The Economics of Statewide Compulsory Unitization Statutes

By

Thiagarajah Natchie Subramaniam

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This Thesis has been approved on the dates shown below

______________________ MAY 15, 2009

Professor Dean Lueck
Agricultural and Resource Economics

Date

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Abstract

The development of property regimes in the oil and gas industry is an area where the common pool problem was eliminated by state statutory intervention. This study examines the implications of economical, political and institutional factors at the state level on statutory behavior and further develops a theoretical frame work to explain the demand for statute adoption. Implications are tested against the state level data on compulsory unitization statutes, well spacing laws, neighboring state laws, oil and gas price, average farm size, federal land, party voting share and interest group presence as well as case studies. The results uncover the impact of institutional and economic forces on statute adoption provide insights on the development of property regimes in large scale natural resources. Interestingly, empirical evidence suggest that neighboring state laws, autonomous regulatory agencies and the presence of spacing laws have a positive influence on statute adoption. However, the overall results from the empirical analysis are less convincing and prevent clear interpretations of most of the variables. Finally, the case study on Texas and Oklahoma legislative history strongly supports the notion that small scale producers disfavor unitization.

CHAPTER 1 – INTRODUCTION

In the absence of efficient property instruments, ownership to large scale and movable natural resources can be complicated amidst multiple claimants. Oil and gas is one such resource, where property regimes have evolved over an extended period of time and efficient property tools have been identified. Hence, an analysis of petroleum property rights can provide useful insights on managing large scale natural resources, where fully fledged property regimes are yet to emerge. This thesis analyzes the evolution of property regimes in the oil and gas industry to identify factors that influence the development of property regimes in natural resources that are movable and fluid. I also intend to model state's behavior in the enactment of compulsory unitization statutes using economical, legal and institutional factors identified in the study.

Oil and gas resources are fluid and usually found in large reservoirs beneath the surface. Often these reservoirs are overlaid by multiple landowners and prevent complete ownership to the reservoir. The incomplete ownership to the reservoir and the fluid nature of petroleum resources can lead to a classic case of open access dissipation in the absence of regulation. This gave rise to the development of property regimes in the oil and gas industry.

During the early days of oil and gas production the 'ad coelum'[1] doctrine restricted the ownership only to the flow. In other words ownership was given only to the extract, which gave rise to the rule of capture regime. Under this regime excess production and waste was inevitable as firms engage in a fierce a race to claim disproportionate shares. Excessive drilling and production generally leads to loss of reservoir energy and may force to prematurely abandon many producing wells. Therefore, to prevent the rule of capture or the common pool problem different regulatory instruments were implemented in the oil and gas industry.

[1] The Ad coelum doctrine refers to the English Common Law under which the land owner is given ownership to anything beneath his/her surface. Under this law multiple claimants will be extracting oil and gas as petroleum reservoirs are overlaid by multiple owners.

Early regulations in the industry mainly focused on preventing the physical waste from rule of capture. Such regulations were inefficient in addressing the economical problems arising from excessive drilling. The first systematic regulation began with the enactment of well spacing rules in Texas which limits the number of wells in a reservoir. However, well spacing regime was inefficient in limiting the production as the law did not impose any restrictions on producers.

The failure of waste prevention and well spacing rules to completely address the problems arising from rule of capture resulted in the first oil and gas crisis in 1930s. During this period the price of crude fell down to 18 cents a barrel and triggered a series of regulations in many oil producing states. Oklahoma and Texas immediately responded to the crisis by issuing state wide orders to limit the production which was famously called as production allowable. Such orders were constantly challenged by the small scale producers because they were usually given a small production quota. Interestingly many states exempted such producers from any form of regulation, possibly due to economic and political concerns associated with regulating small scale producers.

On the backdrop increasing problems with small scale producers and rule of capture waste, the idea of unitization slowly came to light. Unitization requires consolidation of land tracts above the reservoir for cooperative development of oil and gas resources. The underlying principle in unitization is to create a quasi sole ownership where spill over effects from each producer is minimized. However, the transaction cost of negotiating with various stakeholders makes it almost impossible to arrive at successful contracts.

Libecap and Wiggins (1985) show that private negotiation for unitization generally fails and the primary cause of contractual failure is asymmetrical information across bargaining parties regarding relative oil lease values. Often the contracting costs involved in the process of unitization overweigh the gains, in the absence of a compulsion from a regulatory body. This paved the way to the legislative enactment of compulsory unitization statutes that coerce non consenting parties to cooperate in unit agreements. The legislative compulsion for unitization can be viewed as a unique regime in which the state or the regulatory body promotes the cooperative development of a natural resource. Figure 1 shows the cumulative adoption of unitization and well spacing statutes in the United Sates.

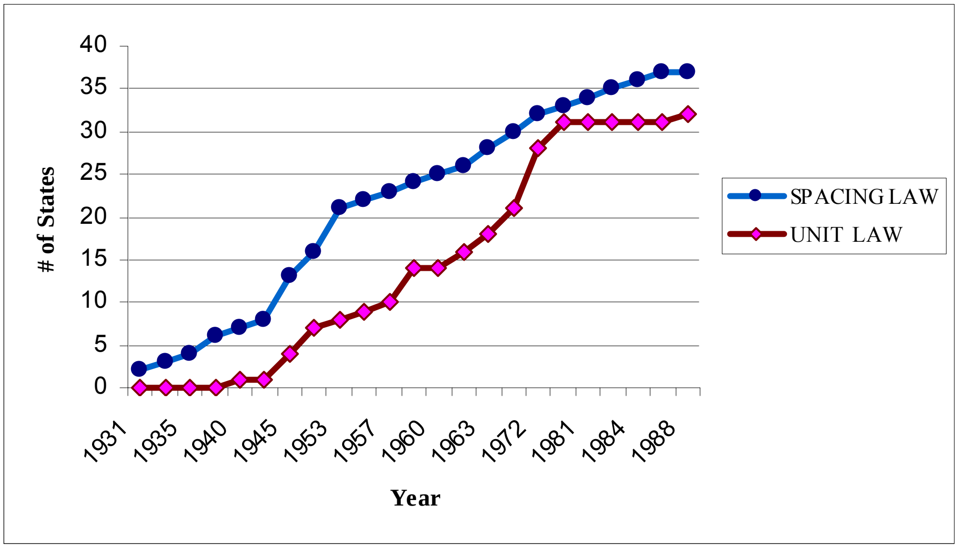

Figure 1.1- CUMULATIVE ADOPTION OF WELL SPACING AND UNITIZATION STATUTES

The first compulsory unitization statute was enacted in Oklahoma and required 63% of the stakeholders to consent before coercing others to join. In Wyoming and Montana where substantial amount of underground resources belong to the federal jurisdiction, unitization is encouraged even before exploration by the Bureau of Land Management. The extent of unitization at the ground level varies across states depending on their economical, political and institutional factors. Table 1.1 summarizes the extent of unitized production in Oklahoma, Texas and Wyoming.

Table 1.1 - UNITS AS A SHARE OF TOTAL STATE OUTPUT (%)

Year	Wyoming	Oklahoma	Texas
1950	51	10	1
1955	55	25	4
1960	64	24	7
1965	70	30	16
1970	67	35	14
1975	82	38	20

Source: Libecap and Wiggins (1985)

Interestingly states like Texas, Pennsylvania and Indiana are yet to enact fully fledged compulsory unitization statutes. According to Weaver (1986) and Asghar et al (1990) the deterrence of small scale and independent producers towards unitization, has prevented the enactment of unitization statutes. Technically, unitization provides operating rights to major player in the reservoir and shares are worked out on the basis of surface acreage owned by each land owner. This may explain why small scale producers disliked unitization, but the paradox is what prevented the state legislature from enacting unitization statutes. In an attempt to understand the impact of small scale producers on unitization and state politics I also provide case studies on Oklahoma and Texas in this thesis.

1.1. Key Questions and Methodology

The purpose of this study is to examine the factors (economic, legal, political, and geological) that influence the statutory development in the oil and gas industry with special emphasis on compulsory unitization statutes. Did rule of capture and rent dissipation influence the enactment of unitization statutes? What impact did the small leaseholders and land fragmentation have on unitization statutes? Why states differ in the adoption of unitization statutes? Further, factors like neighboring state influences and political views are explored in search of a possible explanation for the research question.

1.2 Thesis Organization

Chapter 2 compiles the history of oil and gas conservation in the United States. Chronological events in oil and gas legislation and the evolution of institutions are discussed extensively. The chapter provides a snapshot of issues that emerged in the oil and gas industry from its inception.

Chapter 3 develops an economic framework for oil and gas regulation which relies on the work of Libecap and Smith (2002) and Lueck and Schenerwick (1996). Here, I develop an economic model to explain the development of property regimes in the oil and gas industry.

Latter part of this chapter also develops a theoretical framework for the adoption of compulsory unitization statutes.

Chapter 4 details the empirical data that are available for the study. A brief discussion on different categories of variables is followed by a preliminary analysis of difference of means. Initially I use a two staged linear probability model to tests my predictions and then I use a hazard model to further test my predictions. Chapter 4 also concludes with a case study that explores into the statutory differences in Oklahoma and Texas.

The final Chapter, Chapter 5, outlines the findings and conclusions. Moreover, a discussion on the limitations of this study and possible avenues for future research is explored. The Chapter concludes with implications of predictions that came to light with the study.

CHAPTER 2 – HISTORY OF OIL AND GAS CONSERVATION

This chapter deals with the oil and gas geology and creates a platform for understating property regimes in the context of natural resources that are migratory and fluid. Thereafter, I discuss the emergence of property regimes and land mark events that influenced statutory development.

2.1. Oil and Gas Geology

Oil accumulates in reservoirs of porous sedimentary rock beneath the surface. When such accumulations of oil together with porous rocks are confined by solid formation it creates a structural trap. The most common structural traps are anticlines, faults and stratiographic traps. Oil and Gas, trapped in its structural formations, has spontaneous mobility and moves upward when these formations are drilled. The force responsible for this movement will depend upon the particular type of reservoir energy or "drive" associated with the oil pool (Clarke 1969). Most common types of drives are dissolved gas drive, gas cap drive and water drives. Figure 2.1 illustrates a type of gas cap drive.

Once drilled the efficient utilization of reservoir energy is imperative to have maximum recoverability of petroleum resources. The primary production, production from natural energy in a reservoir (gas cap, water drive, gas in solution), to a large extent decides the amount of recoverable resources. Upon primary production enhanced recovery methods are used where liquids and gases are injected into the reservoir to improve the recovery. In many states more emphasis is given for regulating the enhanced recovery process as opposed primary recovery (Weaver 1986).

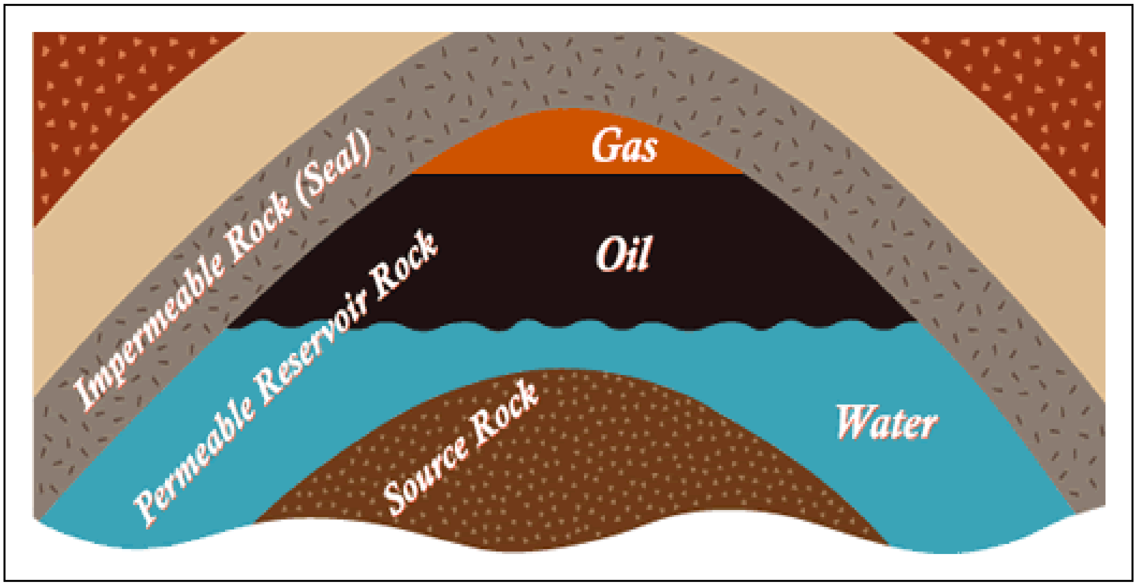

Figure 2.1- GAS CAP DRIVE. Source: www.sjgs.com/anticline.gif. retrieved May 22, 2009

2.2. Ownership of Mineral Rights and Surface Rights

In the United States the right to develop subsurface minerals belongs originally with the ownership of the surface (Benoit 1944). In oil and gas production due to the great expense and the risk of drilling the surface owner often leases out the mineral rights to a mineral interest owner (lessee) for exploration. The mineral interest owner is commonly referred as the operating interest owner and the surface right owner is referred as royalty owner. A royalty owner typically receives a share of one-eighth on all oil and gas produced from his land.

Usually a lessee will be granted a period of five years, primary term, for exploration subject to an obligation of delay payments if a well is not drilled in the first year. If the reservoir is proven to be producing at profitable levels after the primary term the lease could be extend to up to 10 years (Hardwicke 1961). Since many operating interests could be operating in a single reservoir often they engage in a race to capture disproportionate shares.

2.3. Evolution of Rule of Capture

Unlike solid minerals, oil and gas, being fluid, are not confined to lease boundaries and migrate to producing wells across surface boundary lines. Thus, in production of oil and gas under the rule of capture each working interest owner is enticed to drill more wells to acquire maximum share from the reservoir. In the absence conservation techniques and technological understanding of oil and gas engineering in the early era, each new reservoir was drilled and drained rapidly. Waste was inevitable with the production methods adopted, both underground and at the surface.[2]

Although waste prevention laws were prevalent at that time, the enforcement of such laws had to face legal challenges. During the initial periods of oil and gas law, the courts were clearly ignorant of the true nature of oil and gas. Rulings of many lawsuits in this period were in favor of the rule of capture doctrine. In *Hague v. Wheeler,* [3] three mineral owners of a common reservoir had drilled wells and secured gas production. Only two had a market for gas, third driller was shut out of the market. However the later refused to cap his gas well and allowed gas to escape from the wellhead with malicious intent of decreasing the reservoir energy. The court refused to enjoin the wasteful activity and upheld the rule of capture doctrine.

Such rulings implied that the only way of protection against drainage is to have offset wells. Offset wells are defined as wells drilled on the edge of a tract that contains the primary well to prevent excessive drainage. The offset rule, or self-help protection rule, was recognized in *Barnard v. Monongahela Natural Gas Co.*[4] Figure 2.2 shows the impact of self protection rule and the failure of regulation under the rule of capture.

[2] In the East Texas field alone, owners have drilled 13,000 unnecessary well at an annual cost of $50 million, stated in 1930s Dollars. J. Weaver.
[3] 157 Pa. 324, 27A. 714 (1893).
[4] 216 Pa. 362, 65 A. 801 (1907).

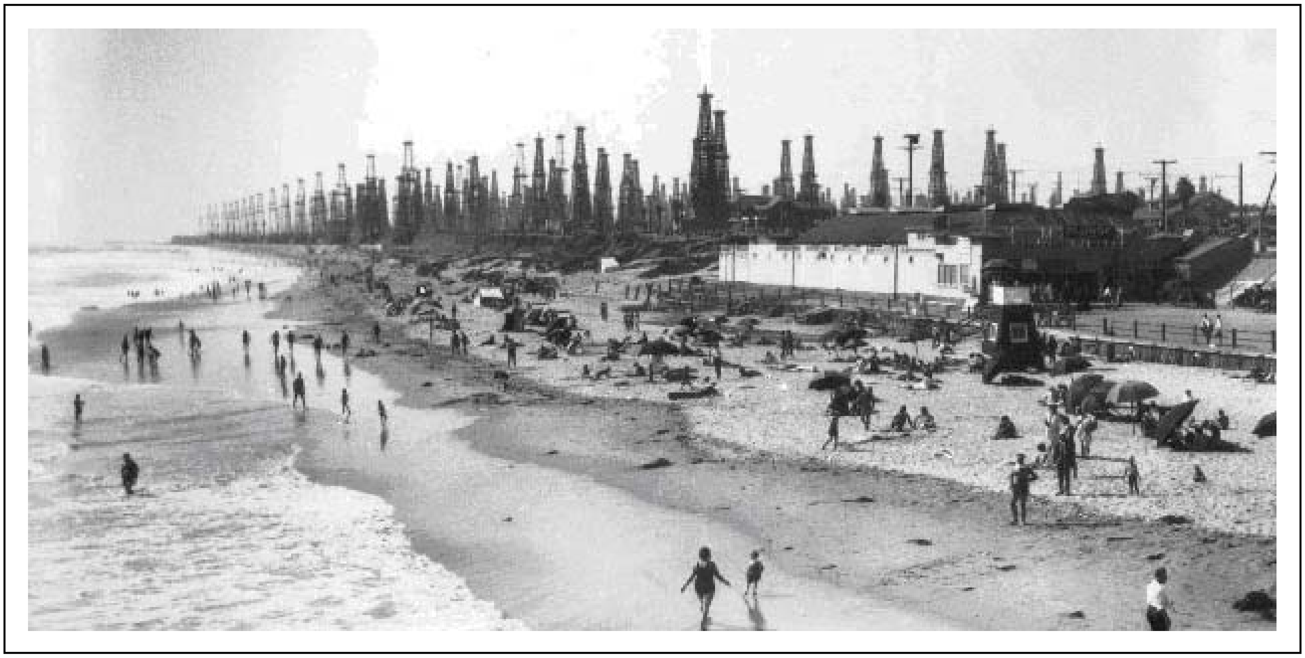

Figure 2.2 – TOWN LOT DRILLING, HUNTINGTON BEACH CALIFORNIA. Source: www.lindsayfincher.com/news/huntington_beach. retrieved on May 22, 2009.

The history of Spindle Top reservoir in Texas exemplifies the effects of a classic rule of capture. Captain Lucas struck oil on the 10th January, 1901. It took 9 days to control the gushing from the reservoir owing to a loss of approximately 850,000 barrels of oil. By the end of 1902 over 600 companies were formed including Exxon Mobil and Texaco with 265 active wells operating in the reservoir.[5] Consequently in 1904, the reservoir was abandoned due to loss of pressure from excess drilling leaving large amounts of oil trapped inside.

The evidence of rule of capture is also well documented for Pennsylvania, California and Oklahoma because of the prominent roles theses states have played in the history of oil production. All oil-producing states have experienced or witnessed the effects of unrestricted oil reservoir development and the regulations in the industry dates back to late 19th century.

[5] The Paleontological Research Institution provides and excellent history of events that took place in spindle top. See http://www.priweb.org/ed/pgws/history/spindletop/lucas_gusher.html.

2.4. Evolution of Regulatory Statutes

The first voice against the rule of capture came from John Carll just 21 years after Drake's well was discovered in 1859. (Herman H. K 1963) He observed the wildcat rush for oil spread out across the country and insisted on systemized plan of action for conservation. Earliest forms of regulations were mainly targeted on surface effects by wasteful production and storage methods.

In early 1893, state legislation was enacted in Indiana to limit the unconfined venting of oil and gas into the air. This legislation was challenged in *Ohio Oil Co. v. Indiana*, and the Supreme Court upheld this regulation as proper legislative authority to prevent the waste[6] of the common property of surface owners[7]. Following Indiana the first waste prevention act in California was passed in 1903. Primary issues addressed by the act were casing and plugging of wells to prevent damage by water intrusion. California passed two more acts in 1911 and 1915 with emphasis on above ground and underground waste. (Baker and Hardwicke 1951)

Despite the efforts made by state legislature little progress had been made on reservoir engineering, concerns over underground and aboveground waste made headings during that time. In 1910, up to 11% percent of California's annual oil output was lost owing to fire while in storage. In 1914, the Director of Bureau of Mines estimated that the costs of excessive wells equaled about a quarter of the value of total annual U. S production (Kiessling 1928). Table 2.1 summarizes the fire damages during the period 1910 to 1920.

With increased problems of excess wells, storage and waste the need for regulation increased. In 1915 Oklahoma instituted the "Corporation Commission" to regulate the economic wastes associated with oil and gas production (McDonald, 1971). Following Oklahoma, Texas legislature declared that oil and gas production to be subject to the regulation of Rail Road

[6] Waste in oil gas is defined as the inefficient, excessive or improper use or the unnecessary dissipation of oil or gas or reservoir energy: Source :http://www.utah.gov/government/agencylist.html – retrieved on 26th of May, 2009.
[7] 177 U.S 190 (1900).

Commission in 1917. In 1919 the Texas Rail Road Commission enacted the first ever wells spacing statute in an effort to reduce the wildcat drilling. Table 2.2 summarizes the adoption of well spacing and unitization statutes chronologically.

Table 2.1- CHRONOLOGY OF STATUTE ADOPTION BY STATES

Year	Well Spacing Statute	Unitization Statute
1920	TX	
1935	OK,CA,NM	
1940	AR,LA,MI	LA
1945	AL,FL,GE,IL,KA	OK,FL,GE
1950		
1955	CL,NV,WA,AZ,ND,OR,SD,UT,WY	AR,CL,NV,WA
1960	NE,MD	CA,MI,AL,NE,AK
1965	OH,MO,ID,IO,PA	AZ,ND,OR,SD,OH,NY,MS
1970	NY	KA,UT
1975	WV	NM,IL,WY.MO.WV.TN
1980	SC	SC
1985	TN,VT,VI	VT
1990	IN	

Source: Legal Aspects of Enhanced Oil Recovery (1977)

Typically, well spacing rule prohibits the drilling of wells less than 300 feet apart or less than 150 feet from an existing property line. The constitutionality of well spacing statutes was challenged in *Patterson v, Stanolind Oil and Gas Co*.[8] The Oklahoma Corporation Commission, pursuant to statutory authority, created a ten acre drilling unit which contended by the plaintiff as deprivation of property without compensation. However, court ruled in favor of the police power exercised by the state and made distinctions between a taking of property and a regulation to prevent waste (Hardwicke 1961).

Although well spacing statutes limited the number of wells the statute did not require the owners to cut down production. Moreover, with the advent of major discoveries like Oklahoma City and East Texas reservoirs during the well spacing era over production became the main problem of the industry. Consequently, regulatory instruments such as market demand proration

[8] Patterson v. Stanolind Oil & Gas Co., 182 Okla. 155, 77 P.2d 83 (1938), *appeal dismissed,* 305 U.S 376 (1939).

and maximum efficient rate proration[9] gained popularity because the objective of such rules were focused mainly on curtailing production.

2.5. Market Demand Proration

Following the major supply shock in 1930 the Texas Rail Road Commission and the Oklahoma Corporation Commission issued statewide production limits. Interestingly each producing well in the state was given with a production quota depending on the well characteristics. These regulations were famously known as market demand proration.

The constitutionality of Market Demand Proration was challenged in *Champlin Refining Co. v. Corporation Commission*.[10] The lawsuit was brought against the Oklahoma Corporate Commission for limiting the state production to 700,000 barrels per month. The ruling in this case determined that it was within state's police power authority to prevent waste through a prorationing (Kramer and Martin 1989).

However the ground realities in Texas were much different to Oklahoma because of large amount of small scale producers. With the onset of production in East Texas Hundreds of small scale producers started operating within a short period of time. Initially the Texas Railroad Commission was hesitant to impose market allowable restrictions on the East Texas field as it was capable of supplying the total US. However, the first proration order on East Texas production was sent out on the 1st of May in 1931 and led the Texas Railroad Commission into turmoil with many lawsuits. Many small scale producers who were assigned a small production quota under the proration rule contended the decision and were exempted from any from of regulation. Indeed in 1946, a Texas court ruled[11] that small leaseholders had the right to drill at

[9] Market demand proration limits the production in accordance with demand in a particular period whereas the maximum efficient rate proration limits the production to efficient rates estimate by the engineers.

[10] 286 U.S. 210 (1932).

[11] Alfred Macmillan, et al. v. Railroad Commission of Texas, 51 F (2d) 400(1931).

least one well on their land with sufficient monthly quota to cover drilling and operating costs (Libecap and Smith, 1999)

Texas also enacted two marginal well[12] protection statutes during 1930's providing incentives for small scale producers to drill (Weaver, 1986).According to Asghar et al (1990) the dominance of small scale producers in Texas is politically driven phenomena. The table 2.3 shows the size distribution of crude oil producing firms in Texas based on average daily production during 1932. The smallest firms, whose average daily production was less than 500bbls, were responsible of only about 2.5% of aggregate daily production but constituted almost 90% of all producing firms. This may suggest that political elements had to favor small scale producers because of the increased number of small scale producers.

Table 2.2 - DISTRIBUTION OF CRUDE OIL PRODUCTION BY NO. OF FIRMS

No. and Percent of Frims	Production Range bbls/day	Percent of Total Daily Production	Total production (000) bbls/day
986 (89.1%)	<500	2.50%	1827
43 (3.9%)	500-1000	3.80%	2797
31(2.8%)	1000-2500	6.50%	4817
14(1.3%)	2500-5000	7.00%	5140
14(1.3%)	5000-10000	8.30%	6099
19(1.7%)	>10000	71.90%	52874
1,107(100%)		100%	73555

Sources: Asghar et al (1990)

2.6. The Emergence of Cooperative Development

As the small scale producers continued to produce at alarming rates, prudent oilmen and major oil companies lobbied for field wide unitization. The idea of unitization was proposed by Henry L. Doherty, President of H. L. Doherty and Company, who delivered a speech on December 9th, 1924, at the API meeting, to the employees of the Cities Service Companies. In his speech he deplored the great waste in oil production, especially of gas and recommended unitization as a

[12] Marginal well is defined as well that produces less than ten barrels of crude per day.

measure to protect the correlative rights of various surface owners.[13] Doherty's' claims were focused around excessive production and wastes leading to the reduction of recoverable oil.

Consequently, within ten days after the beginning of API meeting in Fort Worth, President Coolidge, created the Federal Oil Conservation Board (FOCB) on December 19, 1924. During the period 1925 – 1930 FOCB took the lead in conservation regulation and advocacy programs. Numerous studies were undertaken and reports were made available to oil men at that time via FOCB. Hardwicke and Baker (1961) recalled this period as the "Systemized Study Period".

Ideally, unitization should take place at the time of first discovery of a reservoir or even during the exploration phase. However, much of the information about the reservoir boundaries and productivity becomes available only after drilling certain number of wells. Because of this, unit agreements are generally negotiated after the primary drive of the reservoir has declined measurably (Asghar et al 1990).

Moreover, reaching an agreement on unitization often involves negotiation with many operators and royalty owners. Often failure to reach an unanimous agreement resulted in the formation of voluntary units covering only a fraction of the reservoir.. These voluntary units were constantly challenged by royalty owners under the anti trust laws. The FOCB soon recognized the difficulties in preventing waste and adjusting property rights by voluntary action and consistently recommended regulation by the state governments. State statutes were examined to determine whether more elaborate comprehensive methods were authorized

2.7 Voluntary Unitization and Compulsory Unitization

In spite of many difficulties, the efforts of H.L Doherty first came to light in 1929 with the adoption by the Section of Mineral law of American Bar Association of a policy statement endorsing the concepts of both voluntary and compulsory unitization legislation. In addition, the

[13] Fort Worth Record (Dec, 10, 1924) 2.

section developed a model for compulsory unitization statute. This model allowed majority of operators of a common source of supply to petition the government for an order compelling the minority owners to join cooperative plan of development agreed by many. (Kramer and Martin, 1989)

The first initiatives of compulsory pooling began with certain municipal zoning ordinances designated to limit drilling within the boundaries of municipality. A number of such ordinances were enacted in the 1920's and 1930's, the first of these being an ordinance enacted in Oxford, Kansas. This ordinance was sustained as valid in *Marrs v. City of Oxford.*[14] Another such ordinance was enacted in Oklahoma City, Oklahoma, in 1929, and this was followed by similar ordinances in other cities of Oklahoma, and other states.

Theses zoning ordinances were, in effect, compulsory pooling ordinances in that they limited drilling in the municipal boundaries to one well for each designated spacing unit and provided for non drilling owners to share in the production from the well drilled for each drilling unit. (Howard 1990)

2.8. Institutional and Legislative Push towards conservation

In 1933 a comprehensive program for regulation was formulated under the National Industrial Recovery Act Enacted (NIRA). The program was set forth in the code of fair competition for the petroleum industry that became effective in August 1933. The petroleum administration board was created to oversee Petroleum Code and NIRA. Petroleum code contained provisions for prevention of waste and in production (Hardwicke 1961).

[14] 24 F.2d 541(D.Kan. 1928), aff'd, 32 F.2d 134 (8th Cir, 1929), cert. denied, 280 U.S 573 (1929).

In 1935 congress passed the Connally Hot Oil Act. The act prohibited the movement of interstate and foreign commerce of oil produced in violation of a state statute. The act was passed to aid state enforcement activities but soon became unpopular.

This failure of Connally Hot Oil act led to the discussion of forming a state compact that would limit the production of oil and gas by each state in order to have a "fair Price". Amidst oppositions from Texas, finally an agreement was reached in 1935, called the "Interstate Compact to Conserve Oil and Gas", with the Interstate Oil Compact Commission (IOCC) as the administrative agency. Initially the compact was approved by 6 states. The compact provides no regulation but urging each state to pass adequate laws to prevent physical waste of oil and gas (Kramer and Martin1989).

In 1942 a legal committee of IOCC recommended compulsory unitization of oil and gas reservoirs in an effort to increase secondary recovery operations. In 1940, Louisiana passed the first compulsory unitization statute, applicable to cycling in gas condensed field. In 1945 Oklahoma became the first state to enact a compulsory unitization statute for both oil and gas fields. The act was immediately challenged after the commission forcefully unitized the West Cement Medrano Unit over the objections of several mineral lessees.

During the period of 1950 to 1975 many states adopted the compulsory unitization statute with different stringency levels attached to it. Texas required unanimous agreement of royalty and working owners to form a unit. Oklahoma initially required 85% of the owners to consent, and later revised it to 63%. Initially only 50% of the owners have to consent in order to file an application to from a unit operation. Then a grace period of 30 days will be given to challenge the unit formation by at least 15% of the owners. (Hendricks and Dan 1989)

States with large amount of federal lands such as Wyoming and Montana insisted on unitization before exploration. These Federal Exploratory Units are the most important types of unit agreements that federal government enters into. These units have the greatest potential for efficient development of an area that is productive of oil and gas. Further, these exploratory units are established even before the exact location of the underground resources defined with boundaries. (Libecap and Smith 2002)

The role of state regulatory bodies was redefined with the enactment of Natural Gas Policy Act, Emergency Petroleum Act and Windfall Profits Act respectively in 1973, 1978 and 1980. Agencies were held responsible for decision making on oil and gas prices and management of underground resources.

CHAPTER 3 – ECONOMICS OF OIL AND GAS REGULATION

In this chapter I propose a model for economics of oil production and economics of statute adoption. Former relies on the work carried out by Lueck and Schenewerk (1996) and the later evolves around the empirics of Libecap and Wiggins (1984). The economic model will be analyzed under various property regimes starting from rule of capture. The model is considerate of the rent dissipation, contracting costs and inefficiencies associated with each property regime.

This chapter begins with a brief description of property regimes for which I propose economic models. Subsequently, economic models are developed and analyzed seeking explanation for the evolution of property regimes in the oil and gas industry. Finally, a discussion on economics of statute adoption precedes the predictions.

3. 1. Economics of Oil Production

In the production of petroleum resources sole ownership is considered to be an ideal case where the owner has exclusive rights to the total land overlaying the reservoir. However, the presence of sole ownership is only observed in federal lands, Indian lands and large state holdings (Lueck 1996). The economic model will first consider optimal reservoir production for a single time period under the conditions of sole ownership. The analysis will then examine the behavior of firms under the rule of capture and unitization regimes. In the economic model I use the number of oil and gas wells in a reservoir as the basic unit of economic analysis.

Consider a landowner[15] with total acreage A overlaying a reservoir that produces oil and gas. Landowners maximize profits with respect to a cost function $c(w, s(w), \tau)$ by set up. Where w is the total number of wells and s denotes the stock of recoverable crude over the planning horizon. The stock of recoverable crude s decreases with increasing number of wells (that

[15] Usually in oil and gas production the land owner leases the land to an operator who produces oil and gas. The landowner receives a royalty from the production. This economic model does not differentiate between the landowner and the operator. Here I assume the landowner himself produces in his land.

is $s_w < 0)$.[16] And τ accounts for the technological factors such as drilling methods, drilling waste management, distillation technology, etc.

Production under Sole Ownership

The landowner will choose wells in order to maximize the total value of production:

(1) $$\max_{w} \; V = [pq(w) - c(w, s(w); \tau)]$$

where *p* is the unit price of oil and *q(w)* represents the production as a function of the number of wells. I assume the marginal extraction costs to be positive and non decreasing ($C_w > 0, C_{ww} > 0$). The optimal number of wells can be found by solving the first order identity:

(2) $$pq(w^*)_w = c(w^*)_w + c(w^*)_s c_w$$

The term on the left side of the equation is the value marginal product of having an additional well at the optimum. The right side of the equation captures the complete marginal cost. The first term in the right side is the marginal cost of having an additional well (c_w). Second term is an indirect effect that represents the scarcity cost arising from the stock depletion. With each additional well the amount of stock declines and increases the cost of extraction (c_s); that is $c_s < 0$. The solution implies the optimum number of wells depend on a vector of parameters, $w^* = w(p, s, \tau)$. Substituting w^* into equation (1) yields the value of production from sole ownership denoted by

(3) $$V^* = [pq(w^*) - c(w^*), s(w^*); \tau)]$$

[16] Subscripts denote partial derivatives.

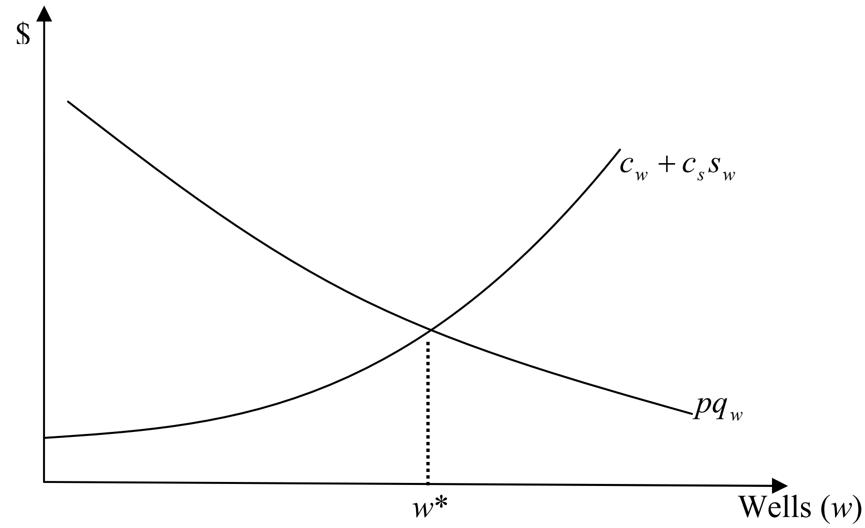

Figure 3.1 - WELL CHOICE UNDER SOLE OWNERSHIP OF THE RESERVOIR

Production under Rule of Capture

This is the case where multiple surface owners with divided subsurface interests operate in the same reservoir and engage in a race for possession. Let a_i represents the acres of land owned by i_{th} land owner who occupies a piece of land overlaying the reservoir. Assuming the reservoir underlying each land parcel a_i is homogenous the objective function of each land owner under the rule of capture is:

(4) $$\max_{q_i} \; V_i^{RC} = [pq^i(w_i) - c^i(w_i, s(W); \tau)]$$

$$\textit{subject to} \quad \text{A} = \sum_{i=1}^{n} a_i \, ;$$

$$\text{W} = \sum_{i=1}^{n} w_i^{rc} \, ;$$

where q^i and,c^i are production and the extraction cost pertaining to the i^{th} landowner respectively. Each land owner's optimal choice of wells (w_i^{rc}), assuming Nash equilibrium, can be found by solving the first order identity:

(5) $$pq^i(w_i^{rc})_{w_i} = c^i(w_i^{rc})_{w_i} + c^i(w_i^{rc})_s s_{w_i}$$

The left hand side of the equation is the value marginal product of having an additional well and the right hand side represents marginal cost. The term s_{w_i} is infinitely small and not immediately observable under the rule of capture. Hence, this portion of the marginal cost is not internalized in decision making. Accordingly the solution for number of wells under the rule of capture can be denoted as $w_i^{RC} = w(p, \tau)$ from equation (5).

Comparing $w^* = w(p, s, \tau)$ under the sole ownership and $w_i^{RC} = w(p, \tau)$ under the rule of capture, it is evident that the effect of stock depletion ($s_w < 0$) will restrict the number of wells in sole ownership. Hence

(6) $w^* < w^{rc}$

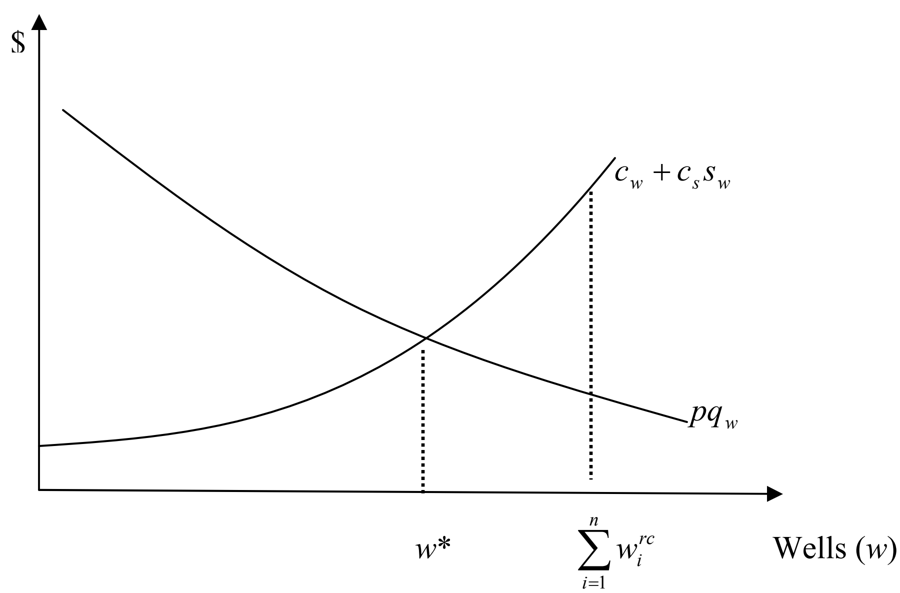

Figure 3.2- WELL CHOICE UNDER THE RULE OF CAPTURE

the total value of the reservoir under the rule of capture is:

(7) $$V^{RC} = \sum_{i=1}^{n}[pq^i(w_i^{RC}) - c^i(w_i^{RC}, s(\sum_{i=1}^{n} w_i^{RC}); \tau)]$$

where n = A / a_i is the number of firms with access to reservoir.

Production under Voluntary Units and Compulsory Unitization[17]

Unitization requires consolidation of land for cooperative development and production of oil ands gas resources. However, contractual costs involved in negotiations largely determine the success of unitization. Therefore an additional cost of contracting (θ) should be included in decision making as opposed to the sole ownership case. Suppose all the landowners with access to the reservoir could negotiate a successful contract the net value of the reservoir is:

(8) $$V^U = [pq(w^*) - c(w^*, s(w^*); \tau; \theta(n))]$$

The cost of contracting (θ) depends on the number of landowners (n) involved in the negotiation. θ can be infinitely large when large number of parties involved in unit negotiations. Accordingly increasing θ can drive down the gains of unitization by increasing the cost side of the objective function. Further, individual shares under the unitization regimes are largely determined by the surface acreage owned by each share holder. Hence, if the reservoir is homogenous[18] the individual share from unitization is:

(9) $$V_i^U = a_i[pq(w^*) - c(w^*, s(w^*), \tau, \theta(n))]$$

accordingly a landowner will choose to be in the unit only if the following inequality is satisfied

(10) $$V_i^U \; (a_i, p, w^*, \tau, \theta(n)) > V_i^{RC} \; (p, w_i, \tau)$$

[17] Models for well spacing and proration are given in the Appendix D.
[18] Homogenous implies that every piece of land above the reservoir produces oil and gas resources at the same rate. In other words the land is homogenous in a_i.

The inequality above intuitively suggests that a landowner will choose to be in the unit only if the gains from unitization are greater than otherwise he would receive. Further, as a_i reaches A, landowner prefers to be in the unit. This may suggest why land owner with large surface acreage above a reservoir always prefer to unitize the field. Therefore the net value of moving from a rule of capture regime to a unitization regime can be denoted as:

(11) $$\overline{V} = V^{*} - V^{RC} - \theta$$

accordingly the marginal value of forming a unit for the i th owner is:

(12) $$\overline{V_i} = V_i^{*} - V_i^{RC} - \theta$$

where v_i is the share of i th landowner.

3.2 Economics of Statute Adoption

In this chapter I develop a framework for statute adoption with emphasis on compulsory unitization statutes. This framework relies on the premise that the probability of statute adoption (PrA) decreases in transaction costs involved in the legislative process. In this framework transaction costs are assumed to be influenced by economical, legal, political and institutional factors at the state level.

In the absence of external factors, the probability of statute adoption solely depends on the gains from unitization ($\overline{V}$). Therefore, the probability of statute adoption can be viewed as a function of only economical factors (*E)* at basic level.

(13) PrA = $f\,(E)$

However, in reality the decision to adopt a statute is influenced by legal, political and institutional factors prevailing in each state. Hence, the probability of statute adoption can be denoted as:

(14) PrA = $f\,(E, L, P, I)$

Where *L, P, I* represents legal, political and institutional factors respectively. The equation (14) sets the framework for generating theoretical predictions for this study.

Proposition 1: *The probability of statute adoption is decreasing in the size of average farm size*

This prediction follows directly from equation (12) in which as a_i approaches A the need for a compulsory unitization statute decreases. Intuitively as the average farm size increases the chance of a reservoir being overlaid by multiple land holdings is greatly reduced. This eliminates the need for reservoir wide unitization or substantially reduces the cost of contracting due to reduced number of operators in a reservoir. If validated, farm sizes at the state level could provide explanations for the absence of compulsory unitization statutes in states like Texas to date.

Proposition 2: *The probability of statute adoption is decreasing in the number of small scale producers in the industry*

This prediction follows from equation (13) in which producers with small a_i would not prefer unitization as the gains from unitization decreases with decreasing a_i. Historically small scale producers were given preferential drilling permits in many states. In unit negotiations such producers often insisted on protecting their regulation-imposed advantage as a condition for joining. (Libecap and Wiggins 1985) In many cases these owners refrained from joining into units to gain disproportionate shares. Therefore the deterrence of small scale producers towards unitization may prevent the enactment of unitization statutes.

Proposition 3: *The probability of statute adoption is decreasing in the value of oil and gas production at the state level*

This prediction directly follows from historical price trends in the oil and gas industry. In 1930 the price of a barrel of crude fell below 18 cents triggering statewide regulations in many states. The underlying principle here is, as the value of oil and gas decreases the need for regulation increases.

Proposition 4: *The probability of statute adoption increases with the presence of an autonomous oil and gas agency at the state level*

Intuitively, the presence of an autonomous oil and gas agency makes crucial information available to the oil and gas stakeholders and facilitates contracting. In other words such agencies reduce the transaction cost of statute adoption by reducing information asymmetry.

Proposition 5: *The probability of statute adoption is increasing in the extent of federal land*

In federal lands unitization is encouraged during the exploration stage. In states with higher proportion of federal lands unitization often involves negotiation with land owners in state and federal land operating in the same reservoir. In such situations the absence of a unitization statute at the state level can prevent the formation of successful units.. Therefore, I expect the proportion of federal lands in a state to positively influence statute adoption.

Proposition 6*: The Probability of statute adoption increases if similar statutes were already enacted at the state level*

Presence of a well spacing statute is indicative of the legislative history of the state and reflective of industry's compliance to regulations. The underlying premise here is moving from a well spacing regime to a unitization regime is less costly than moving from open access to a unitization regime. Therefore, I expect increased demand for statute adoption in state with well spacing statute.

Proposition 8*: The Probability of statute adoption increases with the adoption of similar statutes in neighboring states.*

This phenomena is generally observed in climate change polices where states are vigilant of neighboring state polices. The adoption of similar statutes in the neighboring states reduces the lobbying cost and positively influences statute adoption. Also, I expect the impact from a larger state to be greater than smaller states.

CHAPTER 4: EMPIRICAL ANALYSIS OF STATUTE ADOPTION

In this chapter, I use state-level data on compulsory unitization statutes from 1920 to 1990 by decennial census years. In the later part of this chapter I also include a case study that compares the dominant forces in Texas and Oklahoma in statute adoption. The purpose of empirical analysis is to test the predictions presented in chapter 3. Here I use the statutory enactment of compulsory unitization statutes to test my predictions.

4.1 Description of the Data

I have compiled a state level data set which contains variables for the years 1920 through 1990. This includes observations for 48 contiguous states by decennial census years, forming a sample of 384 observations.[19] The time period covered in the data set captures most of the statutory reforms in the oil and gas industry.

The data are organized into several categories to reflect the different types of forces involved in statute adoption. Broadly, the categories are economic variables, political variables, institutional variables and control variables. The data were collected from a variety of sources including the U.S. Census Bureau, the Bureau of Economic Analysis, the Federal Reserve archives for economics research, the Energy Information Administration and U.S Statistical abstracts. Table 4.1 provides summary statistics and descriptions for variables used in the empirics. Complete list of data sources are given in Appendix A. The following discussion focuses on issues related to variables and predictions.

[19] I have excluded Alaska and Hawaii from the dataset because they are two states which have distinctly different institutional histories relative to the contiguous 48 states.

Table 4.1- : VARIABLE NAMES AND SUMMARY STATISTICS: Generated for 1920 through 1990 for a total of 384 observations

Variable Name	Definition	Mean	St. Dev.	Min	Max
Dependent Variable					
UNIT	Dummy=1 if state has compulsory unitization statute	0.2552	0.4365	0	1
Independent Variables					
Economic Variables					
OIL PRODUCTION	Oil Production (1000 Barrels)	37.7	132.1	0	1250
OIL REAL PRICE	Real Price of Oil ($/Barrel) (Base= 1990)	8.46	12.52	6.88	59.417
VALUE	Oil & Gas Production multiplied by real oil price and real gas price ($)	1488076	3733071	0	33845082
GAS PRODUCTION	Gas Production (Mn cubic feet)	215981	957942	0	8358000
GAS REAL PRICE	Real Price of Gas ($ Per 1000 Cubic Feet) (Base= 1990)	0.984	0.858	0.269	5.356
COAL PRODUCTION	Coal Production (Mn of Short Tons)	11830	31114	0	184700
FARM SIZE	Avg Farm Size of Counties that Produces/Produced Oil (acres)	768	1861	27.8	17272
INCOME	Per Capita Income ($) inflated to base year 1920	4562.07	6057.42	46.89	26504
Political Variables					
DEMOCRATS	Dummy 1 if Democratic majority in last 2 presidential elections /within last 10 years	.54	.49	0	1
GOVERNER	Dummy 1 if Democrat Governors, more than 5 years in last 10 years	.53	.49	0	1
NEIGHBOR	Proportion of bordering states with a statute weighted by population	.25	.36	0	2.3
REGION	Percent of states within U.S. Census geographic region with statute	22.6	26.9	0	76.92
Institutional Variables					
AGENCY	Dummy 1 if an autonomous oil and gas agency is present	0.32	0.46	0	1
SPACING LAW	Dummy 1 if well spacing law is present	.37	348	0	1
Control Variables					
POPULATION	Total Population (Mid Year in 1000's)	3555	3880	77.4	29959
URBAN	% Living in Urban Areas	55.89	19.34	2.05	92.62
EDUCATION	Proportion enrolled in institutions of higher education	108545	196990	375	1802884

4.1.1 Compulsory Unitization Statute Variable

The dependent variable (UNIT) has been coded as a binary variable, which takes a value of one if a state has a compulsory unitization statute in a given year and a value of zero otherwise. This variable was created from the information made available by the state oil and gas agencies and from existing literature. Hereinafter the term statute enactment refers to the enactment of a compulsory unitization statute unless stated otherwise.

The first compulsory unitization statute was enacted in Louisiana in 1940 and the last of its kind was enacted in Vermont in 1988. States like Texas, Pennsylvania and Indiana resists the legislative push towards a compulsory unitization statute to date. Therefore, in the combined dataset, there are 98 observations for which the dependent variable takes a value of one and 286 observations for which it takes a value of zero. Ideally, this value of one or zero would have a consistent meaning across states. However, different stringency levels[20] are attached to the compulsory unitization statutes across states. Therefore, a value of "1" for the dependent variable would only mean the existence of statute in a state and no inferences should be made on the extent of unitization.

Economic Variables

I use several variables to measure the effects of economic factors in statute adoption. I expect these set of variables to influence the demand for a statute adoption by affecting the rent stream from oil and gas production. I have collected price and production data from the sources of Energy Information Administration. These include oil and gas production, oil and gas price at the state level. Production is measured in thousand of barrels whereas the price is measured in 1990 dollars per barrel. I expect decreased prices to increase the demand for statute adoption.

[20] What I mean by stringency level is the percentage of consensus required among the parties to form a unit.

The argument here is decreased value from the current property regime creates incentive to invest on alternate regimes.

Also, the emergence of a new property regime is obviously influenced by the level of resources available. For example, a rich state would have more economic resources to invest and enforce certain regulations better.[21] Hence, I expect the demand for statute adoption to increase with increasing wealth. I have gathered state level data on per capita income[22] to measure wealth, from the Bureau of Economic analysis. These figures were adjusted to 1990 prices using inflation indexes from the Bureau of Labor Statistics.

Further, I expect the demand for statute adoption to be low in states where land holdings are inherently large. In these states the chance of a reservoir being overlaid by a single owner or few owners is relatively high. To capture the degree of land fragmentation I have collected the average farm size data for counties that produced oil.[23]

I also expect the influence of small scale producers to decrease the demand for statute adoption. To measure the effect of small scale owners I use the number of marginal wells in a state. Higher the number of marginal wells greater the influence of small scale owners on unitization.

Political Variables

State political factors are expected to be important in analyzing legislative behavior. I have included a set of variables which measure the state political factors. Further, I have identified a set proxy variables which will account for the regional and neighboring state effects that are likely to influence state legislature.

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[21] The work of Galor and Tsiddon (1996) supports the claim that rich states would have more resources to invest in regulation.
[22] Per capita income for 1920 was collected from the Federal Reserve archive systems for economic research.
[23] For states without oil production I use the average farm size for the state.

In order to capture voters party affiliation I created a dummy variable that will take the value of 1 if a democratic majority in state legislature was witnessed in the last two presidential elections and 0 otherwise. Besides presidential voting share, I expect the Governor party affiliation at the state level to have a direct influence on state legislature. Hence, I also am using a dummy variable that will take the value of 1 if governor party affiliation was democratic for more than 5 years in the last 10 years.

In an effort to account for political contagion effect,[24] I use a variable that measures the proportion of bordering states which had a compulsory unitization statute. This fraction is weighted by population in expectation that larger states may have greater influence on their neighbors than smaller states. Further, to capture the regional effect on a particular state I have included a variable that simply reflects the percentage of states within a Census Division (as defined by the U.S. Census Bureau) that have adopted the statute. I expect the contagion effect and regional effect to positively influence the demand for statute adoption by decreasing the lobbying cost.

Finally, to measure the impact of federal lands on statute adoption, I use the proportion of federal land in a state in a particular period. The data on total land and federal land were compiled from the sources of agricultural census and bureau of land management. In federal lands transaction costs for negotiating unit contracts are minimized by encouraging unitization before exploration by the bureau of land management.

Institutional Variables

Williamson (1991) argues that institutional environment is paramount in contractual governance. In the oil and gas industry institutional environment can be characterized by the regulatory body that administers the production activities and pressure groups that lobby for

[24] The idea of political contagion has received a great deal of empirical attention in relation to international finance markets, particularly monetary crises (Eichengreen, Rose, and Wyplosz 1996; Dungey and Martin 2001).

various property regimes. However, the inseparability of institutional factors and political factors makes it difficult to generate predictions in isolation.

In this thesis, I am using a dummy variable to indicate the presence of an autonomous regulatory agency in a state. In some states the regulatory body is part of a broader institution such as the department of natural resources. In Texas, the Rail Road Commission governs the activities of oil and gas activities. I expect the presence of autonomous regulatory agency to increase the probability of statute adoption by reducing the transaction cost statute. The commissioner of such oil and gas agencies can be elected or appointed. In my opinion an appointed commissioner has more political obligations than an elected commissioner. Thus, when it comes to the question of statute adoption an appointed commissioner is likely to influence the decision in favor of his political ideology. To test this hypothesis I have created a dummy variable which takes the value of 1 if the commissioner of oil and gas agency is appointed as opposed to elected.

My research on legal history (Haider-Markel 1998) suggests that positive legal precedent has an influence on statute adoption. In states with similar statutes already in place the probability of statute adoption is high. To get some sense of the legislative history of the state I am using the presence of a well spacing statute as a proxy. Well spacing statute was the first statute in the oil and gas industry with technical information embedded in it. The presence of such a statute reflects the compliance of the industry for regulations.

Control Variables

I have also included a set of control variables such as the education level, state population, percentage of federal land and years since first oil and gas production to capture the variance across states. State population data was gathered from the bureau of economic analysis.. To measure the educational level for each state, I have gathered the number of persons enrolled in institutions of higher education for each state from the national center for education statistics[25]. Thereafter I calculated the percentage of persons enrolled in institutions of higher education with respect to the state population. A state with relatively high number of intellectuals is likely to have a higher demand for conservation and statute adoption.

I expect that states with a long history of oil and gas production, to wit Pennsylvania, to behave differently than a state that started producing oil and gas recently. To capture this difference I have created a variable that measures the number of years since first production. This is indicative of the maturity of the oil and gas industry in a state. Again, I have no predictions for this variable due lack of evidence suggesting the direction of relationship.

4.2 Analysis of Variable Means

As a preliminary analysis, I examined the difference of mean values for explanatory variables by two categories. The categories are states with a unitization statute and without a statute from 1920 to 1990. Table 4.2 summarizes[26] the mean values and t-values for the null hypothesis that there is no difference in means between two categories. Results from the mean analysis are fairly consistent with preliminary predictions.

In states with unitization statutes the mean value for oil production (OIL PRODUCTION) is significantly smaller than states without statutes. This leads us to believe that the legislative push towards unitization came after decreased production and decreased prices. Surprisingly the average farm sizes (FARM SIZE) for those counties that produced oil is higher in states with a statute. This contradicts my initial prediction that the demand for statute adoption is low in states with large tracts of lands.

Both political variables have a significantly higher means for states with compulsory unitization statutes. In my analysis the governor party association (DEMOCRATS) and presidential

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[25] The purpose of the Center shall be to collect, analyze, and disseminate statistics and other data related to education in the United States and in other nations.''—Section
406(b) of the General Education Provisions Act, as amended (20 U.S.C. 1221e–1).

[26] See Appendix C for details.

voting share (VOTING) are coded to reflect partisanship towards the democrats. Further the contagion effects from neighboring states (NEIGHBOR) have higher means for states with statutes as expected.

The variable that measures the presence of an autonomous regulatory agency (AGENCY) has a higher mean for states with a statute. This may suggest that the autonomous regulatory agency reduces the transaction cost of statute adoption. Further means analysis suggests that 94% of states with unitization statutes also had the well spacing statutes enacted previously.[27]

Control variables for education level and state population along with per capita income have significantly higher means for states with a statute. However, I offer no predication for these variables as the direction of relationship is uncertain.

[27] Idaho, Indiana, Iowa, Maryland, North Carolina, Pennsylvania, Texas and Virginia had well spacing statues but no unitization statues enacted to date.

Table 4.2: DIFFERENCE OF MEANS FOR SELECTED EXPLANATORY VARIABLES

Variable	Group	1950	1960	1970	1980	1990
Oil Production (1000 Barrels)	States without Statute	34.071	37.502	54.72	62.44	39.9
	States with Statute	93.391	85.25	52.18	82.65	33.9
Total Value	States without Statute	84	108	306	646	893**
	States with Statute	244	251	1469	1959	709
Avg Farm Size (Acres)	States without Statute	743.85	905.64	1201	202.21	893
	States with Statute	444.56	1926.4	1194	279.33	709
Per Capita Income ($)	States without Statute	1416	2107	9964	3863	19978**
	States with Statute	1131	2113	9352	3739	17411
% neighboring states with statute	States without Statute	.11	.214	.54	.33**	.35
	States with Statute	.13	.316	.68	.56	.61
Governor Party Association	States without Statute	.4318**	.388	.555	.62	.35
	States with Statute	1	.66	.633	.57	.61
Presence of a well spacing law	States without Statute	.1818**	.333**	.3333**	.444**	.47**
	States with Statute	1	1	.933	.90	.96
Presence of a Regulatory agency	States without Statute	.3636**	.33**	.166**	.29**	.176**
	States with Statute	1	.35	.566	.57	.54
% enrolled in institutions of higher education	States without Statute	15.45	19.49	49.56	37.49	55.2
	States with Statute	14.43	19.42	48.25	41.79	53.5

**indicates significant difference between mean values at 95%

4.3 Empirical Strategy

In order to asymptotically test the predications from chapter 3, I use two approaches. First I estimate a linear probability model on a pooled time series cross sectional dataset. Second, I estimate a hazard model for the enactment of compulsory unitization statutes.

4.3.1 Linear Probability Models

The dependent variable (UNIT LAW) is a binary variable which takes the value of 1 if a state has compulsory unitization statute enacted in time period *t.*

(15) $$y_{it}^{*} = \alpha_i + X_{itk}\beta + u_{it}$$

i= 1,…,48 t= 1,…,8 k=1,…,k

(16) $$y_{it} \begin{cases} 1 \; if \; y_{it}^{*} > 0 \\ 0 \; if \; y_{it}^{*} \leq 0 \end{cases}$$

In equation (16) y_{it}^{*} is the latent variable representing the unobserved legal response in state i at time t. This can be interpreted as the propensity of a state to adopt compulsory unitization statute. X_i is a matrix of independent variables including a constant; β is a column vector of unknown coefficients, i is the number of states in the sample, t is the number of time periods and k is the number of explanatory variables.

Ideally the data should be examined as a panel data with fixed effects for individual states. However, unique issues associated with binary panel data (Beck and Katz 2000) limits the estimation to linear probability models and hazard models.

4.3.1.1. Linear Probability Models

In a binary panel setup linear probability model eliminates the conventional problems associated with binary data.[28] In the first set of specifications (1) through (4) in table 4.3 I use oil price (OIL PRICE) as an explanatory variable along with other covariates. However, the inclusion of oil price (OIL PRICE) also posits an endogeneity problem because statute enactment could have reciprocal effects on oil price.[29] Hence, I use a two staged least squares (2SLS) method to overcome the endogenous effects. Here I use coal production as an instrument to predict the oil price because coal was gradually substituted by oil since its discovery.

Specification (1) in table[30] 4.3 serves as the base model with economical, political and institutional variables as covariates. Control variables were added gradually in specifications (2-4). In specifications (1- 4) coefficient estimates for regional effect (REGION), presence of a spacing law (SPACING LAW) and governor party affiliation (GOVERNOR) are significant and positive. The estimate for the presence of a well spacing statute (SPACING LAW) may suggest that states with regulatory statutes already in place show less resistance to unitization statutes. The significance of regional effect on unitization (REGION) indicates that a state is more likely to adopt a statute as the number of states within the region with statute increases.

Interestingly the estimate for oil price (OIL PRICE) has a negative sign across all four specifications but fails to achieve the desired significance levels. This indicates that the decrease in price had some influence on statute adoption. The estimate for autonomous regulatory agency (AGENCY) turns out to be significant and positive in specifications (1-3). The presence of a regulatory agency supposedly provides a framework to administer production activities and to

[28] Eliminates quasi separation of data points.
[29] The Hausman test confirms rejects the null hypothesis that there is no endogeneity.
[30] The first stage regression results are reported in table A-1 (APPENDIX B).

invest in regulation at the state level. Therefore the significance of this variable indicates that autonomous regulatory agencies decrease the transaction cost of statute adoption.[31]

The coefficient estimates from the linear probability model provides direct estimates for the marginal effects. The right hand side in linear probability models can be interpreted as probabilities. In specifications (1-4) on average, price of oil (OIL PRICE) has an effect of 8% on statute adoption. Among political variables voting share (DEMOCRATS) has an impact of 6% and the governor party affiliation (GOVERNOR) has an impact of 9%. The SPACING LAW stands out with an effect of 32% on the probability of statute adoption.

In table[32] 4.4, I use the state value of oil and gas production (VALUE)[33] instead of OIL PRICE as an explanatory variable among other economic variables. Since the adoption of a statute supposedly influence the production, the UNIT LAW should have endogenous effects on VALUE. To overcome this problem I use a 2SLS method with state population (POPULATION) as an instrumental variable.

The estimates for both political variables turn out to be significantly positive in specifications in table 4.4. This leads us to believe the governor party association (GOVERNOR) along with states general inclination towards the democrats (DEMOCRATS) positively influences the statute adoption. Further, estimates for SPACING, NEIGHBOR and AGENCY are significant with expected sign.

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[31] All models were estimated with dummies for 8 census divisions. Binary panel data rules out the possibility of running fixed effects models as the data set contains panels (17) that do not change dependent variables. Also quasi complete separation of data points prevents the implementation of logistic models.

[32] The first stage regression results are reported in table A-2 (APPENDIX B)

[33] Value of oil production is obtained by multiplying annual oil and gas production with discounted average market price of oil and gas at the well head.

Table 4.3 - POOLED CROSS SECTION TIME SERIES 2SLS: OIL PRICE SPECIFICATION

	(1)	(2)	(3)	(4)
INTERCEPT	-0.010	-0.025	-0.005	0.004
	(0.071)	0.758)	(0.921)	(0.091)
Economical Variables				
OIL PRICE	-0.008	-0.008	-0.008	-0.008
	(0.008)	(0.008)	(0.008)	(0.008)
FARM SIZE	0.001	0.001	0.001	0.001
	(0.0010)	(.0010)	(.0010)	(.001)
Political Variables				
GOVERNER	.0906**	0.088**	0.089**	0.089**
	(0.038)	(0.038)	(0.038)	(0.038)
DEMOCRTAS	.0682*	.0693*	.0710*	.07*
	(0.040)	(0.041)	(0.041)	(0.040)
REGION	0.007**	0.006**	0.006**	0.006**
	(0.001)	(0.001)	(0.001)	(0.001)
Institutional Variables				
AGENCY	0.076*	0.081*	0.080*	0.080*
	(0.045)	(0.046)	(0.046)	(0.047)
Control Variable				
SPACING LAW	0.327**	0.323**	0.325**	0.325**
	(0.049)	(0.049)	(0.049)	(0.050)
EDUCATION		0.001	0.001	0.001
		(0.001)	(0.001)	(0.002)
URBAN			-0.0004	-0.0004
			(0.0001)	(0.0012)
INCOME				0.00007
				(0.0005)
Observations	384	384	384	384
F(18, 365)	30.66	28.84	28.42	25.30
R-squared	0.5315	0.5340	0.5561	0.5301
Adj R-squared	0.5124	0.5137	0.5355	0.5070

** indicates significance at 95% * indicates significance at 90% Standard errors in parenthesis

Table 4.4 - POOLED TIME SERIES CROSS SECTION 2SLS: OIL VALUE SPECIFICATIONS

	(1)	(2)	(3)	(4)
INTERCEPT	-0.001	-0.006	-0.031	-0.163
	(.0717)	(.074)	(.0671)	(0.061)
Economical Variables				
VALUE	1.13e-08	1.15e-08	-4.75e-09	4.65e-06
	(1.79e-08)	(1.79e-08)	(1.57e-08)	(1.95e-07)
FARM SIZE	0.003**	0.003**	0.002**	0.001*
	(0.001)	(0.001)	(0.001)	(0.000)
Political Variable				
DEMOCRATS	0.114**	0.116**	0.083**	0.082**
	(0.378)	(0.038)	(0.035)	(0.035)
GOVERNER	0.086**	0.086**	0.079**	0.077**
	(0.039)	(0.040)	(0.036)	(0.036)
NEIGHBOR	0.160**	0.160*	0.101	0.103
	(0.085)	(0.085)	(0.078)	(0.078)
Institutional Variables				
AGENCY	0.183**	0.182**	0.089**	0.093**
	(0.044)	(0.044)	(0.042)	(0.042)
SPACING LAW			0.369**	0.3619**
			(0.046)	(0.046)
Control Variable				
EDUCATION	0.008**	0.008**	0.005	0.004**
	(0.001)	(0.001)	(0.001)	(0.001)
INCOME		.-0.0001	-0.00003	0.00001
		(0.0005)	(0.0004)	(0.0004)
URBAN				0.0009
				(0.0012)
Observations	384	384	384	384
F(18, 365)	22.66	21.19	28.30	26.89
R-squared	0.4716	0.4715	0.5696	0.5729
Adj R-squared	0.4501	0.4484	0.5496	0.5519

** indicates significance at 95% * indicates significance at 90% Standard errors in parenthesis

Surprisingly the state average farm size (FARM SIZE) variable yields a positive sign across all four models with significance levels at 5%. This contradicts with my initial prediction that states with inherently large tracts of lands are less likely to adopt statutes. The results intuitively suggests that states with small farm sizes disfavored compulsory unitization statutes because unitizing heterogeneous small scale tracts would impose huge transactions costs.

The control variable that measures the education level (EDUCATION) turns out to be significant and positive in all four models. It could be the case that states with high number of intellectuals prefer regulation. However it could also be, the variable capturing some amount of variance of an omitted variable.

The marginal effects of DEMOCRATS were 11% on average. The most prominent effects were NEIGHBOR, AGENCY and SPACING LAW with magnitude of 16%, 18% and 36% respectively on the probability of statute adoption. These results from the linear probability models do not account for time dependence and heterogeneity across states. Therefore I estimate a hazard model to capture the hazard that a state would enact a statute.

4.3.2. Discrete Time Duration Model

Binary Time Series Cross Section (BTSCS) data can be seen as a series of zeros terminating by an event and the occurrence of a statute enactment observed over the time period in a way looks like event history data, with each '1' representing an event.[34] Further, event history methods provide techniques to account for time series and cross sectional effects of BTCS data.

Hence, using the principles of event history analysis I estimate a hazard model that predicts the rate at which states are inclined to enact the statute in each time period, which is

[34] For the hazard model I have removed the sequence of ones after the first one from each panel (state).

famously known as the hazard rate. The probability ($F(t)$) that a state will enact a statute before time t is denoted by

$$(17) \qquad F(t) = P(T < t) = \int_{0}^{t} f(u)du$$

Where $f(t)$ is the first derivative of $F(t)$ with respect to time. The probability of not enacting statute beyond time t is simply

$$(18) \qquad S(t) = 1 - F(t) = P(T \geq t) = \int_{t}^{\alpha} f(u)du$$

The hazard function that a state would enact a statute in time period t is derived from

$$(19) \qquad h\text{ (t)} = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t} = \frac{f(t)}{S(t)}$$

Since hazard can take many different forms, I use a general from weibull distribution to represent the baseline hazard given by Seetharaman (2003) which is given by

$$(20) \qquad h_0(t) = pt^{p-1}$$

The term p is the shape parameter estimated from the data and it indicates a monotonically increasing shape of hazard function (p>1) or a monotonically decreasing shape (p<1). The proportional hazard model with a baseline hazard is given by:

$$(21) \qquad h_{ij} = h_o(t) v_i \exp(\beta x_{ij}) \qquad\qquad v_i \sim (1, \theta)$$

The term h_{it} denotes the hazard rate as the probability of enacting a compulsory unitization statute at time t given that no statute has been enacted until t. whereas $h_o(t)$ represents the baseline hazard at time t and x_{ij} is the vector of explanatory variables. The frailty v_i is a random variable accounts for the unobserved heterogeneity across states with a gamma distribution $v_i \sim d(1, \theta)$. In other words it captures the fixed effects which would be impossible to estimate with other panel data methods.

As a preliminary analysis for hazard models I compared the Kaplan-Meier (KM) estimates for selected variables. In binary variables KM estimates will calculate the cumulative probability of statute enactment for each category and allows graphical comparisons. Figures (4.1- 4.3) show the cumulative hazard graphs[35] for GOVERNOR, DEMOCRATS and AGENCY respectively.

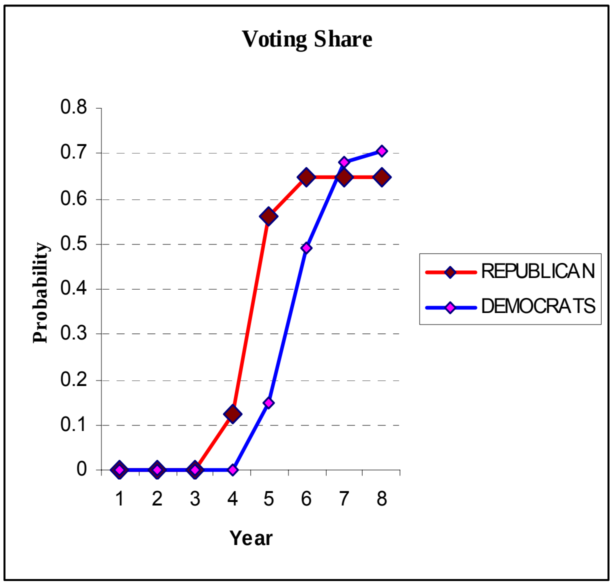

Figure 4.1- : KM ESTIMATES FOR PARTY VOTING SHARE

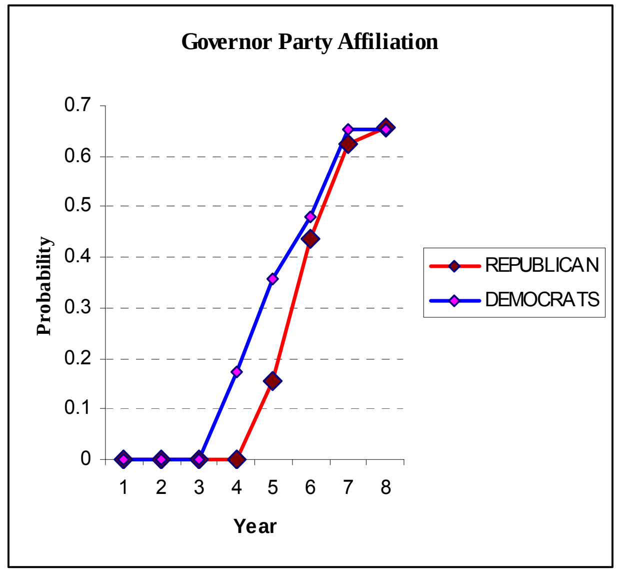

Figure 4.2 - KM ESTIMATES FOR GOVERNOR PARTY AFFILIATION

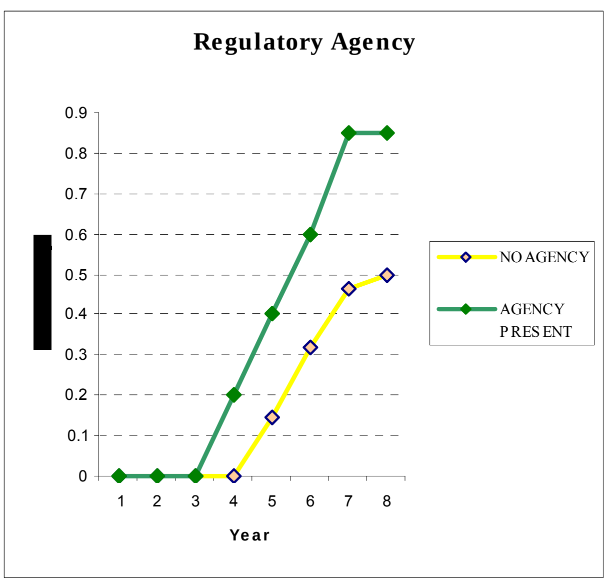

Figure 4.3 - KM ESTIMATES FOR AGENCY

[35] Cumulative Hazard = 1 – Survival Probability from KM estimates (Beck and Katz 1995).

Surprisingly estimates for GOVERNOR and DEMOCRATS yield contradicting results though both measure the democratic affiliation. Based on KM estimates for governor party affiliation (GOVERNOR) indicates that the democratic affiliation increases the probability of statute adoption while states general inclination towards democrats (DEMOCRATS) predicts vice versa.

All Specifications in table 4.5 are estimated as proportional hazard models with a Weibull distribution for the baseline hazard. The significance of theta (θ) in all four specifications indicates the existence of heterogeneity among states. Also the estimate for shape parameter (p) takes a value greater than one, which suggests that hazard rate of statute enactment increase with time.

The estimated coefficient for the presence of a spacing law (SPACING LAW) is significantly positive and consistent with previous estimates. The model predicts a negative coefficient for the value of oil production (VALUE) as expected but not statistically significant. However estimated coefficients are not consistent across specifications for most of the covariates.

In table 4.6 I use a subset of the original dataset which includes observations only from 1940 to 1990. This makes crucial variables available for the study namely the number of marginal wells (MARGINAL WELLS) and the proportion of federal lands (FEDERAL LAND) in a state. Also, for the purpose of in-depth analysis I created an interaction variable that captures the impact of Democratic Party affiliation on rich versus poor states. (DEMOCRATS * INCOME).

Specifications (1 -3) are modeled under the assumption that there is no heterogeneity between states. Whereas specification (1a-3a) use the same variables as in specification (1-3) but with a frailty distribution (Gamma) to account heterogeneity across states.

Table 4.5 - HAZARD MODEL WITH A WEIBULL DISTRIBUTION

	(1)	(2)	(3)	(4)
Economical Variable				
VALUE	-6.18e-08	-4.10e-07	2.53e-10	1.23e-08
	(1.52e-07)	(2.00e-07)	(6.67e-08))	(6.39e-08))
FARM SIZE	-0.008	-0.003	0.008	0.007
	(0.009)	(0.010)	(0.006)	(0.007)
Political Variables				
GOVERNER	-1.150**	-1.195	-0.412	-0.410
	(0.385)	(0.416)	(0.332)	(0.322)
NEIGHBOR	2.347**	1.567	0.5998	0.7728
	(1.042)	(1.120)	(0.802)	(0.780)
Institutional Variables				
AGENCY	0.483	0.727	-0.032	-0.110
	(0.537)	(0.596)	(0.422)	(0.434)
SPACING LAW	3.000**	2.923**	2.8766**	2.845**
	(0.500)	(0.573)	(0.617)	(0.654)
Control Variables				
EDUCATION		0.030	0.026	0.038**
		(0.023)	(0.017)	(0.017)
URBAN			-0.049**	-0.052**
			(0.011)	(0.010)
INCOME				-0.007
				(0.005)
Observations	317	317	317	317
No of Groups	48	48	48	48
No of Adoptions	31	31	31	31
Prop Chi2	<0.000	<0.000	<0.000	<0.000
Wald Chi	86.64	92.24	63.04	71.09
P (Shape)	.101	.0404	.3213	.3462
Theta (Φ)Chi Sq(01)	0.002	0.001	0.446	1.000

** indicates significance at 95% * indicates significance at 90% Standard errors in parenthesis

Coefficient estimates for SPACING LAW, AGENCY and FEDERAL LAND are significant and positive. Significance of the FEDERAL LAND indicates that states with large amount of federal lands prefer unitization. This may also suggest that such states minimize the transaction cots of negotiating with private parties by enacting the compulsory unitization statute. The MARGINAL WELL yielded a negative sign suggesting that small scale producers disfavored unitization.

Interestingly the interaction variable DEMOCRATS*INCOME yields negative and significant estimates in all specifications. This may suggest that poor democratic states favor regulation and statute adoption. Therefore the general claim that democrats are inclined towards regulation has to be redefined to reflect the income effect on it. When DEMOCRATS and INCOME were included separately neither achieved the expected significance levels nor did they yield proper signs.

In specifications (1a-3a) estimates for SPACING LAW, AGENCY and FEDERAL LAND again became positive and significant. Further, the MARGINAL WELL variable yields a negative sign as expected. In specifications (1a-3a), theta θ, the parameter that reflects the heterogeneity was not significantly different from zero. This may suggest that the baseline hazard for statute enactment is same for all the states provided the economical, political and institutional conditions are similar.[36] Interestingly, the ρ value the shape parameter in weibull models, takes a value greater than one, which indicates an increasing hazard with time.

The marginal effects for hazard models are reported in terms of predicted median approval time, so a negative coefficient implies a reduction in the time taken to adopt a statute. Accordingly 1% increase in the extent of federal land reduces the time take to enact a statute by 0.2 years. Likewise the presence of a spacing law increases the statute adoption by 38 years. In other words on average a state with a spacing law adopts a unitization statute 38 years earlier than a state without a spacing law.[37]

[36] This is equivalent to having a constant intercept in panel data.
[37] Marginal effects are reported in Table III (APPENDIX B).

Table 4.6 - HAZARD MODEL WITH INTERACTION VARIABLES AND HETEROGENEITY

	(1)	(1a)	(2)	(2a)	(3)	(3a)
Economical Variables						
VALUE	3.25e-08	3.25e-08	8.21e-11	4.57e-09	1.88e-10	4.56e-09
	(9.46e-08)	(9.46e-08)	(1.10e-07)	(1.14e-07)	(1.09e-07)	(1.14e-07)
MARGINAL WELLS	-.5.5e-06	-.5.5e-06	-1.34e-05	-1.5e-05	-1.26e-05	-1.47e-05
	(1.92e-05)	(1.92e-05)	(1.98e-05)	(2.16e-05)	(2.06e-05)	(2.27e-05)
FARM SIZE	3.7e-03	3.7e-03	4.0e-03	4.7e-03	4.3e-03	4.7e-03
	(6.7e-03)	(6.7e-03)	(7.9e-03)	(8.0e-03)	(8.0e-03)	(8.1e-03)
Political Variables						
FEDERAL LAND	0.016**	0.016**	0.017**	0.018*	0.018**	0.018**
	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)	(0.010)
REGION	-0.017	-0.017	-0.024*	-0.025*	-0.024*	-0.025*
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
DEMOCRTAS * APCI	-0.009**	-0.009**	-0.009**	-0.010**	-0.009*	-0.010**
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)
Institutional Variables						
SPACING LAW	2.957**	2.957**	2.915**	3.092**	2.905*	3.083**
	(0.714)	(0.714)	(0.725)	(0.847)	(0.727)	(0.871)
AGENCY			0.815**	0.924*	0.784*	0.910
			(0.410)	(0.519)	(0.473)	(0.621)
Control Variables						
URBAN					-0.002	-0.0007
					(0.017)	(0.018)
CONSTANT	-8.341**	-8.341**	-9.212**	-9.833**	-9.075**	-9.768**
	(1.347)	(1.347)	(1.467)	(2.047)	(1.796)	(2.602)
Observations	221	221	221	221	221	221
Number of Groups	48	48	48	48	48	48
No of failures	31	31	31	31	31	31
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LR chi2	41.32	37.56	45.38	41.73	45.39	41.73
P(Shape)	1.43	1.43	4.72	5.14	4.73	5.13
Theta (Φ)Chi Sq(01)		1.000		0.365		0.374

4.4 Summary of Empirical Analysis

Among the economic variables the oil price (OIL PRICE) and the value of oil and gas production (VALUE) consistently yielded negative signs without achieving the desired significance levels. Contradicting my initial predictions the FARM SIZE variable turned out be positive in most of the specifications. This may suggest that the demand for statute adoption increases with the farm size. This also raises the question why states with small farm sizes tend to have decreased demand for statute adoption. One plausible reason is that the state legislature was aware of the transaction costs involved in dealing with small scale holdings. Therefore states with small farm sizes may have deferred enacting unitization statutes.

Among the control variables estimates for INCOME turned out to be negative in most cases. This indicates that poor states were more inclined towards statute adoption. However INCOME was not significant in most of the specifications thus preventing any useful interpretations. Interestingly when INCOME was interacted with DEMOCRATS the interaction term stands clearly significant. This would suggest that the democratic affiliation (DEMOCRATS) in a poor state increases the demand for statute adoption. Also, the governor party association (GOVERNOR) at the state level was of the expected sign in 90% of the specifications. The estimates for GOVERNOR AND DEMOCRATS tend to support the idea that some form of democratic affiliation at the state level favors regulation.

Interestingly, the proportion of federal lands in a state (FEDERAL LAND) was invariantly positive and significant. This strongly suggests that states with large amount of federal land will have an increase demand for statue adoption. This further explains the reason for early adoption of unitization statutes in states like Wyoming and Montana.

The number of marginal wells (MARGINAL WELLS) was of the expected sign across all models reiterating the claim that small scale producers negatively influence the adoption of unitization statutes.

Out of the two variables that measure the contagion effects the REGION, proportion of states in the same U.S. Census region with the statute, was significantly positive in all specifications. This may suggest that state legislatures were influenced by the actions of surrounding states. It could also be that the presence of statutes in surrounding states lowered the cost of lobbying.

The presence of autonomous regulating agency (AGENCY) was of the expected sign in 70% of the specifications. This provides convincing evidence to the notion that regulatory agencies lowered the transaction cost of statute adoption. The estimates for SPACING almost always yielded predicted sign with strong significance. This may suggest that moving from a well spacing regime to a unitization regime is less costly than moving from open access to a unitization regime.

State population and urban population merely served as control variables. They yielded mixed signs and significance level. However EDUCATION consistently yielded a positive sign and was significant in 50% of the specification. This supports the idea that states with higher proportion of intellectuals prefer regulation.

4.5 Case Study: Legislative Behavior Texas versus Oklahoma

In the development petroleum property rights Oklahoma and Texas were considered to be the pioneers. Looking back at the history the most prominent legislations were first implemented in these states. However with the onset of great depression these states diverged in their legal doctrine on oil and gas property rights. Today Oklahoma has the most liberal compulsory unitization statute whereas in Texas the infamous compulsory unitization statute requires 100 percent consensus. In this chapter I intend to analyze the factors that modeled the property regimes existing in Oklahoma and Texas.

There is evidence that the political landscape, land tenure patterns, small scale independent producers and the land mark litigations in Texas and Oklahoma gave rise to the legislative trend that we observe today. Stuart MacDonald (2004) in his empirical work suggests that Oklahoma may have been facing severe problems in terms of fractured mineral rights. Further, average farm size in Texas is at least twice as the size of Oklahoma. This leads me to believe the demand for unitization in Oklahoma is higher than that of Texas.

Institutional development in Oil and Gas Industry

In Oklahoma the Corporation Commission governs the oil and gas activities. The commission was established in 1907 and began regulating the production activities from 1914. In 1915 the Oklahoma legislature passed the Oil and Gas Conservation act focusing on correlative rights and waste prevention. In Texas the Rail Road Commission oversees the oil and gas activities. Although the Rail Road Commission was established in 1872, the oil and gas industry did not come under the jurisdiction of the commission until 1916. Three years into the operations the Texas Rail Road Commission lobbied for the enactment of first ever wells spacing statute in the Nation. However Texas well spacing statute provided exceptions to irregularly shaped tracts that cannot be drilled in accordance with the statute. In Texas such exceptions were prevalent almost in every piece of legislation that has been enacted so far. The phenomenon of exceptions is an important distinction between Texas and Oklahoma legislations.

Landmark Events and Legislations

Surprisingly Texas and Oklahoma went through similar events in the same time period. Two years after the discovery of Oklahoma City reservoir the East Texas oil field was discovered in 1930 with more than two hundred square miles of underlying sand. According to Carl Rister (1949) the East Texas field became the ground for Texas experimental laws. Due to massive discoveries and flush production in excess of demand in this period, the posted price of Mid-Continent crude oil plunged to 18 cents a barrel.[38]

[38] Petroleum Facts and Figures, API (1965)

Oklahoma quickly responded to the situation by issuing statewide restrictions on production. In other words these are called proration orders. Leaning on Oklahoma's strategy Texas too issued proration orders. The Oklahoma statute suffered a legal challenge in *Champlin v Oklahoma Corporate Commission*. The federal circuit court in this case upheld the statute as legit by refusing injunction against the statute. Interestingly, in a similar dispute between *Macmillan v. Railroad Commission* in Texas the federal district court came to the opposite conclusion (Asgahar at al 1990).

Moreover, the compliance level achieved in Texas was far less than Oklahoma. Many wells in Texas produced in excess of the limit stipulated by the proration orders. Not to the surprise Texas again exempted stripper wells by enacting a marginal well statute. This limits the authority to restrict the production of marginal well beyond unprofitable levels.

Apart from such exemptions, stripper wells in Texas were given a depletion allowance. This allowance was made available to any well that produced less than 1800 barrels per day. During the post world war II period such depletion allowances attributed to the hindrance of voluntary unitization as the incentive of stripper well owners to join the unit was minimal.

The Rise of Small Scale and Independent Producers in Texas

Figure 4.1 depicts a striking difference in the number of stripper wells between Oklahoma and Texas. In Texas the number of stripper well are increasing at an increasing rate. This may suggest that the incentives provided by the Texas legislature kept many stripper wells operating which otherwise would be abandoned.

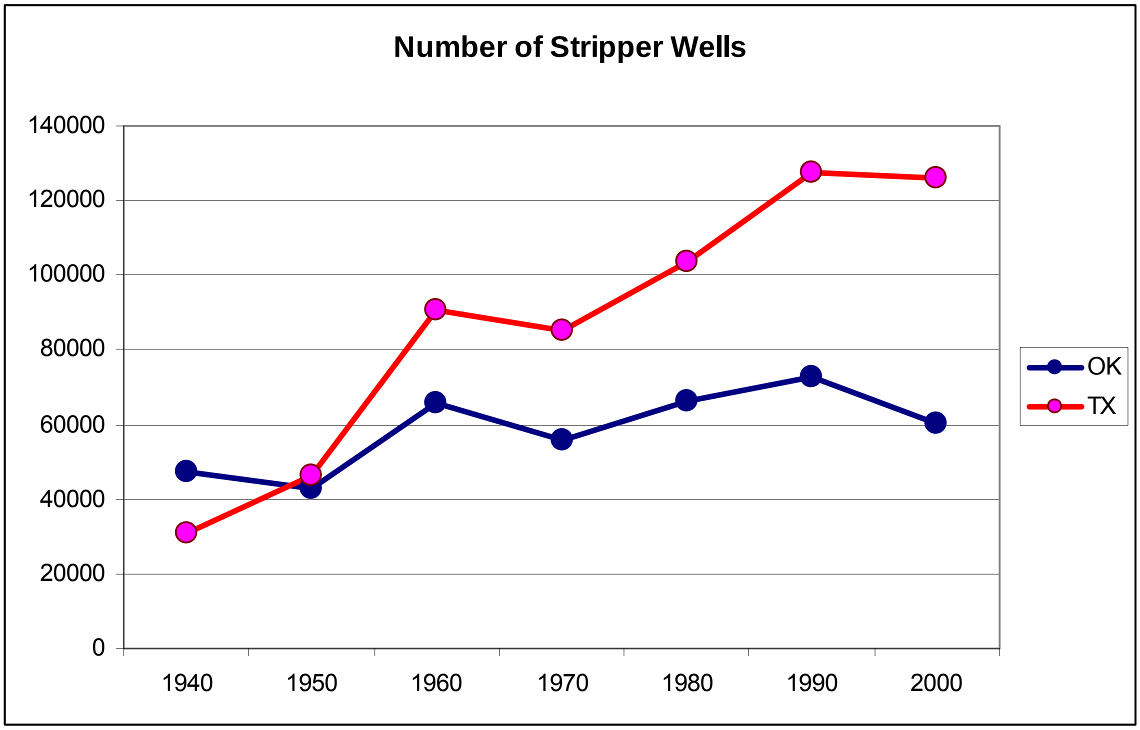

Figure 4.4 – NUMBER OF STRIPPER WELLS IN TEXAS VERSUS OKLAHOMA [39]

Looking back at the history it is evident that the small scale and independent producers had a significant influence on Texas legislature. Texas witnessed various coalitions of small scale and independent producers over the years. On January 18, 1930, a group of 50 independent oil producers met in Wichita Falls to protest the drastic price cut in crude oil, which was initiated by some of the major purchasing companies. One week later, on January 25, the group of independents formally organized the North Texas Oil and Gas Association (NTOGA).[40]In 1936, the NTOGA challenged spacing rules that were being developed at the RRC and also fought for the enactment of depletion allowance for stripper wells.

On May 13, 1940, leaders from the independent oil and gas industry throughout Texas met in Wichita Falls to establish a committee of Texas independent oil producers (TIPRO) composed of three members from each association. TIPRO voted on November 4, 1940, to

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39 Source: http://nswa.us/dyn/showpage.php?id=15; Retrieved 26th of May, 2009.

40 http://www.texasalliance.org/ourhistory.php: Retrieved on the 26th of May, 2009.

relieve the Railroad Commission of the duty of enforcing oil and gas laws, and that a new commission be created with an appointed head take over as the oil and gas regulatory agency. This shows the extent of influence the association had in the oil and gas industry at that time.

The absence of a unitization statute in Texas can be attributed to the influence of small scale and independent producers on the rail road commission. Anecdotal evidence also suggests that the interdependence between state politics and small scale producers has its influence in state legislature. However data availability prevents validating the above claim empirically.

CHAPTER 5: SUMMARY AND CONLUSIONS

The legislative enactment of compulsory unitization statutes can be regarded as a unique property regime in the oil and gas industry. It shows the importance of protecting the correlative rights of various share holders to a natural resource that is fluid and movable. In the oil and gas industry the compulsion towards this significant legal doctrine is an outcome of wasteful production under the rule of capture and high transaction costs involved voluntary regulation.

In the light of staggering evidence provided by engineering and economic studies on the benefits of collective development, the enactment of a compulsory unitization statute is yet to be witnessed in some states. According to Libecap and Wiggins (1985) heterogeneity among firms, information asymmetry and small scale producers at the state level substantially influences the statutory process. The primary objective of the thesis has been to examine the factors that led to the enactment of compulsory unitizations statutes.

Chapter 2 examines the history and the evolution of property regimes in the oil and gas industry. The most important event in the oil and gas history can be regarded as the drastic price drop in 1930s that triggered statewide regulations. This event led Oklahoma and Texas in divergent paths in conservation regulation. The market demand proartion or the maximum efficient rate regulation that emerged during 1930s favored the small scale producers in Texas. The manner in which the market demand regulations were implemented in Texas provided depletion allowances and many exemptions to small scale producers. Such incentives led to the growth of small scale producers as a political entity influencing the statutory process in Texas.

In Chapter 3, I developed a theoretical framework for statute adoption and regulation in the oil and gas industry. The framework for statute adoption primarily relies on the theory of transactions costs. My model predicts that the probability of statute adoption increases with land fragmentation, large extent of federal land and influences from neighboring states.

Chapter 4 tested the hypotheses derived from the oil and gas literature and from my theoretical model using state-level economical, political and institutional data. My preliminary test of predictions includes a difference of means test. I found that those variables supposedly increase the demand for statute adoption had higher means in those states with statute and in the time period after statute adoption. Then, I used a two staged linear probability model to empirically analyze my predictions. The results from the empirical model strongly support the idea that the presence of an autonomous oil and gas regulatory agency, the regional influence and the democrat partisanship at the state level significantly increase the demand for statute adoption. However, the lack of proper variables to measure the net benefits resulting from unitization prevents me from providing conclusive remarks on the economic variables. Further, the study fails to provide clear empirical interpretations to most of the variables due to inconsistent estimates.

I also tested my predictions using a proportional hazard model. The results tend to support the conclusions derived from the linear probability model. Interestingly, it supports the notion that the demand for statute adoption increases with large extent of federal land. Also, the results refute any heterogeneity across states in their baseline hazard to enact a statute.

The lack of conclusive evidence on the part of economical variable is a drawback in this thesis. This problem mainly drives down from lack of proper measures to capture the net benefit stream from a resources and lack of time series data on the subject. In my future research on this topic I intend to tackle the above problem by identifying suitable measures. Another avenue of possible research is looking at the impact of global oil and gas production on the evolution of property regimes.

Finally, it is evident that the evolution of property regimes in petroleum industry had more influence from political forces than economical forces. The influence of small scale producers in Texas and many other states indicate the political forces behind such producers.

Therefore, the development of property regimes in natural resources that are movable and fluid such as oil, wildlife and ground water can be complicated and unique, due to uncertainty of ownership and political process involved in it.

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APPENDICES

APPENDIX A – Complete list of variables and data sources

APPENDIX B – First stage regression results for linear probability model
Marginal effects for hazard models

APPENDIX C – Analysis of variable means by census years

APPENDIX D – Economic Model for well spacing and proraion laws

APPENDIX A: DATA

APPENDIX A

Table A-1: Data Sources

Variable Name	Definition	Source
Dependent Variable		
UNIT	Dummy=1 if state has compulsory unitization statute	Interstate Oil and gas Commission and State Oil and Gas Regulatory Agencies
Independent Variables		
Economic Variables		
OIL PRODUCTION	Oil Production (1000 Barrels)	U.S Statistical Abstracts
OIL REAL PRICE	Real Price of Oil ($/Barrel) (Base= 1990)	U.S Statistical Abstracts
VALUE	Oil & Gas Production multiplied by real oil price and real gas price ($)	Constructed Variable
GAS PRODUCTION	Gas Production (Mn cubic feet)	U.S Statistical Abstracts
GAS REAL PRICE	Real Price of Gas ($ Per 1000 Cubic Feet) (Base= 1990)	U.S Statistical Abstracts
COAL PRODUCTION	Coal Production (Mn of Short Tons)	U.S Statistical Abstracts
FARM SIZE	Avg Farm Size of Counties that Produces/Produced Oil (acres)	U.S Agricultural Census
INCOME	Per Capita Income ($) inflated to base year 1920	Bureau of Economic Analysis
Political Variables		
DEMOCRATS	Dummy 1 if Democratic majority in last 2 presidential elections /within last 10 years	Wikipedia
GOVERNER	Dummy 1 if Democrat Governors, more than 5 years in last 10 years	Wikipedia
NEIGHBOR	Proportion of bordering states with a statute weighted by population	Constructed Variable
REGION	Percent of states within U.S. Census geographic region with statute	Constructed Variable
Institutional Variables		
AGENCY	Dummy 1 if an autonomous oil and gas agency is present	
SPACING LAW	Dummy 1 if well spacing law is present	Interstate Oil and gas Commission and State Oil and Gas Regulatory Agencies
Control Variables		
POPULATION	Total Population (Mid Year in 1000's)	Bureau of Economic Analysis
URBAN	% Living in Urban Areas	U.S Statistical Abstracts
EDUCATION	Proportion enrolled in institutions of higher education	National Centre for Education Statistics

APPENDIX B: FIRST STAGE REGRESSION RESULTS FOR LINEAR PROBABILITY MODELS AND MARGINAL EFFECTS FOR HAZARD MODELS

APPENDIX B

TABLE A-2 – POOLED CROSS SECTION TIME SERIES 2SLS FIRST STAGE

	(1)	(2)	(3)	(4)
INTERCEPT	-3.418**	-4.129**	-3.112	-2.423
	(.1.372)	(1.428)	(1.921)	(1.903)
Instrument				
COAL PRODUCTION	.00006**	.00006 **	-.00006**	-.00006**
	(.00001)	(.00001)	(.00001)	(.00001)
Political Variables				
GOVERNER	1.325*	1.251	1.275	.1.152
	(0.797)	(0.796)	(0.797)	(0.786)
DEMOCRATS	2.219**	.2.287**	2.314**	1.835**
	(0.774)	(0.773)	(0.774)	(0.775)
REGION	0.134**	0.094**	0.099**	0.084**
	(0.019)	(0.029)	(0.030)	(0.030)
Institutional Variables				
AGENCY	0.714	0.926	0.853	1.068
	(0.934)	(0.940)	(0.945)	(0.933)
SPACING LAW	0.618	0.451	0.536	0.757
	(1.037)	(1.039)	(1.045)	(.1.031)
Economical Variables				
FARM SIZE	-.0257	-.0202	-.0177	-.0192
	(0.022)	(0.022)	(0.022)	(0.022)
Control Variables				
EDUCATION	-------	0.061 *	0.065*	-0.019
		(0.035)	(0.035)	(0.042)
URBAN	-------	-------	-0.020	-0.009
			(0.026)	(0.026)
INCOME	-------	-------	-------	-0.036**
				(0.010)
Number of obs	384	384	384	384
F	18.10	17.25	16.26	25.30
R-squared	0.4245	0.4293	0.4302	0.4484
Adj R-squared	0.4010	0.4044	0.4038	0.4212

** indicates significance at 95%   * indicates significance at 90%   Standard errors in parenthesis

TABLE A-3 – POOLED TIME SERIES CROSS SECTION 2SLS FIRST STAGE

	(5)	(6)	(7)	(8)
INTERCEPT	-755.9	-963.5**	-997.7**	-902.8**
	(288.6)	(307.7)	(311.7)	(439.7)
Instrument				
POPULATION	232.6	238.6	242.3**	247.8**
	(32.50)	(32.54)	(32.99)	(37.49)
Political Variables				
DEMOCRATS	64.07	171.9	192.9	205.6
	(265.5)	(270.9)	(272.5)	(275.9)
GOVERNER	136.6	192.2	196.85	196.6
	(253.9)	(254.7)	(254.9)	(255.2)
NEIGHBOR	1173	1221	1285**	1277**
	(543.5)	(542.2)	(550.2)	(551.4)
Economical Variables				
FARM SIZE	9.605	8.942	9.846	10.26**
	(6.965)	(6.950)	(7.072)	(7.208)
Institutional Variables				
AGENCY	1194	1170	1243	1225**
	(272.0)	(271.3)	(290.6)	(297.0)
SPACING LAW			-241.0	-239.0
			(32.99)	(343.1)
Contorl Variables				
EDUCATION	-11.02	5.501	7.864	9.171
	(9.218)	(12.66)	(13.10)	(13.79)
INCOME		-6.947	-7.122	-7.234
		(3.662)	(3.673)	(3.696)
URBAN				-2.594
				(8.465)
Number of obs	384	384	384	384
F(18, 365)	21.21	20.17	28.56	10.59
R-squared	0.4637	0.4679	0.4775	0.5729
Adj R-squared	0.4418	0.4447	0.4532	0.5519

** indicates significance at 95%   * indicates significance at 90%   Standard errors in parenthesis

TABLE A-4 – MARGINAL EFFECTS REPORTED IN TERMS OF MEDIAN TIME TO ENACT A STATUTE FOR SPECIFICATION IN TABLE 4.4

	(13)	(13a)	(14)	(14a)	(15)	(15a)
Economical Variables						
VALUE	4.51e-08	-4.51e-08	-9.71e-11	-4.84e-09	-2.21e-10	-4.83e-09
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
MARGINAL WELLS	2.15e-05	2.15e-05	1.58e-05	1.58e-05	1.48e-05	1.56e-05
	(3.0e-05)	(3.0e-05)	(2.0e-05)	(2.0e-05)	(2.0e-05)	(2.0e-05)
FARM SIZE	-0.005	-0.005	-0.004	-0.004	-0.005	-0.005
	(0.009)	(0.009)	(0.009)	(0.008)	(0.009)	(0.008)
Political Variables						
FEDERAL LAND	-0.023**	-0.023**	-0.021**	-0.019*	-0.021**	-0.019
	(0.012)	(.0012)	(0.010)	(0 .011)	(0.011)	(0.012)
REGION	0.023	0.023	0.028*	0.027**	0.028*	0.027
	(0.015)	(0.015)	(0.016)	(0.012)	(0.016)	(0.012)
DEMOCRTAS * INCOME	0.013**	0.013**	0.011**	0.011**	0.011**	0.011**
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
SPACE LAW	-3.802**	-3.802**	-3.219**	-3.056**	-3.194**	-3.054**
	(1.233)	(1.233)	(1.033)	(0.981)	(1.045)	(0.984)
AGENCY			-0.937**	-0.948**	-0.899	-0.936*
			(0.442)	0(.443)	(0.527)	(0.536)
URBAN					0.002	0.0008
					(0.020)	(0.020)

APPENDIX C: ANALYSIS OF VARIABLE MEANS BY CENSUS YEARS

TABLE A-5: 1950 DIFFERENCE OF MEANS

Variable	Group	N	Mean	t-value
Oil Production (1000 Barrels)	States without Statute States with Statute	44 4	34.071 93.391	-0.86 (E)
Total Value	States without Statute States with Statute	44 4	84 244	-0.91 (E)
Avg Farm Size (Acres)	States without Statute States with Statute	44 4	743.85 444.56	0.4 (E)
Per Capita Income ($)	States without Statute States with Statute	44 4	1416 1131	1.7
% neighboring states with statute	States without Statute States with Statute	44 4	.11 .13	-.08 (E)
Governor Party Association	States without Statute States with Statute	44 4	.4318 1	-7.52
Presence of a well spacing law	States without Statute States with Statute	44 4	.1818 1	-13.91
Presence of a Regulatory agency	States without Statute States with Statute	44 4	.3636 1	-8.67
% enrolled in institutions of higher education	States without Statute States with Statute	44 4	15.45 14.43	1.25

TABLE A-6: 1960 DIFFERENCE OF MEANS

Variable	Group	N	Mean	t-value
Oil Production (1000 Barrels)	States without Statute States with Statute	36 12	37.502 85.25	-.95 (E)
Total Value	States without Statute States with Statute	36 12	108 251	-.96 (E)
Avg Farm Size (Acres)	States without Statute States with Statute	36 12	905.64 1926.4	-.71
Per Capita Income ($)	States without Statute States with Statute	36 12	2107 2113	-.03 (E)
% neighboring states with statute	States without Statute States with Statute	36 12	.214 .316	-1.02 (E)
Governor Party Association	States without Statute States with Statute	36 12	..388 .66	-1.69
Presence of a well spacing law	States without Statute States with Statute	36 12	.333 1	-8.73
Presence of a Regulatory agency	States without Statute States with Statute	36 12	.33 .35	-2.08
% enrolled in institutions of higher education	States without Statute States with Statute	36 12	19.49 19.42	.04

TABLE A-7: 1970 DIFFERENCE OF MEANS

Variable	Group	N	Mean	t-value
Oil Production (1000 Barrels)	States without Statute	18	54.72	0.04
	States with Statute	30	52.18	
Avg Farm Size (Acres)	States without Statute	18	306	-2.55
	States with Statute	30	1469	
Total Value	States without Statute	18	1201	0.01
	States with Statute	30	1194	
Per Capita Income ($)	States without Statute	18	9964	1.59 (E)
	States with Statute	30	9352	
% neighboring states with statute	States without Statute	18	.54	-1.62(E)
	States with Statute	30	.68	
Governor Party Association	States without Statute	18	.555	-.52 (E)
	States with Statute	30	.633	
Presence of a well spacing law	States without Statute	18	.3333	-4.86
	States with Statute	30	.933	
Presence of a Regulatory agency	States without Statute	18	.166	-2.9 (E)
	States with Statute	30	.566	
% enrolled in institutions of higher education	States without Statute	18	49.56	.44(E)
	States with Statute	30	48.25	

TABLE A-8: 1980 DIFFERENCE OF MEANS

Variable	Group	N	Mean	t-value
Oil Production (1000 Barrels)	States without Statute	27	62.44	-.31 (E)
	States with Statute	21	82.65	
Avg Farm Size (Acres)	States without Statute	27	646	-1.47
	States with Statute	21	1959	
Total Value	States without Statute	27	202.21	-.34
	States with Statute	21	279.33	
Per Capita Income ($)	States without Statute	27	3863	.71 (E)
	States with Statute	21	3739	
% neighboring states with statute	States without Statute	27	.33	-2.35 (E)
	States with Statute	21	.56	
Governor Party Association	States without Statute	27	.62	.4 (E)
	States with Statute	21	.57	
Presence of a well spacing law	States without Statute	27	.444	-3.92
	States with Statute	21	.90	
Presence of a Regulatory agency	States without Statute	27	.29	-1.95 (E)
	States with Statute	21	.57	
% enrolled in institutions of higher education	States without Statute	27	37.49	-1.41
	States with Statute	21	41.79	

Table A-9: 1990 Difference of Means

Variable	Group	N	Mean	t-value
1990				
Oil Production (1000 Barrels)	States without Statute	17	39.9	.15
	States with Statute	31	33.9	
Avg Farm Size (Acres)	States without Statute	17	893	-2.53
	States with Statute	31	709	
Total Value	States without Statute	17	893	0.2
	States with Statute	31	709	
Per Capita Income ($)	States without Statute	17	19978	3.29 (E)
	States with Statute	31	17411	
% neighboring states with statute	States without Statute	17	.35	-1.66
	States with Statute	31	.61	
Governor Party Association	States without Statute	17	.35	-1.74(E)
	States with Statute	31	.61	
Presence of a well spacing law	States without Statute	17	.47	-3.86
	States with Statute	31	.96	
Presence of a Regulatory agency	States without Statute	17	.176	-2.62(E)
	States with Statute	31	.54	
% enrolled in institutions of higher education	States without Statute	17	55.2	.64(E)
	States with Statute	31	53.5	

APPENDIX D: ECONOMIC MODELS FOR WELLSPACING AND PRORATION LAWS

Production under Well Spacing Law

Well spacing law restricts the number of wells by stipulating acreage limits per well. Under this regime, assuming a restriction of *d* acres per well, the number of allowable wells for the *i* th owner is:

$$w_i \begin{cases} w^*_i & \text{if sole ownership} \\ a_i / d & \text{if well spacing laws} \end{cases}$$

Substituting the equation (8) onto equation (1) yields landowner's objective function under the wells pacing regime denoted by:

(A-1) $$max\ V_i^{WS} = [pq(w_i^{ws}) - c^i(w_i^{ws}), s(\sum w_i^{ws}); \tau]$$

Subject to: $w_i^{ws} = a_i / d$

It is evident that w is no more a variable but a constant that can be derived from $w^{ws} = w(a_i, d)$. This further indicates that land owner is deprived of the rights to choose the number of wells in his land. The conflict of interests between the land owner's objective and regulatory agency's objective with respect to the drilling oil and gas wells led to much litigation and eventually the well spacing rule became less popular in the light of other efficient property instruments.

<u>Production under "Proration" and "Maximum Allowable" rules</u>

Under this regime regulatory agencies restricted the oil and gas production by stipulating production caps on wells. Given the production limits, landowners' objective function:

(A-2) $\max V_i^{PR} = [pq_i - c^i(w_i, s(w), \tau)]$

Subject to $q_i \leq K_i$

Where K_i is the production cap imposed on the i_{th} well. It's evident that the revenue side of the equation reduces to a constant. This leaves the land owner only with the option of cost minimization. What follows from the theory of micro economics suggests that cost minimization does not ensure profit maximization. In line with this theory, proration laws can lead to situations where the cost of extraction exceeds the revenue generated.