MASTERARBEIT

Titel der Masterarbeit

„Oil & Gas Regulation: Solutions to the Common Pool Problem in the United States“

Verfasser

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angestrebter akademischer Grad

Master of Science (MSc)

Wien, 2013

Studienkennzahl lt. Studienblatt:	A 066 914
Studienrichtung lt. Studienblatt:	Masterstudium Internationale Betriebswirtschaft
Betreuer / Betreuerin:	o. Univ.-Prof. Dipl.-Math. Dr. Jörg Finsinger

Affidavit

I, Florian Dutzler, hereby confirm that my thesis entitled "Oil & Gas Regulation: Solutions to the Common Pool Problem in the United States" is the result of my own work. I did not receive any help or support from commercial consultants. All sources and/or materials applied are listed and specified in this thesis.

Furthermore, I confirm that this thesis has not yet been submitted as part of another examination process neither in identical or similar form.

Vienna, May 2013 Signature

“A path is only a path, and there is no affront, to oneself or to others, in dropping it if that is what your heart tells you . . . Look at every path closely and deliberately. Try it as many times as you think necessary. Then ask yourself alone, one question . . . Does this path have a heart? If it does, the path is good; if it doesn't it is of no use.”

Carlos Castaneda: The Teachings of Don Juan

Keeping in mind my path so far I want to thank my parents, family, and friends for their company along this way. However, I especially dedicate this thesis to my grandfather, who gave me the necessary motivation in the moment I needed it most.

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2 Introduction

The oil and gas industry is one of the essential parts of today's global industry, as its products are main energy sources and raw materials for almost every production process. Just imagine a world not only without gasoline or lubricants, but also most of our clothes, paints, plastic materials, detergents, road surface material, sunglasses, CD's, and toothpaste.[1] Literally, oil seems to be everywhere.

For the last 60 years oil has taken an utmost important part in the world industry influencing global economic strategies as well as politics. Being one of the most demanded commodities for nations it has also experienced more instability, dispute and war than any other good.

This thesis will analyze the characteristics of the oil and gas industry, more precisely of E&P activities in the beginning and introduce their historical evolution. Subsequently the special characteristics and influences of property rights in the U.S. will be explained to gain the necessary background understanding the common pool problem in the American oil and gas sector. Whilst first the common pool problem and solutions for it will be examined in a theoretical manner - later on historical evidence of the problem's existence is further elaborated. Thereupon an empirical part shall analyze the economic implications of suggested solutions and their proofed influence.

[1]Ranken Energy Corporation, *A partial list of products made from Petroleum*, http://www.ranken-energy.com/Products%20from%20Petroleum.htm (03.03.2013)

3 The Petroleum Industry

Since the first oil wells drilled, throughout the oil crisis in the 1970s until the Gulf wars, the international oil business has achieved more influence and power than most of the nations it evolved from. Although the industry historically started only based on the idea of drilling a hole into the ground and finding the "black gold" oil, the modern oil & gas industry is a pool of remarkable political intervention and has had a leading role in science and technology during the last century. Even though the business nowadays bears multiple interesting economic patterns to observe, this chapter will help as a first introduction to the industry itself. Thereafter a more detailed explanation of the common practices of exploration and production will follow, to form the necessary basic technical concepts for the following chapters. Finally an introduction of the historical evolution of the oil & gas industry should round up the background information.

3.1 The Petroleum Supply Chain

The main distinctions between activities of oil & gas companies are usually set in the categories upstream, midstream and downstream, where each forms an own branch within the business.

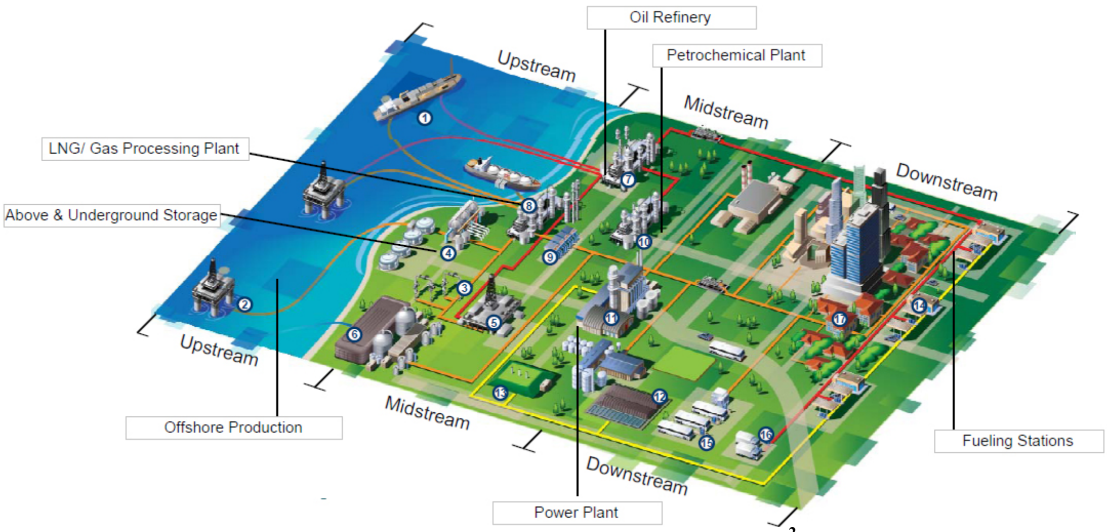

Figure 1: The Oil and Gas Supply Chain[2]

Upstream services, often called E&P (exploration and production) activities, include the search and recovery of crude oil and natural gas. Among these are included the acquiring and location of mineral rights, drilling and completing of wells and finally production and selling of crude oil.[3]

Midstream activities describe the process in-between upstream and downstream, which includes transportation (pipeline/truck) and storage of crude oil, natural gas/natural gas liquids or refined products.[4] Still an exact definition of where midstream starts and up- or downstream ends may sometimes difficult as a pipeline may also be used to transport products within the production process to a central terminal before it is shipped in the "real" midstream segment to a refinery.[5]

The **downstream** business includes refineries, petrochemical plants, distribution networks, and retail outlets. By refining and marketing the oil and gas this division offers the end products as e.g. gasoline, kerosene, etc. to the market and its customers.[6]

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[2] GE Energy, *Stream Dream*, from http://www.gereports.com/ge-energy-expands-tech-reach-with-3b-purchase-of-dresser/ (17.02.13)
[3] Charlotte J. Wright & Rebecca A. Gallun, *Fundamentals of Oil and Gas Accounting*, 2008, p. 2
[4] Petroleum Services Association of Canada, *Industry Overview*, from http://www.psac.ca/business/industry-overview/ (17.02.2013)
[5] Charlotte J. Wright & Rebecca A. Gallun, *International Petroleum Accounting*, p. 155
[6] Petroleum Services Association of Canada, *Oil and Gas industry*, from http://www.oilandgasinfo.ca/our-oil-and-gas-industry/how-does-the-oil-and-gas-industry-work (17.02.2013)

3.2 The Upstream Business

Considering the focus of this thesis on the common pool problem later on, it is important to understand some key technical concepts of the upstream business, as these characteristics (mostly drainage) are the reason for the existence of the problem itself. As a first focus the characteristics of oil reservoirs shall be explained, followed by the introduction of a typical upstream life cycle.

3.2.1 Geology – Where are hydrocarbons?

An oil and gas field has to be seen rather as a sponge made of rock, than as a lake (although often miscommunicated). Usually rocks differ in scale and formation of their grains and thus their characteristics. Thus some rock formations are likelier to contain hydrocarbons than other ones. Oil and gas is commonly situated in layers with high porosity and high permeability, which allows them to flow through it.

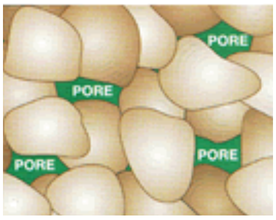

Figure 2: Porosity[7]

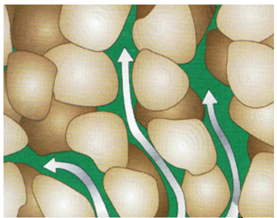
Figure 3: Permeability[8]

Porosity defines whether there is space between the grains in the rock – the more space is in between, the more porous the stone is. Permeability on the other side then states whether it is possible for fluids to move through the grains – thus the rock itself. Besides those two characteristics, the viscosity of the oil is also crucial for the shape of a reservoir. The more viscose a fluid is, the harder it flows – thus as different crude types have distinct viscosity rate, they also influence how easy the production process will be. This characteristic has to be taken into account during production – in the beginning the less viscose crude will be extracted. Later on crude, which cannot move that easily through the rock layers will follow.[9]

[7] MPG Petroleum Inc., *Oil & Gas Fundamentals*, San Antonio, 2003, from http://mpgpetroleum.com/fundamentals.html (21.01.2013)
[8] MPG Petroleum Inc., *Oil & Gas Fundamentals*, San Antonio, 2003, from http://mpgpetroleum.com/fundamentals.html (21.01.2013)
[9] The Seventh Fold, *Reservoir Characteristics*, from http://theseventhfold.com/peak-oil-101/reservoir-characteristics/ (30.01.2013)

Geologists and geophysicists are looking areas in between cap rocks, which are impermeable layers that hinder the oil from further moving up or downwards. Such characteristics create oil & gas traps and are most likely to contain hydrocarbons.[10]

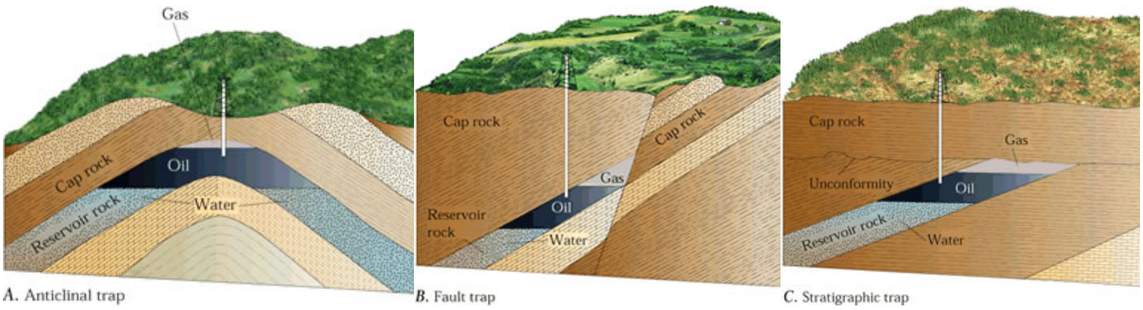

Figure 4: Different for Forms of Oil and Gas traps[11]

Above different forms of oil traps are shown, where oil and gas is kept from flowing away by impermeable layers. Typically the so-called "gas-cap" above and a water layer below are compressing the oil part. As soon as drilling a well "opens the door" to the oil reservoir – which means that it enters it - the pressure drives the hydrocarbons to the surface.[12] Immediately the subsurface pressure pushes the oil and gas out of the well. In exceptionally strong pressure cases a so-called "gush" or "blow-out" can take place, were first the gas blows out with a significant force and later on oil follows by fountains up to 300 feet height.[13] As extraction takes place at the punctured well, the oil has to migrate from the surrounding formation to the exiting point. By doing so it is draining from neighboring areas. As companies drill additional wells, they are creating new low-pressure zones, where oil can escape and flow to the surface – thus increasing production. Still these higher extraction rates increase the gas and water output, which then significantly decreases the sub-surface pressure. Missing pressure on one hand slows the flow of oil and on the other hand leads to oil being trapped in formations, where they can't be extracted economically.[14]

[10] Oil & Gas UK, *Discovering the Underground Structure*, from http://www.oilandgasuk.co.uk/publications/britainsoffshoreoilandgas/Exploration/Discovering_the_Underground_Structure.cfm (15.02.2013)
[11] MPG Petroleum Inc., *Oil & Gas Fundamentals*, San Antonio, 2003, from http://mpgpetroleum.com/fundamentals.html (21.01.2013)
[12] The Seventh Fold, *Reservoir Characteristics*, from http://theseventhfold.com/peak-oil-101/reservoir-characteristics/ (30.01.2013)
[13] Michael S. Clark, *Famous Gushers of the World*, 2012, from http://www.sjvgeology.org/history/gushers_world.html (08.01.2013)
[14] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

3.2.2 The Upstream Life Cycle

Exploration and Production activities usually follow the lifecycle of oil and gas fields, which can be divided into six phases.

Figure 5: Life cycle of Oil and Gas fields[15]

Seismic, geological and geophysical works are performed during **identifying a prosperous reservoir (1)**. Such is work is carried out by using vibrations (explosions), which are reflected differently by geological layers in the earth crust.

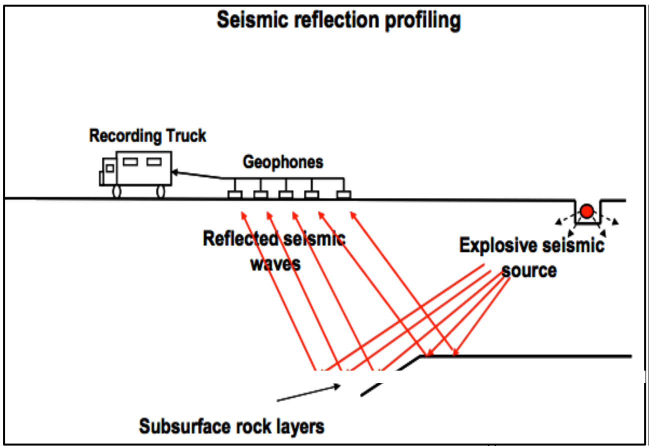

Figure 6: Seismic reflection profiling (onshore)[16]

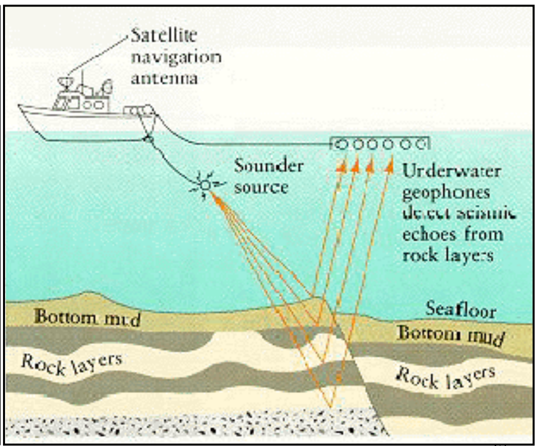

Figure 7: Seismic reflection profiling (offshore)[17]

After a first assessment, exploration wells follow in the **exploration phase (2)**, to get a further idea of how the reservoir is shaped and where hydrocarbons in an economically feasible amount are located. Having successfully completed the first exploration wells, so-called "wild-cats" the project advances into the **appraisal phase (3)**. During this time drillings are mainly used to further test wells and for accumulation of data needed for investment decisions.[18]

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[15] Deutsche Bank, *Oil and Gas for Beginners*, 2010, from www.fullermoney.com/content/2010-09-15/oilgas4beginners.pdf (15.12.2012)
[16] Deutsche Bank, *Oil and Gas for Beginners*, 2010, from www.fullermoney.com/content/2010-09-15/oilgas4beginners.pdf (15.12.2012)
[17] William P. Leeman, *Natural Resources & Societal Issues - A Geologic Perspective*, Department of Geology & Geophysics - Rice University, from http://www.ruf.rice.edu/~leeman/Seisexploration.gif (08.01.2013)
[18] Deutsche Bank, *Oil and Gas for Beginners*, 2010, from www.fullermoney.com/content/2010-09-15/oilgas4beginners.pdf (15.12.2012)

Drilling itself (for exploration, appraisal and development) takes place using a so-called drilling rig, which operates the drill-bit that is carving into the layers of rock. In order to further strengthen the drilled hole and preventing it from collapsing, chasing of steel pipes is used. With the help of it then mud is inserted into the hole to cool down the drill-bit and to transport the drilled rock cuttings. As soon as they contain oil, the reasonable depth may be reached and further investigation by well logging (lowering sensors), drill-stem testing or analyzing drill core samples will take place.[19]

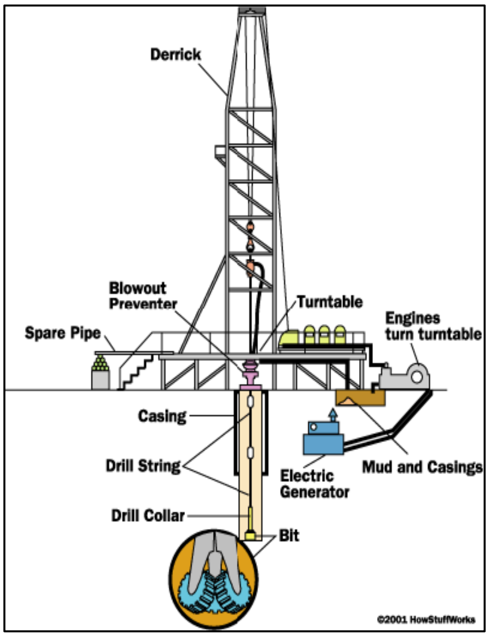

Figure 8: Anatomy of a Drilling Rig[20]

As soon as the appraisal phase is finished and enough data has been collected the **development phase (4)** starts. Decisions, where to position extraction wells are being taken and facilities for post extraction have to be build. While data is the main target in the stages before, in the development phase the goal is to drill for the already located traps in the most efficient way. As soon as oil is stuck, the drill rig is removed and wellheads are installed – oil or gas will flow out due to the subsurface pressure in the reservoir. Depending on the field, they are either designed for oil or gas.[21] Main problem, when extracting oil is, that the faster one extracts the oil the less of the field's capacity can be recovered. Reason therefore is the loss of subsurface pressure at a high extraction rate, which causes that some pockets of oil may become trapped between rock formations inside the reservoir. Therefore a slower extraction is economically more favorable in order to extract as much as possible.[22]

After several years of production an oil field will start its depletion and flow rates, which could be observed in the beginning decrease steadily. In this time, the so-called primary extraction phase of the oil field is ending and secondary production phase can start – which is called the **maturation phase (5)**. Such field enhancement is principally reached

[19] Energy Capital Group, *How Oil Drilling Works*, from http://www.encapgroup.com/drilling/ (01.02.2013)
[20] Energy Capital Group, *How Oil Drilling Works*, from http://www.encapgroup.com/drilling/ (01.02.2013)
[21] Deutsche Bank, *Oil and Gas for Beginners*, 2010, from www.fullermoney.com/content/2010-09-15/oilgas4beginners.pdf (15.12.2012)
[22] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT PressCambridge, Massachusetts, London, England (2005)

by implementing water flood measures. Therefore water is injected via either old or new wells in order to re-establish the subsurface pressure of the former natural reservoir. As water is injected it spreads and pushes the remaining oil to producing wells. Water-cut, the ratio of oil and water will most probably increase in the wells, but as long as it is economically reasonable, oil can be further produced. A properly carried out water flooding campaign should on average recover additional 15% - 20% of the original oil in place.[23]

If necessary tertiary production techniques can further prolong or increase production capacities. Depending of the characteristics of the reservoir, additional physical or chemical processes are used. In case of heavy oil with a low viscosity, steam injection and thus "warming-up" the oil can help to improve flooding characteristics and thus production. Chemical improvement techniques include polymer, alkaline and surfactant flooding, which use different chemical processes depending on the necessity.[24]

After no further economically feasible production can be reached, finally a well enters the **abandonment phase (6)** and has to be shutdown and closed – usually this is called P&A (plug & abandon). Depending on legal requirements, oil companies may keep their non-producing assets and take no further action or have to be abandoned. Such process should not also prevent leakage into ground water levels, but also protect other producing or future horizons. The abandonment itself takes place by first removing the surface facilities and cutting & plugging the chasing of the well below ground or fishing net level. Again depending on legislation, the former well has to be marked for possible future operations. Crucial for the costs of abandonment is the location of the well. While onshore is reasonably costly, offshore operations can cost up to millions of Euros, depending if the platform has to be demounted and the depth characteristics of the field.[25]

[23] US Oil and Gas Corp, Oil Production and Secondary Recovery, from http://www.usoilandgas.net/oilproduction.htm (12.01.2013)
[24] Deutsche Bank, *Oil and Gas for Beginners*, 2010, from www.fullermoney.com/content/2010-09-15/oilgas4beginners.pdf (15.12.2012)
[25] GEK Engineering, *Plug & Abandonment Basics*, from http://gekengineering.com/Downloads/Free_Downloads/Plug-and_Abandonment_Basics.pdf (21.01.2013)

3.3 Oil and Gas History

Although America is regarded as the birthplace of the oil & gas industry the history is from it's beginning on already strongly linked to the Middle East. The very first mentioning of oil was around the 5th century BC, when Herodotus described oil pits near Babylon. Later on in the 1st century, Plutarch described, that oil was bubbling on the ground near Kirkuk (Iraq).[26] The first time mankind was reported to drill holes in order to extract oil, was in China in 347 AD, when Chinese used bamboo to get the black fluid out of the ground.[27]

In Baku (Azerbaijan) people already started using the oil-impregnated soil instead of wood for heating in the 8th history. Various travelers note that in that time the Absheron peninsula, home of Baku, had a long economic connection with oil.[28] In fact Baku and its surroundings can be seen as the first production area in the world. First wells were already dug by hand at the end of the 16th century and reached a depth of 35 meters. The extracted oil was later on exported and sold in Persia, Central Asia, Turkey and India. As the Absheron oil became more and more important in this geographical area, and Peter the Great of Russia even annexed the Baku surroundings to his realm after the Persian campaign in the 18th century.[29] Around 1800, it was again Absheron, which marked a pioneering activity in the oil and gas history, when introducing the first offshore oilfield drilling wells at a distance of 18 and 30 meters from the coastline.[30]

Finally in 1814 the first oil well to produce in the New World was drilled by accident near Marrietta (Ohio) during the search for salt water. At this time oil was still seen as a useless by-product of the needed salty product. The well itself had a depth of approx. 500 meters and produced one barrel a week, which in the light oil prices being at 50-75 cents/gallon does not sound a lot. Although oil was produced or skimmed off a few years earlier, the first well, which produced reasonable amounts, was the "Beatty Well" in southeastern Kentucky. Once again it was intended to be a salt well.[31] However it is

[26] Geo-Help Inc., *History of the World Petroleum Industry*, from http://www.geohelp.net/world.html (03.12.2012)
[27] E. R. Crain, *A True History of Oil and Gas Development*, CWLS InSite, Sept 2004, p. 10-11
[28] Mir Yusif Mir-Babayev, *Azerbaijan's Oil History*, Baku - City that Oil Built, 2002, p. 34-40
[29] Geo-Help Inc., *History of the World Petroleum Industry*, from http://www.geohelp.net/world.html (03.12.2012)
[30] Mir Yusif Mir-Babayev, *Azerbaijan's Oil History*, Baku - City that Oil Built, 2002, p. 34-40
[31] Brandon C. Nuttall, *Oil and Gas History of Kentucky: 1629 to Drake*, University of Kentucky, from http://www.uky.edu/KGS/emsweb/history/predrake.htm (08.01.2013)

reported, that the well produced up to 100 bbl/d.[32] Nevertheless it is very difficult to make a distinction, whether this wells can be seen as the "real" commercial wells in North America, as their main intention was still to find salt water.

First well of the modern era to be registered, already using percussion tools[33], was drilled in Bibi-Heybat in 1846, which is a suburb near Baku. Other pioneering wells in Europe could be observed in Romania in 1957 and Poland in 1954.Besides the above mentioned salt wells, the first commercial well to be reported on North American continent is said to be in Canada, more precisely in Oil Springs, Ontario in 1858, but it was still and hand-dug well.[34]

Before oil became a significant input factor for production companies, it was mainly used for illumination. It was used as such, by refining it to kerosene. Pioneering actors in the distillation of oil was Abraham Gesner, a Canadian with German decedents. After his first attempts were shown to a public audience in 1846, kerosene became an alternative energy source for lamps.[35] Finally in 1857 Michael Dietz invents his clean-burning kerosene lamp, and immediately conquers the market against the whale oil lamps, which were the standard until this time. Besides helping whales to extinguish, it also created a new customer for the oil industry, as crude oil was needed as a raw material for the distillation process.[36]

Another renowned pioneer in oil and gas activities in Texas and the U.S. was Colonel Edwin Drake who in 1859 and drilled a well, which was 69 feet deep.[37] Although he didn't drill the first well in Northern America, he is a crucial figure in the U.S. oil history. Many sources consider Drake as "the driller of the first productive well in the United States".[38] What was exceptional compared to the techniques used at this time is that Drake used metal piping during the drilling process, which helps to keep water, clay and

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[32] Geo-Help Inc., *History of the World Petroleum Industry*, from http://www.geohelp.net/world.html (03.12.2012)
[33] Geo-Help Inc., *History of the World Petroleum Industry*, from http://www.geohelp.net/world.html (03.12.2012)
[34] E. R. Crain, *A True History of Oil and Gas Development*, CWLS InSite, Sept 2004, p. 10-11
[35] Dictionary of Canadian Biography Online, *Abraham Gesner*, from http://www.biographi.ca/009004-119.01-e.php?BioId=38570 (05.01.2013)
[36] Brandon C. Nuttall, *Oil and Gas History of Kentucky: 1629 to Drake*, University of Kentucky, from http://www.uky.edu/KGS/emsweb/history/predrake.htm (08.01.2013)
[37] History.com, *Oil Industry History*, from http://www.history.com/topics/oil-industry (06.01.2013)
[38] Encyclopedia Britannica, *Edwin Laurentine Drake*, from http://www.britannica.com/EBchecked/topic/170909/Edwin-Laurentine-Drake (06.01.2013)

quicksand from entering the drill site. Therefore his famous well in Titusville is seen as the birthplace of modern-day oil history.[39]

Following theses historical milestones the oil production rose steadily in the southern states of the U.S. and modern oil industry had ultimately been born. Just four years after Drakes first well in Titusville, a today re-known businessman entered the oil & gas industry: John D. Rockefeller started a refining business with partners near Cleveland in 1963. Soon business increased, which also was due to the strong geographical position deriving from the existing and planned railroads and the Lake Erie for waterway transportation. While putting efforts on vertical integration (own cooperage shop, building barrels, own wagons for transport) and improving efficiency of the distillation, he further increased his return. In 1865 he bought out his partners and one year later he built another refinery in Cleveland named Standard Works. Following his good business instincts soon became a leading figure in the U.S. oil industry. Rockefeller soon found out that the best way to control the oil industry was by investing in transportation and refining. As barrels were expensive, the best way to transport oil were pipelines beginning at the oil fields as well as the railway afterwards. Thus he tried to negotiate low transportation prices due to size of his shipments. After the refining, the products were shipped and marketed nationwide. In 1870 Standard Oil of Ohio – the mother of latter established oil companies of Standard Oil – was born.[40]

With the success story of kerosene and Standard Oil as a refiner, the crude oil industry boomed and small entrepreneurs started to rush into the business with the black gold. Only a little downfall came, when Thomas Edison invented the electric light bulb, which influenced the demand for kerosene and thus leading to a "first" oil recession in 1878.[41] Luckily in 1886 Daimler and Benz invented the gasoline-powered automobile leading to a new market for crude oil and its refined end products.

Another important milestone of the oil industry took place, when in 1901 the "Spindletop gusher" blew out near Beaumont, Texas. The Austrian engineer Captain Anthony F. Lucas and his team managed to drill a 1000 feet deep well into a salt dome, which ended being one of the most known oil "gushes" in history with a fountain of 100 feet. The oil

[39] American National Biography Online, *Edwin Laurentine Drake*, from http://www.anb.org/articles/10/10-02291.html (06.01.2013)
[40] Live Oil Prices,*The History of Crude Oil*, from http://www.liveoilprices.co.uk/crude_oil/the_history_of_crude_oil.html (06.01.2013)
[41] Educational Broadcasting Corp., *Extreme Oil*, 2004, from http://www.pbs.org/wnet/extremeoil/history/1850.html (06.01.2013)

rushing out of this dome had never been seen before and the well "Lucas 1" produced nearly 100,000 barrel/day (compared to wells before, which only produced 250-300 barrel/day).[42] This discovery led to a major increase in the U.S. oil industry. Following the securitization of enough oil supply, ships and trains also switched from conventional coal-fired engines to oil engines.

The Spindletop gusher set a starting point for the "oil rush" in Texas thereafter and can be seen as a major turning point in the oil and gas history. Although it is not considered neither as the biggest nor the first gush – the news of high impact oil reservoirs to be explored in the Southern States increased the number of entrepreneurs starting business in this sector.[43] Consequently, issues arising on property rights, which had been present in the years before increased dramatically with more parties involved. In order to understand the background of the common pool problem and its possible solutions a short introduction to property rights shall follow.

[42] The Paleontological Research Institution. *Petroleum Education: The History of Oil*, from http://www.priweb.org/ed/pgws/history/spindletop/spindletop2.html (07.01.2013)
[43] Michael S. Clark, *Famous Gushers of the World*, 2012, from http://www.sjvgeology.org/history/gushers_world.html (08.01.2013)

4 Property Rights

The idea of property rights or property in common could be described very fast: “property is what I have or what is mine”.[44] Although this general expression is suitable and probably also understood by almost every six-year old child, it is not that easy. Fact is, that these rights matter significantly in our world and possess a key role in economic development. Rose[45] even questions, if property is the key constitutional right, because it gives individuals the opportunity to be independent and therefore capable of self-government.

4.1 What are Property Rights exactly?

According to Alchian a property right gives the individual the right of “exclusive authority to determine how a resource is used”, no matter if being private or governmental. Still the sole property right is only established properly if oneself, the administrative force or society rules, approves the usage right.[46]

Definition of the access or use of natural resources and the nature of their exchange is done by agents in assigning ownership to private individuals, groups or the state. Libecap furthermore states, that ownership on assets can either be (a) the right using them, (b) *usus fructus* rights, which allow to appropriate return, and (c) *abusus* rights, which permit to change the form, substance or location of them.[47]

Furthermore Barzel states that these rights on assets are not constant over time. Moreover they are a function of the owner’s efforts of protection, of other people’s capture attempts, and of government protection (police and courts). In theory such property rights can never be complete, as individuals will never use their entire potential. By definition it is not possible to perfectly describe the variables/rules of an asset, because one commodity can possess several attributes, which differ from individual to individual. As they do so, by exchange an original owner of an asset can transfer a distinct subset of attribute to another individual. By doing so, two parties own different attributes of the same commodity. As the economic value of these attributes differs between them, economic value is created.[48]

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[44] Laura S. Underkuffler-Freund, *Property a Special Right?,* 71 Notre Dame Law Review, p. 1035 (1995)
[45] Carol M. Rose, *Property as Keystone Right?*, 71 Notre Dame L. Rev. 329 (1996)
[46] Armen A. Alchian, *Property Rights*, The Concise Encyclopedia of Economics, fromhttp://www.econlib.org/library/Enc/PropertyRights.html (07.02.2013)
[47]Gary D. Libecap, *Contracting for Property Rights*, National Bureau of Economic Research (1999)
[48]Barzel, Y., *Economic Analysis of Property Rights,* Cambridge University Press (1989)

4.2 Definition of Property Rights[49]

Property rights can either be defined by private individuals via contractual arrangements or by government, if private definition is not possible. Usually main problems concerning the private definition are real world limitations as in some situations private definitions cannot be achieved optimally or the wealth increasing definition hasn't been complete. Those limitations give rationales for government to assume the definition of property rights.

Still, if government definition is assumed, uneconomic outcomes may follow. First it could choose an inefficient way mean of privatization and therefore reduce the gains from definition. Second, it could renege on the promise to define the property rights and keep them for itself. Finally, if any advantage may occur from the management of the definition of property rights, government could seek impact on the definition just to maintain its power.

4.2.1 Private Definition of Property Rights

The extents to which private property rights will be defined are shown in a function of the costs and benefits of private actors doing so. The benefits can be taken to be exogenous, as the demand of goods is driven by the market and the fluctuation of the will influence the benefits as well.[50]The costs of defining rights may be exogenous too, as changes (e.g.: introduction of barbed wire) may affects the costs of private actors to define property rights. Moreover natural settings may change to cost of definition (e.g.: mountains or rivers). Still many costs cannot be considered as exogenous and at least four types of endogenous costs can be found. First the decision costs of how and to whom to define property rights are not costless (actors have to spend time and resources on meetings). Furthermore the decision costs will increase, as the more actors claiming for rights exist, the more difficult it will become to find accordance among them. Second, transaction costs, as defending the achieved property rights should be considered as well. While one actor may gain by the definition of property rights, another may suffer (by not being included in the allocation), thus not accepting the allocation and willing to achieve property. Defending property rights has to exclude other over space, but over time as well, because new claims may emerge.

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[49] Barzel, Y., *Economic Analysis of Property Rights,* Cambridge University Press (1989)

[50] Terry L. Anderson, P.J. Hill, *The Evolution of Property Rights: A Study of the American West*, Journal of Law and Economics, Vol. 18, No. 1 (1975), p. 163-179

There are several possibilities to decide and defend on property rights. On the one hand it may occur contractually by defining the rights for different groups and excluding them from each other (Group A & B get different land, agree to use only their own). This solution will increase welfare for both groups because they don't need to defend their rights. On the other hand a possible outcome may be the usage of violence to improve its situation in the definition of rights. Finally another endogenous costs are the costs of racing for property rights, because private actors will try to be the first (thus gaining rent) if property rights are privatized. These costs again will reduce the rents available and thus the overall social welfare.

4.2.2 Government Definition of Property Rights

As an alternative to the costly definition of property rights by private individuals, governmental institutions may allocate them more efficiently. Most articles based on the Anderson-Hill definition of property rights by private actors themselves accuse the alternative of government to define rights as naïve. Nevertheless government may be beneficial by integrating it into the basic model.

In fact government property rights definition may increase welfare, as the costs for government to define rights can be considered lower compared to private definition rights. These lower costs derived from the definition of government itself because of its legitimate possession of a monopoly on the use of force. Government will coerce its citizens, if they agreed to be coerced. In the case of property rights, private individuals will accept to be coerced, as it is the same for all individuals. This ability of government offers potential lower costs of defining property rights than by private individuals.

As transaction costs of private group decisions increase geometrically, a definition by the elected members of individuals (government) will lead to a more efficient solution. Not only the number of the number of contracts between the involved individuals will reduce, but also all not involved individuals may be free to engage in wealth-increasing activities. As government has a monopoly on the use of force the defending of the decided property rights will also by more efficient, because the costs of enforcing rights decline if only one side is armed. Finally those implications will reduce overall costs for society and therefore increase welfare.

By definition of its monopoly on violence, government may not only control violence over private rights, but also avoid the problem of premature racing for property rights.

4.3 Common Pool Resources

As explained above individuals or government should establish a successful definition of property rights. Still for some distinct cases such a definition of ownership will not be or cannot be made. In fact some rights on assets will stay communally owned, thus remain public goods, which can be used by all individuals. Keeping in mind the chapters before, this means that the community refuses to define these rights to be owned either by individuals or the state. Demsetz argues that a reason for the refusal is that the benefits from definition/privatization of are either too low or the costs of definition is just too high.[51]

Still the sheer missing definition of private/state property rights does not define common pool resources. As Wade observes, a public goods become only a common pool resource if it is not infinite. As example public goods as lighthouses, weather forecasts, etc. can be mentioned. However, what makes a common pool resource is their characteristic of being finite – meaning of A uses it, less remains for B. Hence such goods are potentially threatened by congestion, depletion or degradation.[52]

Although Demsetz did not include the distinct between public good and common pool resource he remarks that as a result of the missing definition of property rights in common resources, nobody is responsible for the asset in question and thus no one can be expelled from the usage of it. The usual paradigm: "this is mine and I decide how it is used" therefore cannot be applied. The problem in this case is that individuals exploit the available assets, even though they don't have to think on the future implications of their practices.[53]

[51] Andrew T. Balthrop, *Oil and Gas Production: An Empirical Investigation of the Common Pool*, 2012 Economics Dissertations, Paper 80

[52] Robert Wade, *The management of common property resources: collective action as a alternative to privatization or state regulation*, Cambridge Journal of Economics (1987), Vol. 11, p. 96

[53] Howard Demsetz, *Toward a theory of property rights*, 1967, The American Economic Review 57, p. 355

4.4 The Rule of First Possession

As the term may reveal already before, the rule of first possession grants the ownership of a property right on a first-come, first-serve principle. Such a rule is commonly an attractive form of property rights distribution, as it endorses the definition of rights to parties that already have experience in exploiting this distinct resource and a direct stake in access to the resource. Moreover the rule recognizes the investments taken by the individuals and thus rewards them for their risks being first movers and innovators. Furthermore such a scheme also assures the situation that the existing party, with the best knowledge and understanding of the resource is established as owner. Additionally such allocation can be seen as economically more optimal as the claim sizes are rather defined in an optimal way, than they would have been in case of politic or bureaucratic assignation. As Libecap states, usually mobile, unobservable environmental/natural resources as groundwater, air, fish and wildlife stocks show exactly the characteristics defined by Demsetz, were benefits from property right definition are low and costs for proper definition is high.[54] First possession examples can be furthermore found analyzing emission permits, spectrum allocation and most recently in patent and copyright assignment.[55]

RESOURCE	POSSESSION RULE	STOCK- FLOW AND DURATION OF RIGHT
Chattels (abandoned, lost, unclaimed)	recover or show intent to recover	stock - permanent
Commons (pasture, forest, turf)	graze, gather wood or turf	share of stock – internal capture rule
Groundwater – absolute ownership	bring water to surface	flow –current pumping
Groundwater – correlative rights	bring water to surface	share of stock – internal capture rule
Intellectual property	first to invent, write	stock - varies (17 - 100 years)
Land	occupation, cultivation	stock - permanent
Minerals (hard rock)	locate mineral deposit	stock - permanent
Ocean fisheries	land fish	flow - current catch
Petroleum	bring oil to surface	flow - current production
Radio spectrum	broadcast a signal	stock - permanent
Water - appropriation doctrine	develop a diversion plan	stock - permanent
Water - riparian doctrine	pump or divert	flow- current use
Wild game	kill or capture	flow- current kill

Figure 9: Examples of First Possession Rules[56]

[54] Gary D. Libecap, *Assigning Property Rights in the Common Pool: Implications of the Prevalence of First-Possession Rules for ITQs in Fisheries*, Marine Resources Economics, Vol. 22., p. 408-410
[55] Dean Lueck, *First Possession*, The New Palgrave Dictionary of Economics and Law (1998), p. 14-28
[56] Dean Lueck, *First Possession*, The New Palgrave Dictionary of Economics and Law (1998), p. 13

4.4.1 The Rule of Capture

However further distinction of the first possession rule can be observed as shown in the table of the former subchapter. In the cases of natural resources, such as fishing, oil, and groundwater the rule is altered to be a special case of first possession, namely the "rule of capture". In this case the ownership rights are established to the party, which historically invested in the extraction of the resource. Still the part does not gain property rights on the stock of the resource itself, but rather of its flow.[57] Such rules are only used for so-called "fugitive" resources, for which a constant position cannot be observed. The capture in this case only takes place, when the resource is literally extracted of the common pool and is under "controlled ownership" – thus in the case of an animal is killing it, for water or oil pumping it up and having it stored. The specialty of such rules is, that after the party has captured the resource, it may use them with all property rights that are assigned to it, including the *usus fructus* as well as the right to sell it.[58]

4.4.2 Specialties in Oil and Gas Industry

As explained in the above chapter a common solution for the establishment on property rights is the rule of first possession. Moreover its special form, the rule of capture was observed more in detail. Nevertheless, there are certain issues, when the rule of capture is applied in the oil and gas industry. Following the geological background given above, one has to consider, that oil and gas are migratory resources and thus face drainage between established units of property rights. Hence it was not possible to establish the rights in a similar way as made for coal or other solid materials – but accordingly for flowing or moving materials.

The most famous description of the rule of capture in the oil and gas industry by Robert E. Hardwicke is following: "The owner of a tract of land acquires title to the oil and gas he produces from wells drilled thereon, though it may be proved that part of such oil or gas migrated from adjoining lands".[59] However, for a legal point of view, the owner of the drained resource has no legal right recovery of the drained part and only may protect his property by further drilling on his own acreage. Most references for the distinct oil and gas cases have been made either from solid minerals, underground waters or wild

[57] Gary D. Libecap, *Assigning Property Rights in the Common Pool: Implications of the Prevalence of First-Possession Rules for ITQs in Fisheries*, Marine Resources Economics, Vol. 22. , p. 408-410
[58] Dean Lueck, *First Possession*, The New Palgrave Dictionary of Economics and Law (1998), p. 13
[59] Robert E. Hardwicke, *The Rule of Capture and Its Implications as Applied to Oil and Gas*, Texas Law Review 391, p. 393 (1935)

animals. Solid materials had generally had the characteristic in common, that until the resources are discovered and extracted no certainty on the existence of such can be made. Underground water and wild animals' cases are found in many references in early cases, because of the same fugitive nature. In law term therefore, when talking about oil and gas a classification under wild minerals or minerals *ferae naturae.* Main concern of lawmakers during the evolution of the law of capture has not only been protecting the landowner and his rights, but also not harming the industry as such in producing from a common pool. Moreover the shape of the industry and the high initial investments needed, further promoted the definition of rights, which were in favor for investing parties as well.[60] The case of *Westmoreland & Cambria Natural Gas Co. v. De Witt*, which was held in the Pennsylvania Supreme Court is nowadays highly cited decision and can be seen as one of the most influential cases for the usage of the rule of capture applied to oil and gas. The nature of gas in this case was described as following:

"Gas, it is true, is a mineral; but it is a mineral with peculiar attributes, which require the application of precedents arising out of ordinary mineral rights, with much more careful consideration of the principles involved than of the mere decisions. Water also is a mineral; but the decisions in ordinary cases of mining rights, etc., have never been held as unqualified precedents in regard to flowing, or even to percolating, waters. Water and oil, and still more strongly gas, may be classed by themselves, if the analogy be not too fanciful, as minerals ferae naturae. In common with animals, and unlike other minerals, they have the power and the tendency to escape without the volition of the owner. Their 'fugitive and wandering existence within the limits of a particular tract was uncertain,' ... They belong to the owner of the land, and are part of it, so long as they are on or in it, and are subject to his control; but when they escape, and go into other land, or come under another's control, the title of the former owner is gone. Possession of the land, therefore, is not necessarily possession of the gas. If an adjoining, or even a distant, owner, drills his own land, and taps your gas, so that it comes into his well and under his control, it is no longer yours, but his."[61]

Therefore one can argue, that lawmakers had already an understanding of how to treat oil and gas accordingly in order to establish enforceable decisions. As Kuntz stated, there were clear incentives of granting favor to the investing parties. He further observes that even if it would have been possible to track oil and gas migration, and drainage therefore could be compensated, it would not be an appropriate solution. Although in this case property rights could then be defined on surface rights, lessees would face the danger of draining other's resources and thus be more risk aware. Form an economical point of view, such a rule would diminish overall welfare as less exploration and production would take place.[62]

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[60] Eugene O. Kuntz, *Law of Oil and Gas*, from http://www2.mccombs.utexas.edu/faculty/david.spence/rule-of-capture.doc (15.01.2013)
[61] Bruce M. Kramer & Owen L. Anderson, *The Rule of Capture – an Oil and Gas Perspective*, Environmental Law Vol. 35 (2005), p. 899-949
[62] Eugene O. Kuntz, *Law of Oil and Gas*, from http://www2.mccombs.utexas.edu/faculty/david.spence/rule-of-capture.doc (15.01.2013)

4.4.3 Application of the Rule of Capture in Oil & Gas

While the definition of the law of capture in the oil and gas industry seems quite simple, allowing the landowner to extract oil or gas under his ground and get it into his final possession by controlled capture. By doing so, he will ultimately reduce the amount of oil in place and furthermore may produce legally oil from other land tracts as it migrates to his tract by drainage. Still disputes can arise – namely in the question: what does extracting within his own tract mean? A well drilled on the landlords trace will in fact extract the oil on his ground and thus grant possession to him. However, it is not the well site, which has to be taken into account in this regard, but rather where the well is bottomed. In case the bottom of the well does not lie within the landowner territory it can be clearly seen as violation of mineral rights. Moreover such a practice would not only extract the allowed drained oil, but rather the neighbor's oil-in-place. Therefore not only control of the resource is crucial, but also the point of extraction.[63] Moreover it is also not easily stated, when e.g. is "under control". Although in early cases control was already regarded, when a well was drilled and the reservoir reached, in recent cases oil or gas is only captured, when it passes the well to the surface. Further practical implication also rose concerning waste – if a producer drilled into the gas cap of a reservoir and is not in favor of marketing the gas, common practice was flaring (burning) it. Cases have observed, if although through capture of the gas, the producer may do whatever he wants to do with "his" gas, it is in the common sense of wasting the resource in such a way. While on the civil law background no interference to this behavior is possible, conservation laws were issued respectively in order to prevent waste from common pools.[64]

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[63] Eugene O. Kuntz, *Law of Oil and Gas*, from http://www2.mccombs.utexas.edu/faculty/david.spence/rule-of-capture.doc (15.01.2013)
[64] Bruce M. Kramer & Owen L. Anderson, *The Rule of Capture – an Oil and Gas Perspective*, Environmental Law Vol. 35 (2005), p. 899-949

4.5 Petroleum Property Rights

As Drake had successfully drilled his well in 1859 and thus started the modern oil era, disputes on oil & gas became more common and a definition of property rights was necessary. However, the physical characteristics of reservoirs were not completely understood at this time. In the common law systems, usually property rights on land were stated to carry with them "dominion upwards to the heaven and downwards to the center of the earth".[65] Problems arising from this definition were step-by-step solved introducing the rule of first possession in each field. First an introduction to the characteristics of mineral rights in general and afterwards oil and gas lease contracts shall explained.

4.5.1 Mineral Rights

Mineral rights – property rights on minerals - are defined as the right to extract mineral from a certain land in a state. Such minerals can be gold, coal, metals, other minerals and oil or gas.[66] In most civil law countries mineral rights stay in the sovereignty of the state itself and therefore require the authorization of government before individuals are allowed to exploit the minerals. Contrarily in the United States, mineral rights remain in the sovereignty of landowners, who own the surface. The property rights are seen separated in "surface rights" and "mineral rights".[67] The landowner is from a property rights point of perspective again able to decide, what to do with his rights. These may include selling or leasing his subsurface rights to other parties. Such an exchange and transaction is in an economically sense an increase of welfare, because the buyer or lessee values the assets higher than the owner. Following such transactions it is possible, that mineral and surface rights are held by different parties leading to a so-called situation of *severed minerals* or *split estate.* In the case that mineral and surface rights are both controlled by one party a *unified estate* is the case.[68]

4.5.2 Oil and Gas Leases

Although oil and gas companies could buy mineral rights, the common approach is to establish lease contracts due to the fairly high risk in exploration and the high capital necessary for such investments. By executing such a contract, the landowner (lessor) permits the oil & gas firm (lessee) to extract hydrocarbons from the mineral rights below

[65] Garrett, Rufus S. Jr., *Effect of Drilling Regulations upon the Law of Capture*, S.W. Law Journal (1950)
[66] Office of Geological Survey, *Mineral Rights*, State of Michigan: Department of Environmental Quality from http://www.michigan.gov/documents/deq/ogs-oilandgas-mineral-rights_257977_7.pdf (21.02.2013)
[67] Geology.com, *Mineral Rights*, from http://geology.com/articles/mineral-rights.shtml (17.02.2013)
[68] Timothy Fitzgerald, *Understanding Mineral Rights*, Montana State University (2012) from http://msuextension.org/publications/OutdoorsEnvironmentandWildlife/MT201207HR.pdf, (21.02.2013)

his property.[69] Terms of lease agreements should include following three principles: (1) signing bonus after completion of the contract, (2) share of royalty payments based on the resources extracted from leased lands, and (3) agreement during which time the firm is required to drill a well. The mineral owner thereupon received payments from the lessee for the operation and usage of his mineral rights. Usually royalty payments are paid on a monthly basis in cash, and have to be calculated before operation expenses. Royalty shares tent to differ from 15% to 25% of revenues made.[70] In some cases also rental payments are being paid if no production can be established and thus no royalties incur – if such a clause does not exist, the lease contract ends after the primary exploration term and the landowner may lease the mineral rights to other interested parties.[71] The terms and duration of lease contracts may vary among each other – furthermore every state in the U.S. has its own legal premises on oil and gas leases, which can differ in scope and detail. Some states also require a proof of complete unitization of the prospective drilling project, meaning that agreements on the share of each mineral rights owner are agreed and established.[72] However more detailed information on field unitization will follow in the last chapter.

[69] Office of the Attorney General, *Oil& Gas Leases, Landowner's Rights*, State of New York (2008) from http://www.cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/Oil%20-Gas%20Leases-%20NYS%20Attorney%20General.pdf (25.02.2013)
[70] International Energy Network Ltd., *Mineral Rights*, London, http://www.ieneurope.com/pdf/Mineral.pdf
[71] Office of Geological Survey, *Mineral Rights*, State of Michigan: Department of Environmental Quality from http://www.michigan.gov/documents/deq/ogs-oilandgas-mineral-rights_257977_7.pdf, (21.02.2013)
[72] Geology.com, *Mineral Rights*, from http://geology.com/articles/mineral-rights.shtml (17.02.2013)

4.5.3 Advantages of U.S. Petroleum Property Rights

Contrarily to the established systems in other countries, where the government issues and negotiates licenses to/with oil companies, which allow them to search and extract hydrocarbons the U.S. system is rather based on individuals owning the property rights. Hence in the U.S. mineral rights are treated like real estate, and thus the oil firm has the possibility to approach the distinct owner of mineral property rights and negotiate a private contract. Agreement thus does not only lead to success for big players, as it often does in international negotiations with governments, but also with SME in the oil and gas sector. Due to this framework, negotiations on average take shorter time to completion of an agreement. Furthermore the compared to civil law countries relative low costs for negotiation lead to lower entry barriers for new enterprises and furthermore reduce the concentration in the industry.[73]

[73] International Energy Network Ltd., *Mineral Rights*, London, http://www.ieneurope.com/pdf/Mineral.pdf (26.02.2013)

5 Common Pool Theory

A common pool problem is stated when two or more individuals share the same property rights over one resource. Such a problem derives from the incomplete definition of property rights on an asset, which were described more in detail in the former chapters. A common pool problem will ultimately lead to a faster use or extraction of a resource than a socially optimal solution would be, due to the fact that individuals are racing in order to extract from the common pool.

5.1 The Tragedy of Commons

In 1833, the English Professor William Foster Lloyd started to observe the reoccurring devastation of common pasture in England. He questioned himself, why cattle on common pastures were punier and stunted, than cattle on private pastures. Lloyd's answer dictated that in fact this outcome was caused by human exploitation driven by individuals self interests.[74]

The assumption is that the herdsmen try to maximize their own profits. They do so by selling their animals on local markets and their individual costs will the usage of the pasture on their land (which the animals eat). In the private case, the herdsmen would limit the amount of animals to a number, which does not overgraze his land. However, if the land on which the animals are grazing is not his private property, but common property, his incentives change. His individual costs would not prevent him from having more animals and thus overgrazing, as there is no future disadvantage for him. Contrarily if he refuses to use the common pool of pasture today, he may not find enough resources for his animals tomorrow, as the other herdsmen already used it. His strategy will therefore be to maximize his individual profits by overusing the common resource.[75]

Garrett Hardin further develops Lloyds's observations in his famous work "The Tragedy of Commons", which also marked the term used today, when speaking about such an economic setting. He further remarks, that such a selfish behavior as described above is a logical cause of the situation that every herdsman must survive in the short-run. Moral implications or the understanding that such a strategy will in the long run destroy the herdsman's own habitat are therefore thrown away. Hardin concludes that in a world of angel like agents (unselfish and idealistic) a distribution governed by the rule "to each

[74] Garrett Hardin, *The Tragedy of Commons*, Science, Vol. 162, p. 1243-1248 (1968)
[75] Robert Wade, *The management of common property resources: collective action as an alternative to privatization or state regulation*, Cambridge Journal of Economics (1987), Vol. 11, p. 100

according to his needs" may be successful. However, if in such an "angel society" only one "non-angel" would be sufficient to destroy the whole setup. Such an evil agent would first gain over the idealistic herdsmen due to the fact that he acts egoistic and only profit maximizing for him. Moreover his behavior will change the strategy of the other agents, as they see, that their idealistic approach led them to a loss. Hardin thus declares that an unmanaged common pool will lately end in ruin for all participants depending on then. Thus e completes that the epithet "tragedy" is justified in such situations.[76]

5.2 Common Pool Drawbacks

For a better reasoning, a mathematical model as well as logical considerations shall be used, to further elaborate drawbacks given to society by a common pool problem. By doing so, an understanding for the fact, that the common resource will be drained faster than under single allocation of property rights should be drawn. Furthermore implications for the best outcome in the view of society should follow by using the models. Finally the most likely drawbacks besides increased drainage shall be further explained.

5.2.1 Increased Production Rates[77]

Before analyzing the special example of multiple individuals, we first have to state a base case. As start we consider an asset (here being an oil field), which is hold by a single landlord (the whole property rights of the oil reservoir are held by him). The owner now has to decide whether he will extract the oil today or at a later time (to keep it simple only two periods – today and tomorrow – are assumed). In order to calculate the profits and the costs of the landlord, variables are introduced with P_t being the price in period t and Q_t being the extraction rate in period t. Furthermore the landlord has marginal costs which occur per Q_t units extracted in period t of $MC_t (Q)$.

Q_t …………..Extraction rate in period t
P_t…………..Price rate in period t
$MC_t (Q)$ ……Marginal costs of extracting a rate Q in period t

Now suppose that the landowner can choose whether he extracts at a rate of Q_1 today or if the extracts at a rate of Q_2 tomorrow. If he decides to produce today his additional profits will be P_1 - $MC_t (Q_1)$. As explained in technical introduction, the characteristic of oil

[76] Garrett Hardin, *The Tragedy of Commons*, from http://www.econlib.org/library/Enc/TragedyoftheCommons.html (22.02.2013)
[77] Stephen L. McDonald, *Petroleum Conversation in the United States*, Baltimore: John Hopkins University Press (19719

reservoirs is that pumping at a fast rate reduces the ultimate amount of oil that can be extracted from the field. In total less oil will be retrieved by the fast rate of extraction. The number of units that cannot be extracted tomorrow because it was produced today will be denoted with *b*. The loss of tomorrow would be $b*[P_2 - MC_2 (Q_2)]$ which furthermore has to be discounted with the discount rate *r* (as the loss will occur tomorrow and not today) leading to a total loss of $[1/(1+r)]*b*[P_2 - MC_2(Q_2)]$ if the landlord decides to produce one unit today instead of tomorrow. Deducting this loss from the profits made today one can see that the discounted marginal return of extracting a unit today will be:

$$[P_1 - MC_1(Q_1)] - b\,[1/(1+r)][P_2 - MC_2(Q_2)]$$

Having stated the marginal return of pumping today, the marginal return for tomorrow can be stated with the same methodological approach. If the landowner will pump one additional unit of oil tomorrow the additional marginal profit will be $[P_2 - MC_2 (Q_2)]$ which again occurs in the future and thus has to be discounted by r. The discounted marginal return of pumping one unit tomorrow is therefore:

$$[1/(1+r)][P_2 - MC_2 (Q_2)]$$

Assuming Q_1* and Q_2* will be the rates of extraction which maximize the present value of the landowner, one can argue that those rates have to equal the marginal return of pumping a units today and pumping another unit tomorrow, shown in following equation:

$$[P_1 - MC_1 (Q_1*)] - b\,[1/(1+r)][P_2 - MC2 (Q_2*)] = [1/(1+r)][P_2 - MC_2 (Q_2*)] \qquad (1)$$

In order to test this equality to hold suppose that the marginal return of extracting today is higher than the marginal return of extracting tomorrow:

$$[P_1 - MC_1 (Q_1)] - b\,[1/(1+r)][P_2 - MC_2 (Q_2)] > [1/(1+r)][P_2 - MC_2 (Q_2)]$$

If the marginal return from the left side of the upper equation (extracting today) is higher, the landowner will shift his production from tomorrow to today in order to increase his present value. This will respectively implicate that the marginal returns have to be equated as shown in (1) for profit maximization. The marginal social benefit of one unit of oil (in period *t*) is measured in P_t and therefore an extraction rate for profit maximization will ultimately also lead to the maximum social welfare.

Having observed the base case of a reservoir being owned by only one landlord helps to broaden the model to the common pool problem, where two or more individuals are possessing property rights. As introduced before in the U.S. states, the rule of capture was used to determine property rights over an oil reservoir - meaning that every barrel of oil extracted from a well situated on a landowner's property belongs to the landowner. Imagining and oil field that spares over several acres also more than one landowner will have the right to extract oil at their wells. Therefore the equation has to be adjusted to the other landowners pumping from the same field. Assuming that the landowner, who was used in the first examples chooses to extract less oil today, and the others continued extracting at the same pace, than the landowner will lose a fraction of the oil contained in the field to the others (the fraction lost will be denoted *x*). The landlord will only find the fraction (1-*x*) tomorrow if he chooses not to pump it today (the others extracted *x* in the meantime). The condition for profit maximization shown in (1) has therefore been adjusted by this common pool problem by including the portion lost to others in the equation:

$$[P_1 - MC_1(\bar{Q}_1)] - b\,[1/(1+r)][P_2 - MC_2(\bar{Q}_2)] = [1/(1+r)][P_2 - MC_2(\bar{Q}_2)] \quad (2)$$

With $\bar{Q}_1$ and $\bar{Q}_2$ being the profit maximizing rates of extraction in period 1 and period 2. Observe that if all the other landowners of the pool would not extract anything (x=0) the equation would be the same as shown in (1). In the above stated we assume that x> 0 thus implicating that the landowner has an incentive to extract faster than he would without this restriction. Therefore the optimal extraction rate of (2) will be higher than the optimal extraction rate in (1) – namely $\bar{Q}_1 > Q_1*$. This means that the landowner loses the portion *x* of each barrel he doesn't pump out today. Furthermore the oil reservoir is limited and thus its shrinking over time will give incentives to all landowners to extract the oil at the fastest extraction rate possible in order to prevent his neighbors of pumping it instead of him. The overall extraction will be faster than it would have been if the oil field had belonged only to one landowner. Having a faster rate of extraction by all landowners to maximize their own profit therefore leads to a rate that is not longer socially optimal. Each one of them will pump more today, as postponing the extraction is costly as the others would drain the reservoir in the meantime. By transforming the stated equations, this effect can also be observed graphically:

$$P_1 = MC_1(Q_1) + SUC$$

where the *SUC* (social user cost) is defined with SUC = $(1+b)[1/(1+r)][P_2 - MC_2(Q_2)]$

The left side of the equation (P_1) can be seen as the marginal revenue from extracting one unit of oil today instead of tomorrow, while the right side (MC_1 (Q_1) + SUC) shows the marginal cost to society by pumping that additional unit today. If there was just one landowner as in (1) than the private user cost equals the social user cost and the following equation would hold: $P_1 = MC_1 (Q_1{*}) + SUC$

Nevertheless this equation has to be adjusted to the common pool problem, because in that situation the private user cost is lower than the social user cost. Pumping out one unit today decreases the costs for the landowner, but increases the social cost for society. The main fear of the landowner is to lose profit because his neighbors extract it before he does. However society does not care at all who pumps the oil out (assuming the efficiency of all landowners is the same). Having more than one landowner leads to a change in the equation because the individual landowner's private user cost now has to equal (1-x)*SUC, which also has to deducted from social user cost. For the common pool scenario therefore following equation holds:

$P_1 = MC_1 (\bar{Q}_1) + (1 - x)\ SUC$

The two stated equations for the single landowner and the multiple landowner scenarios could now be interpreted in a graphical way as shown in the figure below. As one can see the extraction of more than one landowner leads to an extraction rate exceeding the social optimal solution.

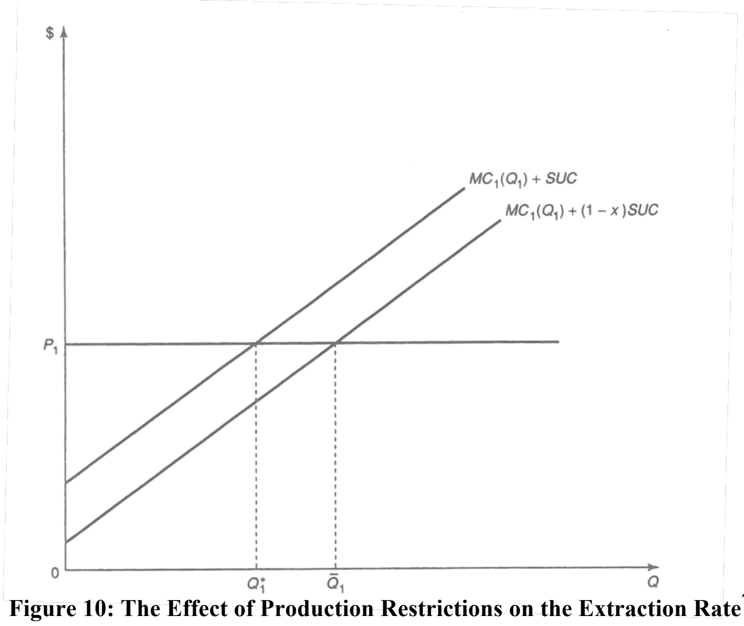

Figure 10: The Effect of Production Restrictions on the Extraction Rate[78]

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[78] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

5.2.2 Higher Storage Facilities

The extraction of oil at an earlier time, as suggested in the mathematical model most certainly led to higher production rates, although market demand was at a lower level. As a consequence oil had to be stored in tanks on the surface until it was finally supplied to customers. Costs incurred subsequently led to welfare loss as the socially ideal storage would have been where the oil already was initially – thus in the ground. Although the social optimal procedure would have been a production to meet demand, landowners had incentives to pump out the oil at an earlier date in order to prevent the other landowners from extracting it in the meanwhile. Therefore the common pool problem is not only likely to decrease production efficiency, but also to cause unnecessary storage costs.[79]

5.2.3 Lower Exploration Efforts

Another fact from the common pool problem can be found in the lower incentive for costly exploration. The potential gain from exploration will be reduced because the future landowners of the explored parcel will extract the oil at a faster pace and thus diminish the gains obtained from the exploring party. A landowner could therefore prefer to invest his capital rather in property rights at existing and explored reservoirs than exploring himself. From a societal view this tactic won't be economically ideal.[80]

5.2.4 Price Instability

Finally prices can be expected to be more volatile due to the oil rushes. While the exploration incentives tend to be lower, landowners will prefer rather to exploit established reservoirs than taking risky investments into new areas. Such a tactic will/would lead to following industry practices: after a new exploration discovery, all landowners will rush to the new reservoir and try to build their wells on it. The fast increase of supply will lead to a shock in the market and prices will fall. Once the field is draining and extracting rates fall, the price will increase again, thus leading to an increase and a very more volatile market.[81] From a company's perspective volatile markets can

[79] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)
[80] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)
[81] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

ruinous, because they lead to price and cost pressures and operating in a very volatile business environment makes it difficult to plan and decide on investment decisions.[82]

5.2.5 Ultimate Recovery

As in a common pool situation as producers face incentives to extract maximum recoverable volumes, the production rate increases compared to the socially optimal case. However, such increase in production rate does not only affect the supply of oil, but also the reservoir itself. As stated in the technical section, oil has to be seen as a sponge, where extraction takes place by puncturing the oil trap. During production therefore the oil has to flow through the reservoir, depending on the subsurface pressure. Technically, the faster oil is extracted from a field, the faster the pressure reduces and finally oil becomes stuck in the formations. Thus the enhanced production is likely to decrease the ultimate recovery from a reservoir due to production anarchy from a common pool.[83]

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[82] Rigoberto Ariel Yépez-García & Julie Dana, *Mitigating Vulnerability to High and Volatile Oil Prices*, The World Bank, 2012

[83] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

6 Solutions to the Common Pool Problem

Although competition, as shown in the previous chapter, will not result in a social welfare optimum, there are still possibilities to mitigate the effects of the common pool externality. Although unregulated and unrestricted production was observed to cause production anarchy, scientists has encountered and provided three main solutions to the common pool problem:

(1) Single Ownership
(2) Unitization
(3) Prorationing

Both single ownership and unitization are regarded to be private solutions to the common pool, as no governmental interference was necessary to successfully complete rent dissipation. In single ownership, all property rights are transferred to one landowner and thus a former existing common pool problem is completely internalized. Unitization gives the same incentives for economically optimal production by definition of one single operator although maintaining the initial parties on the field. However, as will be shown on empirical examples, such unitization efforts were not always possible to complete.

If initial negotiation was unable to reach a consensus, rather flexible solutions by private prorationing could be reached. In this case all parties situated on a reservoir maintained their output via production quota assignments. As these voluntary prorationing agreements will again depend on negotiation success and moreover on compliance of the involved parties. In case of no possible agreement or due to regular violation of restrictions government may step in to prevent waste of resources from uncompleted private solutions. Such conversation laws can then ultimately head to a state-enforced solution to the common pool problem.[84]

In the following sub-chapters each solution to the common pool problem of them will be observed in a more detailed manner and further substantiated by empirical evidence. Subsequently the historical success or failure of proposed solutions should provide implications (1) on the necessity of regulation used and (2) the characteristics needed for successful implementation.

[84] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

6.1 Single Ownership[85]

The easiest way derived from mathematical models in the chapter before would be to allocate the entire property (in this case mineral rights) of one reservoir to one single landowner, who then would extract the oil at a socially optimal extraction rate. Nevertheless such a hypothesis would only hold, if the sum of profits that the single landowner will obtain were bigger than the sum of the profits earned by multiple landowners. Only this characteristic would give the incentive for the single individual to buy up the land of other landowners and turn the investment into profit by doing so. The single landowner would than increase the social welfare by coordinating the optimal extraction on the different properties he bought before. Ultimately he will thus earn higher profits than if each landowner pumped extracted the oil himself. Resulting from the higher profits, he would than be able to pay each former landowner an amount in excess of the amount he would have earned, if he extracted it himself. Still when looking at the single private landowner solution, one will agree that negotiating the acquisitions of several property rights from other landowners will cause to remarkable transaction costs through setting up all the contracts.

6.2 Prorationing

While single ownership or unitization might be the favorable solution to internalize the common pool problem, as elaborated in the last chapter, such unitization contracts often face several drawbacks before they can be completed. Thus, besides those two solutions to the common pool, another in historical terms prominent answer to the common pool problem evolved. By output restricting contracts firms agreed on maximum allowed production level for each producer. As will be shown later on, the firm size is crucial for being in favor for output restrictions or not – key reason is the possibility of big companies being able to internalize the effects from a common pool. Doing so, a rent partly rent dissipation can take place and thus partially solve the problem. Due to its rather low transaction costs in negotiation prorationing became the most common practice of internalization of the common pool problem.[86]

First a representative process shall be used as an introduction on the regulative practices for prorationing. Afterwards a model will be drawn to analyze the incentives for

[85] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)
[86] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

restriction and contracting success. Finally economic implications due to introduction of prorationing will be revealed.

6.2.1 Practices on Output Restriction[87]

As the exact construction of restriction procedures differed between fields and from state to state as an introduction only representative process of prorationing will be used. The first step was to assign a maximum allowable rate of production to each well/acreage in the state. Every month a prospected market demand was estimated using the current oil price. This demand production and its implications on the current inventory level were used to calculate the target rate of production. If the target rate of production exceeds the maximum allowable rate of production, each well/acreage was allowed only to produce its maximum allowable rate. If the target rate is lower than the maximum rate first the production was allocated to special so-called stripper wells that were exempted from prorationing. The remaining rate was then distributed to the unexceptional regulated wells in the proportion of their respective maximum allowable rates.

6.2.2 Incentives for Production Restrictions[88]

Besides the incentives for a faster rate of extraction in a common pool, there are also cases where a firm is in favor for output restriction to gain from a rent dissapation. Libecap and Wiggins show, that besides no restrictions or regulation by governments should lead to production anarchy, a firm still may consider a voluntarily restriction of output. The following model should exhibit how firms are willing to enter production restricting contractual agreements (prorationing) or not, depending on their size. Moreover their preferences for on defined quota arrangements are observed. As a base model – the variation of the dominant firm model to a common property resource is applied.

The profit function of company i is denoted, where $p =$ the parametric market price, $q_i =$ the output by firm $i, \bar{q_i}$ =the output of other firms on the field and $C_i(q_i, \bar{q_i})$= the average cost function of the company hold following function:

$$(1)\ \pi_i = pq_i - C_i(q_i, \bar{q_i})q_i$$

[87] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

[88] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

Assumption is that oil mitigation leads to cost interdependence, thus differentiation of (1) leads to the non-collusive profit maximizing output.

(2) $p = C_i(q_i, \bar{q_i}) + \left(\frac{\partial C_i}{\partial q_i}\right) q_i = C_i(q_i, \bar{q_i}) + \left(\frac{\partial C_i}{\partial q_i}\right) S_i Q$

where$Q = q_i + \bar{q_i}$ and $S_i = \frac{q_i}{Q}$. Optimum can be observed where the marginal extraction costs equal the price. Marginal extraction costs include both the direct costs of additional output created as well as the increased costs due to inframarginal production. If we now assume to hold Q, which it the total output, constant and reduce S_i, the output share of firm *i,* to a arbitrarily small amount, the inframarginal cost effects will be completely external. At this point the firm will produce, where the parametric market price equals the firms average cost function, being at $p = C_i(q_i, \bar{q_i})$. As the company's share rises there is more incentive to restrict output below $p = C_i(q_i, \bar{q_i})$.

Reason is that the firm has to further cope with the costs arising from the inframarginal costs effects, being $\left(\frac{\partial C_i}{\partial q_i}\right) S_i Q$ in order to satisfy the equation. Nevertheless it is likely that large companies show lower direct production costs for any level of output, because wells situated on a bigger space of acreage. Therefore they reach for a larger effective pool and thus drive production costs down. Moreover the internalization of cost increases from other firm's production increases with more shares in the common pool, as the possible loss of rival production decreases.

(3) $\frac{\partial C_i}{\partial \bar{q_i}} = \left(\frac{\partial C_i(q_i, \bar{q_i})}{\partial \bar{q_i}}\right) S_i Q > 0$

As shown, large firms face incentives to limit field output due to the cross-unit costs effects from the common pool production. Contrarily, if a big entity reduces its production unilaterally, small companies will increase their output. Hence not only the restriction of own output volumes is crucial for the big firm, but also the prevention of small firms expanding at the same time. Moreover oil drainages between concessions further complicate these efforts by big firms. Production in general depends, as stated in earlier chapters depends on the oil in place below the leased land as well as from possible drainage from neighboring areas. Therefore small producers, due to its relatively small amount of leased land and thus oil place, tend to be much more dependent on oil drainage, than bigger players. As output increases, so is draining – hence small firms do not face incentives to restrict production and are therefore not keen to enter any agreements, even though such restrictions would on an aggregate basis of all companies on the one hand reduce production costs and increase the ultimate recovery rate.

Based on the explained mechanisms it can be further concluded, that that size of companies influences the positions, whether a firm is in favor for the restriction of output or not. In order to include small firms for output restriction, big companies will have to give small firms quota allocations to redeem them for their “lost” output and drainage from the reduced output practices. Such redemption will most likely be based on wells, as then a small firm is able to increase its share on the common pool by drilling additional wells and thus increasing its overall quota. An allocation on acreage basis would clearly have a better outcome for big companies, as in this scenario draining is eliminated. Finally an allocation rule based on historical output would not be approved by small players, as there is no option to increase their production share in this option. Hence, from the stated model, it will follow, that big firms are in favor for output restriction. Although small firms are not in favor, they might enter into agreements if the allocation rule is based on wells under control, which allows them to increase their production. Thus, from the stated model, it will follow, that big firms are in favor for output restriction. Although small firms are not in favor, they might enter into agreements if the allocation rule is based on wells under control, which allows them to increase their production.

The above model leads to further implications on the contracting success, allocation rules, drilling efforts and compliance on agreements. Higher concentration of production on a field (thus less, but bigger firms), will lead to more rapid and complete agreements, because all parties are in favor to output restriction. Moreover, if agreements are reached on non-concentrated fields (more, small firms) the allocation method will be rather based on wellhead, whereas on concentrated field acreage is likely to be used for quotas. Finally small companies will tend not complying with the agreements and violated their allocated quotas by overproduction. Once again the concentration of the field will influence whether such compliance is met or not – as big and small firms face different incentives on output restriction.

Depending on the firm’s size, a party will be either in favor or opposed to increase the well density on a reservoir. As stated in the technical part, the more wells are drilled, the faster extraction takes place and the more drainage is likely to occur. Small producers face considerable incentives to increase drainage by drilling new wells, as these are the only mean they can increase their production. Thus a non-concentrated fields with many small landowners, through more players opposed to restriction is likely to be regulated by a quota rule based on numbers of wells during negotiation or state intervention. Such a rule will ultimately lead to more drilling campaigns in small firm's concessions to increase their share of production and thus lead to more well density. Firms as well as states face incentives to stabilize the market by restriction of production, but still there are again different positions on a restriction between opposed parties likely.

An oil well faces three stages of production if no production restrictions are in place. First a flush face will report significant high amounts, due to the subsurface pressure pumping it up to the surface. Afterwards the production will normalize and later follow a steady decline of subsurface pressure. Still before it completely stops to flow, a steady but relatively long phase can be observed. Wells in such stages are so-called stripper wells and are further defined by having a production below ten barrels per day. The main problem with such wells is, that for the low oil volumes produced, they face a relatively high extend of production costs.[89]

6.2.3 Incentives for Price Stabilization

Assuming that prices are very volatile because of the above stated industry practices of rushing from one explored field to the next one, producers with high production costs will face considerable problems in being competitive in such a market. As economic theory states, small firms are more likely to be in such positions, as first they cannot profit from either economies of scale or scope. Furthermore, big companies will be rather prefer shutting down stripper wells, as the relative production added to their portfolio can only be seen as minor. Hence in a proper designed private restriction scheme, favoring small firms via a wellhead allocation, small companies would also be in favor for prorationing due to the resulting stabilized price. Such practices would diminish the production rate and subsequently the supply of crude leading to stabilization of prices, which ultimately help small high cost producers to survive.[90]

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[89] Nabil T Khoury, *Prorationing and the Economic Efficiency of Crude Oil Production*, The Canadian Journal of Economics, Vol. 2, No. 3, pp. 443-448 (1964)

[90] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, 2002, p. 595

6.2.4 Private Prorationing Solutions[91]

As observed in the model above, firms will face incentives to restrict their production in a common pool setup. However such a strategy is heavily depending on the firm size. Thus in order to establish a working prorationing regime, big companies will have to offer small companies a favorable allocation scheme in order to prevent violation. As the model further explicates, an agreement on output restriction is more likely to take place, the bigger companies on a field are and therefore the more concentrated it is. Such a phenomenon can be observed due to the fact, that (1) bigger firms face more incentives to restrict and (2) that negotiations become easier, the less parties are involved. Generally prorationing schemes were established to align the involved landowners and to reach rent dissipation. Contrarily to unitization no actual transfer of production rights is occurring und thus tract value of landowner didn't need to be anticipated before negotiation. Main advantage of prorationing was that production shares were automatically adjusted by ongoing production (production declines, loss of sub-surface pressure, flooding). Both other mentioned solutions to the common pool problem, such an easy adjustment wasn't possible. Furthermore in private prorationing solution the allocation rules will be, as described above, set by the involved parties in order to achieve a consensus on output restriction – still by partially negotiation success on restriction, in some cases not the entire the rent dissipation can take place and margins will be lost.

6.2.5 Governmental Prorationing Solutions

Due to the private solutions available, why would government than decide to use prorationing even it may not be socially optimal? Although in theory possible solutions to the common pool problem exist, their implementation can be difficult when applied in real life. Due to above mentioned differing incentives of firms negotiation is difficult to achieve, if too many parties are involved. In case of failure of private solutions (big) firms will lobby for state enforcement in order to restrict output. Taking into account all the drawbacks of a common pool problem stated earlier and implementation difficulties on private solutions, one may argue that in such a light government intervention to restrict prices is still the best way to increase the social welfare, rather than permitting anarchical exploitation.

[91] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

Observing the mechanism of prorationing in the southern States of the U.S. one can draw that it has the same characteristics as a cartel, whereas the state acts as the cartel manager itself. Due to the restriction of supply the price of oil is kept above the competitive level, which therefore leads to above-normal profits of the oil companies. As known from economic basics, such a scheme leads to a loss of consumer surplus and therefore welfare loss. Furthermore the distribution of the welfare throughout the U.S. makes the prorationing of the production in the southern states even more questionable in an economic point of view. Wherefrom one can draw that these regulatory policies were mainly promoted by the producing states as they increased the profit obtained.[92]

[92] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

6.3 Unitization

Besides the first private solution of transferring all property rights to a single landowner, the same logic would occur, if parties form a Union. However, such solutions imply considerable negotiation effort and may fail if transaction costs are too high. Therefore unitization practices in theory will be introduced as well as implications on compulsory rules established by government.

6.3.1 Voluntary Unitization

As stated in the technical part, enhanced oil recovery (EOR) techniques usually work with water-injection, where water is used to flood the retained oil-in-place and force oil out via the re-established sub-surface pressure from the injected water. However such enhancing production techniques require proper planning for the entire reservoir and the placement of injection wells on strategic situated reservoir points. As one can imagine, during the production restriction in the early 20th century, secondary recovery would not have been possible due to the different allocation of production rents in prorationing techniques. Enhancing a field in such a case would have favored only a few firms by draining oil from the rest (who therefore were clearly opposed to use these recovery techniques). Clearly no agreement would have been encountered. Still, as landowners were facing production decline and revenues decreased – unitization seemed to be the solution to the lockout on EOR.[93]

In unitization only one operator is responsible for production, thus he will try to exploit the field in an economically optimal manner (as a single landowner would do) – thus leading to maximization of welfare. However, such a share of production has to be negotiated in the beginning, which is the crucial point before such a solution can successful –too high transaction costs should be avoided by early negotiation settlement.[94]

Still, absolute and relative tract values have to be assigned to each company to achieve agreements between the involved parties. Especially this definition is difficult, because the settlement depends often on rough estimates on the oil-in-place of a reservoir, the ultimate oil or gas recoverability and drainage within the rock layers. As these

[93] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, 2002, p. 595
[94] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

characteristics are most commonly not available or subject to large errors in the first place, negotiation can face adamant obstacles. [95]

Furthermore the above stated problems increase, as more landowners are negotiating and therefore different expectations on the reservoir increase. As Barzel shows, the negotiation of multiple contracts leads to an exponential increase of transaction cost, which therefore will be a less probable option when it comes to a common pool problem.[96] The main problem in this private solution is getting all landowners to agree on one aligned view of reservoir composition, as initial information and knowledge tends to differentiate significantly. Besides general information varieties, risk profiles of involved parties may also influence negotiation targets. Finally some landowners may be tempted to obtain higher yields by trying to negotiate a higher price for their land. In such scenario of unitization strategies like that will lead to the attempts of landowners getting a higher share in the overall profits – which can ultimately head to a lockout and therefore uncompleted unitization efforts.[97] However, Libecap and Wiggins also state that the stage of negotiation is crucial for the success of unitization. Bearing in mind that main problems are the different views on the reservoir in the negotiation phase, the knowledge of the parties on the reservoir can influence the negotiation success. At the beginning in the exploration phase, little is know and thus the difference in views is smaller. Contracting in such early phase is therefore easier than in the development phase, where party's knowledge will be more contrarily.[98]

6.3.2 Compulsory Unitization[99]

Although voluntary unitization will provides a solution to the common pool problem, its introduction may become difficult due to above-mentioned concerns. Small firms owning only a minor part of the reservoir could therefore by their veto easily hinder the successful unitization of a field. In this case it may be helpful for government to give the establishment of unitization contracts assistance via law. If a landowner has the property rights, which are minor to a certain percentage he will be forced into a unitization

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[95] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, 2002

[96] Yoram Barzel, *Economic Analysis of Property Rights,* Cambridge University Press (1989)

[97] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, 2002

[98] Gary D. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, The Journal of Political Economy, Vol. 93, No. 4, pp. 690-714 (1985)

[99] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, pp. 606-607 (2002)

agreement by legislature. Introduction of such laws will help to force agreements in unitization were a lockout of parties is observed.

However, such a practice may harm the economic outcome to a certain extent. As Demsetz argues, the restriction on the trade of property rights impels infinite transaction costs and thus diminishes efficiency of private agreements. By theory the private unitization is perfect, when every parties is agreeing on the negotiation, which means everyone is in his view better off – Pareto efficiency is the outcome. If the state now imposes a restriction for parties having a too small portion of the field, he automatically makes this party worse off – thus neglecting Pareto efficiency. Still, paradoxically it may improve the economic efficiency, by decreasing bargaining costs through the threat of forced unitization. Only the possibility of compulsory unitization taking place will threaten parties in not creating a lockout on unitization. Nevertheless in order to believe such a threat possible, the state will have to impose compulsory unitization on several cases to be reliable.

7 Empirical Evidence

While the theoretical part analyzed the possible outcomes and implications from a common pool problem in the oil industry as well as solutions to it, this empirical part should further investigate the historical observations on beforehand-explained theories. First the possible drawbacks from the common pool problem will be remarked, followed by examples on unitization and prorationing.

7.1 Common Pool Drawbacks

As stated a common pool problem will, from a theoretical viewpoint, lead ultimately to extraction anarchy – applied to oil and gas the production rate will increase, unnecessary storage will be used, lower exploration will take place.

7.1.1 Increased Production Rate

Empirically the competition in the early oil industry during the 1920s and 1930s probably led to an excessive extraction rate in the Texas oil fields. The estimation of the actual recovery rate of oil reservoirs in this time was around 20-25 percent of the oil field's capacity. Assumption is that a controlled (and slower) extraction the withdrawal percentage could have been from 80 up to 95 percent from those oil reservoirs.[100] One could argue that at the early years of production the oil was needed more than it was expected to be in the years following, and thus preferring the earlier and faster extraction because the social benefit was higher. However due to the fairly constant prices over time and the substantial oil which was probably lost because of the fast extraction, one can suggest that this fast rate of extraction was not socially optimal at all.[101]

7.1.2 Increased Storage Facilities

Furthermore the extraction of oil at an earlier time led to storage of the oil and thus to welfare loss. The socially ideal storage would be where the oil already was – in the ground. Nevertheless landowners had incentives to pump out the oil at an earlier date - although there was not enough demand – in order to prevent the other landowners from extracting it in the meanwhile.[102] Empirically e.g. the storage facilities of the unregulated Texan field Hendrick more than doubled to ten million barrels stored within the first five

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[100] Federal Oil Conservation Board, 1926, p. 30 and 1929, p.10

[101] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

[102] W. Kip Viscusi, Joseph E. Harrington, John M. Vernon, *Economics of Regulation and Antitrust,* The MIT Press Cambridge, Massachusetts, London, England (2005)

months of production causing additional costs of around four million dollar. In contrast the neighboring Yates field (which was even bigger in scope) had succeeded in private production controls – as the parties thus were regulated and no anarchy in extraction could take place storage was kept to a minimum. Although being a bigger field, storage capacity of around eight hundred thousand barrels seems quite dwarfed by the ten million mentioned before.[103] Besides leading to overspending, storage of oil influences the risk profiles of the companies and made it more insecure. Libecap and Smith e.g. state that, in 1910 oil catching fire during stored at surface level lost more than ten percent of California's annual output.[104] In order to maintain production on the field, the allowed quota of the field was subsequently lowered from 225 barrels down to 37 barrels within one year.

7.1.3 Lower Exploration Efforts

Another (more systematic study) was made by Morris Adelman, which observed the additional exploration and due to prorationing. Adelman suggested that in 1961 these additional annual costs of prorationing (including drilling) could be accounted to be higher than 2.15 billion USD (in 1961 dollars).[105] However in the event of ongoing exploration efforts and success in the United States, it is very unlikely that prorationing harmed further exploration.

7.1.4 Price Instability

In fact, the proposed oil price instability due to the oil rush on fields and the relatively high incremental production added by prorationing, one could clearly observe that it led to instable markets in the beginning of the 20th century when neither unitization nor prorationing was established to combat extraction anarchy. Between 1913 and 1933 almost 70 price changes in nominal crude prices can be observed. Looking at the figure below one can clearly note, that prior to output restriction price instability was a common situation for firm conducting business in the early oil & gas business.[106]

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[103] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 89 (1984)

[104] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, 2002

[105] Morris A. Adelmann, *Efficiency of Resource Use in Crude Petroleum, Southern Economic Journal*, Vol. 31, p. 101-122 (1964)

[106] Gary D. Libecap, *The Political Economy of Crude Oil Cartelization in the United States, The Journal of Economic History*, Vol. 49, No 4, p. 842 (1989)

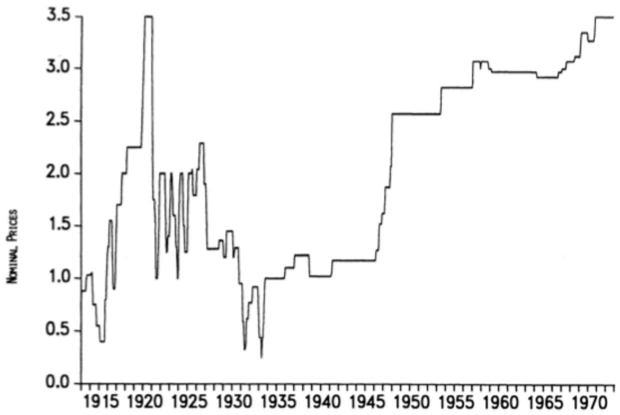

Figure 11: Nominal Crude Oil Prices 1913-1972 (USD/bbl)[107]

7.1.5 Ultimate Recovery

The examination of the lives of twenty fields in Arkansas, Louisiana, Oklahoma and Texas clearly undermine the theoretical assumptions that prorationing increases the ultimate recovery. Whilst the ten fields that were developed before the prorationing show an average production rate of 8.6 percent of the peak rate in the 15th year, the fields developed in the era of proration show a much higher percentage of 73.9 of the peak rate in the 15th year. However this evidence neither takes into account the specific field compositions nor compares the rates to the social optimum.[108]

[107] Gary D. Libecap, *The Political Economy of Crude Oil Cartelization in the United States, The Journal of Economic History*, Vol. 49, No 4, p. 842 (1989)
[108] Erich W. Zimmermann, *Conservation in the Production of Petroleum*, Yale University Press (1957)

7.2 Prorationing

Historically prorationing evolved after the discovery of major oil reservoirs in Texas and Oklahoma in 1920 – as stated in theory the characteristics of a common pool led to incentives for large firms to restrict output based on private agreements. However, as will be shown, the introduction of prorationing rules and their allocation definitions did not always succeed and government intervention took place or was requested. The theory assumed in will be further elaborated on the empirical evidence found on prorationing.

7.2.1 Incentives for Production Restriction[109]

As stated in the theoretical part on incentives for prorationing, large firms are likely to favor output restriction whereas small firms will be in a contrary position. As Libecap and Wiggins observe, the extent of resistance shown by companies can be observed looking at them. E.g. entering private prorationing agreements, complying with state regulation rules, promotion of prorationing by testimony in front of agencies and law-making bodies as membership of advisory bodies for restriction implementation can be seen as a supportive position on output restriction. Contrarily e.g. failure in compliance with restrictions (state or private), court challenges or testimony against production limitations would imply of a firm to be in opposition to prorationing. When looking empirically at the Seminole field in Oklahoma, hypothesis drawn from theory are further undermined. During a meeting for a vote on prorationing in 1927, out of 20 operators 16 were in favor for output restriction. The total percentage of wells held by those in favor amounted 73 percent, where twelve them were among the 15 largest companies on the field. Although one the four opposed firms, namely Barnsdall (8th biggest company on Seminole) voted against the introduction, the company is in general not likely to have been opposed to restrictions due to its activity favoring prorationing. The three firms still voting against restrictions were operators with only two out of 447 completed wells on the reservoir. Furthermore the advisory board, which was established in the same year in order to restrict exploratory drilling, was composed only of top ten companies when considering well ownership. One year later further seven firms restricted drilling, six of them again being top ten firms. Finally in 1929, from 35 producing operators 17 closed voluntarily on Sunday to endorse formal controls.

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[109] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 87-98 (1984)

On the Oklahoma City field a similar situation could be observed. Out of around 700 wells producing before restriction took place in 1928, 365 were closed voluntarily, whereof 212 belonged to the five of the ten largest companies. After almost two years the voluntary restrictions of the biggest players (ITIO, Slick, Philips, Franklin, Skelly) totaled 71 percent leading to an absolute lower production amount of 3.6 million barrel. However, small companies violated and challenged the prorationing rules in the meantime. A total of 16 firms could be elaborated, whereof only two had more than ten wells, while the rest owned less than five wells.

The biggest field in the southern states – the East Texas field furthermore emphasizes the theory stated. Already during the establishment of prorationing schemes by the Texas Railroad Commission in 1931, most of the biggest companies were in favor and even supported the setting of quotas with their capital. Gulf, Texas Company, Arkansas Fuel and Sinclair even stated to be in favor with any output regulation scheme, not depending on the structure of it. The two largest producers (Humble, Gulf) promoted a private solution for restriction paying more to enterprises which showed compliance on output quotas and a refusal of oil from non-complying firm. Still, small companies were opposed to the restrictions by bigger players, although per well allocation was favorable to them. Analyzing 50 lawsuits or violations brought to the Texas Railroad Commission only one violator was among the 24 biggest companies on the field – all the others were smaller. Once again the importance of drainage can be seen in a case, where seven firms lodged a claim on prorationing quotas. Although those seven only had acreage of around hundred acres production reached 500 barrels per acre per day – which was to extraordinary high compared to the field average of ten barrels per acre per day. Clearly one can observe that by their geological position, their dependence and in this case advantage on drainage there were in opposition to output restriction.

7.2.2 Increased Drilling

Output restriction by quotas favored landowners to own multiple wells on their territory. Although there were also restrictions on how many acres had to be between each well, one could suggest, that more wells were drilled than it had been socially optimal. E.g. Data obtained from the Hendrick field in West Texas, which was discovered in 1927 and unrestricted during the first year, suggest above-mentioned assumptions. Besides being comprised of favorable geological conditions allowing the oil to flow relatively easy, more wells then necessary were drilled. Technically speaking well density of one well per eighty acres would have been enough to extract the reservoirs oil easily. However, on Hendrick, one well (costs at that time: $ 57,000) could be found on every ten acres. The additional drainage of oil in the beginning by un-necessary drilled well led to a fast decline of sub-surface pressure. Thus pumping of oil had to be used prematurely and caused additional costs increases of $ 0.10 per barrel. Assuming that these additional wells costs occurred were not necessary for an optimal extraction, once again real resources were spent and led to a loss in social welfare.[110]

Furthermore looking more in detail at the Hendrick, Yates and East Texas fields one can also observe the theory, that small companies are likely to face more incentive of increased drilling. On Hendrick small companies owned more wells per tracts during the initial contracting, than big firms did. Such can be shown by the fact that concentration of firms by acreage (7.4) was much higher than concentration based on wells owned (10.5). Thus one can imagine that small firms were lobbying for a solution rather based on wellhead than on acreage – which ultimately was fulfilled by using a quota, which was based on both wells and acreage with a ratio of 50:50. Concentration of firms based on well ownership, decreased significantly (13.3) during only six months after the introduction of output restriction. Clearly this indicates that more wells than necessary were drilled in the timeframe and decreased social welfare on the Hendrick field. The Yates field observed the opposition of one producer (Simms - owning nine percent of production, but only six percent of acreage), which was based on his strategically good drainage position of the field. Simms even managed to influence the introduction of the same 50:50 quota as in Hendrick, when state restrictions emerged. Following the begin of state regulation, small firms again faced drilling incentives by the regulatory regime and therefore 51 additional wells with costs of 0.75 million dollar were spudded. On the East Texas field no output restrictions took place until military intervention in 1931, because in the beginning the high amount of small firms on the field (85 percent) had a clear majority in the opposition to regulation. However, after the per well quota (225 barrels per well) was established by the Texas Railroad Commission, small firms started intense drilling operations, while bigger ones held reduced their efforts. Two year after the introduction of restriction schemes, the 24 biggest companies owned on average one well on each 14 acres, contrary to small firms, which had such an average, well every nine

[110] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 88-89 (1984)

acres.[111] In a review from the U.S. House of Representatives it was concluded, that the introduced prorationing schemes in Texas led to increased drilling of 23,000 wells leading to unnecessary costs of 600 million dollar.[112]

7.2.3 Private Prorationing[113]

Analyzing private contracting success in fields in Oklahoma and Texas it is likely that, as stated in theory, private prorationing took only place if certain characteristics were met. The hypothesis is that number of firms based on a reservoir is crucial for the success of private solutions. The lower concentration on a field is the lower is the possibility to reach agreements as well as the chance to meet compliance. In order to observe concentration, the Inverse or the Herfindahl Index (IHI) is used. It measures the market dominance of big firms in a market and thus creates a variable able to verify the effective competition, as it is insensitive to small firm bias. In mathematical terms it is stated:

$$\text{Effective producers} = \frac{1}{\left(\frac{p}{100}\text{of firm 1}\right)^2 + \left(\frac{p}{100}\text{ firm 2}\right)^2 + \ldots + \left(\frac{p}{100}\text{firm } n\right)^2}$$

where p can be e.g. market share in percent of the respective company. The higher the index is, the lower is the market power of big firms and vice-versa.[114] In the special case of oil and gas, the market share in the above example will be substituted by number of wells under ownership on the field.

The private efforts on output restriction evolved first between 1926 and 1935, thus empirical examples of five big fields encountered during this time period will be used. Ranked by total cumulative production figures they are East Texas (1st), Oklahoma City (4th), Seminole District (5th), Yates (14th), and Hendrick (22nd).

Field	Numbers Equivalent	
Yates	1.9	5.9
	September 1927	July 1928
Hendrick	10.0	13.2
	September 1927	July 1928
Seminole City	11.2	15.7
	May 1929	August 1929
Oklahoma City	5.0	6.3
	December 1929	December 1932
East Texas	64.6	35.3
	March 1931	February 1933

Source: Oil Weekly.
Note: Numbers equivalents for all fields except Seminole City are calculated by well ownership. For Seminole City, continuous well data were unavailable and output data were used.

Figure 12: Concentration over time[115]

[111] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, pp. 95-96 (1984)
[112] The Cole Commitee, U.S. House of Representatives, p. 503 (1939)
[113] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, p. 90 (1984)
[114] David C. Johnston,Daniel Johnston, *Introduction To Oil Company Financial Analysis*, p. 262
[115] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, p. 90 (1984)

Looking at the table above, one can see that the ranking of concentration stayed on the same level. From the beginning Yates had the highest concentration, due to the fact that only 6 companies were present at its discovery. East Texas on the very other side had less influence of big companies, as not less than 147 companies were present after its discovery in 1930. Furthermore concentration changed over time, and the fields became less concentrated over time, which is caused by firms entering. Only East Texas had an increased concentration at later time – reason in this case is the consolidation of companies via lease buyouts.

On the table below, a summary of the fields can be seen. It includes the time of discovery, the absolute number of firms based as well as the IHI, the time it took from discovery to private or state prorationing agreements as well as established allocation scheme and effectiveness of the agreements.

	Yates	Oklahoma City	Seminole	Hendrick	East Texas
Discovery Date:	July 1927	December 1928	July 1926	June 1927	October 1930
Numbers Equivalent of Firms Based on Well Ownership:[a]	1.9 (6) (September 1927)	5.0 (18) (December 1929)	14.0 (27) (May 1927)	10.0 (18) (September 1927)	64.6 (147) (March 1931)
Time from Discovery to Private Contract Agreement:	2 months	1 month	none completed	none completed	none completed
Time from Discovery to State Regulation:		1 year	1 year	10 months	7 months
Effectiveness of Output Controls:	Full compliance under private agreement	Early compliance, with small lot drilling violations increased and state regulations were necessary	Full compliance only with state control	Full compliance only with state control	No compliance except during military occupation in 1931 and the NIRA in 1933
Primary Allocation Rule:	Acreage under private agreement	Under state regulation, per well	Per well[b]	50% acreage 50% per well[b]	Per well

Source: Oil Weekly, selected issues.
[a]*n*, absolute number of firms shown in parentheses.
[b]The Hendrick and Seminole allocations were based on production potential, which could only be increased by drilling additional wells.

Figure 13: Concentration and Contracting Success[116]

As one can see the contracting success, thus the establishment of private output restrictions, is strongly influenced by the concentration of the field.

[116] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, p. 92 (1984)

On Yates, which has the highest concentration a consensus by involved parties was reached only 2 months after it's discovery. Due to the fact, that the first used allocation method was based on wells and therefore led to increased drilling, the rule was changed to consider productive acreage as base end of 1927. There were only 6 firms based at the Yates field, which eased the contracting significantly (as theory stated). Biggest player was the Mid Kansas Oil Company with 71 percent of the total number of 17 wells at the initial time. One year later, its share dropped to 35 percent of the by then 203 wells. By this drop, one can first observe the massive drilling which took place during this year, as well as the implication, that smaller companies drilled more wells. Yates output plan was set to 150,000 barrels per day, which was relatively low compared to a potential of four million barrels per day. The high restrictions on output are further exceptional taking into account the shallow depth of the field (300 m) and thus the relative low drilling costs of $15,000 per well.

Oklahoma City was the second most concentrated field behind the smaller Yates. Reason therefore was the substantial stake of the Indian Territory Illuminating Company, which held 67 percent of acreage at initial negotiation. As the field's characteristic was that it was located in a rather deep formation, average drilling costs were relative high at $ 155,00 per well. Thus first private agreement reached on Oklahoma City was mainly restricting the number of wells to be drilled. Moreover wells were shut down on defined timeframes to furthermore reduce production. As through explorations the field extended towards city grounds and small firms on the field increased. However, almost 80 percent of the firms entering the field had 5 or less wells under their control. The more the concentration decreased, the more difficult it became to monitor the compliance of firms involved. Finally the biggest operators lobbied at the Oklahoma Corporation Commission for state-enforced prorationing, which was then established in 1929. Due to the high amount of small companies involved, an allocation scheme based on well ownership was chosen. The restricted output of the field was set at 200,000 barrels per day although potential production could have been over three million barrels at that time. Despite the efforts on restriction, small companies often violated their rates and led to higher production than intended.

The three remaining fields Seminole, Hendrick and East Texas did not succeed to negotiate private agreements on output restriction. By the difference in concentration one can see that the hypothesis (of more too much firms making it impossible to find private solutions) is likely to hold. Thus on the petitions of large operators, all three fields were brought under state prorationing. Again, as proposed by theory the allocation rules were based on wellheads.

7.2.4 Prorationing by State Intervention

As shown in the previous chapter, private solutions were highly influenced by the number of parties involved. Two field managed to negotiate private agreements, while the remaining three finally had to petition for state regulation. On Seminole and Hendrick, state enforcement began in 1928 and compliance to restrictions was achieved by state intervention. East Texas was another case. Although being one of the biggest fields in the U.S. until today[117], it faced the lowest concentration of the observed fields. Initially almost 150 companies had ownership rights, driven by the average drilling costs of $ 26,000 per well because of its relative shallow depth. Such an environment decreased entry barriers and let to a substantial entry of small companies. Three years after it's discovery in 1930 more than thousand firms had drilled over 10,000 wells into the reservoir. As no private agreements could be negotiated, the Texas Railroad Commission, the Texan oil & gas regulator, stepped in and declared state prorationing. However, firms did not comply the production quotas and production rapidly increased. In 1930 it finally peaked at a daily production of over one million barrels a day. Violations were common practice on the field and even force the Texan governor to close it twice under material law.[118] Only military occupations and the later on the introduction of the National Recovery Administration (NRA) oil codes led to an improvement. Under the NRA codes the prorationing was shifted from state authorities to federal government. Besides the monthly setting of allocation allowances, the NRA codes also included a federal enforcement on quotas by declaring any interstate shipment of hot oil (oil produced in excess of allowable rates) illegal. Although the NRA codes were the declared unconstitutional by Supreme Court, the introduction of the Connally Hot Oil Act in 1935 led to the same prohibition of hot oil trade.[119]

Empirical history supports the theory, that the number of parties involved is the main cause for successful prorationing. Other factors like drilling costs or size of the field were

[117] U.S. Energy Information Administration, *Top 100 Oil & Gas Fields (2009)* http://www.eia.gov/oil_gas/rpd/topfields.pdf (08.03.2013)
[118] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, p. 94 (1984)
[119] Gary D. Libecap, *The Political Economy of Crude Oil Cartelization in the United States, The Journal of Economic History*, Vol. 49, No 4, pp. 833-855 (1989)

not related to the establishment. While Yates and East Texas were both shallow reservoirs and thus low drilling costs – still they had different outcomes on prorationing success. Furthermore Oklahoma City and East Taxes were both the largest fields in size – however, Oklahoma City succeeded in in the first output restriction and East Texas did not.

7.2.5 Restriction Practices

In general the regulatory bodies of the states set the allowable rates as pointed out in the theory section. Nevertheless each state had its proper mechanism, which differed in their scope and definition. In Texas the Texas Railroad Commission was the governing body on output restriction, which set the quotas of allowed production per well. Nevertheless not all wells were target of output restriction. Stripper wells, which had high production costs but were producing less than ten barrels a day, were totally excluded from regulation. Moreover the quota set, was not only dependent on the acreage but also on depth, which was taken more into consideration. Thus the Railroad Commission gave additional incentives for owners of small acreage to drill deeper than necessary and therefore increase production costs. Although spacing rules were set to prevent overdrilling, the Commission granted exceptional rights to small companies on a regular basis. Such practices included the right for small firms to cover their occurring costs from drilling and operations by drilling at least one successful well, which does so. Such exemption rules were established due to the high political influence of small producers. Moreover such small producers were in favor of violation on prorationing rules without such exceptional concessions granted. The Commission therefore had no other choice than complying with the political pressure, in order to ensure a functioning output restriction.[120]

[120] Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the common pool: Prorationing of Crude Oil Production*, The American Economic Review, Vol. 74, p. 92 (1984)

7.2.6 Incentives for Price Stabilization[121]

As Libecap points out, the political interference on crude output led to a stabilization of the nominal crude oil prices with the introduction of the NRA oil codes as well as the Connally Hot Oil act. By the setup of an Oil States Advisory Committee with its members Kansas, New Mexico, Oklahoma, and Texas "government cartel" started to set quotas on production. Whilst its participants in the beginning regularly violated it, later on through political negotiation the rates were kept on a stabilized level. Main reason for such a political influenced approach can be once again found in the lobbying from firms. Prior to the introduction of an accordance fight of overproduction, the price per barrel was at only at $0.10 in May 1933. Producers in this case were facing severe problems to survive. More high cost and stripper wells (which had less than ten barrels output per well) were distributed in older reservoirs situated in Kansas, Oklahoma, Northern and Central Texas – hence production costs of these states were higher (see table below).

State	Production Cost
Illinois	$1.35
Kansas	1.05
Louisiana	0.90
Oklahoma	1.02
Texas	
West	0.62
North	1.26
Central	1.08
East	0.56
State Average	0.69

Figure 14: Average Production Costs Across States[122]

Thus producers from regions with relatively high production costs were in favor for production restriction to raise prices. Exactly this behavior can be observed by the states Oklahoma and Kansas lobbying for state prorationing. Besides those states also small producers inside of Texas were using their political power to enact restrictions.

The NRA oil codes, which were introduced in 1933 by federal governments helped to set prorationing quotas and furthermore declared interstate shipping of oil produced in excess of allowable state rates (hot oil) for illegal. Although the scheme was declared unconstitutional in 1935 it set the way into the formation of a cartel. While the Connally Hot Oil Act introduced the same shipment restrictions on hot oil, the involved states

[121] Gary D. Libecap, *The Political Economy of Crude Oil Cartelization in the United States, The Journal of Economic History*, Vol. 49, No 4, pp. 833-855 (1989)
[122] Gary D. Libecap, *The Political Economy of Crude Oil Cartelization in the United States, The Journal of Economic History*, Vol. 49, No 4, p. 836 (1989)

started to renew their efforts on production restriction. Governors finally agreed on an interstate oil compact. The regulatory agencies still stayed establish in the individual states, but met quarterly for discussions on prices, production plans and regulatory issues. Essential for the outcome of the efforts were the estimates provided the Bureau of Mines to the states as well as the Connally Hot Oil Act.

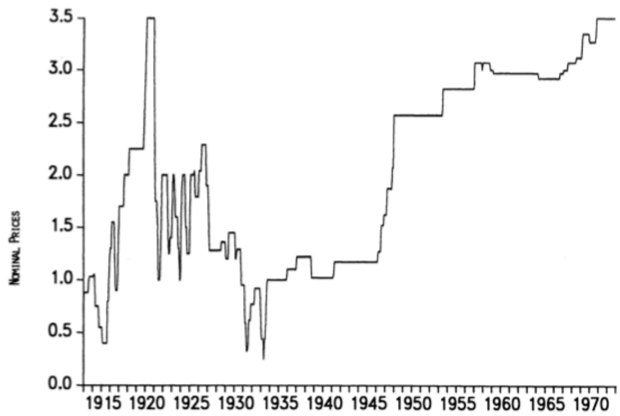

Figure 15: Nominal Crude Oil Prices 1913-1972 (USD/bbl)

After the establishment in 1935 the Interstate Oil Compact succeeded to keep nominal oil prices at a range around one dollar per barrel (see graph above). The hike from 1946 until 1948 was the removal of the World War II price controls, when the nominal price was subsequently adjusted. Besides this post-war phenomenon nominal prices were kept stable until the establishment of yet another output restricting agency: the OPEC.

7.3 Unitization

The first part of the 20th century was clearly influenced by private and state restrictions on production in order to overcome the problems associated with a common pool. Although unitization was available at earlier stages it did not evolve accordingly at this time, but started rather late to be seen as an alternative to prorationing. However as stated in theory such agreements were more difficult to reach than the "relatively" easy prorationing schemes imposed by government.

7.3.1 Voluntary Unitization

Empirically seen, unitization became more popular at the time the first field enhancement technologies evolved after World War II. Before that it rarely found – e.g. in 1947 Bain observed 3,000 fields in the U.S. and just encountered twelve of them fully unitized.[123] However, Boyce adds that 18 unit agreements were reached in California from 1929 to 1942. In 1951 already 181 unitization efforts were successful and covered over 2.6 million acres. Still he concludes that unitization agreements in the first production phase, when no EOR measures are necessary, unitization was unlikely to occur. Only the introduction of water injection increased unitization efforts. Still unitization of larger field was more successful based on Weaver, who concluded that the 207 largest fields in Texas (accounting 78 percent) more than 50 percent were unitized. Nevertheless he states that unitization was a long process, which at least lasted from 15 to 20 years.[124]

As stated in the technical section, oil & gas reservoirs heavily depend on the sub-surface pressure and if such pressure decreases rapidly through extensive drilling, so does the ultimate recovery. Therefore the gains of oil field unitization can be substantial to its owners. *Oil Weekly* e.g. estimates that unitization at an early stage would have lead to a two to five percent higher ultimate production in solution gas fields. Moreover the Fairway field in Texas was estimated to would have had an increase of 130 million barrels of oil, if unitized. Although a complete unitization is favorable, it may occur that only partial contracting takes place. In such cases the loss of welfare is still predicted to be reasonable high – the *Oil and Gas Journal* e.g. estimates that fully unitized fields show ultimate recovery rates around 44 percent whereas only partly unitized would score 39 percent. However, not only total recovery decreased but also drilling increased. E.g. on

[123] Joe Bain, *The Economics of the Pacific Coast Petroleum Industry: Part III*, Berkeley: University of California Press (1947)
[124] John R. Boyce, *Prorationing vs. Unitization Solutions to the Common Pool Problem with Monopsony,* University Calgary (2011)

the Texan Slaughter field injection wells with costs of $ 156 million were drilled to prevent migration of oil between the 28 established subunits on the field, although economically they were unnecessary.[125]

7.3.2 Compulsory Unitization

Compulsory unitization practices were introduced with the growing consideration of unitization instead of prorationing. In Oklahoma first laws were drafted in 1945, which imposed a compulsory unitization as soon 85 percent of the landowners were in favor of a unitization agreement. Although small firms opposed the proposed law and went to court challenging it, opposition reduced on the following years and in 1951 an amendment to the existing law decreased the percentage further 20 percentage points down to 63 percent. Contrarily the Texan resistance was much higher – small companies lobbied politically and succeeded in preventing compulsory unitization laws.[126] Weaver concluded that on the average number of fields being unitized in Texas increased from 20 per year before introduction of compulsory rules to 50 per year.[127]

As stated in the theoretical part, different views on the reservoir are crucial for negotiation. Libecap and Wiggins analyze, that in earlier stages it is likelier to establish unitization agreements than at later stages of the E&P production cycles. Empirically in the U.S. different laws on unitization undermine the hypothesis. While federal law required unitization in the exploration phase and thus at early stage of the process, unitization laws in Oklahoma and Texas allowed unitization only after the reservoir had been appraised and developed, which is at a later stage. Furthermore differences could be found between Texas and Oklahoma. While Texas had no unitization law in enforcement, Oklahoma had drafted laws, that allowed compulsory unitization if 63 percent of the parties on a field were in favor. Finally Wyoming had no special unitization laws, but federal laws, which favored an early unitization at exploration stage, were in usage.[128]

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[125] Gary D. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, The Journal of Political Economy, Vol. 93, No. 4, pp. 690-714 (1985)
[126] Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, Journal of Legal Studies, 2002, p. 596
[127] John R. Boyce, *Prorationing vs. Unitization Solutions to the Common Pool Problem with Monopsony,* University Calgary (2011)
[128] Gary D. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, The Journal of Political Economy, Vol. 93, No. 4, pp. 690-714 (1985)

Year	Wyoming	Oklahoma	Texas
1948	58	9	0
1949	56	9	0
1950	51	10	1
1951	53	11	2
1952	64	15	2
1953	54	15	2
1954	48	16	4
1955	55	25	4
1956	57	26	4
1957	69	26	5
1958	71	22	5
1959	65	18	6
1960	64	24	7
1961	71	28	11
1962	76	27	11
1963	75	33	11
1964	70	28	11
1965	70	30	16
1966	74	31	18
1967	73	35	16
1968	74	31	12
1969	69	35	11
1970	67	35	14
1971	72	35	14
1972	83	34	16
1973	84	35	17
1974	85	34	19
1975	82	38	20

SOURCE.—Lists of unitized fields in Wyoming, Oklahoma, and Texas were compiled from files at the Texas Railroad Commission; the Wyoming Oil and Gas Conservation Commission; the Bureau of Land Management, North Central Region Office; and the Oklahoma Corporation Commission. Output data are from the International Oil Scouts Association, *International Oil and Gas Development Yearbook*.

Figure 16: Production for Fieldwide Units as a Share of Total State Output (in %)[129]

Looking at the table above one can see, that the unitization efforts within the three states were different. The table shows the percentage of output from unitized fields to the total state output. Texas had no laws in unitization favor and in is clearly visible, that output of unitized fields was therefore also low. Oklahoma had a better performance due to the fact, that it had compulsory unitization law. However, this was not a better outcome than in Wyoming, because unitization took place after the development of a field. Wyoming had by far the best outcome on unitization due to the fact that federal laws enforced a early unitization during the exploration phase.[130]

[129] Gary D. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, The Journal of Political Economy, Vol. 93, No. 4, p. 702 (1985)
[130] Gary D. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, The Journal of Political Economy, Vol. 93, No. 4, pp. 690-714 (1985)

8 Conclusion

The common pool problem led to severe waste of in the evolving oil and gas industry in the 19th century by giving involved parties the clear incentive to extract more oil from the pool than economically optimal. The mentioned waste of resources can be further noticed by the presence of empirical evidence on increased storage costs, higher price instabilities, and ultimate recovery factors prior to introduced regulatory effort.

The proposed solutions helped to overcome the common pool problem, whilst externalizing the problem itself. However several drawbacks during their introduction occurred. While prorationing was used during the first half of the 20th century, unitization practices raised only in second half.

Private prorationing faced problems during introduction, when number of parties on fields were too high – thus the concentration too low. In such cases no agreement on output restriction could be reached and participants applied for state enforced prorationing.

State prorationing in most cases succeeded to restrict production, but still the case of East Texas exhibits, that with a very high number of firms on one field, even with state power it can be difficult to restrain violation of output quotas. However the introduction of the Interstate Oil Compact helped to stabilize crude oil prices successfully during a period from 1933 until 1970. This cartel-like interference was marked by political lobbying of high cost producers and led to the federal-wide prorationing establishment. Besides stabilization, prorationing also led to substantial increase of ultimate oil recovery compared to prior production anarchy. Concluding, due to above-mentioned outcomes it is reasonable that restriction practices improved overall welfare.

Finally unitization practices led to the chance of solving the common pool problem via transfer of production shares. In the event of EOR techniques being necessary to further sustain production on mature fields one can as well conclude that even through high transaction costs may harm the value created, it is in total an increase of welfare. Nevertheless contracting success on unitization is again heavily dependent on the parties involved. Whereas in private solutions it is likely, that no agreement is reached, compulsory unitization laws may lead to success. However, agreements will only be reached if the legislation is set accordingly. As stated, compulsory regulation should take place at early stages in the lifecycle of an oil & gas field, as at this time the likelihood of successful negotiation is higher than after development (as personal values differ more with maturation of the project). Finally it can be stated, that in the U.S. the definition of compulsory unitization laws was crucial for success. Although the federal laws insisted on unitization before exploration took place, Texas and Oklahoma only allowed unitization after development of the fields. Historically federal legislation led to a far more successful outcome – thus increasing social welfare.

Even though the proposed solutions of the common pool problem led to incentives for higher costs via increased drilling, it is still probable that their introduction led to substantial improvement of ultimate recovery rates as well as decreased additional costs, which would have occurred with production anarchy. Based on empirical evidence found in sources covering theses topics, I suggest to state that the solutions increased overall welfare.

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11 Abstract

The oil and gas industry is one of the essential parts of today's global industry as its products are the main energy source and raw material for almost every production process. However, in the early years it faced drawbacks arising from the fact that oil and gas are part of a so-called common pool.

A Common pool is defined by the fact that its property rights were not successfully established and hence it is common goods. We face such situations in our everyday life using streets, parks, lights and many more commonly available services. Nevertheless there are problems arising, if such a common good contains resources, which are not endless. In such cases, racing for the good takes place and ultimately need to waste of recourses.

This paper shall help to get a proper view on the common pool problem in the oil & gas industry and its premises. Subsequently possible solutions will introduced to the reader in order to point out their evolution by using empirical examples.

Finally the usage of existing historical examples undermines the hypothesis, that overall regulation led to a solution of the common pool problem and increased overall welfare.

12 German Abstract

Der Öl- und Gassektor ist heutzutage einer der wichtigsten Faktoren in unserer globalen Wirtschaft, da seine Produkte als essentielle Rohmaterialen so gut wie aller angewandten Produktionsprozesse dienen. Dennoch war dieser Sektor gerade in seinen Anfangsjahren durch Missstände resultierend aus einer Allmendeproblematik geprägt.

Allmenderessourcen liegen im Falle einer imperfekten Definition von Eigentumsrechten vor und führen dazu diese als Gemeingüter zu sehen. Wir erleben solche Situation jeden Tag während der Benutzung von Straßen, Parks, Beleuchtungen und vielen anderen Gemeingütern. Wenn aber ein derartiges Gemeingut endlich ist, kann ein Wettkampf um die verfügbaren Gemeinressourcen eintreten.

Diese Arbeit soll helfen einen angemessenen Blickwinkel auf die Allmendeproblematik zu bekommen und die Besonderheiten im Hinblick auf den Öl- und Gassektor zu verstehen. Nachfolgend sollen mögliche Lösungen für die Problematik erörtert werden um abschließend ihren empirischen Erfolg zu analysieren.

Schließlich kann mit Hilfe der historischen Bespiele die Hypothese bestätigt werden, dass die beobachteten Regulierungen zur Lösung der Allmendeproblematik geführt haben und insgesamt die allgemeine Wohlfahrt erhöht haben.

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Work Experience

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OMV Exploration & Production GmbH, Vienna, Austria, www.omv.com

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If you have any questions on this document or wish to receive any further materials I collected and used for this thesis, feel free to contact me.

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