

145) One should note that, strictly speaking, in E_2 strong plaintiffs are indifferent between settling and litigating. At first glance, the indifference of strong plaintiffs suggests that there is a continuum of mixed strategies for these plaintiffs in this equilibrium and two pure strategies, one where they sue and one where they settle. Yet if strong plaintiffs sue with positive probability then z_2 no longer minimizes the loss function. For any k_2 probability of suits the developer can find a δ such that $z_2+\delta$ is an offer that dominates z_2 because if the offer is superior to z_2 then it is a dominant strategy for plaintiffs of all type to settle. Yet $z_2+\delta$ is dominated by all the offers in the interval $[z_2, z_2+\delta]$ for any δ. So if strong plaintiffs litigate with probility when offered z_2, then there is no sequential equilibrium. Thus E_2 remains the only sequential equlibrium.

From a Bayesian point of view one might argue that it is inconsistent if the plaintiff and defendant act in a Bayesian way but the court does not. In other words, the court's beliefs (t) should also be properly updated given the prior actions of the players. Recall the definition of t^*:

$$t^* = \frac{pk_1^* \beta_1[1-f(c_1^*)]+(1-p)k_2^* \beta_2[1-f(c_2^*)]}{pk_1^* \left[\beta_1[1-f(c_1^*)]+(1-\beta_1)[1-g(c_d^*)]\right] +(1-p)k_2^* \left[\beta_2[1-f(c_2^*)]+(1-\beta_2)[1-g(c_d^*)]\right]}.$$

If we retain the assumption that defendant and plaintiff take t as fixed and allow the court to announce t, then the question is whether there exists an equilibrium t such that $t=t^*$.

If E_2 is the equilibrium for some t then the answer to our question is trivial because in equilibrium there are no trials and hence the court's beliefs do not matter; all sequential equilibria where everyone is compensated outright (E_2) are trivially proper.

Theorem 2

There exist's at least one t such that $t^*=t$.

The generic uniqueness of self-fulfilling equilibria on the other hand is not possible to prove because the derivative of t^* with respect to t is not necessarily monotone. An alternative to the assumption that t is fixed is to assume that the defendant and the plaintiff both know that the convex combination of high and low compensations handed out by the court in the absence of conclusive evidence is equal to the Bayesian expected damages. While such Bayesian restrictions on t have great game theoretic appeal, they are less meaningfull in judicial contexts because, as I argue in the next section, courts may not behave as Bayesian players.

Rules

A number of rules limit the behavior of court, most often they are embodied in precedent and in burden of proof. These rules are well known in advance by the litigants, or at least by their lawyers. The rules of litigation show little concern for Bayes' rule, they tend to set t at 0 or 1. Because trials are redistributive games as opposed to production games, whether the plaintiff ends up with high or low compensation has little impact on the economy. By setting t at 0 rather than at some strictly positive level in civil cases, courts would in fact discourage trials and minimize total legal expenditures. Since trials consume resources for purely redistributive purposes, they are a net social cost. Courts would thus have reason to set t at 0. In contrast, states would have reason to set t at 1 when they are the plaintiffs--as seems to be almost always the case when the judiciary is part of the state. One reason for setting t at 1 is that it reduces the cost of state action. Thus courts have no clear economic incentive to behave in a Bayesian way and they have political incentives to behave otherwise.

Beyond the social and political reasons for setting a fixed t, there are important cost considerations that suggest courts may not want to behave as Bayesians. If t is Bayesian, then it is specific to each trial and each set of pre-trial circumstances. Bayesian behavior would, in effect, force courts to solve the game theoretic problem *for each different case separately*. Indeed the priors over residual cases--those not decided by conclusive evidence--depend on all of the initial conditions, the fixed costs, the evidence production functions, the settlement level, and the range of damages. This implies that judges and juries not only have to deal with the evidence and decide if it is conclusive, but they must also cope with all the information necessary to solve the game theory problem. In reality, I believe, this does not happen. At the very least, it would greatly increase the social cost of trials; a fixed rule for determining inconclusive cases would be far less expensive. Indeed, both plaintiff and defendant would have strong incentives to misrepresent the elements of the case. Therefore the court would have to

carry out its own estimation of the relevant parameters. The issues of updating costs and social incentives suggest that, although there is strong game theoretic justification for full Bayesian updating, judicial systems may not necessarily function in this fashion.

In fact, courts in the Western world are often bound by precedent; that is, their actions are highly constrained for each case and each set of circumstances. The stylized facts of most judicial processes not only suggest t is fixed, but, in an even greater departure from Bayesian rules, it is in fact either 0 or 1. In other words the burden of proof rests with the plaintiff (t=0), or, when the state is involved as prosecutor, it may rest with the defendant (t=1). The Anglo-Saxon judicial system, as well as the French court system in civil cases presumes innocence for the defendant and requires evidence beyond reasonable doubt or that the preponderance of the evidence go against the defendent to convict.[146] Other judicial systems presume for the plaintiff in criminal cases: this seems to have been true for the Spanish Inquisition as well as for the French judicial system when the state prosecuted criminal cases.

The ability to vary the burden of proof in this model leads to another conclusion: when the burden of proof rests completely on the shoulders of the plaintiff, the defendant does no research, *i.e.* c_d=0. Doing no research does not imply bearing no court costs, since the defendant still bears the cost of going to court (F_d). Defendants do no research because, unless the plaintiff presents evidence that damages are high, the court awards only low damages. The impact of the rule t=0 on the probability of an out-of-court settlement is ambiguous because the defendant's decision to separate the different types of plaintiffs or not is largely determined by the savings from settling versus going to trial. When t is 0, however, the settlement offer is smaller than for any other value of t; and the expected total losses from having to play the

146) William Spencer and Cornelius Gillam, *A Textbook on Law and Business*. New York: McGraw Hill Co., 1952. page 68.

game are smallest for the defendant. Furthermore when t is 0 the assumption that research is private information is irrelevant for two simple reasons. First, the defendant does no research and thus has nothing to hide. Second, plaintiffs want to reveal their evidence to the court when it shows that the compensation should be high. Plaintiffs do not care whether they reveal their evidence when that evidence documents low compensation because that information does not affect the court's decision.

The model analyzed assumes that the court decides to award either A or B. An alternative formulation that gives much greater insight into eminent domain litigation is focused on the assumption that the court considers whether S is 'appropriate.' Here the court forces the plaintiff to bear the burden of proof and obliges the developer to offer at least B as compensation. Then when a compensation offer has been appealed, the court can either find it appropriate (and award S) or too low and award A). The plaintiff presents evidence that the settlement is too low and the defendant evidence that it is appropriate. For convenience, this new model will be called the appeal model. The loss function of the developer can be rewritten as

$$\text{(VIII)}\quad L'_d=p\Big[[1-k_1]S+k_1\Big[\beta_1\Big[f(c_1)A+[1-f(c_1)]S\Big]+(1-\beta_1)\Big[g(c_d)S+[1-g(c_d)]S\Big]+c_d+F_d\Big]\Big]$$
$$+(1-p)\Big[[1-k_2]S+k_2\Big[\beta_2\Big[f(c_2)A+[1-f(c_2)]S\Big]+(1-\beta_2)\Big[g(c_e)S+[1-g(c_d)]S\Big]+c_d+F_d\Big]\Big].$$

The profit function of a plaintiff of type i can be rewritten as

$$\text{(IX)}\quad \Pi'_i=[1-k_i]S+k_i\Big[\beta_i\Big[f(c_i)A+[1-f(c_i)]S\Big]+(1-\beta_i)\Big[g(c_d)S+[1-g(c_d)]S\Big]-c_i-F_p\Big].$$

Note that it is a dominant strategy for the defendent to do no research. This allows considerable simplification, the loss function becomes:

$$\text{(14)}\quad L'_d=p\Big[[1-k_1]S+k_1\Big[\beta_1\Big[f(c_1)A+[1-f(c_1)]S\Big]+(1-\beta_1)S+F_d\Big]\Big]$$
$$+(1-p)\Big[[1-k_2]S+k_2\Big[\beta_2\Big[f(c_2)A+[1-f(c_2)]S\Big]+(1-\beta_2)S+F_d\Big]\Big].$$

and the profit functions:

$$(15)\quad \Pi'_i=[1-k_i]S+k_i\left[\beta_i\left[f(c_i)A+[1-f(c_i)]S\right]+(1-\beta_i)S-c_i-F_p\right].$$

In this case there also exists an equilibrium with properties similar to those derived above.

Theorem 3

Theorem 1 and Corollary 2 hold when the defendant seeks to maximizes L'_d subject to $S \geq B$ and plaintiffs of type i seek to maximize Π'_i. In other words there exists generically a unique sequential equilibrium to the appeal game with the same comparative static properties as those described above.

The appeal model can be used to gather some intuition about compensation offers when eminent domain rights are exercised. In most cases the holders of eminent domain privileges make offers of compensation to holders of property rights. The property rights owners can either accept the offer or appeal it in a judicial setting. In case of a suit, the court must decide whether the offer was sufficient or whether the property rights owner should receive higher compensation. Adding to this model the further restriction that t is 0 accurately describes the contract appeal process in the case of marsh drainage in Normandy--and indeed most property rights litigation in eighteenth-century France--a topic we turn to next.

Settlement Litigation and Norman Drainage

The model that most closely approximates the problem of litigation over drainage projects in eighteenth-century Normandy has two basic properties: $B=S$ and $t=1$ for contracts between the developer and communities over property rights to marshland and $t=0$ for all other contracts (for historical evidence and a more detailed discussion of institutional obstacles to drainage in eighteenth-century Normandy, see Chapter 2). In the case of marsh drainage, the litigation game began when a developer decided he wanted to drain a marsh. The developer

then secured a royal grant, which was a permit to carry out the project. Included in the grant was a compensation (settlement) offer for all owners of property rights affected by the project. Obviously, the developer could fail to mention certain property rights in the contract, leading to a zero compensation offer for the damages suffered by the owners of the property rights in question. The property rights owners had three years to accept the contract implicitly--by not appealing it--or to appeal its validity. Appeals were judicial and began when the owner of a property right filed a brief before a royal court. The developer would often face a number of different potential plaintiffs: owners of rights over marshland, proprietors of mills damaged by the project, downstream landowners who might bear a higher risk of flooding, etc.

Let us first consider the game between the developer and individuals other than the proprietors of marshland. In these civil cases plaintiffs bore the burden of proof, thus $t=0$ is the correct modeling assumption. If property rights owners proved that the distribution of cost and benefits did not in fact reflect the original distribution of property rights or that damages remained uncompensated, then the court could strike the contract down and award the plaintiff higher compensation. None of the proposed drainage contracts available made compensation offers to anyone except owners of marshland. There are also no recorded appeals by owners of other property rights until after the projects were completed. The intuition behind the zero settlement offers to mill owners and downstream landowners is that the cost of litigating compensation for damages to mills, increased flooding, or other, smaller matters, was usually greater than the expected award if for no other reason than the fact that this litigation took place before the king's council in Paris, far away from Normandy. Thus, except when there were very large damages that were easy to document--after the drainage project had occurred--the zero offers were accepted.

Developers also had to make compensation offers to the owners of the marshland. In Normandy, marshes were jointly owned by communities and lords, and their shares of the property was uncertain. Lords remained the titular owners of the marshes that they had rented to communities who had acquired use rights to the marshes. Part of the task of drainage contracts was to aportion the marshland between lord and community, a process ruled by the medieval law of *triage*. What mattered here was the extend of the community's use rights because the law awarded two-thirds of the marshland to communities with strong use rights but only one-third to communities with weak use rights. The communities' use rights were based on medieval--feudal--contracts that they had negotiated with the lord. In the case of property rights based on feudal contracts, unlike other civil suits, the burden of proof always rested on the lord, whether he was plaintiff or defendent. Thus unless the lord could prove that the community's use rights were weak, the community was entitled to two-thirds of the marsh. In drainage contracts the developers usually received half the drained land as compensation for draining the marsh while the community and the lord divided the other half between themselves. The owner of strong property rights, whether lord or community, received one-third of the drained land (two-thirds of one-half) and the owner of weak property rights one-sixth.

The *triage* rule awarded a community with strong use rights two-thirds of the marsh and veto power over the project. Indeed, in a community with strong use rights, the marsh was part of the common land and its use was ruled by customary law. Since draining the marsh implied dividing it into separate parcels and a shift from communal to private pasture, drainage would necessarily lead to a change the customary pattern of using the marsh. Although customary law could theoretically have been modified by the royal judiciary at high cost, in effect reform of customary law required the unanimous consent of everyone concerned. Because drainage restricted access to the marsh, anyone with use rights could file--and win--a judicial

appeal claiming that his customary rights had been violated. Thus any villager able to bear the costs of litigation could hold out strategically for a share of the surplus from the project.

The issue of customary law sheds light on the compensation offers for marshland that were included in the drainage grant. In the grant, the developer could either assign strong or weak use rights to the community--the lords share of the marsh was simply the residual. If a developer offered a community strong use rights, he possibly would have faced an appeal by the lord but more importantly, he would have been vulnerable to the strategic behavior of groups of villagers trying to appropriate the surplus from the project, and drainage would have been greatly delayed. If the drainage contract only recognized the communities' weak use rights and if it was unopposed by the community, then drainage would have proceeded swiftly. Developers could only protect themselves from strategic behavior by offering communities only one third of the marshland, which is exactly what developers offered in eighteenth century Normandy.

Drainage rarely occurred because communities almost invariably appealed drainage contracts. Most communities had firm beliefs that their documents could back their claims to strong use rights to the marshes in question. Moreover the burden-of-proof rules favored communities when neither they nor the lords could document their claims, that is when no conclusive evidence was brought before the court. Courts could have decided these cases in a number of ways: they could have sided with the lords and given them two thirds of the marsh and ordered drainage to proceed--in effect setting t at 0; they could have sided with communities and given them two thirds of the marsh as well ordering drainage; or they could have decided to give the communities two thirds of the marsh and left the drainage decision to the communities, in effect setting t at 1. Because burden of proof was on lords in the case of feudal property, the courts had to award strong property rights to the communities; and because

they could not order changes in customary law, the courts had to leave the drainage decision to the communities.

Returning to the model it is easy to see that if $t=1$, the probability that strong property rights are attributed to the lord and the marsh is drained, is at most $p(1-\beta_1)+(1-p)(1-\beta^2)$. In contrast, that probability is at least $p(1-\beta_1)+(1-p)(1-\beta^2)$ when $t=0$. If we assume that the optimal level of search always leaves some cases undocumented, then strong property rights are attributed to lords with strictly greater probability when the burden of proof is on communities than when it is on lords. As a result, the effective burden-of-proof rule was the least favorable to drainage because when strong property rights were attributed to communities marshes did not get drained. If the burden of proof had been on the communities far more drainage would have occured.

One alternative would have been for the courts to have refused to hear any such rent-seeking cases; however French royal courts were themselves rent-seekers: French court officials bought their titles for life and were paid a small salary but allowed to "tax" plaintiffs and defendants in the cases they heard. Thus, French court officials had no desire to limit the number of cases brought before them. The costs of litigation alone would not have stopped the drainage of marshes in the eighteenth century; in fact the costs of litigation were small compared to the profitability of projects. What stopped drainage was the inability of the French government to give its judiciary true authority over local custom and thereby clarify property rights. In the absence of such authority the judiciary was free to pursue its own rent-seeking activities, and marshes remained undrained.

To make the analysis complete we must confront the question of why communities appealed the developers' settlement offers. Indeed, because draining marshes greatly increased the productivity of land, developers argued that even with only one-sixth of the drained marsh

the villager would be better off than with a whole marsh undrained. If this were true than communities should not have litigated because in all events they were worse off-- even when they won, further litigation over customary rights prevented drainage. However the incentives to appeal the drainage contract were big if they won communities were entitled to twice as much land than if they accepted the contract, clearly making all villagers better off. Villagers could easily aggree to appeal a drainage proposal not realizing that their united opposition to the developers would be transformed into competition for the surplus should they win their suit. Such an explanation is appealing because villagers never faced a decision to file such an appeal more than once and because it does not rely on any assumption that villagers could be made worse off by drainage projects. However if individuals in communities actually believed that they were worse off with only one-sixth of the marsh then suits would occur automatically.

Developers attempted to drain marshes despite the formidable odds against them for two reasons. The royal government promised institutional reforms after 1750, and although reforms failed to occur, developers may well have thought that the institutional problems associated with draining marshes would be resolved. Some developers no doubt thought that their position at the French court would help them secure sufficient royal backing to enforce drainage. Draining marshes was also attractive because it was potentially very profitable, as the rates of return analyzed in Chapter 2 show. Developers were willing to bear the institutional cost, which were small relative to the profits, for a small probability of success.

Institutions seem to explain why developers systematically offered low levels of compensation to communities. Moreover the fact that burden of proof was on the lord made it easy for communities to win their appeals, thus institutions, again, seem to explain the extraordinarily high amounts of litigation in eighteenth-century Normandy--a subject of considerable interest to historians. More importantly the inability of courts to mandate drainage after

property rights issues had been resolved in favor of communities made it virtually impossible for drainage to occur. Had there been another burden-of-proof rule in the case of feudal property rights then more marshes would have been drained in eighteenth-century France.

Conclusion

This chapter points to the importance of asymmetric information in court outcomes, but it departs from the previous literature by recognizing the fact that plaintiffs and defendants can do research to gather evidence for their case. In this model the ability to document one's claims affects court decisions directly and settlements indirectly. In this setting the defendant can choose either to separate different types of plaintiffs and face some litigation or to offer everyone high compensation. The distribution of court costs among plaintiffs and defendent clearly affects court outcomes and out-of-court settlements. Yet when the plaintiff bears the burden of proof, the defendant chooses to remain uninformed, independent of the cost of information. The model thus illustrates the importance of legal rules once litigation expenditures are endogenized, for defendant and plaintiff value evidence differently. Furthermore, when the difference between the expected value of court outcomes of strong and weak type plaintiffs is high relative to court costs (that is when there is a lot of uncertainty about who the plaintiff is) the defendant has an incentive to make an offer that will separate the weak plaintiffs from the strong. If cases are frequently settled out of court, as happens today, then the model suggests that by the time the settlement offer is made, little uncertainty about the type of the plaintiff remains.

A model that describes learning not only after, but also before, the settlement offer has been made, may offer more insight into the issue of out-of-court settlement. The model analyzed in this chapter should therefore be extended to allow for two-step spending on research to fully endogenize informational asymmetries. Under this more complex model,

plaintiffs and defendant would start with a simple information structure and choose how much research to do in a first phase. Using the information he has gathered, the defendant would then make a settlement offer, which the plaintiff could accept or reject depending on the information he had acquired. If he refused, the game would go to court after another round of research. Individuals would then present their information, and the court would give a verdict. A more sophisticated model of this sort would be appealing because it would describe more fully the strategic play in litigation and settlement.

But even the simple model described in this chapter provides significant insight into how specific institutional rules--rules such as burden of proof on the plaintiff or respect for precedent--constrain the equilibrium settlement offers and litigation probabilities. The model also suggests that rules that force the plaintiff to bear the burden of proof may well be superior to Bayesian behavior from the point of view of the court for they discourage trials relative to other rules. Moreover a fixed burden-of-proof rule greatly decreases the costs of judicial action over one that is endogenous to every type of trial brought before the court.

The model also singles out the institutional features of the Old-Regime French judiciary that prevented drainage in Normandy. Drainage was profitable despite the judicial costs of sorting property rights between seigneurs and communities. Because court costs are sunk, developers were faced with a choice: they either could bear those costs or not litigate. If drainage had been unprofitable as a result of high court costs, as some developers claimed, there should have been no litigation. Therefore it was not the high court costs of litigation that prevented marshes from being drained but the inability of judicial system to resolve issues of property rights internal to the community. The lack of judicial finality can be attributed to the rent-seeking nature of courts and to the costs of reforming customary law. To explain the persistence of developers to bear litigation costs one should note that the important issue was not

the profitability of such projects, rather it was the division of these profits. Furthermore, at any stage in the game past court costs are all sunk but the expect profits are unchanged.

The central issue behind the eighteenth-century litigation was the division of the profits earned from drainage between developer and property rights owners. This issue was resolved in courts. Developers chose to separate weak from strong type communities despite the very low probability that communities were of the weak type. The model suggests that doing so was rational because the extraordinary difference between high and low compensation to communities relative to court costs may have made separating between community types profitable. Drainage, of course, should have proceeded once this round of litigation was resolved, because the costs associated with litigation were sunk costs. In most cases marshes were not drained because another layer of property rights existed, and no binding contract governing them could be legally enforced. Thus, drainage schemes did not occur in eighteenth-century France because the judicial system lacked both power and finality.

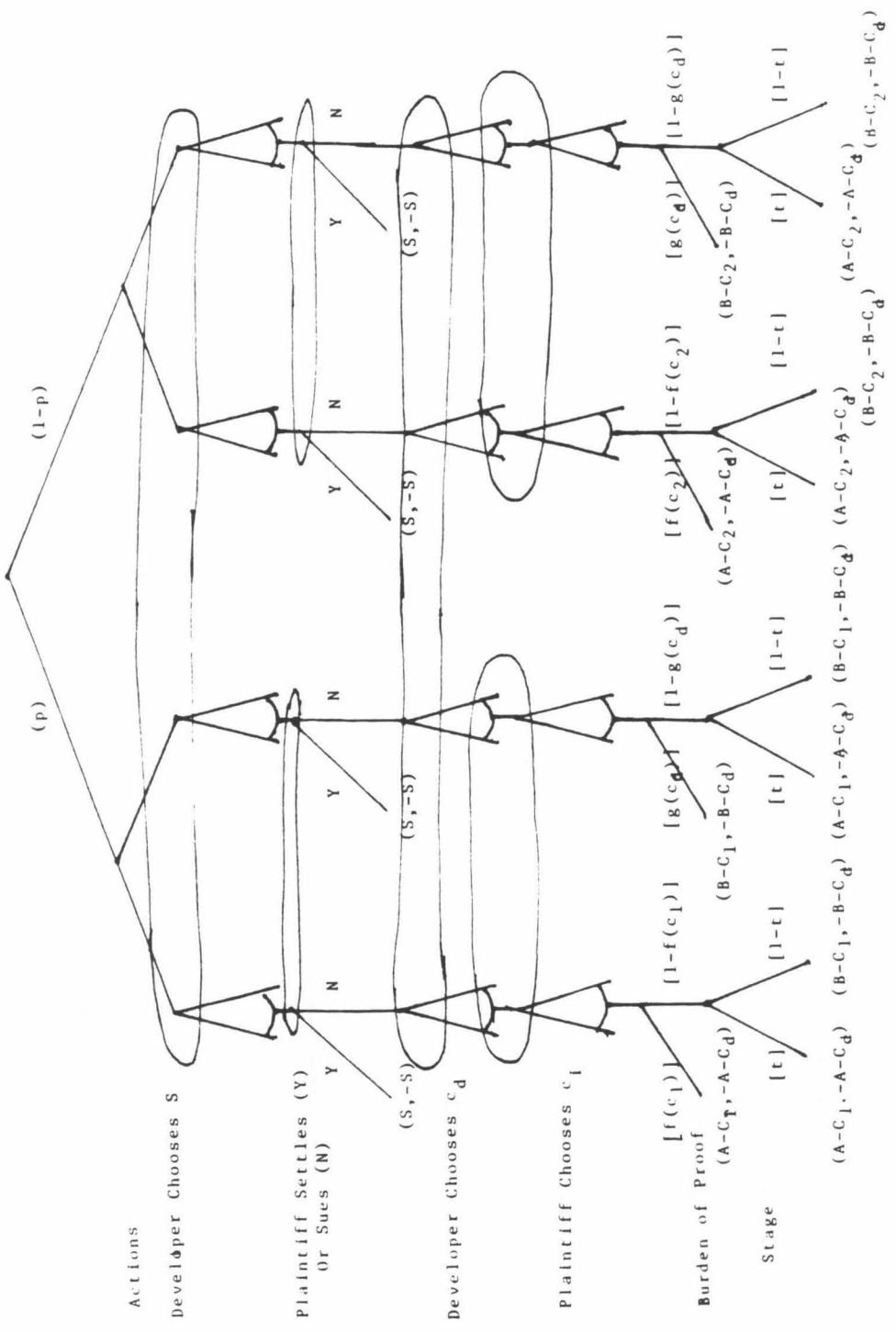
The goal of economic history is not only to document economic development but also to explain that development and different experiences across countries. These goals demand a focus on the effect institutions have on economic growth. Models like the one in this chapter began to explain the impact of different institutional rules on economic activity.

Appendix 3

Figures and Proofs for Chapter 4

Figure 10

Schematic Game Tree



Proof of Corollary 1

By the envelope theorem and the second order conditions $\frac{\partial c_e^*}{\partial k_i}$ has the same sign as $\frac{\partial L^2_2}{\partial c_2 \partial k_i}$. In turn the sign of $\frac{\partial L^2_2}{\partial c_2 \partial k_i}$ depends solely on the sign of $\frac{\partial q^*}{\partial k_i}$. Because β_1 is smaller than β_2, $\frac{\partial q^*}{\partial k_1}$ is positive, thus $\frac{\partial c_d^*}{\partial k_1}>0$.

Symmetrically $\frac{\partial c_d^*}{\partial k_2}<0$. We can also show that $\frac{\partial^2 c_d^*}{\partial k_1^2}<0$ and $\frac{\partial^2 c_d^*}{\partial k_2^2}>0$.

Proof of Lemma 1

Without loss of generality we can assume that $k_2^*(0)=1$ Otherwise $S^*=0$ which leads to a trivial problem. In this case no compensation is ever paid and no trials ever happen. Furthermore accepting an offer of A with probability one is a dominant strategy because trials are costly to plaintiffs, so $k_1^*(A)=k_2^*(A)=1$.

To prove the lemma, first examine type 2's litigation decision. Going back to (III) and differentiating with respect to k_2 gives

$$(16)\quad \Phi_2=-S+\beta_2\left[f(c_2^*)A+[1-f(c_2^*)]D\right]+(1-\beta_2)\left[g(c_d^*)B+[1-g(c_e^*)]D\right]$$
$$-c_i-F_p+k_2(1-\beta_2)\frac{\partial g c_d^*}{\partial c_d}\frac{\partial c_d^*}{\partial k_2}t(B-A)=0.$$

Clearly $k_2(1-\beta_2)\frac{\partial g c_d}{\partial c_d}\frac{\partial c_d}{\partial k_2}t(A-B)$ is the only part of (16) that depends on k_2 and it is non-negative and increasing in k_2 (from corollary 1). Therefore we only need to evaluate Φ_2 at k_2 =1. If Φ_2 is positive at 1 then the type 2 sues with probability one, if Φ_2 is negative, type 2 accepts with probability one. Differentiating (16) with respect to k_1 gives

$$(17)\quad \frac{\partial^2 \Pi_2}{\partial k_2 \partial k_1}=$$

$$t(B-A)(1-\beta_2)\left[\frac{\partial g(c_d^*)}{\partial(c_d)}\frac{\partial c_d^*}{\partial q}\frac{p(1-p)k_2^*}{\left[pk_1^*+(1-p)k_2^*\right]^2}-k_2^*\frac{\partial g(c_d^*)}{\partial c_d}\frac{\partial^2 c_d^*}{\partial q^2}\frac{-2(1-p)p^2k_1^*}{\left[pk_1^*+(1-p)k_2^*\right]^3}\right.$$

$$\left.+k_2^*\frac{\partial^2 g(c_d^*)}{\partial(c_d^*)^2}\frac{\partial c_d^*}{\partial q}\frac{\partial c_d^*}{\partial q}\frac{-(1-p)p^2k_2^*}{\left[pk_1^*+(1-p)k_2^*\right]^3}\right].$$

Because of corollary 1 and because $g(.)$ is increasing and concave, (17) is negative. It is important to note that changes in k_1 only affect the profitability of going to court. As k_1 increases the value of going to court falls for type 2 because the developer spends more on each case when his priors that he faces weak types increases. As the value of going to court falls strong plaintiffs sue less, however (16) may not bind so k_2^* is weakly decreasing in k_1

Now let us look at the optimization problem for type 1 plaintiffs. Differentiating (III) with respect to k_1 gives us a first order condition

$$(18)\quad \Phi_1=-S+\beta_1\left[f(c_1^*)A+[1-f(c_1^*)]D\right]+(1-\beta_1)\left[g(c_d^*)B+[1-g(c_d^*)]D\right]$$

$$-c_1-F_p+k_1^*(1-\beta_1)\frac{\partial g(c_e^*)}{\partial c_d}\frac{\partial c_d^*}{\partial k_1}t(B-A)=0.$$

Clearly $-S+\beta_1\left[f(c_1^*)A+[1-f(c_1^*)]D\right]+(1-\beta_1)\left[g(c_d^*)B+[1-g(c_d^*)]D\right]-c_1^*-a$ does not depend on k_1. $k_1(1-\beta_1)\frac{\partial g(c_d)}{\partial c_d}\frac{\partial c_d}{\partial k_1}t(B-A)$ depends on k_1 but not on S and is strictly decreasing in k_1 from corrolary 1. To compute the reaction function of k_1^* to k_2, differentiate (18) with respect to k_2:

$$(19)\quad \frac{\partial^2 \Pi_1}{\partial k_1 \partial k_2} =$$

$$t(B-A)(1-\beta_1)\left[\frac{\partial g(c_d^*)}{\partial (c_d)} \frac{\partial c_d^*}{\partial q} \frac{-p(1-p)k_1^*}{\left[pk_1^* + (1-p)k_2^*\right]^2} - k_1^* \frac{\partial g(c_d^*)}{\partial c_d} \frac{\partial^2 c_d^*}{\partial q^2} \frac{2(1-p)^2 p k_2^*}{\left[pk_1^* + (1-p)k_2^*\right]^3} \right.$$

$$\left. + k_1 \frac{\partial^2 g(c_d)}{\partial (c_d)^2} \frac{\partial c_d^*}{\partial q} \frac{\partial c_d^*}{\partial q} \frac{(1-p)^2 p k_1^*}{\left[pk_1^* + (1-p)k_2^*\right]^3} \right].$$

Note again that $g(.)$ is concave, thus $\frac{\partial^2 \Pi_i}{\partial k_1^2} \geq 0$. What is also important is that changes in the other type's probability of going to court only affect the profits of going to court, not those of accepting. Since the profits of going to court rise with type 2's probability of going to court, the probability that type 2 refuses the settlement k_2 is weakly increasing. For fixed S we now know that the best response function of type 1 is monotonic increasing, and type 2's is monotonic decreasing, with respect to the other types acceptance probability. There is, thus, at most one equilibrium pair for each settlement offer (S) such that k_1^* is best response to k_2^* and vice versa.

Proof of lemma 2

Definition 6: let $\Phi_2(x,y)$ be the value of the f.o.c. for strong plaintiffs when they sue with probability x and weak plaintiffs sue with probability y. Let $\Phi_1(x,y)$ be the value of the f.o.c for weak plaintiffs when they sue with probability x and strong plaintiffs sue with probability y.

The proof of lemma 2 is a simple dominance argument. I show that $\Phi_2(k_2^*(x), x)$ is greater than $\Phi_1(k_2^*(x), x)$, so weak plaintiffs want to sue less than strong plaintiffs in any equilibrium.

$$(20)\quad \Phi_2(k_2^*(x), x) = -S + \beta_2\left[f(c_2^*)A + [1-f(c_2^*)]D\right] + (1-\beta_2)\left[g(c_d^*)B + [1-g(c_d^*)]D\right]$$

$$-c_2^* - F_p + k_2^*(1-\beta_2)\frac{\partial g(c_d^*)}{\partial c_d}\frac{\partial c_d^*}{\partial k_2} t(A-B).$$

However the optimality of c_2^* guarantees that

(21) $\beta_2\left[f(c_2^*)A+[1-f(c_2^*)]D\right]-c_1^* > \beta_2\left[f(c_1^*)A+[1-f(c_1^*)]D\right]-c_2^*$.

Note also that $k_2^*(1-\beta_2)\frac{\partial g(c_d^*)}{\partial c_d}\frac{\partial c_d^*}{\partial k_2} t(A-B)\geq 0$.

So let $\Phi_2'(k_2^*(x),x) = -S+\beta_2\left[f(c_1^*)A+[1-f(c_1^*)]D\right]+(1-\beta_2)\left[g(c_d^*)B+[1-g(c_d^*)]D\right]-c_1^*-F_p$.

Clearly $\Phi_2(k_2^*(x), x) > \Phi_2'(k_2^*(x), x)$.

Define $\Phi_1'(k_2^*(x), x)$ by:

(22) $\Phi_1'(k_2^*(x),x) = -S+\beta_1\left[f(c_1^*)A+[1-f(c_1^*)]D\right]+(1-\beta_1)\left[g(c_e^*)B+[1-g(c_d^*)]D\right]-c_1^*-F_p$.

We can dominate $\Phi_1(k_2^*(x),x)$ by $\Phi_1'(k_2^*(x),x)$, simply because

$$k_2^*(1-\beta_1)\frac{\partial g(c_d^*}{\partial c_d}\frac{\partial c_d^*}{\partial k_1} t(B-A)\leq 0.$$

$\Phi_{2'}(k_2^*(x),x) > \Phi_1'(k_2^*(x),x)$ because β_2 is greater than β_1

and $f(c_1^*)A+[1-f(c_1^*)]D) > (g(c_d^*)B+[1-g(c_d^*)]D)$.

so $\Phi_1(k_2^*(x),x) < \Phi_1'(k_1^*(x),x) < \Phi_2'(k_2^*(x),x) < \Phi_2(k_2^*(x),x)$. Note from the proof of lemma 1 that IX is decreasing in k_1. Thus, $k_1^*(x) \leq k_2^*(x)$.

Proof of lemma 3

Both (16) and (18) are monotone decreasing with respect to S ($\frac{\partial^2 \Pi_i}{\partial S\,\partial k_i} = -1$). Given that $k_2^*(A)=0$ and $k_2^*(0)=1$ there must exist (z_2) such that $k_2^*(S)=0$ if and only if $S>z_2$, and $k_2^*(x)=1$ if $S<z_2$.

Thus z_2 is the reservation offer of type 2.

Similarly define $\overline{z_1}$ such that $k_1^*(S)=0$ if and only if $S>\overline{z_1}$. Define $\underline{z_1}$ as the S such that weak plaintiffs sue with probability one if and only $S<\underline{z_1}$. $\underline{z_1}$ and $\overline{z_1}$ exist because the best response of type 1 is a continuous decreasing function of S.

Proof of lemma 4

Look at (18) at z_2, evaluate it at $k_2=1$, $k_1=0$

$$(24)\quad \beta_2\Big[f(c_2^*)A+[1-f(c_2^*)]D\Big]+(1-\beta_2)\Big[g(c_d^*)B+[1-g(c_e^*)]D\Big]$$

$$-c_2^*-a+k_2(1-\beta_2)\frac{\partial g(c_e^*}{\partial c_d}\frac{\partial c_d^*}{\partial k_2}t(A-B)=z_2 \text{ because of the definition of } z_2.$$

Furthermore using the same argument as in lemma 2 one can show that:

$$\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+(1-g(c_d^*)]D\Big]-c_1^*-F_p<z_2.$$

But at $S=\overline{z_1}$,

$$(25)\quad -S+\beta_1\Big[f(c_1^*)A+[1-f(c_1^*)]D\Big]+(1-\beta_1)\Big[g(c_d^*)B+[1-g(c_e^*)]D\Big]-c_1^*-F_p=0.$$

So $\overline{z_1}<z_2$.

Proof of Theorem 2

When the second equilibrium is selected at t then t automatically verifies theorem 2. This case is clearly uninteresting from a Bayesian point of view because there is no need for updating because no trials occur. So assume that only the first equilibrium (E_1) is selected.

$$t_1^*=\frac{p(k_1^*\beta_1[1-f(c_1^*)]+(1-p)(\beta_2[1-f(c_2^*)]}{pk_1^*\Big[\beta_1[1-f(c_1^*)]+(1-\beta_1)[1-g(c_d^*(1)^*)]\Big]+(1-p)\Big[\beta_2[1-f(c_2^*)]+(1-\beta_2)[1-g(c_d(1)^*)]\Big]}.$$

Define $t^*(t)$ to be the Bayesian probability of high damages when no evidence is brought to the court given that the court announced t. Since the first equilibrium is selected for all values of t between 0 and 1, to show that there exists a self-fullfilling equilibrium it is sufficient to show that (a) $t^*(t)$ is continous, (b) $t^*(0)>0$ and (c) $t^*(1)<1$).

(a) $t^*(t)$ is continous because

$pk_1^*\left[\beta_1[1-f(c_1^*)]+(1-\beta_1)[1-g(c_d^*(1)^*)]\right]+(1-p)\left[\beta_2[1-f(c_2^*)]+(1-\beta_2)[1-g(c_d(1)^*)]\right]$ is weighted sum of positive reals that are never all 0.

(b) $t^*(0)>0$ because the denominator of t^* is non-zero since the solution to the expenditure problem for plaintiffs of either type always lead to interior solutions so $f(c_i^*)<1$.

(c) $t^*(1)>1$ because the denominator is always less then the numerator since the solution to expenditure problem for the developer always leads to an interior solution so $f(c_i^*)<1$.

Therefore when only the first equilibrium is selected for any value of t there exists a least one t that is part of a self-fulfilling equilibrium. When the second equilibrium is selected for some t then it is automatically self-fulfilling.

Proof of theorem 3

The proof is again carried out by backward construction, note that defendants spend nothing, second plaintiff expenditures are given by:

$$(26)\ \frac{\partial f(c_i^*)}{\partial c}=\frac{1}{\beta_i(A-S)}\ ,\ i=1,2.$$

The concavity of $f(.)$ insures that there will be a unique spending level for each type and for each settlement level. Strong types spend more than weak types and research decreases as the settlement increases.

1. Optimal litigation levels

The first order conditions for type i are now :

(27) $$-S+\beta_i\left[f(c_i^*)A+[1-f(c_i^*)]S\right]+(1-\beta_i)S-c_1-F_p \text{ or}$$

(28) $$-S\left[1-[(1-\beta_i)+\beta_i(1-f(c_i^*)]\right]+\beta_i\left[f(c_i^*)A-c_1-F_p\right].$$

Thus (28) is a razor's edge reaction function. If (29) is positive, i sues with probability one, and if it is negative, i always settles. Differentiating (29) with respect to S yields

(30) $$-\left[1-[(1-\beta_i)+\beta_i(1-f(c_i^*)]\right]+\frac{\partial c_i^*}{\partial S}(1+\beta_i\frac{\partial f}{\partial}c_i(A-S).$$

Note that $\frac{\partial c_i^*}{\partial S}$ is negative. Hence (27) is negative, so (26) is monotone with respect to S. This allows us to define one reservation offer for each type (z_i). Once again settlement offers other than, z_1 , z_2 are weakly dominated. These two settlement offers lead to two equilibrium candidates:

$$E_1 = (z_1,0,1,0,c_1^*,c_2^*,0\ ),$$

$$E_2 = (z_2,1,1,0,c_1^*,c_2^*,0).$$

By the same argument as in the proof of corollary 3, the equilibrium will be unique generically.

Chapter 5

Conclusion

This research was begun as an investigation of the economic impact of the French Revolution. Understanding the economic consequences of 1789 would lead, I thought, to a better grasp of the Revolution. A focus on economic questions had the enviable characteristics of simplicity and of measurability. Unlike social and political historians who seek to understand the causes of the French Revolution, I could resolve my questions simply by determining what institutions changed, and then measuring the economic consequences. The procedure was simple: first identify the institutions reformed by the Revolution, then model theoretically the impact of the new institutions on transaction costs and finally assess the economic impact of changed transaction costs on specific segments of the French economy. Although the direct measurement of transaction costs was rarely possible, indirect measurements sufficed to show how important institutions were to economic growth.

The procedure outlined above leads to two general conclusions. First, although recent historiography has moved away from the old Marxist view of the Revolution[147] as the dawn of a new economic era, there is nonetheless no doubt that the Revolution dramatically changed the economic history of France. Second, the research suggests that Old-Regime institutions shackled the economy with high transaction costs and blocked the spread of more productive methods in agriculture. The research has investigated the problems of high transaction costs in two specific settings: drainage and irrigation, however it is possible to extend the conclusions of the studies much further. Let us confront each of these conclusions in turn.

The French Revolution Revisited

The recent historiography of the French Revolution from Cobban through Sutherland

147) See for example the introduction of D.M.G. Sutherland, *France 1789-1815*.

has been critical of the Marxist thesis that the Revolution marked the beginning of a new political and economic order exemplified by the rise of the bourgeoisie. In an unfortunate consequence of their rejection of the Marxist model, historians have also rejected the investigation of the economic consequences of the Revolution. This study shows how important institutional change, during and after the Revolution, was for the promotion of irrigation and drainage. Beyond the limited setting of agricultural improvement I also want to argue that the Revolution significantly decreased the cost of any reform, and therefore was a significant event both in the economic and political history of France.

Let us first examine the contributions of the Revolution in the context of drainage and irrigation. Most of the legislation governing property rights in Old-Regime France had been codified in the Middle Ages. The allocation of authority over these property rights between the central government and local groups was also mostly medieval, despite some modifications in the sixteenth and seventeenth centuries. In the eighteenth century, changes in technology and demand made investments like drainage and irrigation profitable. But such investment in agriculture required a reallocation of property rights. Had all resources been freely traded in competitive markets, a Coasian reallocation might have occurred. But in the case of irrigation and drainage projects, important resources were peculiar to a project and owned by specific individuals or groups. Each of these groups held veto power over the project and attempted to appropriate the profits from the project. Veto players attempted to claim the profits of the project through lengthy and expensive judicial appeals of developer's permits. The Revolution was the first time that veto players were sufficiently constrained by law that projects could occur. Both before and after 1789, institutions dictated at what price these resources were transferred from the owners to the developer. After 1789, property rights were transferred with much lower transaction costs.

The impact of the Revolution on transaction costs is best illustrated by the analysis of the transaction costs induced by a specific set of institutions: those that govern the strength of rights of eminent domain and those that locate the power to grant such rights. When the developer of a project gathers rights of eminent domain, transaction costs may occur in a number of ways. If rent-seeking individuals (such as eighteenth-century local administrators, or a city) hold the power to grant rights of eminent domain then they will attempt to extract the surplus from the developer. Any bribes, for example, made to granting powers are transaction costs. Moreover, the strength of the developer's rights of eminent domain will itself dictate the price that he will pay for the land he needs. The capitalized value of the *ex ante* rent is the reservation price of the landowner and if the market for land was competitive, that capitalized value would be the price paid by the developer. Thus the difference between the capitalized value of rent and the price actually paid for land by the developer is a further transaction cost.

Both bribes to corrupt authorities and compensation above the market price for land are transaction costs that may be incurred even if the developer's rights of eminent domain are well defined, yet other transaction costs will occur because of uncertainty. The power of the authority that grants the right of eminent domain may be uncertain, and other authorities (such as seigneurial lords) may challenge the grant. The developer's power of eminent domain may itself be based on an uncertain grant, and that power can also be challenged either by granting authorities or by landowners. Both types of uncertainty impose further transaction costs on the developers of drainage and irrigation projects. Indeed, challenges to the validity of grants are determined in court, and court procedures can be lengthy and costly. Moreover, rent-seeking courts create even higher transaction costs. Bribery to secure eminent domain rights, compensation above the market price, bribery to uphold the same rights, and litigation to determine the

extent of authority were all transaction costs faced by eighteenth-century developers of drainage and irrigation. The Revolution, dramatically and simply, eliminated them all.

These transaction costs were eliminated by three basic reforms. First, during the Revolution, reforms made challenges to grants of eminent domain by the state unprofitable. The state appropriated complete authority over eminent domain issues and restricted the authority of the judiciary in eminent domain question. Second, the Revolution and Napoleon created an administrative structure with enough power to dictate to landowners the price at which they would be compensated for their assets. Third, the reforms of the judiciary not only restricted its authority in economic matters but also ended all rent-seeking problems. These reforms affected questions other than rights of eminent domain. The centralization of France, achieved early on in the Revolution, destroyed all local veto players in questions of drainage and irrigation. The Revolution, thus, seems to have had a dramatic impact on transaction costs in irrigation and drainage.

The nineteenth century also provided institutions that decreased the maintenance costs of drainage and irrigation projects and resolved most revenue problems. The new institutions--*associations* or *syndicats*--grouped the landowners that benefited from projects. The *associations* could use the power of the state to assess landowners for their share of the costs of a project, and many of the revenue problems that had plagued Old-Regime developers disappeared. The power of the state was an instrument that had never been available to eighteenth-century developers, and drainage and irrigation projects had often been poorly maintained and a financial drain on the developer. *Associations* also decreased the costs of projects by eliminating the ability of landowners to behave strategically toward the developer. Indeed, once a developer formed an *association*, landowners could either join and bear a share of the costs or they would be excluded from the benefits of the project.

The reduction of transaction costs due to reforms during the Revolutionary period had a signi ficant impact on agriculture in Normandy and Provence. In Normandy all the communal marshes were divided and drained between 1820 and 1850; in contrast there had been no drainage whatsoever between 1714 and the Revolution. In Provence during the period 1820-1860 the irrigated area nearly doubled, a change that led to an increase in total output greater than 5%. In contrast there was no increase in irrigated land between 1700 and 1760. After 1760, limited irrigation development occurred, but only at very high transaction costs. The institutional change of the Revolution lowered transactions costs and led to renewed investment in agriculture.

The institutional changes that reduced the cost of promoting agricultural improvements were embedded in a much larger context. The French Revolution of 1789 was an important political and economic event not only because of the reforms that occurred immediatly, but also because it gave the central government the means to achieve further reform. All the institutional changes that occurred from 1789 on were based on two events that marked the death of the Old Regime: the establishment of a supreme legislative assembly (June 1789), and the abolition of feudal privileges (August 4 1789). The Third Estate's goals in establishing the *Constituante* may well have been to limit the arbitrary power of the king but, in fact, as the Third Estate seized power from the crown it established an executive with unprecedented power.

As a result of centralization, the actions of the *Constituante* do not stand alone. Using the new power of central government, subsequent regimes, regardless of their political orientations, promoted, enacted, and protected reforms that reduced transaction costs. Napoleon, after all, was responsible for the administrative structure of France based on prefects. Simmilarly, it was not until after the Restoration of 1815 that the rules of *associations*, groups of landowners

that administered drainage and irrigation projects, were codified.[148]

Prior to 1789 any of the dozen *Parlements*--regional courts of appeal--had the right to object and propose amendments to laws before they registered (accepted) them. Without the acceptance of the *Parlement* the law had no validity in the region. Although ultimately *Parlements* could not refuse to register a law, they could add very substantial costs, simply in terms of delay to any reform. Furthermore each *Parlement* could bargain for different amendments, leading to Royal laws that differed from place to place.[149] As a result, reform was a very slow and costly process in the Old Regime. In contrast, the Revolution simply erased most of these costs. The central government could decide virtually alone on new legislation. Although the shares of power of the executive and the legislative branches of government varied between 1789 and 1860, none of the national governments that succeeded the *Constituante* ever relinquished the power that the central government had acquired during the Revolution. Beyond the extraordinary increase in the power of the central state--a fundamental consequence of the French Revolution--a number of other reforms decreased the transaction costs of agricultural investments. Foremost was a set of judicial reforms that ended all rent-seeking behavior in the judiciary. These reforms also transferred jurisdiction over most economic matters to the prefect--the national government's local representative. The adoption of an administrative approach to the resolution of disputes over property rights eliminated all veto players and greatly reduced transaction costs in the planning stages of most projects.

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148) I do not wish to imply that the governments that succeeded the Old Regime were free traders. Quite to the contrary, they promoted state intervention in the economy in as intense a fashion as the Old Regime. This intervention however, was different than in the past because it was not based upon a rent-seeking bureaucracy, nor did it have to deal with the millennial accumulation of privileges. Thus, after 1789, governments were freer to promote economic growth than in the past.

149) Roland Mousnier, *The Institutions of France under the Absolute Monarchy*. Chicago: University of Chicago Press, 1979, vol. II p. 259.

When the Third Estate convened as the *Constituante* it was also giving France a means of institutional change that was far simpler than anything the country had known before. After 1789, a majority within the legislative assembly and the approval of the executive were sufficient for the enactment of reform into law all over France. As a result reforms that had seemed impossible in the closing days of the Old Regime were achieved often overnight. The French Revolution, thus, greatly decreased the cost of institutional change in France. This alone, it would seem, makes the Revolution an important event in the economic and political history of France.

The Long-Term Costs of Eighteenth-Century Institutions

The institutions of the eighteenth century raised transaction costs sufficiently to deter investment in agriculture. The investigations suggest that in Normandy transaction costs might have led to a reduction in output of 3% while in Provence the lack of irrigation led to a reduction in output greater than 5%. The shortfalls in output were calculated by assuming that changes in rent due to improvement captured the net increase in output. In fact, the change in rent due to improvement should be, in equilibrium, equal to the change in output minus the increased input of labor and capital. Thus, if drainage and irrigation had succeeded in the eighteenth century, output would have increased more than the 3 to 5% suggested above; however, total factor productivity would have changed by less.[150] Beyond these local conclusions each of the studies suggests that the institutional structure was largely responsible for the lack of investment in the French economy.

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150) I chose to focus on output because eighteenth-century governments were more preoccupied with the level of output of French agriculture than with productivity. See AN H^1 1489.

The argument that institutions played a significant role in the backwardness of French agriculture relative to that of England has been implicitly challenged by O'Brien and Keydor and by George Grantham. O'Brien and Keydor argue that soil and technology are the primary explanation of French retardation.[151] Yet if this remains true over the whole of France, soil and technology fail to explain why landowners in areas that suffered extensively from drainage failed to enclose, consolidate, and drain their fields. Although O'Brien and Keydor may be correct in suggesting that mixed husbandry was more appropriate for Britain than it was for France, they fail to explain why the French chose to forego improvements entirely in the eighteenth century. O'Brien and Keydor are able to show that England was proportionately better endowed for agriculture on the basis of soil type. They do not explain why, in the areas that had similar land characteristics as England's, agriculture did so poorly in terms of productivity.

George Grantham suggests that lower levels of urbanization in France than in England depressed the demand for livestock and made the conversion of arable to artificial pasture unprofitable.[152] Grantham calculates the returns of artificial pasture in a specific scenario. He assumes that the fodder would be used to fatten animals that have worked on the farm for years and thus only gain weight slowly.[153] Grantham also fails to account for part of the benefits of cattle-raising, such as manure. Moreover, it is not clear that fattening old animals would have been the most profitable use for fodder--one alternative would have bee to raise young animals either for sale as draft animals or even to butchers. In any case Grantham's data seem to show

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151) Patrick O'Brien and Caglar Keydor, *Economic Growth in Britain and France, 1780-1914*, London: George Allen and Unwin, 1978, pp. 104-112.

152) George Grantham , "The Diffusion of the New Husbandry in Northern France. 1815-1840", *Journal of Economic History*. 39 (1978), pp. 311-337. See tables 7-10, pp. 328-330.

153) A different scenario would allow the owner to use the pasture strictly for intensive cattle raising; however, neither this alternative scenario nor using fodder prices--and accounting for transport costs directly-- were explored by Grantham.

only that the costs of converting fields from fallow to pasture were relatively close to the revenues. Given the competitive nature of agriculture his results are not too surprising. His study analyzed the marginal gain from converting an extra field from the three-field system to pasture, with any other changes in production. In effect Grantham computes the marginal derivative of farming profits with respect to pasture, and in the competitive industry of farming that derivative is zero. Yet the important gains of mixed husbandry, as shown by Allen, had mostly to do with the better drainage allowed by consolidation and enclosures, not increased pasture *per se.*[154] Grantham does not tackle the issue of the profitability of drainage, enclosure, consolidation, and conversion to pasture schemes, which demanded some cooperation between landowners. Thus, the thesis that institutional barriers were responsible for much of French retardation remains unchallenged.

In the eighteenth and nineteenth centuries, the French economy grew more slowly than the economy of Britain.[155] Although endowments and technologies differed between Britain and France, institutions were important causes of French retardation. To argue this point is difficult, for there is a lack of evidence on the transaction costs imposed by French institutions on investors. When transaction costs make certain activities unprofitable, these activities do not occur, and it is impossible to measure directly their institutional costs. It is possible, however, to measure the transaction costs of related activities and derive some more general conclusions; this study accomplishes just that.

Each of the preceding chapters focused on a set of institutional constraints and its impact on a specific economic activity in a specific region; in turn the conclusions suggest that

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154) Robert Allen, "Enclosures and Productivity Growth," *U.B.C. Dept. of Economics, Discussion Paper* 1984.

155) Patrick O'Brien and Caglar Keydor, *Economic Growth in Britain and France, 1780-1914*, chapter 3.

other potentially profitable activities failed to occur in other parts of France. Drainage in Normandy tells us something about the fate of enclosure, consolidation and drainage improvements in eighteenth-century France. Irrigation in Provence leads to the conclusion that the division of authority in eighteenth-century France made it difficult to take advantage of economies of scale inherent on certain new technologies. The size of the market was severely limited in Old-Regime France by institutional constraints--tolls, tariffs and quotas to cite only three. Finally, the theoretical chapter suggests that the differences between the British and French paths of agricultural development were in part due to difference in burden of proof in litigation over property rights. Let us examine each of these questions in turn.

Consider drainage in Normandy. Drainage did not occur because the unanimity rules of Norman communities allowed groups of landowners to hold out strategically for an increased share of the profits from drainage. Strategic behavior took the form of judicial appeals and resulted in unending litigation. Because the appeals courts granted staying orders, none of the social gains from irrigation were ever captured. The same sort of strategic behavior would have been possible for any landowner in France facing a proposal to drain, enclose and consolidate the lands of his village. Ideally one would want to study the question of enclosures in eighteenth century France directly; however, in all of France fewer than a dozen villages saw their lands drained, enclosed and consolidated in the eighteenth century, thus there is little direct evidence on transaction costs associated with such improvements during the Old Regime.[156] Only by studying related activities, such as the drainage of marshes for example, can one get evidence on the level of transaction costs associated with enclosures.

156) Philip Hoffman, "Institutions and Agriculture in Old-Regime France," p. 10. The near total absence of drainage, enclosure, and consolidation schemes carried out in France, makes it very difficult to carry out counterfactual calculation of the profits that such projects would have earned. One alternative, not yet explored, would be to use British cost data, which is available, and estimate counterfactual profits if French prices had prevailed in England. Such an approach would yield interesting conclusion for northern France, which is similar to England.

It is because of threats of litigation similar to those faced by Norman drainers that little investment in enclosure, consolidation, and drainage took place.

Jean Meuvret has shown that there is little evidence that landowners were legally prevented from enclosing their fields.[157] One would, thus, think that if enclosure had significantly raised output then it would have occurred on its own. Robert Allen's studies of rural England suggest that enclosure alone, however, did not raise output significantly but that a combination of drainage, enclosure and consolidation did.[158] To achieve this triple improvement required the coordination--willing or coerced--of all the landowners of the village. Unlike Britain where promoters of enclosures could rely on the threat of parliamentary acts, and whereas the approval of the owners of a majority (of two-thirds, most often) was sufficient to decide for a drainage, enclosure and consolidation scheme, in France unanimous consent was necessary. Although Jean Meuvret was correct in pointing out that there were few institutional obstacles to enclosure alone, this was not the case for drainage, enclosure and consolidation schemes because they modified the custom.

In France, unanimous consent was also necessary for division of the commons, another improvement that eighteenth century royal officials tried to achieve with little success.[159] Unanimous consent rules were based on customary law. Custom ruled common lands as well as access to fallow fields. As a result, landowners who enjoyed benefits from either the fallow or the commons could base their appeal against improvement projects on their customary rights. Royal courts had jurisdiction over such appeals against improvements, and they could not refuse to hear such appeals because drainage, enclosure, and consolidation did modify

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157) Jean Meuvret, *Le Probleme des Subsistences a L'Epoque Louis XIV*, part II, vol. 1, pp. 16-19.

158) Robert Allen, "Enclosure, Capitalist Agriculture and the Growth in Corn Yields in Early Modern England," *U.B.C. Dept. of Economics, Discussion Paper#* 86-39, and "Enclosures and Productivity Growth," *U.B.C. Dept. of Economics, Discussion Paper* 1984.

159) Philip Hoffman, "Institutions and Agriculture in Old-Regime France", pp. 10-14.

custom. Thus the institutional costs faced by Britain's famed triple improvements of drainage, enclosure, and consolidation were at least as high as those faced by Norman drainage schemes. As the chapter on Normandy has shown, once the issue became the modification of customary law, it was not even certain that the project would ever get out of court.

Royal courts often sided against the promoters of improvements because an opposite decision would have led to dangerous precedent. The customary law formed by precedent served as the basis for the privileges of regions, towns, villages, lords and other groups (e.g. wealthy landowners). Opening customary law to reform also threatened the privileges of royal justice officials who were, most often, nobles and wealthy landowners. Customary law, unlike royal law, was thus very costly to change and to reform because royal justice officials found it in their interest to demand many amendments and to lend a favorable ear to the appeals of landowners and seigneurs opposed to reform. As Philip Hoffman has shown in the case of laws favoring enclosures and division of the commons, the royal judiciary was often "successful in emasculating most of the royal legislation."[160] As a result, no enclosures--particularly those of the sort that would promote drainage and consolidation--ever occurred in Old-Regime France. The investigation of drainage in Normandy does not allow us to measure the institutional costs associated with drainage, enclosure and consolidation, but it points to the causes of these costs. Furthermore, the failure of institutions to constrain distributional problems in drainage schemes in Normandy suggest that drainage, enclosure and consolidation projects would have fared even worse because the magnitude of distributional issues was even greater.

By the middle of the eighteenth century, the cost of poorly drained, vastly dispersed narrow strips had become apparent to many large landowners in France. There is widespread

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160) Philip Hoffman, "Institutions and Agriculture in Old-Regime France," p. 14.

evidence that both seigneurs and large landowners were slowly creating consolidated landholding throughout the Paris basin, the major grain producing area of France. In effect these landowners were attempting to gather all the property rights in an area so as to internalize the costs and benefits of improvement. Yet the consolidation movement was uncoordinated and proceeded only at a slow pace because each improver was only concerned with a few specific parcels and by the Revolution few areas had been consolidated successfully. One could argue that landowners were in effect attempting a Coasian reallocation privately. Two factors weighed against such private attempts to acheive efficiency. First, as large landowners create ever greater consolidated holdings, small landowners become local monopolists and may strategically hold out to claim the surplus of consolidation. The idea that individuals will be willing to sell their assets at the competive price underlies most Coasian reallocation theory; however, when an individual is a monopolist his reservation price is irrelevant. What mattered in issues of consolidation was the division of the surplus between small and large landoweners. Second, although it might have been possible for large landowners to secure all the privately owned land in an area they would not necessarily have secured the right to do away with common lands, which were ruled by customary law. Once again various individuals would have had high incentives to block consolidation to claim part of the surplus. Thus, without the threat of legal coercion--as existed in England thorugh parliamentary acts--private attempts to attain greater efficiency in agriculture through consolidation failed.

The complete lack of enclosure, drainage and consolidation schemes had a far greater impact than the absence of drainage of marshes. While comon lands, marshes, fens, moors and heath represented more than 15% of French agricultural land as late as 1840, the amount of arable that could have been improved was far greater. Jean Meuvret stressed the dramatic losses in productivity per acre associated with *billionage* an agricultural technique that

involved creating a series of ridges and furows in a field to improve drainage. Meuvret suggests many regions amounting to nearly half of northern France suffered from bad drainage. In the absence of general drainage schemes French landowners resorted to *billionage*, which by all accounts dramatically reduced per acre yields.[161] Using data from the 1840 census of agriculture we can make a guess at the impact of better drainage on the overall performance of French agriculture.[162] In 1840, northern France produced 57% of total agricultural output and 60% of the grain of the nation. The assumption that half of northern France would have benefited from better drainage is equivalent to assuming that 25.5 % of all France should have been improved. If enclosure, drainage and consolidation lead to yield increases in grain of 20% in French heavy soils--that is improvement had an impact equivalent to what Allen found for England--than total grain output would have increased by about 5%.[163] However enclosure drainage, and consolidation would have brought far greater increases in output than the calculation suggests because enclosure should have led farmers to raise more livestock; the shortage of livestock is but another of the failures of eighteenth and nineteenth century agriculture. Clearly, if the state had reformed customary law, output would have increased by more than 10% over all of France, yet further research is necessary to determine the role of institutions in the backwardness of French agriculture.

A second set of Old-Regime institutional constraints on the French economy is highlighted through the research on irrigation in Provence. Despite its absolutist trappings, the

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161) Jean Meuvret, *Le Probleme des Subsistences,* part 1 pp. 110-114. Meuvret lists the Angoumois, Beauce, Brie, Flandre, Perche, Picardie, Poitou as in the north well as areas in the Southwest of France as areas that suffered from bad natural drainage. We should add that most of Normandy and Britany fall in that category.

162) *Statistique Agricole de la France*. Paris: Imprimerie Nationale, 1845. Vols. 4, 5, 6,7, tableaux A, G, H. See also Hugh Clout, *Agriculture in France on the Eve of the Railway Age*. London: Crown Helm, 1980.

163) Robert Allen, "Enclosures and Productivity Growth," *U.B.C. Dept. of Economics, Discussion Paper* 1984, Tables 2 and 3. Allens offers only per acre analyses of the impact of enclosure and drainage on British agriculture.

Old Regime was an institutional structure characterized by widely diffused authority, and a large number of organizations with veto power. In Provence, strategic behavior due to extreme diffusion of authority was responsible for the lack of development of irrigation in the eighteenth century. To be sure, irrigation was not very important outside the South of France. Most of the North of France needed drainage rather than irrigation, and even in the South the amount of land susceptible to low-cost irrigation was always limited. The study's conclusions go beyond issues of irrigation and suggest that the division of authority in Old-Regime France was an important institutional constraint on the economy as a whole. The division of authority allowed many institutional constraints on the size of markets to survive in eighteenth-century France. The question of market size in eighteenth-century France has gone almost uninvestigated.[164] Yet it is an important component of the economic environment and one where institutions embodied in law, as well as other transport costs, play an important role.

By the eighteenth century no region or town could impose new institutional restraints on trade (such as tariffs) without the approval of the king; however, it was much more difficult for the state to remove such barriers. Trade barriers are important to economic growth because they tax inputs and outputs. Tariffs make any economic activity less profitable and more importantly, they decrease the size of the market. As a result some improvements in techniques may not be adopted and economies of scale may not be realized. The task of measuring the impact of trade must be left to a further study, yet this work suggests why these barriers survived and prospered for so long. The power to levee tariffs, and other basic import restrictions, as well as the power of guilds to regulate the labor market were all privileges granted by the

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164) See, however, David Weir, "Markets and Mortality in France 1600-1789," mimeo 1984. Weir shows that for wheat, by one measure at least, market integration greatly increased in eighteenth-century France. Unfortunately he does not investigate the impact of the Revolution on market intergrations.

state to a town, or to a trade organization in return for funds or political support. Every town, every region, every organization and most elite groups in France had their privileges. The removal of these privileges without compensation would have had tremendous distributional consequences and would have been opposed by all intermediary organizations, either political ones such as the Estates or judicial ones such as the *Parlements*. At no time in the seventeenth or eighteenth century did the state have the funds necessary to compensate privileged groups for the losses inherent in any reform.

The study of irrigation shows far the state had alienated authority over rights of eminent domain and that it was powerless--until the Revolution--to recapture that authority. More generally, over the course of the centuries, the state had alienated most of its authority over privileges. When, in the eighteenth century, reform became essential, the state was unable to respond. The costs of such divided authority were probably enormous. They affected not only agriculture, but in all likelihood manufacturing as well. Only further research can establish without doubt the impact of divided authority on investment in agriculture and manufacturing. Such research should investigate the importance of institutional constraints on market size and in turn the impact of limited markets on the French economy. It seems clear, however, that institutions did shackle the French economy.

This study has focused on the impact of institutions on eighteenth-century France. I have been concerned throughout with the question of why Frenchmen failed to invest in agricultural improvements in the eighteenth century, when Britons were doing so. Another comparative question in British and French agrarian history comes to light through the conclusion of Chapter 4. Burden of proof may be an important explanatory factor of the difference between landownership structures in Britain and France. The differences in landownership structures between Britain and France emerged in the late Middle Ages when confrontations

between peasants and lords crystallized property rights.

The importance of landownership structures to economic growth has been stressed by Robert Brenner in a series of papers.[165] Brenner argues that from the Middle Ages onward England's agriculture was always more advanced--capitalistic--than that of France because lords retained ownership of the land in England while in France they lost control of the land to a peasantry disinterested in profit maximization. Brenner makes his argument through an analysis of the medieval conversion of arable land to sheep run in England, an event that did not occur in France. The Marxist presumption of the lack of rationality of peasants has been thoroughly attacked by political economists,[166] yet in this case it is largely irrelevant. The question of the peasantry's interest in medieval economic growth is moot, considering that medieval sheep runs were enterprises restricted to lords. Sheep runs did have a significant impact on productivity,[167] but they demanded large amounts of land, far more than peasants, who are by definition smallholders, could muster. Thus, the "capitalistic" improvements Brenner believes were responsible for England's performance were not options peasants could consider. So where peasants owned the land, the convertion of arable land to sheep runs would have been taxed by significant transaction costs. Indeed, to convert arable land to sheep runs in an area of scattered plots would require buying out all the peasants, who would then attempt to hold the project by refusing to sell. The important question is rather why were French lords so indifferent to economic growth? In other words, why did French lords not buy out peasants and thereby regain control of the land? And why did they lose control of the land in the first place?

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165) Robert Brenner, "Agrarian Class Structure and Economic Development in Pre-Industrial Europe," *Past and Present*. 70 (February 1976): 30-75; and "The Agrarian Root of European Capitalism," *Past and Present*. 97 (November 1982): 16-113.

166) See, for example, Samuel Popkin, *The Rational Peasant: The Political Economy of Rural Society in Vietnam*. Berkeley: University of California Press, 1979. Especially the introduction.

167) Robert Allen, "Enclosures and Productivity Growth," *U.B.C. Dept. of Economics, Discussion Paper* 1984.

The answers to such questions flow out of a comparison of property rights law. English lords were able to transform their long-term feudal leases into short-term leases when peasant families bequeathed property to their heirs. They could then readily evict the peasants and convert land into sheep runs if prices warranted. The lords could do this because they had ultimate title to the land. If a peasant could not show a deed then he could not own the land, no matter how long he had farmed it. In England the burden of proof thus rested squarely on the shoulders of the peasants. With such strong property rights the effective size of the firm was the manor, and when relative prices dictated that sheep runs were more profitable than arable land it was relatively costless for the lord to effect the transition from the open field to enclosed pasture.[168] The large size of the manor also further decreased the cost of responding to increased trade and relative price changes. One such widespread response in the late Middle Ages was conversion of land from arable to pasture.

In France, by contrast, early on the lords lost title to the land that they had rented out. One reason for the alienation of feudal property was that, by the late Middle Ages, royal courts laid the burden of proof squarely on the lord in cases of property rights to land.[169] Unless the lord could show that he maintained control over the feudal rent--by varying its amount for example--and that the rent had been collected regularly, tenure became customary and the peasant received possession of the land. Once tenure was customary, the rent could no longer be revised and entry fines (fees levied by lords when title to land was transferred from one peasant to another) were fixed as well. Soon the peasant could sell his access to the land, therefore he had acquired effective title as well. As a result, whenever a lord's administrative

168) J.A. Yelling, *Common Field and Enclosure in England 1450-1850*. London: Archon Books, 1977, pp. 23-26.

169) George Duby, ed. *La France Rurale*. Paris: Editions du Seuil, 1975, Vol. 1, pp. 498-501 and 575-576, and vol. 2, pp. 78-81.

abilities lapsed, part of his property was thus transferred to the peasant and soon French lords owned only demesne land.[170] By the late Middle Ages, lords rarely held enough land in the demesnes to create sheep runs. Furthermore, not all demesne land was consolidated, some of it was scattered among peasant holdings. Any attempt to create consolidated holdings would have made the last few peasants monopolists and effective veto players. Thus France did not adopt the farming techniques of England.

Burden of proof in property law may seem an unimportant institutional detail, yet the difference in that detail between England and France seems to explain much of the differences between their landownership structures. In France, burden of proof was placed on the lord in cases of property to land and as a result landownership was far more dispersed in France than in England. A dispersed landownership structure leads to high transaction costs when coordination is necessary, as would be the case should peasants try to convert their holdings to sheep runs. Further costs are imposed when there are no outside sources of coercion. Thus the cost of capturing whatever gains British agriculture realized from 1400 to 1789 were simply higher in France.

The three general conclusions all suggest how important institutions and the law are to economic performance. Each study suggests how institutions were responsible for the poor performance of the French economy and each general conclusion, in turn, makes a claim about the long-term costs of the French institutional structure. These claims should be investigated in a quantitative fashion because we do not know how much French agriculture suffered from the failure to drain, enclose and consolidate landholdings in the eighteenth century, nor do we know the impact of barriers to trade on total output under the Old Regime. Finally the impact

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170) Marc Bloch, *French Rural History*. Berkeley: University of California Press, 1966, pp. 70-88.

of the French landholding structure relative to that of England over four centuries should be investigated. Yet institutions seem to have been responsible for the failure to enclose, the persistence of small markets and the erosion of seigneurial property. Institutions must therefore have imposed a large cumulative cost to the French economy.

Despite Pierre Goubert's wise assertion that the Old Regime could only survive as long as it could avoid paying its debts, historians have refused to view the fiscal crisis as the primary cause of the Revolution.[171] Rather they sought to indict the closing days of the Old Regime as a social and cultural failure. The relative merits of such an approach, or of one that seeks to understand the objective demands imposed on the state will not be discussed. It should suffice to point out that fiscal reform could not have occurred without dramatic social change because the basis of Old-Regime society was fiscal privilege.

The eighteenth century was a time of widening markets and increased urbanization and both altered relative prices. Thus opportunities for investment existed, yet the allocation of property rights and privileges under the Old Regime left so little of the profits to entrepreneurs that investment was, to say the least, risky. Moreover, reform of privileges was impossible within the political structure of France despite the fact that many investors and government officials agreed on the need for economic and judicial reform.[169] Such reform could not occur without dramatic political change which is just what the Revolution brought.

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171) Pierre Goubert *L'Ancien Regime*, vol. 1, p. 144.

169) Keith Baker, *Condorcet from Philosophy to Social Mathematician*. Chicago: University of Chicago Press, 1975, pp. 57-61. The *Cahiers de Doleances* compiled in 1788-89 are a good source of such demands for reform. Indeed few of the writers of the *cahiers* and few of those who represented France at the Estates general of 1789 were without assets. See D.M.G. Sutherland, *France 1789-1815*, p. 42, and Beatrice Hyslop, *The General Cahiers of 1789, with the Texts of Unedited Cahiers*. New York: Columbia University Press, 1936.

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Archival Sources

National Archives

Série F ^{10} cartons 208-09, 311-24.

Série F ^{12} cartons 1513-1515.

Série F ^{14} cartons 127, 141-142, 627-630, 6300, 6391, 11168

Série F ^{II} carton 910.

Série H ^{1} cartons 1226, 1260-61, 1303, 1307-1310, 1387, 1488-1499, 1511-1515, 1625-1627.

Série D ^{XIII} carton 1.

Departmental Archives

I. Calvados (Caen)

1. Departemental series

Série C cartons 4073-78, 4192, 4197-205, 4210, 4214-15, 4227-4230, 4239-43, 4255, 4258, 4260, 4263-67, 4270-77, 4288, 4293, 4297-98, 6771.

Série H cartons 8163-66 (Abbaye de Troarn).

Série S cartons 998, 1004, 1067-68, 1267-73, 2270, 5271.

2. Communal Archives

Amfreville 9 E 009/40.

Bavent 9 E 046/69 , 9 E 046/109 (Robehome).

Bures 563 E dt/15.

Janville 9 E 344/46.

Petiville 9 E 724/49 (Varavile).

Ranville 9 E 530/81-89.

Saint Samson 9 E 657/33.

Toufreville 9 E 698/48-50 Etang, Communaux.

Vimont 9 E 761/75 (Saint Pierre Oursin) Etang, Communaux.

3. Notarial Archives

The notarial archive for Troarn are all at the departmental archives in Caen. I sampled the archives of the *Notaire* at Troan for land sale and lease every four years from 1702 to 1870. Two years (1778, 1798) was missing. The call numbers go from 8E25117 (1702) to 8E25365 (1870).

II. Vaucluse (Avignon)

1. Departmental series

Série C volumes 34-46, 61.

Série E, fond Bressy du Thor numbers 1-14.

Série 4 G 2-5.

Série H Celestin d'Avigon 57-59, Chartreux de Bompas 150, 182-184, Cordeliers d'Avignon 37-39, Hopital ste Marthe 162-167.

Série 1 L 365-378.

Série S ^{6} Usines Et Cours D'Eau. This Série was under classification at the time I saw it. Documents had until then been assigned to boxes on the basis of the village of origin and which project they concerned. Thanks to the amiable cooperation of the staff at the archives, I

was able to consult all the documents relevant to Cavaillon, Avignon and l'Isle sur Sorgues, three towns with lots of canals and water wheels. This series is precious because it holds much evidence on the working of the nineteenth century administration.

Printed documents 1 doc 220-225

2. Communal Archives

Cavaillon BB 21-24 archives of the Bishop, (available in Cavaillon).

Avignon CC piece a l'appuis des comptes (account records) every five years from 1700 to 1790 (available at the Departmental Archives in Avignon).

3. Notarial Archives

The notarial archives for Cavaillon have been given to the Departmental archives in Avignon. Cavaillon always had at least four *Notaires* between 1700 and 1860. I sampled the Blaze archives (fond Rousset) once every five years from 1700 to 1860. Because the Blaze archives had few land contracts before 1750, I also sampled the Lieutard archives (fond Liffran) from 1700 to 1745. The call numbers are Rousset 905-1048 and Liffran 659-729.

III. Bouches Du Rhones

1. Communal Archives

Aix en Provence, series AA. cartons 34-46.

Libraries

Mediatheque Cecano (Avignon Municipal library)

Manuscripts 1558-60, 1605, 1632-35, 2060, 2433-36 2459, 2511-13, 2549, 2575, 2741, 2826, 2852, 2931, 2932, 2933, 2955, 3334.

Bound volumes of rare printed documents 46198 46824

Bibliotheque Méjanes (Aix en Provence Municipal library)

Manuscripts 722(609), 741(614), 831(846), 834(848), 837(851), 840(853),

Bound volumes of rare printed documents F 335, F 415

The primary sources of data I have not used in this study were the Archives des Bouches du Rhone because of a lack of time and resources. While there is a lot of data on institutions and irrigation in these archives, the wealth of printed data as well as the information available in manuscript form in the Vaucluse did not make it necessary to use them.