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Negative Externalities and Environmental Regulation: An Application of the Principal-Agent Model

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By

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Abstract

This thesis considers enforcement strategies in the context of principal-agent relationships in industries where there is a high risk for negative externalities. The 2010 *Deepwater Horizon* oil spill—the largest accidental spill of all time—is used as a case study to highlight the regulatory issues that arise in industries with the potential for far-reaching and negative impacts on society. An in-depth analysis of the events surrounding the disaster makes it clear that complex principal-agent relationships between agencies and firms are common in the industry, as are problems with conflicting objectives, improper incentives, and moral hazard. As these are all features of the principal-agent model, this economic analysis tool is used to provide insight for resolving issues and proposing a new optimal enforcement strategy for the industry. As many features of the offshore drilling industry central to the creation of an enforcement strategy are common in other industries with high risk for negative externalities, the recommendations in this thesis can be applied generally to these other industries as well.

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Chapter I

Introduction

On April 20, 2010, BP's exploratory Macondo well blew out, resulting in an explosion on board the drilling rig *Deepwater Horizon* and the largest accidental oil spill in history. The oil flowed into the waters of the Gulf of Mexico for 87 days before the well was sealed off, with an estimated 4.9 million barrels spilled. In addition to the casualties on board the rig, the explosion and consequent spill caused environmental damage to the Gulf and nearby shorelines that is still being realized today (National Commission, 2011). For the offshore drilling industry, environmentalists, and citizens of Gulf Coast states, the *Deepwater Horizon* disaster became a symbol of the worst case-scenario—of what should never be endured again.

Investigations both internal and external began, and individuals on board the rig, as well as the involved companies were put on trial for various environmental and safety infractions. As the operator and leaseholder of the drill site, BP bore most of the blame. However, Transocean, the provider of the rig and its crew; Halliburton, the manufacturer of the cement that failed to seal the well; and even the government, responsible for regulation of the industry; were also held at fault. Liability for damages incurred was spread thin, with fingers pointed by all parties in every direction but their own.

In order to prevent accidents like *Deepwater Horizon* from happening again, an optimal enforcement strategy must be developed to implement a more strict and effective safety culture on all levels of the offshore drilling industry. To determine such a strategy, the events leading up to the blowout of the Macondo well and subsequent explosion and oil spill need to be examined to ascertain what went wrong and who was at fault. A number of investigations from various perspectives are available, but each must be carefully evaluated with an eye for biases based on authorship in order to determine what truly happened. Once a clear picture of the shortcomings in the industry with a focus on preventative measures is obtained, economics can be used as a framework for reworking the current system and devising potential mechanisms to constitute an optimal enforcement strategy.

This thesis examines the relationships between the involved parties through the theoretical perspective of the principal-agent model. The model examines the relationship between a principal (contractor) and agent (the contracted) and the inherent conflicts of interest that exist between the two. The principal and agent confront the issue of agreeing to a contract that provides appropriate incentives to both maximize profits and to produce an efficient level of effort. The conflicts of interest exist in that the principal requires full effort from the agent to maximize firm profit, while the agent needs to exert enough effort to meet contractual obligations without overexerting himself. This, combined with asymmetric information between the parties, leads to problems with contract design regarding incentives and production of efficient outcomes.

Although extensive literature on the principal-agent model exists, very little deals with industries with high risk for negative externalities, or more specifically, the offshore drilling industry. Since the *Deepwater Horizon* spill occurred recently, and was on a scale greater than any spill before, it provides new insight into the adjustments that must be made in the industry to avoid worst-case scenarios such as this, and to alleviate the damages they cause. Additionally, there is insufficient literature that deals with potential resolutions of the specific shortcomings in the industry that were highlighted by the *Deepwater Horizon* disaster. Problems within the offshore drilling industry as it today exists have yet to be tackled in light of the principal-agent relationships that pervade it, and with this fresh take on the issues, possible components of an optimal enforcement strategy can be proposed.

Current enforcement strategies in the offshore drilling industry do not provide companies with the incentive to spend resources on promotion of a safety culture. Additionally, in an industry like offshore drilling, there exists the issue of moral hazard. Onshore regulators have no way of knowing exactly what effort levels are being exerted by employees on oil rigs at all times. Safety regulations are in place, but employees can evade many of these. Due to the nature of the problems in the industry, a study of the principal-agent model and how issues with these relationships are resolved can reveal suggestions for change. Principal-agent relationships exist both between and within companies in the industry, and appropriate alterations on all levels will serve to improve regulation and safety throughout. By identifying several sets of these relationships: characterizing the government as a principal to BP; BP as a principal to the subcontracted companies

Transocean and Halliburton; and BP and Transocean as principals to their employees; incentives for resolution of their lack of safety precautions can be determined.

Many industries that operate with a high risk for negative externalities are rife with principal-agent relationships between enforcers and companies, as well as within and between profit-maximizing companies themselves. Thus, with lessons learned through a review of the *Deepwater Horizon* case study, detailed knowledge of the principal-agent model and relevant contracting issues, and strategies for enforcement suggested by economists in related literature, many of the recommendations made in this thesis can be generally applied to other industries that have high risk for negative externalities.

With the complex and costly investigations and legal proceedings that have surrounded this incident, it is clear that change is necessary. The way in which companies are regulated needs to be simplified, and as a regulator, the government needs to have a more active role in enforcing its policies. With strong top-down enforcement, involved companies should feel the burden of responsibility to enforce safety policies internally as well. But how can an optimal enforcement strategy for promotion of a stronger safety culture in the industry be designed?

Without an in-depth analysis of the largest accidental oil spill of all time, *Deepwater Horizon*, in light of the principal-agent model and its issues with incentives between contractors, there will be a lack of change in the offshore drilling industry that may result in a similar accident occurring again. Offshore drilling in the United States happens almost exclusively in the Gulf of Mexico, and this area has suffered enough consequences from the ineffective regulation of these highly risky operations. Because other industries can serve to benefit from this kind of study as well, the research gains even more value. Using this framework, recommendations for components of an optimal enforcement strategy can be determined to promote socially beneficial change in the offshore drilling industry, as well as other industries with high risk for negative externalities.

Chapter II

Case Study: *Deepwater Horizon*[1]

To fully understand the shortcomings within the offshore oil drilling industry, an examination of the most prominent and devastating oil spill in history is critical. Beginning with a history of the regulation of offshore drilling in the United States and background information on key players in the industry, this chapter highlights problems that have persisted in the enforcement of safety protocols and transparency between involved agencies since its beginnings. Given this context, an in-depth analysis of the events surrounding the Deepwater Horizon *disaster allows for flaws in the organization of the industry and implementation of crucial regulations to be clearly determined.*

2.1 A History of the Regulation of Offshore Drilling in the United States

Offshore oil drilling began in the 1890s, but with time there have been significant advances in the manner in which it has been conducted and regulated. Innovation in the industry has largely been due to an increased demand for oil over the past century, as companies have strived to find new ways to reach this growing consumer-base. In the most recent developments, the drilling industry has moved further and further offshore into deeper waters, changing the risks involved in drilling operations (National Commission, 2011).

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[1] Section 2.12 of this Chapter is an alphabetized Glossary of technological and industry-specific terms for the reader's reference.

The Constitution's Property Clause gives ownership of offshore natural resources to the nation, and deems the federal government responsible for managing and protecting said resources. The Outer Continental Shelf Lands Act of 1953 was the foundation for federal regulation of offshore oil and gas development. The Act gives the government the conflicting responsibilities of promoting offshore drilling, while at the same time regulating it to protect the environment. For example, money from lease sales, rents, and royalties goes to the U.S. Treasury, making acceleration of the industry in the government's interest. In terms of the environment, the Act includes only a limited number of concerns, and the Secretary of the Interior has discretion over how much consideration to give these. Additionally, the timeframe provided for approval of drilling projects does not allow for a thorough evaluation of these concerns (National Commission, 2011).

Offshore drilling is a complicated process that requires contracting many different services from many different companies. Because of this, delay in one step can cause challenging delays elsewhere, increasing time pressures for each task. For example, drilling vessels used to be contracted on day-rates, creating incentive to get the job done as quickly as possible. Government agencies have a history of contributing to a timesaving culture, as they often overlook "corner cutting" strategies. For instance, the U.S. Geological Survey has granted oil companies waivers from complying with orders and has failed to conduct regular and thorough inspections of drilling sites (National Commission, 2011).

In the early 1970s, conflicting ideas regarding the offshore drilling industry arose especially prominently. On the environmental front, the Santa Barbara oil spill in 1969 prompted new legislation for the first time since 1953. The National Environmental Policy Act (NEPA) dramatically increased the federal role in oversight for environmental protection and resource conservation, with the requirement of "environmental impact statements" from oil companies. The federal courts applied requirements from the Act strictly, and about 20 additional environmental laws were made in this decade (National Commission, 2011).

Alternatively, the OPEC oil embargo in 1973 prompted more new policies to be instituted to encourage oil production as Americans turned away from foreign dependency for energy. The Department of Energy was created in 1977, and the National Energy Act was passed in 1978. In 1982, the Secretary of the Interior created the Minerals Management Service (MMS), with the goal of expanding offshore drilling to promote domestic energy supplies. The agency would regulate these sites as well as collect billions of dollars in revenue for the U.S. Treasury through lease sale royalty payments, which in the previous decade had become its second largest revenue source. Even so, the government felt the offshore drilling industry could provide more profit, and MMS was charged with reforming royalty collection. Soon after, the government created a program to lease "acre-wide" drilling areas rather than just tracts of interest, resulting in a large increase in supply and lower prices for leases. These simultaneous and conflicting restrictions and expansions of offshore drilling resulted in difficulties in enforcing any policies at all (National Commission, 2011). As with the oil industry, MMS had the "incentive to promote offshore drilling in sharp tension with its mandate to ensure safe drilling and environmental protection" (National Commission, 2011, p. 72).

From later in the 1970s through the 1980s, more spill related disasters occurred and the government continued to change and strengthen enforcement policies. The Outer Continental Shelf Lands Act Amendments of 1978 transformed federal offshore leasing, giving most of the power to the Secretary of the Interior. Again, dueling responsibilities were to "obtain a proper balance between the potential for environmental damage, the potential for discovery of oil and gas, and the potential for adverse impact on the coastal zone" (National Commission, 2011, p. 77). The Secretary from the Coast Guard department was given control over safety regulations, charged with using the best technology available, but also taking cost into consideration. This Act was the first of several laws that included an exemption for Gulf of Mexico leases: development and production plans would not be necessary for these, which in effect exempted them from NEPA's requirement for environmental impact statements (National Commission, 2011).

During this time period, the frequency of spills did not decline, but consequences from the spills became less severe. This was mostly attributed to improvements in technological design and equipment rather than in human error and management. In order to save time, operators started to form alliances and contract out work for different parts of the drilling process, including outsourcing more and more research and design to specialists. This largely improved technology, but also resulted in fewer personnel in the drilling companies with knowledge about technology development and deployment. In a technologically complex industry full of many unknowns, high costs, and risks, this put a strain on the level of expertise of those actually performing and overseeing drilling operations (National Commission, 2011).

By the 1990s, the Gulf of Mexico was almost the only location in the United States where offshore drilling was still legal. "Ultra deepwater" drilling was developing, and innovation was constant. With such drastic changes, many old drilling platforms became essentially useless and were completely abandoned. Deepwater exploration brought new environments that presented technological challenges. Drillers' jobs were now more demanding, as they were dealing with unknown territory as well as a greater volume of mud and drilling fluids (National Commission, 2011).

The Deepwater Royalty Relief Act of 1995 relaxed access of leases in the Gulf, allowing for more oil companies to get involved in deepwater drilling. The trend away from internal expertise continued as oil companies merged and grew, providing additional finances and more long-term growth strategies with higher returns, but also higher risks. The oil and gas industry failed to match money spent on development and production with money spent on drilling safety, oil spill containment technology, and response planning (National Commission, 2011). There was a "fail[ure] to ensure that agency regulators had the resources necessary to exercise…the political autonomy needed to overcome the powerful commercial interests that opposed more stringent safety regulation" (National Commission, 2011, p. 83). From 2008 through 2010, the government and oil industry were "earning even greater revenues from ever-more ambitious exploration" (National Commission, 2011, p. 68).

2.2 The Risks of Deepwater Drilling

Drilling for oil requires tapping into porous and hydrocarbon-filled rock, known in the industry as the "pay zone". Wells drilled in deeper waters have higher pressure from the rocks above, and drillers must balance this pressure by pushing hydrocarbons into the well, while also exerting counter-pressure from inside the well. This is a very risky process—there cannot be too much counter-pressure, but too little counter-pressure can lead to an uncontrolled intrusion of hydrocarbons into the well and a subsequent blowout. Despite all the room for profit, the field of deepwater drilling is still largely unexplored and full of technical challenges. For example, blowout preventer technologies need to be updated to deal with new well conditions. Additionally, the environmental and geological conditions of deepwater locations are mostly unknown (National Commission, 2011).

2.3 A History of the Minerals Management Service (MMS)

The Minerals Management Service (MMS) was created in 1982 with the conflicting responsibilities of enforcing safety and environmental protection and promoting offshore drilling. In terms of environmental protection, The National Oceanic and Atmospheric Administration (NOAA) was authorized to make recommendations to MMS about environmental impacts. However, MMS was not required to follow this advice, and thus, NOAA spent minimal time and resources making their recommendations. No MMS director ever possessed strong technical abilities or expertise in regards to drilling safety, which may be why a general deficiency in these areas persisted throughout the company. Additionally, the midrange salaries of federal engineers were too low to attract individuals with a qualified level of experience in the field. Other problems in the agency included internal management shortcomings paired with a lack of communication between regional offices (National Commission, 2011).

In terms of safety regulations, the agency created hundreds of pages of technical requirements for pollution prevention and control, drilling, well-completion operations, oil and gas well-workovers, production and safety systems, platforms and structures, pipelines, well production, and well-control and -production safety training. To assess compliance with these requirements, MMS was to conduct unscheduled inspections of offshore drilling operations using a national checklist. The actual inspections only covered a subset of the list, 80% of which had to do with safety. There was no oil and gas inspection certification program or exam required for inspectors to become certified, and many inspectors simply planned to learn about the drilling industry while at the facilities conducting inspections. In an evaluation by the Outer Continental Shelf Safety Oversight Board, it was determined that "MMS lack[ed] a formal, bureau-wide compilation of rules, regulations, policies, or practices pertinent to inspections, [and did not] have a comprehensive handbook addressing inspector roles and responsibilities" (National Commission, 2011, p. 94).

In 1990, the Marine Board of National Research Council determined that MMS needed to place less emphasis on finding "potential instances of non-compliance" (National Commission, 2011, p. 86), and more on detecting accident-prone situations. The agency was also required to update their program in accordance with changes going on in offshore drilling environments, but in the

1990s, the resources available to them declined and federal regulations increasingly lagged behind. The United States Coast Guard, with responsibility over the vessels and facilities working on the Outer Continental Shelf, was also facing budgetary restraints at this time and hadn't majorly revised marine-safety rules since 1982. Ultimately, the overlaps in responsibility between MMS and the Coast Guard led to a shortage of resources for both (National Commission, 2011).

Lack of due diligence was evidenced in many ways. Although third party tests found blowout preventers on drilling rigs had a high possibility of failure under deepwater conditions, MMS started testing them less frequently based simply on industry claims that they were very reliable. Eventually, MMS did conclude that operators were basing their representations of the blowout preventers' effectiveness on inconsistent information, however they never revised blowout preventer regulations. Despite the fact that so many third party contractors were getting involved in the drilling industry, MMS did not update regulations to account for this. Additionally, the issue of conflicting responsibilities remained: MMS directors continuously acknowledged that royalty issues took up most of their time, taking away from regulatory oversight duties (National Commission, 2011).

In 1996, MMS implemented a safety and environmental management program holding drilling site operators responsible for participating. However, only voluntary compliance was required because they wanted to be seen as a partner to the industry, rather than an enemy. Regulatory incentives such as this were met with a lot of opposition from various federal agencies and oil companies, with the argument that they were too burdensome (National Commission, 2011).

Another problem with MMS as a regulator arose due to technicalities. As desk job employees working typical office hours, regulators could not keep pace with around-the-clock oil drilling. On-call responsibilities were assigned out to senior engineers who did not even have full access to MMS databases due to security purposes. These complications led to operators from oil companies "shopping around" until they could find an approving engineer for each of their projects (National Commission, 2011).

2.4 A Condensed History of British Petroleum (BP)

British Petroleum (BP) was founded as Anglo-Persian Oil Company in 1909, and became BP in 1954. With decades of expansion and success, the company made a name for itself in the global energy market. As oil drilling developed over time, the company did as well. In 1989, the executive Vice President of Sohio (BP's American subsidiary) reorganized BP around a rigid performance ethic and high-risk, high-return opportunities. Advances in technology encouraged the exploration of new and risky prospects, since out in deepwater these risks were often rewarded with large oil deposits. In the early 2000s, BP held the most acreage in the Gulf and one-third of deepwater reserves. At any given time, the company had numerous ongoing projects, each of which required coordination between different contractors, as well as investment before they could become profitable (National Commission, 2011).

A company involved in a dangerous industry, BP has always had a questionable safety reputation. For example, in 1989, the *Exxon Valdez* spill was the largest oil spill in history. BP had a controlling interest in Alyeska, the company that failed to respond quickly or effectively to the oil spill. BP's poor safety reputation extended beyond drilling operations and included other questionable decisions. In 2002, BP falsified inspections of fuel tanks at a Los Angeles refinery, and in 2007, BP pled guilty to a criminal violation of the Clean Water Act to resolve criminal liability relating to pipeline leaks of crude oil in Alaska. Explosions and fires at a BP Texas City Refinery in 2005 were caused by organizational and safety deficiencies at all levels of BP (Cleveland, 2013).

2.5 The Macondo Well Project

In the past decade, MMS divided the Mississippi Canyon, an undersea area in the north-central Gulf of Mexico, into numbered federal oil and gas lease blocks. On March 19, 2008, the agency leased Mississippi Canyon Block 252 to BP. The lease, Lease Sale 206, would last for ten years, beginning on June 1, 2008. BP was the lease operator, with 65% control (BP, 2010).

Upon obtaining the lease, BP began crafting an exploration plan to drill the Macondo well. The MMS personnel in charge of reviewing permits and requests from BP did not have any guidelines or requirements for evaluation of aspects critical for well safety. However, with a lack of internal expertise, it is unlikely they would have been able to properly interpret this information, had it existed. Due to the categorical exclusion of leases in the Gulf of Mexico, there was no NEPA review of the well's permitting. In fact, no agency gave significant attention to any federal laws in terms of environmental mandates for this lease block (National Commission, 2011).

MMS approved BP's final exploration plan on April 6, 2009, and approved an *Application for Permit to Drill* on May 22, 2009. Several modifications were made throughout the drilling process, which is typical of this kind of operation (BP, 2010). To comply with the Oil Pollution Act of 1990, BP created an Oil Spill Response Plan, which was also approved by MMS, despite its lack of attention to detail. For instance, the plan included text directly copied from the NOAA website that mentioned sea life inexistent in the Gulf. MMS did not further analyze any part of the plan (National Commission, 2011).

The BP Macondo well engineering team, BP subsurface team, and selected specialist contractors designed the Macondo well as an exploration well. This kind of design allows for later completion if exploration leads to sufficient hydrocarbons, and thus oil, being found. Taking into account estimated pore pressures and strength of the area's geological formations, the plan included everything from well equipment and operations to sealing of the well and testing of the seal's reliability (BP, 2010).

BP hired offshore drilling contractor Transocean to provide the rig and crew needed for drilling operations, and specialized contractors on board Transocean's semi-submersible rig, *Marianas*, began drilling the Macondo well on October 6, 2009. Operations continued until November 8, 2009, when a hurricane halted drilling and caused sustained damage to the rig. *Marianas* went off contract, and BP submitted an *Application for a Revised New Well*, updating the Macondo well plan to replace *Marianas* with the *Deepwater Horizon* rig. This application was approved by MMS on January 14, 2010. Also owned by Transocean, *Deepwater Horizon* had been under contract with BP in the Gulf of Mexico for nine years. In this time, it drilled approximately 30 wells, two-thirds of which were exploratory wells. The rig not only had experience with drilling jobs such as this one, but it was considered to be one of the best performing rigs in BP's fleet in terms of safety and drilling, and had not had a single "lost-time incident" in seven years of drilling (National Commission, 2011). *Deepwater Horizon* had passed several tests and inspections since it entered Transocean's service, including "regular inspections" by MMS. According to Transocean, none of these tests ever indicated any repairs be made by the rig crew (Transocean, 2011). However, a September 2009 BP safety audit produced 390 items and 3545 man-hours of work needed on the rig, showing that it was behind on many maintenance checks and tests, some of which were high priority (National Commission, 2011).

Drilling recommenced on February 6, 2010. The crew on board *Deepwater Horizon* at any given time consisted of rotating groups of workers from various companies, including Halliburton cementers, Sperry Sun mudloggers, mud engineers from M-I SWACO, ROV technicians from Oceaneering, and tank cleaners and technicians from OCS Group (National Commission, 2011). BP crewmembers on board included two Well Site Leaders, who represented BP's authority on the rig; a Well Site trainee; and three subsea personnel. Transocean's team consisted of drill, marine, and maintenance crews, with the Offshore Installation Manager (OIM) in charge as the senior Transocean manager. The senior toolpusher led the Transocean drill team, with two toolpushers, drillers, and assistant drillers below him. The captain of the rig was also from Transocean, and was in command during emergency operations following the blowout of the well (Transocean, 2011).

2.6 Investigations Following the *Deepwater Horizon* Disaster

After the Macondo well's blowout and subsequent rig explosion and oil spill on April 20, 2010, investigations of the involved regulatory agencies and companies, as well as relevant decisions made by them, were extensive and thorough. Each report on the disaster highlighted events leading to the blowout differently, allowing for various interpretations of where fault lay. Only by a methodical examination of a range of the reports surrounding the incident, with an eye for bias, can the story of what really happened be pieced together.

It is beyond the scope of this thesis to analyze every extensive investigation of the disaster. Thus, major reports from conflicting entities were selected for close examination. As the operator in charge of the Macondo well project, BP's internal investigation, "*Deepwater Horizon*: Accident Investigation Report", was chosen. It is noted that a team within BP conducted the report, giving it an inherent bias. This bias becomes clear through aspects of the report such as its specific referral to the "BP Macondo well team" throughout, rather than BP as a whole corporation (BP, 2010).

The second report selected was that of Transocean, a company contracted by BP, but with no allegiance to them. Transocean's internal report team consisted of experts from relevant technical fields and specialists in accident investigation (Transocean, 2011).

Finally, a major government report on the incident was chosen, as it was a party uninvolved in actual drilling operations. President Obama's National Commission on the BP *Deepwater Horizon* Oil Spill and Offshore Drilling conducted this investigation, which is unique from the other two reports in that it seeks to build drama and gain sympathy for the environmental and human impacts of the spill (National Commission, 2011).

All three investigations began within a month after the incident and had their limitations. Because the explosion caused so much destruction, there was a scarcity of physical evidence. Additionally, the environmental impact from the spill will not be fully realized for years to come.

The BP report (2010) puts the burden of blame for the explosion on a "well integrity failure" that allowed hydrocarbons to escape up onto the rig, as well as blowout preventer failure. However, BP does acknowledge fault in some decisions made on board the rig, both by BP and Transocean employees (BP, 2010).

Transocean's report (2011) summarizes the incident as "a result of a succession of interrelated well design, construction, and temporary abandonment decisions that compromised the integrity of the well and compounded the risk of failure" (Transocean, 2011, p. 10). However, it ultimately places all blame on BP, noting that the company had certain oversight responsibilities as operator of the project: surveying the geology of the area, designing the well and cement specifications based on this, obtaining approval from MMS, contracting work to various experts, overseeing and performing quality assurance on all aspects of drilling operations, and approval and advisement over all decisions made by involved parties. The report states that “BP failed to properly assess, manage, and communicate risk” (Transocean, 2011, p. 10), and was operating based on finishing the drilling during a narrowing window for safe operations. Transocean only deems itself responsible for providing the rig and drilling crew, monitoring the presence of gas in drilling mud, and adjusting mud properties and weight as needed. Supervision of cement operations was attributed to Halliburton; most monitoring and maintenance of logs during drilling to Sperry Sun; and most mud testing and recommendations to M-I SWACO (Transocean, 2011).

The National Commission’s report (2011) puts blame in more general terms, citing overall failures in risk management and safety culture by BP, Halliburton, and Transocean. In addition, the report notes that deepwater drilling is a relatively new industry without sufficient information or rules in place to help avoid risks or deal with the consequences when these risks are realized. With a move to deepwater drilling, there was a lag in updating safety, containment, and response equipment, as well as drilling practices. Some blame is placed on the federal government for making policies to accelerate offshore exploration and development faster than technology and legislation could keep up (National Commission, 2011). It is worth noting that the report by a federal agency is the only one that places major blame on the federal government for the disaster.

2.7 Early Problems with the Macondo Well Project

BP’s report (2010) lists two events that occurred in the months leading to the blowout of the Macondo well that may have been mishandled. On March 8th, a well control event similar to the actual blowout occurred. Despite successful damage control, the team's response time was deemed too slow. There is no evidence that Transocean took any documented, corrective actions with the rig crew regarding this. A report on the event was completed, but findings were not listed and changes made to prevent this kind of event from happening again were "still under review" at the time of the April 20th blowout (BP, 2010).

Drilling of the final section of the well began on April 2nd, but was stopped for a few days due to a lost circulation event. The well was drilled to its final depth of 18,360 feet on April 9th. Five days were spent evaluating the well and ensuring it was in good condition. It was verified that no gas was entrained in the mud, and no appreciable volumes of gas were recorded, indicating stability. However, the lost circulation event was cause for extra caution and reevaluation of plans (BP, 2010).

2.8 Unconventional Plans for Temporary Sealing of the Well

Once it was determined that the "pay zone" the drilling had tapped into would be profitable, it was time to temporarily abandon the well. Completion of the project would be handed over to a new rig after the removal of the riser and blowout preventer from the wellhead (National Commission, 2011).

Due to the lost circulation event on April 2nd, the production casing choice was reevaluated. The original recommendation had been to use long-string casing, which according to the BP (2010) and National Commission (2011) reports was the less risky option. BP and Halliburton engineers used computer programs to model potential outcomes of the cementing process, and as a result changed their recommendation to using a “liner”—an allegedly more complex and leak-prone option for this scenario. Within BP, this decision was not well received. An in-house BP cementing expert reviewed Halliburton’s recommendations and changed certain inputs when he evaluated potential outcomes. His results showed the long-string casing to be more effective, so the recommendation was switched back (National Commission, 2011).

Transocean’s investigation (2011) of the accident highlights this as one of BP’s poor decisions leading to the blowout. Blame is placed mostly on BP, but also on Halliburton for not adequately testing the cement program. The report lists alternative technology BP could have used instead, as well as a deferred installation of the casing that could have been chosen over the long-string production casing. Transocean’s is the only report that claims the option used was more risky (Transocean, 2011).

Another deviation from the original well abandonment plan involved the number of centralizers used. Although the plan had called for sixteen centralizers, Weatherford only had six in stock at the time. An alternative was to use “slip-on” centralizers, but the BP team and Wells Team Leader, John Guide, distrusted these on the basis of the technical difficulties that might arise from them. A Halliburton engineer ran OptiCem to help predict the outcome of the cement job based on the variables. The results from this indicated that the Macondo well would need more than the six available centralizers. The BP Drilling Engineering Team Leader, Gregory Walz, obtained permission from his senior manager to order the maximum amount of slip-ons possible for immediate transport. According to OptiCem results, this new total of 21 centralizers would improve the cement job outcome. Walz then emailed Guide that he and the senior manager felt they needed these additional casings in order to honor the OptiCem results. He additionally stated that the newly ordered slip-ons would be of special design and only one piece. However, upon their arrival, a BP engineer reported the casings were actually of conventional multi-piece design. Guide responded to Walz's email, arguing that the slip-ons were not specially designed and that it would take ten hours to install them. Additionally, a BP drilling engineer agreed that they probably didn't need the extra slip-ons, and ultimately only six centralizers were used (National Commission, 2011). This convoluted decision-making process and lack of attention to expertise was characteristic throughout the drilling of the Macondo well.

MMS approved of temporary well abandonment, including the last-minute changes, on April 16th (BP, 2010), although this was not the final version of the plan that was actually used. The plan began with placement of production casing, which would be challenging because of lost mud circulation problems and the delicate rock formation at the bottom of the well. Next, it listed that Halliburton would pump a specialized cement blend down the casing string and then up into the annular space to seal the well off. This would not be successful unless it isolated the hydrocarbon-bearing zone from the annular space. BP's plan also included placement of the cement plug 3300 feet below the ocean floor, which was both unusual and deeper than MMS regulations allow without analysis and subsequent exemption (National Commission, 2011).

A main cause leading up to the blowout that was listed by the National Commission (2011) and Transocean (2011) reports, but not BP's (2010), was this temporary abandonment procedure. Because of BP's unnecessary decision to replace mud with seawater 3300 feet below the mud line, the National Commission's report (2011) states that more stress was placed on the cement job at the bottom of the well. Additionally, the decision to displace mud from the riser before setting a surface cement plug or other barrier in the production casing would make the cement barrier the only barrier between the oil and the rig (National Commission, 2011). Transocean's report (2011) states that BP had an overall lack of risk assessment and safety procedures, including those involving last-minute adjustments to a continuously altered temporary abandonment plan, which was never approved by MMS in its final form. The report claims that the biggest flaw in the plan was the displacement of large amounts of drilling mud, which it deems was unnecessary. M-I SWACO gets little blame for developing the displacement procedure, since it is BP that ultimately approved it (Transocean, 2011).

2.9 Failure of Cement Job to Seal the Macondo Well

Once temporary abandonment procedures were approved, preparations for the cement job began: the float collar would need to be converted so that fluids could no longer come back up the casing. To convert the valves, mud was pumped down through the casing. Although the team pumped fluids up to a high pressure, flow was not established. The BP Well Site Leader, Robert Kaluza, and an engineer contacted BP's John Guide and decided to increase pressure. M-I SWACO had predicted that 6 BPM would be required to circulate the mud, but although the pump rate never exceeded 4 BPM, mud did begin to flow. BP's team concluded that the pressure gauge was broken and the float collar had converted (National Commission, 2011). Transocean's report highlights this as another of BP's poor decisions, as it reflected another deviation from the original plan. The report states BP may have acted this way due to time constraints, despite the anomalies (Transocean, 2011).

With the float collar deemed successfully converted, it was time to begin the cement job. Cement would be pumped down, followed by mud to push the cement up through the annular space for a long and continuous seal of the well. This is a difficult task involving a reliance on indirect measures such as pressure and volume to gauge progress deep down in the well. BP was very concerned with "losing returns" by fracturing the formation at the bottom of the well, which would result in critical cement flowing out and being lost, and leave the annular space open to hydrocarbon flow. Concerns such as these put constraints on Halliburton's cementing design, including limiting circulation of drilling mud through the wellbore before cementing, rather than "bottoms upping" the cement. Additionally, the cement would be pumped down at a low rate, even though faster rates usually result in more efficiency. As a safeguard against errors, extra cement is often used. However, in this case the volume of cement to be pumped down was limited, leaving little margin for error. Nitrogen foam cement would be used to lighten the cement slurry, reducing the pressure the cement would exert on the delicate rock formation (National Commission, 2011).

Halliburton had begun designing the cement job months earlier. Prior to use, it was required that the cement slurry be tested. The earliest cement testing by Halliburton showed severe failings, and these results were never reported to BP. In March, BP received lab test results from Halliburton indicating that the design was still unstable under different conditions. The Halliburton engineer on board that commissioned the test did not comment on the instability and there is no evidence that BP examined the data at all. In mid-April, more specific well condition information became available, so Halliburton conducted more tests. The first test indicated instability, but was not reported to BP. For a follow-up test, Halliburton altered the conditions slightly, and finally got results indicating stability. However, due to the time frame, it is unclear if the Halliburton cement team on board *Deepwater Horizon* saw these positive results before pumping the cement job, and BP did not receive the results until almost a week after the blowout. Additionally, there is no evidence of either party requesting the results (National Commission, 2011). The BP internal investigation (2010) concedes the point that although Halliburton did not conduct all of the relevant tests before final cement placement, the BP Macondo well team was also at fault for failing to ensure they did so (BP, 2010). Both parties lacked the incentive to confirm safety precautions were taken.

After the primary cement job was pumped, a BP representative and Halliburton's Service Supervisor performed an evaluation and determined that the float collar was closed and holding. 5.5 barrels of flow-back were observed, although it had been predicted that 5 barrels of flow-back would indicate success. Despite a 2007 MMS study noting that cementing problems were one of the most significant factors involved in recent well blowouts, a BP engineer decided that this was within an acceptable margin of error. There were no lost returns, so according to the original abandonment criteria, the job was considered a success. Both BP and Halliburton agreed they had done a great job. BP's abandonment plans stipulated that if there were no losses while cementing the long-string, a cement evaluation test by technicians from Schlumberger would not be necessary. Thus, the technicians were sent home, saving BP both time and $128,000 (National Commission, 2011).

All three reports cite the failure of the cement job as a major cause of the well's eventual blowout. Specifically, both the annulus cement barrier and cement in the shoe track and float collar failed to isolate hydrocarbons from entering the well. BP's report (2010) places blame on BP and Halliburton. The BP Macondo well team did not fully conform to BP's Engineering Technical Practice when they failed to conduct a formal risk assessment of the annulus cement barriers and provide effective quality assurance on Halliburton's technical services. The well team also did not give BP zonal isolation experts the opportunity to perform effective quality assurance of the cement design, although the report makes no mention of BP management demanding this opportunity be provided. The report states that Halliburton probably did not supervise the in-house cement job. Additionally, in the investigation of the blowout, a third party tried to replicate the cement design, and results from testing of this indicated the cement used was most likely unstable (BP, 2010).

Transocean's report (2011) places blame for the failed cement job on mismanagement within BP, rather than on Halliburton's cement design. The report states BP was at fault for requesting a complex cement design; not conducting critical tests despite the risky conditions; and failure to use "bottoms up" circulation or test the cement job after it was completed. Additionally, it states that it was BP's responsibility to fully communicate information about the testing (or lack-thereof) of the cement and other barriers in the well to the crew. Because they did not do this, all of the drill crew actions were performed under the assumption that there was nothing wrong with the well or cement job—a point mentioned repeatedly throughout the report. There is a brief reference to Halliburton's failure to properly test the cement design, but blame is focused on BP. This is unique from the other two reports, which repeatedly mention Halliburton's fault in the cement design, testing, and communication with BP, and in beginning the job before positive results on the cement design were obtained. Finally, Transocean states their employees had no role in any part of the cement design or installation (Transocean, 2011).

The National Commission's report (2011) offers specifics of the failure of the cement job that the other reports do not. For example, the team's decision to use a long-string casing instead of a liner should have inspired more caution in BP and Halliburton, and the process of choosing the number of centralizers to use highlighted the poor communication between BP and Halliburton. Additionally, BP failed to consider what anomalous pressure readings may have indicated in relation to float valve conversion and circulating pressure. Lost returns should not have been the only indication that the cement job needed to be tested, so that the

Schlumberger team would not have been sent away. There was further lack of communication regarding cement testing when Halliburton did not report the results to BP, and in turn, BP did not request the results. Finally, BP did not exercise special caution before relying on the primary cement barrier (National Commission, 2011).

2.10 Failed Temporary Abandonment of the Macondo Well

The cement job had been completed during the early morning hours of April 20, 2010, the day of the well's blowout. There were a few anomalies in the crew on board that day. The BP Well Site Leader had flown back to shore four days earlier for a required well-control class, so Robert Kaluza was temporarily on board to fill in for him. Additionally, "VIPs" from Transocean and BP were on board for a tour and update on the proceedings, and had been giving the crew high praises for their work (National Commission, 2011).

With the casings, centralizers, and cement job in place, a BP engineer sent the temporary abandonment procedures to on board officials at 10:43AM on April 20th—the first time the BP Well Site Leaders saw the final procedures (Transocean, 2011). There was "no evidence that these changes went through *any* sort of formal risk assessment or management of change process" (National Commission, 2011, p. 120), despite the fact that MMS regulations require approval of temporary abandonment procedure plans at least 48 hours before the process begins (Transocean, 2011). The *Application for Permission to Modify* the temporary abandonment plan that had been approved by MMS was different than the final plan sent out, as well as previous versions of the plan that had been proposed. The rig crew did not see the final temporary abandonment plan until their 11:00AM meeting. The procedure called for a positive pressure test, running the drill pipe into the well 3300 feet below the ocean floor, displacement of 3300 feel of mud with seawater, a negative pressure test, setting of a cement plug 3300 feet below the ocean floor, and setting the lockdown sleeve. Some of these steps would never be completed (National Commission, 2011).

First, the crew performed a positive pressure test to ensure the integrity of the production casing. This step was required by MMS. They ran the test twice, and pressure remained steady each time, indicating there were no leaks from inside the well. The drilling crew, BP's Kaluza, and a visiting BP executive deemed the test a success (National Commission, 2011).

The next step was a negative pressure test to evaluate the integrity of the casing and the bottomhole cement job, as well as to ensure that outside fluids were not leaking into the well. This was the only test included in the plan that would have detected if fluids like hydrocarbons could leak in through the bottom of the well. For the test to be successful, there should have been no flow out of the well or pressure build up inside the well for a sustained period. It was critical that the well be able to withstand the underbalance of pressure that would occur after temporary abandonment was completed. If the test failed and hydrocarbons could leak in, diagnosing and fixing the problem could take days. For a key part of the procedure, BP chose unusual spacer fluids to separate the oil-based drilling mud from seawater. M-I SWACO made a large quantity of this spacer out of two different lost-circulation materials left over on the rig. In accordance with the Resource and Conservation Recovery Act, BP would have needed to dispose of these materials as hazardous waste onshore had they not made the decision to use them in this way. The unique spacer created was never thoroughly tested for its purpose (National Commission, 2011), and it may have been selected as a time- and money-saving shortcut for BP.

The negative pressure test was first performed on the drill pipe, which required opening it and bleeding its pressure to zero to watch for flow. When the crew did this, they could not get the pressure down to zero, and upon closing it again, the pressure jumped right back up. At this point, both toolpushers and both Well Site Leaders were present, as well as the BP and Transocean executives leading the rig tour. The test results indicated that fluid spacer was leaking down past the annular preventer, so the Transocean Offshore Installation Manager ordered it be more tightly closed. When they opened the drill pipe for a second try, the pressure did go down to zero, but as soon as it was closed, the pressure again jumped back up. After repeating this a third time, the pressure jumped up even higher—something was amiss (National Commission, 2011).

BP and Transocean team members discussed the readings. A very experienced toolpusher, who was moving on to teach in Transocean's well control school the following day, was involved in the test (National Commission, 2011). He explained the irregular pressure readings as an anomaly called the "bladder effect", which he and a driller stated they had seen before. The rig crew and BP Well Site Leader found the explanation plausible without much question, and deemed the test successful. However, there is no evidence that a "bladder effect" has ever occurred, or is even possible (BP, 2010).

According to BP's report (2010), the team began the test on the drill pipe because this was the crew's "preferred method". However, around 5:30PM, the test was moved over to the kill line. Both the BP (2010) and National Commission (2011) reports explain that in the original application approved by MMS, this was the designated site for the negative pressure test. BP's Well Site Leader made the decision to move it in order to correct the crew's mistake (BP, 2010). However, Transocean's report (2011) states that moving the test to the kill line was a mistake that led directly to results being misinterpreted, and blame is placed on BP for making this decision. According to this report, a successful negative pressure test on the kill line could never have been achieved due to flaws in the displacement plan, including the unique spacer used and its presence below the closed annular preventer. This reasoning removes blame from the Transocean drill crew, who had been performing the test on the drill pipe (Transocean, 2011). The kill line test should have indicated the same pressure as the test on the drill pipe, but although the kill line test was deemed successful, pressure remained on the drill pipe. There is no evidence that the Well Site Leaders or crew ever explained these two different pressure readings, and "based on the available information, the 1400 psi reading on the drill pipe could *only* have been caused by a leak into the well" (National Commission, 2011, p. 124-5).

In addition to this inconclusive explanation, BP's report (2011) places some blame on management for the incorrect interpretation of the negative pressure test.

MMS regulations lacked specific minimum procedures and success/failure criteria for negative pressure tests, and neither BP nor Transocean provided any guidelines either. Thus, crewmembers were left to make the decision of what a "successful" test meant at their own discretion. Because of this, BP and Transocean rig leaders should have been more careful during the test. The Transocean Well Control Handbook stated that the rig crew should have consulted the Transocean 'manager' with the results of the test, although who exactly this is was not stated. The crew did not follow this protocol (BP, 2010).

Transocean's report (2011) also states misinterpretation of the negative pressure test results as a major cause of the blowout, blaming MMS and the industry for a lack of established standards for the test, and BP as the operator for deeming the test successful (Transocean, 2011).

The National Commission's report (2011) lists the negative pressure test as a major problem as well, and points out that the test should not have been the only measure of cement integrity relied upon. Despite the fact that pressure data had continued to indicate that fluids were entering the well, crewmembers only looked for explanations, rather than accepting what the test was indicating: the cement had failed to seal the well. Like the other reports, the National Commission's report (2011) mentions the lack of standard procedures for the test and its interpretation. MMS is blamed for this, as well as BP and Transocean for their lack of specific protocol or trained personnel. Additionally, BP had no regulations for reporting back to shore with anomalous data (National Commission, 2011).

After the negative pressure test was completed, it was time for displacement of 3300 feet of mud with seawater. During displacement, there is greater risk for a kick, and drillers from Transocean and mudloggers from Sperry Sun were the crewmembers responsible for detecting one. These crewmembers were supposed to monitor data that included the volume of mud in active pits, an increase of which would mean something was flowing into the well. Flow into and out of the well was also to be monitored—when flow out is greater, this indicates a kick. Visual "flow checks" were one way the crewmembers could have monitored this, as well as ensured flow out of the well stopped when the pumps were shut off. The driller and mudlogger were specifically in charge of monitoring the drill pipe pressure, which is a more ambiguous indicator of a kick (National Commission, 2011). The Transocean Well Control Handbook stipulated that the well should be monitored at all times, but did not explain how this should be done in special circumstances, like during in-flow testing or cleanup. Drillers, indicated by Transocean's policies as responsible for monitoring a well's flow conditions and shutting off the well at an indication of flow, should have had multiple ways to monitor flow under any circumstances. Although instructions for the closing of a well with a small influx of fluids were given, there was no mention of what to do in an emergency situation such as loss of well control. Protocol additionally did not include how to handle continuous flow (BP, 2010).

Around 8:00PM, the displacement of 3300 feet of mud with seawater began. Displaced mud was rerouted between pits to accommodate the constantly incoming volume. During displacement, a Sperry Sun mudlogger told a Transocean assistant driller that pit levels could not be monitored during offloading of the mud onto

Deepwater Horizon's supply vessel, *Damon Bankston*. The assistant driller responded that the mudlogger would be notified when the offloading stopped, but during this time no reliable flow data was recorded. Additionally, when offloading did end a couple hours later, the assistant driller did not notify the mudlogger (BP, 2010), highlighting the lack of communication between involved companies. The drill pipe pressure had been decreasing as it was supposed to until 9:00PM, when pressure began to slowly increase. There was a lot going on, and no one noticed this. Because mud was being sent from many locations into the active pit system at this time, the National Commission's report (2011) indicates it may have been difficult to adequately monitor active pit volume (National Commission, 2011).

The crew needed to dump spacer fluid returned to the surface overboard, but first had to conduct a "sheen test" to make sure all the oil-based mud had been removed from the riser. At 9:08PM, they shut down the pumps to perform the test, and the BP Well Site Leader deemed there was no oily sheen in the sample (National Commission, 2011). Transocean's report (2011) states that spacer had not yet reached the surface at the time of the test, which is the only reason it was interpreted as successful (Transocean, 2011). A mudlogger performed a visual flow check to ensure the well was not flowing while the pumps were off. Although no one noticed at the time, Sperry Sun monitoring data was clearly indicating that the drill pipe pressure had continued to increase, rather than stay constant or decrease, as it should have. Four minutes after the pumps were turned back on, a pressure-relief valve on one of the pumps blew, and a team of the chief electrician, assistant driller, and three other personnel was sent to fix it. They were still doing this when the explosion occurred (National Commission, 2011).

Around 9:18PM, the pressure of one of the pumps discharging displaced well fluids and mud overboard spiked, and all three pumps were shut down (BP, 2010). The shut down meant the cement plug placement would be delayed (National Commission, 2011). The toolpusher reported to the senior toolpusher that displacement was “going fine”, so the pumps were restarted for a little, only to be shut down again as drill pipe pressure continued to rise and remain higher than kill line pressure (BP, 2010). At 9:36PM, Transocean’s on-duty driller, Dewey Revette, ordered a crewmember to bleed off the drill pipe pressure to eliminate the difference, which worked for a second before pressure started to go up again. Despite this evidence of a kick building, no crewmember performed a visual flow check or took actions to shut in the well. At 9:39PM, drill pipe pressure finally started to decrease. The National Commission’s report (2011) states that in retrospect, this indicated that hydrocarbons were beginning to push heavy drilling mud out of the way past the drill pipe (National Commission, 2011).

Revette first realized a kick had occurred around 9:40PM when drilling mud began spewing on to the rig’s deck. The toolpusher and assistant driller immediately routed mudflow from the riser through the diverter system, sending it to the mud gas separator rather than overboard (National Commission, 2011). The Transocean Well Control Handbook states that flow should be diverted to the mud gas separator during certain well control situations, but in the case of gas expansion in the riser, it is indicated that flow should be diverted overboard (BP, 2010). The National

Commission's report (2011) indicates that if this had been done, the crew would have saved precious time and chances for ignition would have been reduced (National Commission, 2011), providing another example of the problems caused by a lack of attention to safety protocol.

At 9:45PM, the assistant driller called the senior toolpusher to report that the well was blowing out and they were shutting in the well by closing the annular preventer. This is about the same time that *Damon Bankston* was warned to stay back because of well problems (BP, 2010). Unfortunately, it was too late. Gas was already above the blowout preventer when shut-in began, and the mud gas separator was completely overwhelmed by flow from the well. The first explosion occurred at 9:49PM, and was followed quickly by a second (National Commission, 2011).

In all three reports, the delayed action of the rig crew is listed as a major mistake that led to the failure of the annular preventer to fully seal the well. Sperry Sun data indicating a kick and warranting closer examination was available much earlier than detection occurred. Although Transocean's handbook calls for well monitoring at all times, it does not specify how to do so in special circumstances, which BP's report (2010) lists as a mistake of Transocean's (BP, 2010). Transocean's report (2011) states that once the influx was detected, the crew acted properly and according to their training, and that the explosion was inevitable (Transocean, 2011). The National Commission's report (2011) concludes that there should be automated alarms put into monitoring systems on board drilling rigs that can detect anomalies requiring attention from the crew (National Commission, 2011).

BP's report (2010) was unique in placing blame for the failure of some of the systems on board *Deepwater Horizon* for the blowout, indicating Transocean maintenance was at fault. For example, the National Commission's report (2011) states that the problem was the decision to rout flow to the mud gas separator (National Commission, 2011), whereas BP's report (2010) states it was the design of the mud gas separator that was flawed, since it was overwhelmed by the influx. Additionally, the design of the heating, ventilating, and air conditioning (HVAC) system allowed for a gas rich mixture to enter the engine rooms, creating a potential ignition source. The report states that the system should have had an automated function to help prevent fire and gas from entering vulnerable locations, and that the engine room HVAC system should have been designed to block gas automatically (BP, 2010). Transocean's report (2011) states that the fire and gas detection system, which was integrated with the HVAC system, was designed and maintained according to regulations, and functioned as it should have on the night of the blowout. Furthermore, it states that the HVAC system actually served to help ensure safety of personnel on board (Transocean, 2011).

2.11 Failure of Emergency Procedures Following the Blowout

Following the blowout, multiple emergency mechanisms failed to seal the well and subsequently, prevent the explosions. According to both BP's (2010) and the National Commission's (2011) reports, the blowout preventer was one of the main mechanisms that failed. Although the recommended time for recertification was five years, parts of the blowout preventer had not been recertified in nine years.

Additionally, its maintenance was not properly recorded, which Transocean was blamed for (National Commission, 2011). BP's report (2010) concedes blame in that there were potential weaknesses in testing methods and the maintenance management system for the blowout preventer, as well as the fact that the crew was not adequately prepared to use it. It places blame on Transocean for not fully addressing what to do in high-flow emergency situations after well control is lost (BP, 2010).

Unlike the other investigations, Transocean's (2011) states that "forensic evidence from independent post-incident testing by Det Norske Veritas (DNV) and evaluation by the Transocean investigation team confirm that the *Deepwater Horizon* [blowout preventer] was properly maintained and did operate as designed" (Transocean, 2011, p. 11). However, the report does cite that there were some minor leaks in the blowout preventer, found both before and after the accident, although it claims these had no effects on functionality (Transocean, 2011). This is the only report to dedicate an entire section to the blowout preventer and its design, purpose, and functionality, probably because it was the property and responsibility of Transocean.

After the kick was detected, the annular preventer inside the blowout preventer was activated, followed by the variable bore ram, but flow rates at this point were probably too high for these mechanisms to effectively seal the well (National Commission, 2011). This is in direct contrast with Transocean's report (2011), which states that the blowout preventer was fully operational and functioned properly. The report cites the influx of hydrocarbons for the failure to fully seal the well, rather than the blowout preventer itself (Transocean, 2011).

The blowout preventer's "deadman system", which had been installed to automatically trigger the blind shear ram in the case of lost power and communication also failed. Failure of this system was attributed to poor maintenance, rather than damage from the explosion. BP's (2010) and the National Commission's (2011) reports both state that two control pods critical to the system were faulty: one's battery was almost dead and another had defective solenoid valves. It was reported that Transocean did not change the batteries on the control pods as often as was required. Additionally, the National Commission's report (2011) states there had been no surface testing of the deadman system, which would have led to discovery of blowout preventer hydraulic leaks (National Commission, 2011).

Transocean's report is the only one that states the control pods on the blowout preventer were "fully functional at the time of the incident" (Transocean, 2011, p. 158), despite conceding problems with the battery and solenoid valve. Thus, the report claims full functionality despite these issues. As blowout preventer maintenance was mostly Transocean's responsibility, it is clear why they argue they were not to blame for its shortcomings. While the other reports indicate that it was the explosions that prevented the deadman system from engaging, Transocean reports that the system did engage, however the blind shear rams it activated did not fully seal the well (Transocean, 2011). These types of discrepancies between the reports are evidence of the shifting of blame that has been consistently occurring since the disaster due to a lack of clear accountability set forth in the industry.

The emergency disconnect system (EDS) was another backup mechanism that should have closed the blind shear ram, severed the drill pipe, sealed the well, and disconnected the rig from the blowout preventer, but it failed as well (National Commission, 2011). Although Transocean protocol gives no mention of when, or if, the EDS should be activated, the subsea supervisor attempted to activate it within minutes of the blowout (BP, 2010). In order to do so, the Offshore Installation Manager's approval was needed, meaning there was a slight delay due to communication (National Commission, 2011). Panel indicators lit up, so activation appeared to be successful. However, the rig never actually disconnected, possibly due to damage to the system from the first explosion (BP, 2010).

A BP senior manager, Transocean manager, and subsea engineers returned to the site the day after the explosions to dispatch an ROV to the blowout preventer (National Commission, 2011). This operation was undertaken with the intention of activating the blind shear ram to seal the well, but it failed to do so. BP accepted some of the blame for this, since Transocean policy called for testing of the ROV intervention system at the surface, which had not been done (BP, 2010).

The National Commission's report (2011) uniquely lists failures within the industry and the government as two major reasons for the blowout, placing almost all blame on ineffective supervision of offshore drilling, and specifically on MMS as a regulatory agency that had failed in enforcing its safety regulations for years. It points out that the industry and government were not adequately prepared for the risks involved with deepwater drilling, and that there had not been enough reform in industry practices and government policies over the years as deepwater drilling had developed. These failures went beyond BP to other operators in the industry as well, with better management and communication cited as necessary both within and among companies. Additionally, key engineering and rig personnel needed better training. The duty was placed on BP as the operator to have coordinated the various corporate cultures, internal procedures, and decision-making protocols of the contractors involved in operations. Specific to the Macondo well blowout, BP needed a better engineering perspective present throughout the end of the process, as peer review had only occurred during the early planning stages of drilling. This lack of expert perspective led the BP Macondo well team to make decisions on an as-needed basis, without proper risk analysis or specialist review. Examples of these decisions included the choice to use six versus twenty-one centralizers and the many alterations made to the temporary abandonment procedure. The entire decision-making process on site lacked risk assessment as time- and money-saving changes were made to plans. The report highlights nine timesaving decisions that were made instead of their less risky alternatives, and BP was named as either definitely or possibly responsible for making all of said decisions (See Figure 1).

Decision	Was There A Less Risky Alternative Available?	Less Time Than Alternative?	Decision-maker
Not Waiting for More Centralizers of Preferred Design	Yes	Saved Time	BP on Shore
Not Waiting for Foam Stability Test Results and/or Redesigning Slurry	Yes	Saved Time	Halliburton (and Perhaps BP) on Shore
Not Running Cement Evaluation Log	Yes	Saved Time	BP on Shore
Using Spacer Made from Combined Lost Circulation Materials to Avoid Disposal Issues	Yes	Saved Time	BP on Shore
Displacing Mud from Riser Before Setting Surface Cement Plug	Yes	Unclear	BP on Shore
Setting Surface Cement Plug 3,000 Feet Below Mud Line in Seawater	Yes	Unclear	BP on Shore (Approved by MMS)
Not Installing Additional Physical Barriers During Temporary Abandonment Procedure	Yes	Saved Time	BP on Shore
Not Performing Further Well Integrity Diagnostics in Light of Troubling and Unexplained Negative Pressure Test Results	Yes	Saved Time	BP (and Perhaps Transocean) on Rig
Bypassing Pits and Conducting Other Simultaneous Operations During Displacement	Yes	Saved Time	Transocean (and Perhaps BP) on Rig

Figure 1: Examples of Decisions That Increased Risk at Macondo While Potentially Saving Time
Note: From *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling*, National Commission on the BP *Deepwater Horizon* Oil Spill and Offshore Drilling

Additionally, the report states that it is "critical…that companies implement and maintain a pervasive top-down safety culture…that rewards employees and contractors who take action when there is a safety concern even though such action costs the company time and money" (National Commission, 2011, p. 142), indicating a rewards system could help avoid risk in this industry. When there is not adequate time for a full risk analysis, only proven alternatives should be used, but this was not the case on *Deepwater Horizon*. Furthermore, Halliburton did not have controls in place to make sure lab testing was performed in a timely manner, or that test results were gone over thoroughly, either internally or with BP. Although BP acknowledged that Halliburton was not very reliable with necessary, timely testing of cement, they still did not require Halliburton to complete the tests or report results back to BP before ordering the cement job to begin. This again highlights BP's failure to communicate effectively both internally and with contractors, leading to critical decisions being made without full knowledge of context. For example, the rig crew was not notified of the difficulties surrounding the primary cement job, so they were not as cautious when performing negative pressure tests and monitoring the well (National Commission, 2011).

BP is not the only company blamed for lack of communication in the report. Although it did not result in disaster, in December 2009 another Transocean rig had a similar incident in the North Sea. Transocean failed to communicate the lessons learned from this to its crew. The earlier incident also occurred while displacing mud with seawater, and the negative pressure test was also incorrectly deemed successful. Hydrocarbons entered the well, and mud spewed onto the rig floor, but the crew was able to successfully shut in the well before a blowout occurred. The incident cost the crew 11.2 days of work and more than 5 million British pounds in expenses (National Commission, 2011). An internal PowerPoint about the incident stated: "[f]luid displacements for inflow test [negative test] and well clean up operations are not adequately covered in our well control manual or adequately cover displacements in under balanced operations" (National Commission, 2011, p. 140), indicating more vigilance was necessary, as well as perhaps an updated well control manual. This PowerPoint was never shown to the *Deepwater Horizon* crew. An "operations advisory" was sent out in April 2010 to some rigs in the North Sea, reiterating lessons learned, and “mandatory” actions were set forth, including specified operations for when only a single mechanical barrier is present, such as was the case on *Deepwater Horizon*. However, again, the *Deepwater Horizon* crew never saw these advisements (National Commission, 2011).

The National Commission’s report (2011) places ultimate blame for the incident on regulatory agencies. In the investigation of MMS after the *Deepwater Horizon* blowout, “MMS staff…reported that leasing coordinators and managers discouraged them from reaching conclusions about potential environmental impacts that would increase the burden on lessees, ‘thus causing unnecessary delay for operators’” (National Commission, 2011, p. 98). It was also discovered that MMS managers altered scientists’ findings about environmental impact in order to expedite plan approvals; there may have been employee financial incentive to meet deadlines for leasing or development approvals. Furthermore, MMS regulations did not fully address the new practice of deepwater drilling. For example, there was no requirement or protocol for conducting and interpreting a negative pressure test. The government is blamed when the report states that “efforts to expand regulatory oversight, tighten safety requirements, and provide funding to equip regulators with the resources, personnel, and training needed to be effective were either overtly resisted or not supported by the industry, members of Congress, and several administrations” (National Commission, 2011, p. 142). MMS not only lacked resources and political support, but also personnel with proper expertise and training. For example, they made the decision to approve BP’s request to set the cement plug 3300 feet below the mud line in less than ninety minutes simply because BP convinced the approving official that this was necessary for setting the lockdown sleeve. The fact that there was an MMS regulation that plugs cannot be set more than 1000 feet below the mud line except in special situations was overlooked. Finally, MMS engineering's review of the temporary abandonment plan relied on initial well design, and lacked a full risk assessment (National Commission, 2011).

The stories told by the selected investigations list similar events leading to the blowout of the Macondo well and subsequent well control efforts, however each report places emphasis on different parts of the decision-making process. Read alone, each report cites specific blame for each mistake made during operations, but upon comparison, it becomes clear that fault is not so straightforward. The complex nature of the industry and relationships between agencies within it results in a convoluted narrative with a lack of third party verifiability.

2.12 Glossary

Annular preventer: "large, donut-shaped rubber elements…that encircle drill pipe or casing inside the [blowout preventer]" (National Commission, 2011, p. 109); must be shut to seal off annulus around the drill pipe (National Commission, 2011)

Annulus: space "between the exterior of the steel casing and the surrounding rock formations" (National Commission, 2011, p. 114)

"Bladder effect": "heavy mud in the riser was exerting pressure on the annular preventer, which in turn transmitted pressure to the drill pipe" (National Commission, 2011, p. 123); no evidence that this phenomenon actually exists (National Commission, 2011)

Blind shear ram: "designed to cut through drill pipe inside the [blowout preventer] to seal off the well in emergency situations…could be activated manually by drillers…by an ROV, or by an automated emergency 'deadman system'" (National Commission, 2011, p. 109)

Blowout preventer: large mechanical device installed as the "last line of defense against loss of well control" (National Commission, 2011, p. 13); seals, controls, and monitors well (National Commission, 2011, p. 13)

"Bottoms up" circulation: "all of the existing mud in the wellbore is displaced with fresh mud…removes unwanted debris and conditions the mud"; "The American Petroleum Institute (API) recommended practice suggests circulating a full bottoms-up prior to cementing" (Transocean, 2011, p. 55); allows for detection of the presence of hydrocarbons at the well's bottom (National Commission, 2011)

BP zonal isolation experts: in charge of monitoring different zones that may have different pressures or fluids, and keeping them separate (BP, 2010)

BPM: barrels per minute; measure of flow rate in well (Transocean, 2011)

Casing: "series of steel tubes…creates a foundation for continued drilling by reinforcing upper portions of the hole as drilling progresses"; "after installing a casing string, the crews drill farther, sending each successive string of casing down through the prior ones, so the well's diameter becomes progressively smaller as it gets deeper" (National Commission, 2011, p. 107)

Cement plug: engineers send cement down to the bottom of the well, then pump mud after it until cement is pushed back up into the annular space; "if done properly, the slug of cement will create a long and continuous seal around the production casing, and will fill the shoe track in the bottom of the final casing string" (National Commission, 2011, p. 115)

Centralizers: installed to hold casing string in the center of the wellbore; "cement pumped down the casing will flow evenly back up the annulus, displacing any mud and debris that were previously in that space and leaving a clean column of cement…if the casing is not centered, the cement will flow preferentially up…the larger spaces in the annulus…and slowly or not at all in the narrower annular space…can leave behind channels of drilling mud that can severely compromise a primary cement job by creating paths and gaps through which pressurized hydrocarbons can flow" (National Commission, 2011, p. 112)

Damon Bankston**:** offshore supply vessel owned by Tidewater Marine and contracted by BP to carry supplies "such as drilling equipment, drilling chemicals, food, fuel oil, and water to and from the *Deepwater Horizon*" (Transocean, 2011, p. 18); provided emergency assistance during blowout (Transocean, 2011)

“Deadman” system: automatic mode function on blowout preventer; should trigger “the blind shear ram after the power, communication, and hydraulics connections between the rig and the [blowout preventer] [are] cut” (National Commission, 2011, p. 131)

Displacement: replacing contents of riser with other contents; in this case, replacing mud with seawater and vice-versa (National Commission, 2011)

Diverter system: “provides two alternate paths for gas or gas-bearing mud returning to the rig from the well” (National Commission, 2011, p. 130); can be diverted to mud gas separator or overboard (National Commission, 2011)

Drill pipe: steel piping that runs down through the well to allow for fluids to be pumped down (Transocean, 2011)

Drilling mud: plays a role in controlling hydrocarbon pressure; “used to lubricate and cool the drill bit during drilling”; “sophisticated blend of synthetic fluids, polymers, and weighting agents that often costs over $100 per barrel” (National Commission, 2011, p. 107)

Emergency disconnect system (EDS): “designed to close the blind shear rams (BSRs) and detach the [riser] so that the rig can move away” (Transocean, 2011, p. 137)

Float collar: “installed at the top of the shoe track to prevent the cement from flowing back from the outside of the casing to the inside of the casing when pumping stops” (Transocean, 2011, p. 49)

Halliburton: company contracted for cement job and support on and offshore (Transocean, 2011)

Hydrocarbon: organic compound found in crude oil (National Commission, 2011)

"Kick": unplanned influx of gas or fluid that pushes mud upward faster and faster, reducing pressure on gas and increasing speed of kick; oil and gas enter the well if mud weight is too low (National Commission, 2011)

Kill line: "one of three pipes…that run from rig to the [blowout preventer] to allow the crew to circulate fluids into and out of the well at the sea floor" (National Commission, 2011, p. 123)

Liner: "shorter string of casing hung lower in the well and anchored to the next higher string" (National Commission, 2011, p. 111)

Lockdown sleeve: "mechanical device that locks the long-string casing to the wellhead to prevent it from lifting out of place during subsequent production operations" (National Commission, 2011, p. 120); usually set by completion rig, but BP chose to have *Deepwater Horizon* place it, with the theory that they would do it faster (National Commission, 2011)

Long-string production casing: also known as casing string; "single continuous wall of steel between the wellhead on the seafloor, and the oil and gas zone at the bottom of the well" (National Commission, 2011, p. 111)

"Lost returns" or **"lost circulation":** when pressure of drilling fluids is too high, rock at the bottom of the well will fracture and "drilling fluids will flow out of the wellbore into the formation instead of circulating back to the surface" (National Commission, 2011, p. 106)

M-I SWACO: subsidiary of Schlumberger; drilling-mud subcontractor (National Commission, 2011)

Mud gas separator: part of diverter system; "consists of a series of pipes, valves, and a tank configured to remove gas entrained in relatively small amounts of mud…the gas is then vented from an outlet valve located high on the derrick" (National Commission, 2011, p. 130)

Mudloggers: employed by Sperry Sun "to monitor the [well monitoring] system, interpret the data it generated, and detect influxes of hydrocarbons, or kicks" (Transocean, 2011, p. 18)

The National Oceanic and Atmospheric Administration (NOAA): part of the United States Department of Commerce; responsible for protection of coastal and ocean resources

Negative pressure test: "performed before the mud in the wellbore and riser is displaced with seawater…confirms the integrity of barriers in the well (such as cement barriers, mechanical barriers, casing, and seal assembly) by simulating the reduction in hydrostatic pressure that occurs when heavy mud is displaced with lighter seawater, and the [blowout preventer] stack and the riser are removed" (Transocean, 2011, p. 29)

Nitrogen foam cement: cement with nitrogen foam injected into it "to lower its density and thus the pressure on…fragile formations" (Transocean, 2011, p. 56)

Oceaneering: subsea engineering and technology company; provided remotely operated vehicle (ROV) technicians (Transocean, 2011)

OCS Group: engineering and consulting firm in oil and gas industry; provides management, inspection, and other technical services (National Commission, 2011)

Offshore Installation Manager (OIM): Transocean's senior manager on board *Deepwater Horizon* (Transocean, 2011)

OptiCem: computer simulations program used to help predict the outcome of the cement job based on the variables (National Commission, 2011)

Pore pressure: "pressure exerted by fluids in the pore space of rock" (National Commission, 2011, p. 106); needs to be balanced with pressure from drilling fluids to prevent hydrocarbons from entering the wellbore (National Commission, 2011)

Positive pressure test: tests the integrity of the production casing (National Commission, 2011)

Resource and Conservation Recovery Act: 1976; main governance over disposal of hazardous waste (National Commission, 2011)

Riser: "the pipe that connected the rig to the well assembly on the seafloor below" (National Commission, 2011, p. 23)

Schlumberger: company contracted to provide specialized well and cement logging services, including equipment and personnel; owns M-I SWACO (Transocean, 2011)

Sheen test: "performed to verify that the displacement of synthetic oil-based mud was complete and that it was appropriate to discharge the remaining water-based fluids in the riser overboard into the sea" (Transocean, 2011, p. 30); used a sample of well fluids coming from the riser (Transocean, 2011)

Shoe track: "end section of the casing…contains cement that, together with cement in the annulus, serves as the primary barrier preventing the hydrocarbons in the reservoir from flowing up the well…acts as a plug between the inside of the casing and the formation" (Transocean, 2011, p. 44)

"Slip-on" centralizers: "devices that slide onto the exterior of a piece of casing where they are normally secured in place by mechanical 'stop collars' on either side"; distrusted because of these separate stop collars that "can slide out of position or…catch on other equipment as the casing is lowered" (National Commission, 2011, p. 112)

Solenoid valves: "energized to activate the high-pressure shear circuit for 30 seconds when [deadman system] is activated" (Transocean, 2011, p. 147)

Spacer fluids: "any fluid used to physically separate one drilling fluid from another and to avoid contamination between the two" (Transocean, 2011, p. 90); usually water-based, but BP uniquely chose to "create a spacer out of two different lost-circulation materials left over on the rig" (National Commission, 2011, p. 122)

Sperry Sun: subsidiary of Halliburton; contracted to install monitoring system on rig; employed mudloggers who monitored the system (Transocean, 2011)

Subsea personnel: BP employees; record well control-related equipment maintenance (BP, 2010)

Toolpusher: part of drilling crew from Transocean; in charge of drillers and assistant drillers (Transocean, 2011)

Transocean: contracted to provide rig (initially *Marianas*, and later, *Deepwater Horizon*) and crew (Transocean, 2011)

Underbalancing: "allowing pressure in the formations to exceed pressure in the well" (Transocean, 2011, p. 78)

Variable bore rams: "can close around a range of tubing and drill pipe outside diameters" (Transocean, 2011, p. 141)

Weatherford: contracted for technology such as centralizers, float collar, and shoe track, as well as personnel to help advise installation and operation of their equipment (Transocean, 2011)

Well Site Leader: BP's authority on board *Deepwater Horizon* (BP, 2010)

Wellbore: "hole drilled by the rig, including the casing" (National Commission, 2011, p. 106)

Wells Team Leader: from BP; supervises managers (National Commission, 2011)

Chapter III

Economic Context: The Principal-Agent Model

With the story of the Deepwater Horizon *disaster pieced together, the next step is to examine the analytical framework through which potential mechanisms of an optimal enforcement strategy can be determined. The principal-agent model was selected as this framework due to the flawed contractual relationships on all levels of the offshore drilling industry and subsequent lack of oversight of drilling operations that led to the Macondo well blowout. Thus, it is important to understand principal-agent relationships and how problems within them can be resolved.*

Incentive theory focuses on tasks that are too complicated or too costly for a profit-maximizing individual, such as a principal, to perform himself. An agent is a utility-maximizing individual contracted by a principal to perform said task, chosen because he possesses some special knowledge that will help him carry out the task better than the principal could have (Sappington, 1991). These two parties often have different objectives, and the principal-agent problem arises from the need to align these objectives (Laffont & Martimont, 2001).

When selecting an optimal agent, a principal takes several factors into account, including who will cost him the least and who will be most reliable. Additionally, he must balance the policy instruments used to attract agents. For example, although a high interest rate would bring a bank high returns on successful loans, the interest rate cannot be raised too high because it will deter people with relatively reliable ideas, and not those with risky ones. Since people with more risky ideas are more likely to default to bankruptcy and never repay interest, a high rate will not dissuade them from taking out a loan (Sappington, 1991).

Conflicting objectives and decentralized information are the fundamental problems of the principal-agent model. A principal has the objective to provide the least incentives possible, while still motivating the agent to perform well, whereas an agent wants to receive the most incentives possible, while performing at a comfortable level. Additionally, both parties are privy to information the other is not, especially an agent who is cognizant of his full effort capacity (Laffont & Martimont, 2001). Once a contract has been agreed upon, a principal has no way of perfectly monitoring an agent's behavior, and must instead trust the agent to perform efficiently and to the best of his abilities. For example, when a principal has alternate agents available, a contracted agent is incentivized to perform better at a lower cost to the principal. However, the agent may not implement strategies to improve his future performance if he fears he might be replaced. The principal's problem arises in how to motivate an agent to perform with a high level of effort, even though he has imperfect information regarding his agent's activities (Sappington, 1991), as exemplified in the offshore drilling industry and *Deepwater Horizon* case study.

Agents have private information of two types: adverse selection and moral hazard. Adverse selection, or hidden knowledge, is any information an agent has regarding cost or value of his actions that his principal is unaware of. When he chooses to use this information to his advantage, he is participating in adverse selection. For example, only an agent can know exactly how quickly and efficiently he can perform a task, while his principal can only assume he is performing to the best of his ability. Moral hazard, or hidden action, is anything an agent does that his principal cannot or does not observe him doing. For example, an agent might spend an hour on a task that he could actually effectively complete in thirty minutes, but his principal would have no way of knowing this. A third problem regarding information is nonverifiability, which arises when there is no third party to observe information a principal and agent both know. For example, if a principal and agent are both aware of potential outcomes from their contract, but unsure of what the value of the actual outcome will be, they cannot contract upon it and thus a third party cannot verify the information (Laffont & Martimont, 2001).

Adverse selection stems from the fact that an agent is hired by a principal to perform a duty the principal is unable to complete as well himself. By performing this duty, the agent gains knowledge and information unknown to his principal, including "the exact opportunity cost of [the] task, the precise technology used, [and/or] how good is the matching between the agent's intrinsic ability and this knowledge" (Laffont & Martimont, 2001, p. 37). In some cases, an agent is able to use this to his advantage when agreeing to or working under a contract. Due to adverse selection, when possible, principals often choose to include information in the initial contract that can be verified by a third party, such as quantity produced. Additionally, a principal has ways to improve the information available to him through setting up monitoring and auditing structures, such as hidden cameras. If the principal, agent, and a third party can observe a signal after the agent has done some work, the contract can reflect both what the agent says and what the signal indicates (Laffont & Martimont, 2001). A principal can also deal with the issue of hidden information by linking reports between two agents in similar environments who would encounter similar problems. For example, two tenant farmers working on adjacent pieces of land would endure the same unpredictable weather conditions. Thus, their landlord (the principal) could expect similar results from both harvests and incentivize honest hard work by either comparing the reports or making his two agents report on the conditions of not only their own harvests, but also each other's. However, in this case, the agents could work together to thwart their principal by choosing to underreport. To counter this, the principal might offer incentive for one agent to "tell on" the other (Sappington, 1991). The problem of adverse selection can be difficult to avoid, since the contract is often made before the agent learns information about his performance abilities (Laffont & Martimont, 2001).

Moral hazard arises because an agent can perform actions that are unobservable by both his principal and a third party, such as a Court of Justice. Without verification of the value of such actions, a contract cannot cover them. Effort level of an agent's performance is central here, as well as his personal objectives and motivations. The value and amount of output produced is directly affected by how much effort the agent chooses to put forward. For example, a regulated firm may make investment decisions that will reduce costs for producing a socially valuable good, but these decisions will be unobservable to the regulator. As with adverse selection, asymmetric information leads to uncertainty here, since a principal can never really know the extent of effort his agent is capable of putting forth. However, once production does occur, the results can be verified. Production level is directly related to the level of effort an agent puts forth. This means a principal can indirectly contract an agent's effort by judging it based on output (Laffont & Martimont, 2001).

An incentive scheme that works well for resolving moral hazard is one that induces positive and costly effort. Incentive feasible contracts are those that satisfy the constraints of incentives and of voluntary participation. In essence, a principal must devise a contract that will incentivize his agent to perform well at a reasonable cost to the principal, and the contract will be devised "ex ante", or before production occurs. This generally leads to the principal choosing the "second-best cost" for inducing effort from his agent. As this is a trade-off for "second-best effort", there is an allocative inefficiency due to the conflicting objectives. In the case of risk-neutral agents, non-observability does not pose a problem. If a risk-neutral agent works hard and produces sufficient output, he will be rewarded; if not, he will be penalized. However, as long as he receives his contracted reservation level—or minimum compensation requirement—at the least, he will be satisfied. This is known as his participation constraint. Sometimes, an agent can be induced to exhibit his best efforts by making him the residual claimant in terms of gains. In cases of risk-averse agents, an agent must be required to bear some burden of the risk associated with insufficient production in order to give him any incentive to work hard. The agent must get a risk premium when he accepts this contract, and will be induced to exhibit less effort than a risk-neutral agent (Laffont & Martimont, 2001).

Nonverifiability arises when there is some parameter affecting future pay-off in a relationship that cannot be determined by a principal and his agent upon entering their relationship. Therefore, when they create their contract, there is no third party that can enforce said contract, as no third party can verify if the statements of either party involved are true or false. In these cases, the principal and agent sometimes decide to make the contract "ex post", or after the fact, when they can bargain over the now commonly understood results of their relationship. This works well with a risk-neutral agent (Laffont & Martimont, 2001).

When creating a contract, decisions must be made regarding different aspects of how it will be enforced. One such decision regards the choice between negligence and strict liability rule in scenarios where offsite damage may occur based on the level of care exerted by an agent. In the case of a negligence rule, a third party Court of Justice imposes a certain due care standard. If the agent exerts care greater than or equal to this, his principal's losses will be internal—only losing elements such as the assets needed for production. Conversely, if the agent exerts effort below the due care standard, his principal's losses will be both internal and external—not only will resources be lost, but also legal compensation may be owed to victims affected by the agent's lack of care. In the case of a strict liability rule, a principal must pay damages to victims regardless of the level of care that was exerted by his agent. Courts need to take moral hazard into account when determining the due care standard to set under a negligence rule (Newman & Wright, 1992). The offshore drilling industry includes moral hazard on many levels.

In addition to decisions that must be made while devising a contract, many different "frictions" can arise between a principal and agent. Asymmetry of pre-contractual beliefs is a friction that occurs if a principal and agent have different beliefs about contingencies that may arise during the term of the contract. In this case, the principal will modify the contract based on what his agent knows or doesn't know in order to get what he wants from it. For example, in the case of the landlord and tenant farmer, the two parties may anticipate different weather conditions that would in turn affect production levels. This will alter how the principal and agent negotiate the initial contract (Sappington, 1991).

Risk-averse agents lead to frictions in contract formation as well. Because the agent cannot be expected to bear the full burden of the consequences if due to circumstances beyond his control his performance is poor, the principal must account for these kinds of extenuating circumstances in the contract. Often, the principal offers the agent excess payment above his reservation level. However, this leads to a new problem for the principal: because the agent is offered such a high payment from the outset, his incentives to perform to the best of his abilities diminish. Additionally, the agent is essentially insured against bad outcomes, meaning he will exert less effort to avoid these outcomes (Sappington, 1991).

The negotiability and non-binding nature of contracts causes friction in that outside forces often allow for changes to the commitment of both parties. For example, an agent can terminate his contract in situations where he is not making at or above his reservation level. Thus, his principal often designs a contract in which the agent shares some of the surplus of his labors. This incentivizes the agent to exert more effort, albeit not necessarily to his full potential (Sappington, 1991).

Public observability is a common friction of principal-agent relationships. Although a contract can be enforced through a principal and agent regularly verifying the agent's performance, if no third party can confirm this, many intangibles arise (Sappington, 1991).

An incentive problem often seen in centrally-planned economies where the government uses past performance to set future goals is underperformance by an agent, who will not want to set the bar too high the first time. This can be alleviated when the productive environment varies over time, since this makes it easier for a principal to induce his agent to tailor performance accordingly. When a varying productive environment is not available, the principal can benefit similarly by changing his agent's tasks. Again, agents will perform better if they know they are not setting a bar they will need to continually reach (Sappington, 1991).

Chapter IV

Literature Review

Although little literature exists that applies the principal-agent model to problems within the offshore drilling industry, previous research and studies of industries with high risk for negative externalities and environmental damage have examined firm behavior in the light of the principal-agent model and incentive schemes. Economists have attempted to devise enforcement structures that incentivize the promotion of safety cultures and socially optimal outcomes. As Deepwater Horizon *occurred recently and set a new precedent for the damages that can be caused by a lack of incentives for safety precautions, there is insufficient contemporary literature on the mechanisms for an optimal enforcement strategy for industries with high risk for negative externalities. An examination of the literature that does exist is beneficial for determination of the potential components of a contemporary optimal strategy.*

4.1 Why Do Firms Comply with Enforcement?

Cohen (1998) examines why firms comply with enforcement, as well as the motivation for said enforcement. Overall, he states that firms choose to comply based on negative and positive incentives (Cohen, 1998). Lazear (1998) examines this idea in the context of bonus and penalty schemes that result in the same compensation, and why each produces different results. Psychologically, workers are attracted to schemes where they are rewarded rather than schemes where they will probably be penalized, and would only prefer a penalty scheme if it resulted in more compensation. Each scheme provides different incentives, so firms need to be aware of what they are incentivizing when devising a contract. Penalty schemes "are used when adding output or effort beyond some point has no value" (Lazear, 1998, p. 367). For example, when working on an assembly line, getting to work before a shift starts has no more value than getting to work on time. Penalty schemes are used when there is a maximum amount of value like this that can be achieved, and workers are punished only when they work below the critical level. Bonus schemes "are used when reducing output or effort below some point has no cost" (Lazear, 1998, p. 367). For example, setting up a Halloween display before Halloween has increasing value the earlier it is set up. Bonus schemes are used when there is a critical level of value that must be achieved, and workers are rewarded for reaching this target level sooner (Lazear, 1998). Cohen (1998) deals with negative and positive enforcement on the firm level. If, for example, a fine for noncompliance is too low, a firm will not have enough incentive to comply. Cost-subsidies are one option for increasing compliance, because they affect the cost-benefit analysis performed by firms when making compliance decisions. Additionally, because most firms are risk-averse, after an initial incident they will be more stringently regulated and have incentive to be more cautious. Aligning the interests of the firm with shareholders can help with firm compliance because shareholders often desire firms to have a strong safety culture. Cohen (1998) points out noneconomic incentives for compliance, such as social norms and general sentiments of rule following (when rules are considered fair), which are often overlooked when economists examine firms' compliance decisions (Cohen, 1998).

4.2 Resolving Moral Hazard

The issue of moral hazard often arises among industries with high risk for negative externalities. Many economists have tackled the question of what kind of enforcement strategy works best for these scenarios. Page (1991) creates a model for determining the optimal contract in principal-agent relationships with incomplete information. He notes that there is existing literature regarding principal-agent relationships with moral hazard, and in these cases, the principal is assumed to have full knowledge of the agent's utility and what type of agent he is. However, the principal cannot directly observe the agent's actions and therefore make payoffs based on his actions. Thus, a contract under moral hazard must contain "payoffs contingent on a mutually observable state of nature so as to induce the agent to take an action that is in the best interest of the principal" (Page, 1991, p. 323). The additional problem of adverse selection, or incomplete information, is one that has not been dealt with as comprehensively and arises from situations in which the principal does not know the type of agent he is hiring. In the model devised by Page (1991), to select the optimal contract for principal-agent relationships with moral hazard and adverse selection, the principal uses a probabilistic mechanism. In the design of this mechanism, there must be incentive for the agent to sign the contract, as well as incentive to report his type truthfully (Page, 1991).

4.3 Strict Liability versus a Negligence Rule in Cases with Moral Hazard

Many economists deal with the issue of strict liability versus a negligence rule in the case of moral hazard. Viscusi & Zeckhauser (2011), as well as Cohen (1987), agree that strict liability is preferable to a negligence rule in industries with negative externalities and moral hazard. Viscusi & Zeckhauser (2011) discuss that cases with a negligence rule require a due care standard be set. In the case of an accident occurring, a firm or individual's negligence must be checked against this standard. In industries with moral hazard, such as offshore drilling, monitoring the precise level of care a firm or individual is exhibiting is nearly impossible. Thus, holding an agent strictly liable for damages caused is much more realistic and efficient than trying to measure their culpability based on a negligence rule and due care standard (Viscusi & Zeckhauser, 2011).

Cohen (1987) examines offshore oil operations close to shore and monitored by the United States Coast Guard, discussing how firms in this industry expend resources to evade detection by said monitors. A strict liability standard would institute a severe penalty on any firm that did not self-report damages to the government, whereas a negligence rule would only penalize a firm if the damages occurred due to a lack of preventative care, which would require third party monitoring to assess. Thus, Cohen (1987) claims that a strict liability standard provides a higher level of net social welfare than a negligence rule (Cohen, 1987). In a more recent paper, Cohen (1998) furthers his argument for strict liability by pointing out that it is usually less expensive to enforce than a negligence rule (Cohen, 1998).

Other economists provide arguments for how a negligence rule can be made efficient in industries with moral hazard. Newman & Wright (1992) discuss a mechanism that allows a negligence liability system to be implemented, even when effort is not observable. In order for this to work, the contract between principal and agent must be designed to allow third party, such as court, observability. Although an agent's explicit actions are not observable, some sort of results will be required that will imply the agent's actions and level of effort. A negligence rule works by the law setting a due care standard that must be met by the agent. Newman & Wright (1992) state that as long as effort is observable (in this case, through the contract), both strict liability and a negligence rule induce equal levels of care that minimize expected labor costs (Newman & Wright, 1992).

Some economists, such as Segerson & Tietenberg (1992) go further to claim that a negligence rule can be preferable to strict liability standards. They investigate using imprisonment, as opposed to fines, as a punishment to incentivize workers to exhibit more cautious behavior. If efficient fines could always be achieved, fines would be preferable to incarceration due to its higher social and private costs. However, in some cases, a firm's or individual's assets may not be enough to cover efficient penalties, so adding the threat of incarceration makes up for insufficient incentives. When it comes to imposition of criminal sanctions, a negligence rule works better than strict liability because sentences can be shortened to lower social and private costs (Segerson & Tietenberg, 1992).

4.4 Regulation in Industries with High Risk for Negative Externalities

In the literature about industries with high risk for negative externalities, regulation as a form of enforcement is debated among economists. Some assert that regulation is absolutely necessary. Cohen, Gottlieb, Linn, & Richardson (2011) use the *Deepwater Horizon* incident as motivation for determining what kind of enforcement mechanisms could incentivize firms in the oil drilling industry to promote a better safety culture. The authors call for government involvement in the industry due to principal-agent problems within oil companies that might cause them to enforce a safety culture below the social optimum. In their literature review, the authors define safety culture as "the set values promoted by the firm's policies that lead employees to prioritize health, safety, and the environment" (Cohen, Gottlieb, Linn, & Richardson, 2011, p. 1858). They go on to define common characteristics of firms that are highly reliable in terms of safety, as well as firms that have weak safety cultures (Cohen, Gottlieb, Linn, & Richardson, 2011).

Some economists call for an increase in regulation among the industries due to certain circumstances. For instance, Cheung & Zhuang (2012) design a game to compare government-regulated companies both with and without competition, and how they comply with safety regulations. In the games set up by Cheung & Zhuang (2012), the government and oil companies are the players, behaving rationally and trying to maximize utility based on risk. Both players need to make decisions regarding allocation of resources towards regulation (government) and following regulation (oil companies). If the more probable possibility of no oil spill occurs, both players can save on resources by ignoring safety precautions. In the construction of the game, many variables are accounted for: probability of government enforcement, company compliance, and spill occurrence; cost to company for following regulations, shutting down operations, and oil spills; cost to government for checking up on companies; revenue of company on its own, companies following regulations, company that does not follow regulations when the other does, company that does follow regulations when the other does not, and companies that both do not follow regulations; and expected losses and revenues for both the companies and government. Additionally, the authors must make several important assumptions in order for the game to work, including the assumptions that if regulations are followed, there is no risk of a spill; that if a company follows regulations, it is more expensive than a spill would be, incentivizing them to take risk; and that the only difference between companies in the game is their decision of whether or not to follow regulations. Through comparing the results of one- and two-company games, the authors conclude that competition produces incentive for companies to avoid safety measures, because with more competition, a company's risk threshold increases. Due to these results, the authors believe that with more competition, more strict regulation becomes necessary. In their conclusion, they note that competition usually helps a market by reducing prices for consumers, pushing forward innovation, and more. However, with the deregulation of industries that carry high risks, such as airlines and electric utilities, there has been an increased prioritization of maximizing profit over practicing safe procedures (Cheung & Zhuang, 2012).

Arguments are made for decreasing regulation as well. Miller & Whitford (2007) discuss the issue of self-interest and its role in incentivizing effort level and behavior. In principal-agent relationships, the principal often turns to coercion or rulemaking to get his agents to behave as he wants them to, despite the fact that this may not lead to the most efficient outcomes. In the same thread as the Invisible Hand that guides the market, the authors of this paper hope that individuals following self-interests will drive efficient allocation in principal-agent relationships. Because both principals and agents are individuals motivated ultimately by their own self-interests, the authors believe that with the right set of incentives, coercion and monitoring of agent behavior will no longer be necessary (Miller & Whitford, 2007).

4.5 The Role of Monitoring

Within the discussion of optimal enforcement strategies for this industry comes the question of monitoring and to what extent it can be efficient. Miller & Whitford (2007) and Cohen (1987) agree that some extent of monitoring is necessary due to moral hazard in the industry. Although Miller & Whitford (2007) promote the idea of self-interest driving firm and individual incentives towards efficient allocation in their principal-agent relationship, they concede that due to risk-aversion and asymmetrical information, it can be very difficult to avoid monitoring entirely. If the principal takes on the risk, the agent has incentive to put forth less effort. However, it is inefficient to put all the risk on the agent. It seems that in situations where monitoring is cheap and easy, the principal will choose to bear the risk, but otherwise will shift some or all of it to the agent (Miller & Whitford, 2007). Cohen (1987) points out that in cases like oil spills, agent activity must be monitored because spills can occur due to outside forces that are not the fault of the agent. However, in the model he presents, he concludes that with an increase in penalties, monitoring can be decreased (Cohen, 1987).

Rather than simply *accepting* that some amount of monitoring is unavoidable in industries with moral hazard, some economists believe that despite its costs, monitoring is an essential tool in the promotion of safety culture among firms. In his more recent paper, Cohen (1998) reviews some theories as to the best strategies for monitoring and enforcement. He states that firms respond to the probability of detection plus the level of punishment they receive if caught. This means that increasing monitoring and/or raising penalties for noncompliance might help promote rule following. According to one model, the lower the probability of detection is, the higher the penalty will be, and vice versa. Monitoring can be costly, so incentivizing self-reporting is suggested as a way to reduce these costs. This could include a higher penalty for firms that fail to report pollution or misreport information. Although studies show this often decreases monitoring costs, it also leads to more sanctions, which can be costly to impose and collect (Cohen, 1998).

Grau & Groves (1997) construct a model by which to determine the effect that monitoring and fines can have on spill frequency and size. The Coast Guard is responsible for enforcing the law that there can be no oil spills within 12 nautical miles of the U.S. coastline. The spills the Coast Guard monitors are of a much smaller scale than spills that occur in deepwater drilling. After making their assumptions, the authors conclude that increased probability of Coast Guard monitoring decreases oil spill frequency and size, while fines have no effect. This may be because the fines for these kind of spills are so small, and therefore do not provide enough incentive. However, monitoring is proven to be an effective mechanism for incentivizing firm compliance with safety regulations (Grau & Groves, 1997).

4.6 Enforcement Strategies

When it comes to enforcement strategies in industries with high risk for negative environmental externalities, most economists agree that multi-layered enforcement is needed. Viscusi & Zeckhauser (2011) use the *Deepwater Horizon* oil spill as an impetus for devising a new system of liability for firms engaging in activities with a risk for environmental damages. Through a two-tier strict liability scheme, a balance is created between the risks firms in these industries bear and the costs of the damages that could be potentially incurred in extreme circumstances. A crucial component of the authors' strategy is holding one firm liable from the start and therefore taking on full responsibility for compensation of damages. It is noted that this firm can still contract out to other firms, serving as their principal, but the individual contracts created will have to specify what said firms are responsible for should there be an incident. This puts incentives in the hands of one principal company that has the most knowledge and control over the outcome of the activities. Because said principal will be held ultimately responsible for any incident that occurs, it will have incentive to promote risk-averse behavior among its agents (both employees and other contracted firms). The first tier of the liability scheme consists of a financial resource requirement—the firm must be capable of affording to cover the potential damages it could cause. The second tier helps allow for small- and medium-sized companies to remain competitors in these risky industries by imposing an annual tax equal to the expected costs beyond damages amount. For example, if total damages would potentially be $50 billion and a firm can afford to cover $20 billion with its financial assets, it will be required to pay $30 billion in taxes over the year. Because BP put $20 billion into a reparations fund following the *Deepwater Horizon* incident, the authors suggest this as the financial resource requirement for a firm drilling in the Gulf of Mexico. With traditional liability structures, smaller firms often recognize that the losses from an oil spill may be so extensive that they would never be able to pay for them, causing them to act more recklessly. However, with the two-tier liability system, firms will have incentive to take the socially optimal and more cautious path (Viscusi & Zeckhauser, 2011). Incentive systems such as these are equally if not more important than regulation, because government salaries will not be enough to attract the most experienced and competent people to regulator jobs.

In a similar, yet slightly more complex strategy featuring third-party insurance in place of a tax, Cohen, Gottlieb, Linn, & Richardson (2011) also devise a multi-layered enforcement scheme. Following a study of different enforcement mechanisms that could potentially be used, the authors make their recommendation as to which set of these policies seems it will most effectively promote a safety culture in the industry. First, they believe that the liability cap should be raised and set on a well-by-well basis. This means firms will be liable for damages of the worst-case scenario projected for their specific well and its conditions. Second, third party insurance will be required to cover all costs up to the liability cap, as well as potentially more than this. This allows for smaller firms to afford drilling riskier wells. Third party insurance will also provide a monitoring mechanism with greater incentive to assess a company's actions than the government as a monitor has, because the insurance company will be liable in the case of a spill. With insurance comes a problem with moral hazard, and risk-based fees should be used to assuage this. Risk-based fees would require firms to pay based on a third-party rating of the safety of the well they are working on. In cases where insurance coverage is impossible for the level of the liability cap, demonstration of financial responsibility will be required. Thus, a firm will show they are able to cover the cost of damages themselves, without insurance (Cohen, Gottlieb, Linn, & Richardson, 2011).

Miller & Whitford (2007) support the strategy of incentives that will promote self-interested behavior to align with efficient allocation in principal-agent relationships. A pure incentive contract is one in which agents are offered compensation, and a commonly effective version includes a flat wage. This provides the agent with enough incentive to accept the contract and exert some level of effort, plus a bonus when high levels of effort are displayed. This kind of contract works well with self-interested agents. However, the economists introduce 'the principal's moral hazard constraint', because "bonuses large enough to produce the efficient incentive effect are prohibitively expensive for the principal" (Miller & Whitford, 2007, p. 213). Because the self-interested principal is often a firm driven by profit-maximization, and a certain level of bonuses would cut into said profit, the principal often chooses the less efficient method of monitoring or incentivizing their agents to perform. In the model proposed by the authors, the agent's efficacy plays a large role. Efficacy is defined as the agent's ability to affect the outcome of his efforts—the less able he is to better or worsen the final product, the more incentive he will need to work harder. Additionally, if the cost to the agent of high effort is much greater than the cost of low effort, he will need more incentive to exert the extra effort. Lower efficacy and/or high cost of high effort levels will lower the chances that incentives will be a profitable choice for the principal, even if they are efficient. As level of efficacy grows, the bonus a principal needs to offer diminishes, and thus profits are higher. Thus, the greater the effect the agent has on the outcome of his work, the more likely a pure incentive, bonus-based contract will be profitable to the principal (Miller & Whitford, 2007).

4.7 Employer versus Employee Responsibility

A common discussion in the literature is that of employer versus employee responsibility and punishment. Cohen (1998) tackles the issue of employer versus employee responsibility. If the employee commits a violation on the behalf of the firm, then who is responsible for taking the punishment? No matter whom the law deems responsible, the employer can pass on the costs to the employee through their contract. However, sometimes the employee will be simply unable to afford the sanction, in which case the employer would have the incentive to promote more cautious behavior, as they will have to cover the fine. Another way to handle this question of responsibility is to have some employees liable for environmental damages and on a fixed wage contract, while employees responsible for increasing profits are on separate incentive contracts (Cohen 1998).

Although economists like Cohen (1998) question the effectiveness of placing risk and punishment on the employee, economists such as Polinsky & Shavell (1993) promote the idea of employee punishment as a way to incentivize a safer work culture. They use the economic theory of deterrence to determine if it is socially desirable to punish employees when there is already corporate liability. A benefit of publicly imposed sanctions is that they can often be greater than what the firm could have imposed on its employees. For example, if a firm were to withhold wages in the case of an employee causing harm, this might not be enough to incentivize him to be careful. With state involvement, employees will have more incentive to exhibit the socially optimal level of care. Additionally, the state can threaten criminal charges and/or imprisonment on an employee that does not pay their fines—a company is not able to do this. With these more dramatic incentives, employees will exhibit more care, decreasing the amount of expected harm and therefore costs of the firm. In order to make this socially optimal, firm liability must be lowered, making firm liability plus the fine imposed on the employee(s) equal to the expected level of harm. If not, prices will be driven up higher than the socially optimal price to cover firm liability. The socially optimal outcome is equal to the level of care and output that maximize social welfare. Social welfare is determined by the utility a consumer gets from output, minus disutility of work to the employee, cost of taking care, and expected harm. In the conclusion, the authors mention several other ideas about how to incentivize the socially optimal level of care from employees. One such idea is an efficiency wage, which means making wages excessively high to attract workers. However, if they cause harm and their wages are withheld there will also be more for them to lose. An idea the authors strike as ineffective is that of imposing punitive damages and criminal fines on the corporation, because this will not change the firm's ability to incentivize its employees to take more care (Polinsky & Shavell, 1993).

4.8 The Government as an Enforcer

The issue of the government as an enforcer is touched upon in the literature. Cohen (1998) points out that the government's goals might not always align with maximizing social welfare. Additionally, the government will fail to enforce policies strictly if compliance costs are too high for the firm to cover on its own. This often happens in cases where a firm has a lot of local employees that will lose their jobs if the firm shuts down. Some employees of enforcement agencies can further their careers by enforcing more strictly, giving them incentive for more strict enforcement (Cohen, 1998).

4.9 Summary of Findings

In the literature surrounding industries with high risk for negative externalities, there are several common themes that economists examine and try to resolve. In doing so, they must make assumptions and generalizations about the industries and firms in them in order to draw any kind of conclusions. Most economists promote a strict liability standard over a negligence rule, due to the difficulty of measuring level of care in industries with moral hazard. The economists that provide scenarios where a negligence rule works as well as a strict liability standard have to make special accommodations for this. When discussing moral hazard, there is a consensus that monitoring is essential. However, the levels of monitoring recommended vary between economists, with some attempting to decrease the level as much as possible. In terms of regulation, the economists all agree that some degree of outside enforcement is necessary due to principal-agent problems within industries with negative externalities. Some economists believe regulation should be increased, while others believe agents can be incentivized in ways that will allow for regulation to be drastically decreased. Those that argue for less regulation see regulation as inefficient, since it often comes from an ineffective or uninformed source, such as the government. For an enforcement strategy in this industry, all the literature points to schemes with multi-layered enforcement. The economists account for the fact that holding firms liable for damages may push small companies out of the industry. Many proposals are made to hold firms accountable for damages despite their lack of resources, and at the same time, disallow them from taking larger risks and simply declaring bankruptcy if something goes wrong. Literature from after the *Deepwater Horizon* disaster notes that the amount of damages firms are held liable for needs to be increased. Some economists support the idea of imposing criminal sanctions on employees responsible for damages, because this provides more incentive than the firm could have provided on its own. However, Cohen (1998) points out that even if employees are held liable for their mistakes, the firm will still suffer consequences from damages done. Finally, economists agree that the government as an enforcer might not be the socially optimal option. Incentives are needed for the government to enforce at the socially optimal level, since government employees can sometimes profit from the risky behavior of firms that provide the U.S. Treasury with royalties. Additionally, government salaries are not always enough to attract the most qualified candidates for carrying out enforcement policies.

Chapter V

Application of the Model[2]

With the necessary background information gathered, it is possible to synthesize potential mechanisms to compose an optimal enforcement strategy for industries with a high risk for negative externalities. Section 5.1 of this Chapter identifies agency problems and questions that arise in the examination of said problems. After ascertaining these unresolved issues, Section 5.2 proposes potential solutions.

5.1 Identifying Agency Problems

In the investigations and literature surrounding the *Deepwater Horizon* disaster, there is much analysis of the technical and mechanical failures that led to the blowout of the Macondo well. Although these events were the direct causes of the oil spill, behind each event were firms and employees making decisions that allowed them to occur. A series of principal-agent relationships with inefficient incentive schemes existed, both among and within the involved agencies, which provoked the improper decisions that led to the blowout.

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[2] As some of the more industry-specific technical terms reappear in this Chapter, the reader is reminded to refer to the Glossary, Section 2.12 at the end of Chapter II.

5.1.1 What kinds of incentives can the government have to choose to promote safety rather than place emphasis on making a profit?

According to the Constitution's Property Clause, the United States government is given ownership of offshore natural resources. Thus, management and protection of the Outer Continental Shelf where these resources exist is the responsibility of the government. Due to the potential profits from drilling in ever-deeper waters, the government has promoted policies to accelerate offshore exploration and development faster than technology and legislation can keep up, while enforcement of industry regulations has fallen by the wayside (National Commission, 2011).

In order to exercise the government's duties, the Secretary of the Interior created the Minerals Management Service (MMS) in 1982. MMS was charged with regulation of offshore drilling sites, through both leasing areas to be drilled and enforcing safety standards set to protect the environment and local residents from these potentially hazardous activities (National Commission, 2011). Herein lies the first problem with incentives. Royalties from lease sales made by MMS went straight into the United States Treasury, providing the agency with incentive to lease as many areas as possible, perhaps without proper safety evaluations of the sites or the permits submitted by drilling companies. The government is responsible for promoting socially optimal outcomes, however its interests will not always align with these outcomes, especially when it stands to make a profit.

5.1.2 What incentives can be given for experts on the technicalities and safety concerns of industries with high risk for negative externalities, like offshore drilling, to want to work as enforcers and monitors in such industries?

Directors at MMS were hired with more emphasis on the role of leasing than on their expertise regarding the drilling industry, repeatedly acknowledging spending more time on royalty issues than oversight responsibilities. At the same time, due to midrange government salaries, experts in the field were not attracted to the agency. Although MMS had "hundreds of pages of technical requirements for pollution prevention and control, drilling, well-completion operations, oil and gas well-workovers (major well maintenance), production safety systems, platforms and structures, pipelines, well production, and well-control and -production safety training" (National Commission, 2011, p. 84), the enforcement of these requirements was ineffective. Unscheduled inspections of offshore oil operations only covered a subset of the regulations, and were conducted by inspectors who did not need to complete any kind of certification program for their job. Inspector responsibilities were not included in any sort of MMS handbook or guidelines (National Commission, 2011).

5.13 What incentives can be given to companies, as agents, within industries with high risk for negative externalities, such as the drilling industry, to make them act more cautiously?

When international oil and gas company BP was granted a leased area to drill in the Mississippi Canyon of the Gulf of Mexico in March 2008, the firm became an agent to MMS. As the principal, MMS was in charge of reviewing all permits and requests from BP regarding exploration and drilling of the lease block. The MMS personnel responsible for assessing and approving these applications did not have any guidelines or requirements for evaluation of aspects critical for well safety, and with the agency's lack of internal expertise, probably would not have been able to effectively interpret this information anyway. No other agency performed any kind of inspection or required any disclosure of information regarding the lease block in terms of environmental laws and mandates outside MMS regulations (National Commission, 2011).

As an example of the internal inefficiencies of MMS, consider BP's Oil Spill Response Plan, created to comply with the Oil Pollution Act of 1990, and approved by MMS. This plan suffered from an astounding lack of attention to detail, including text copied directly from the National Oceanic and Atmospheric Administration's website, which mentioned sea life inexistent in the Gulf. MMS did not further analyze any part of the plan. The failure of MMS to provide stringent enforcement of its policies was highlighted by the fact that the final plan for temporary abandonment of the well used by BP was not the plan MMS saw or approved, and included unusual methods outside MMS regulations (National Commission, 2011).

Although most associations between a controlling entity and its subsidiaries can be categorized as principal-agent relationships, the nature of these contracts and incentive schemes does not always cause problems. However, problems did arise between the principal, MMS, and its agent, BP, due to improper incentives and moral hazard. As previously explained, the lack of incentive for MMS to effectively enforce safety regulations on BP was due to the conflict of MMS' interest in collecting royalties for the government. Further lack of incentive lay with BP, because due to MMS' lack of expertise and attention to detail, the firm did not face any consequences for lack of thoroughness or questionable decisions in their permit applications. Additionally, due to the absence of strict inspections or check-ins from MMS, BP had less incentive to follow safety protocol carefully. For example, *Deepwater Horizon* had been in BP's service for almost a decade. In a September 2009 safety audit by BP, 390 items on the rig were found to require more than 3500 hours of work to meet safety standards. Clearly, the rig was behind on maintenance and testing, but it was selected to drill the Macondo well regardless, and MMS did not express any kind of concern or opposition (National Commission, 2011).

As owner of *Deepwater Horizon*, Transocean was indirectly an agent to MMS as well, with responsibility for keeping its rig up to safety standards. Interestingly, in Transocean's investigation (2011) of the *Deepwater Horizon* disaster, several inspections of the rig by MMS are mentioned. According to Transocean, none of these tests ever indicated any action be taken by the rig crew (Transocean, 2011). MMS had either been allowing the rig to pass inspections too easily or failing to follow-up on inspections and make sure changes were made, explaining Transocean's lack of incentive to keep up-to-date on maintenance and testing.

5.1.4 What kind of contract can be designed to incentivize safety interests within involved companies (operators and subcontractors), given the moral hazard existent in these industries?

Moral hazard added problems to the principal-agent relationship between MMS and BP due to the very nature of the industry. Without an inspector on board at all times, MMS was never able to fully monitor BP's operations out in the middle of the ocean. This kind of monitoring would have been costly, inefficient, and unrealistic. Once BP was granted the lease and approved for drilling, only those directly involved in drilling operations knew exactly how cautious they were being, as much can be distorted for the sake of getting plans approved or passing safety inspections. Thus, the contract between MMS and BP needed to be more carefully designed to provide BP with incentive to follow safety regulations, without the need for constant monitoring from MMS.

5.1.5 What kind of contract can an operator, like BP, draw up with its contracted subsidiaries to hold them more accountable for performing their duties with due care?

The relationships between MMS as an enforcer and BP and Transocean were not the only ones with principal-agent problems involved in the Macondo well blowout. BP contracted work to several different companies throughout the course of drilling operations, becoming the principal to those subcontractors as agents. First, BP contracted Transocean for the use of their rig, *Deepwater Horizon*, and its crew. During drilling, most men on board the rig were from Transocean, and as agents they did not have enough incentive to exercise caution, since BP was the name on the project and operator of the lease site. As a principal, BP failed to incentivize its agent, Transocean to make the best decisions regarding safety, or to hold them liable for failing to do so. In its investigation of the blowout, Transocean stated that BP had responsibilities as the operator, including oversight of all decisions made and work done on the well. Clearly, Transocean's contract did not give the company incentive to take on the burden of any of these things itself. For example, a well control event occurred on March 8th that Transocean's team did not respond to in a timely manner. Despite this criticism, no changes were made to prevent a similar event from happening again. BP did not require Transocean to make these changes, nor properly incentivize them to choose to make changes on their own (National Commission, 2011).

Another example of Transocean failing to exercise proper caution due to lack of incentives from BP was when interpreting the negative pressure test during temporary abandonment of the well. An experienced Transocean crewmember essentially invented an effect to explain the anomalous readings from the test. Because BP failed to provide any guidelines for success/failure criteria of this critical test, the crewmember's superiors accepted the explanation without much question. Additionally, there were no requirements for this kind of unusual information to be sent back to shore for more expert analysis or approval, giving Transocean crewmembers little incentive to thoroughly consider their conclusions (National Commission, 2011). Less moral hazard existed in this relationship, due to the presence of BP employees on board the rig during drilling operations.

Another important company BP acted as principal to was Halliburton, the agent contracted to design the cement used to seal the well, as well as install it. Throughout the design process, Halliburton failed to report cement test results to BP on multiple occasions. However, BP did not provide them with the incentive to do so, nor ask for the results when they were not provided (National Commission, 2011). Halliburton lacked incentive to both conduct all necessary tests and to report results of tests that were conducted, since BP did not keep tabs on or request either. Because the cement slurry being designed was unusual, BP had even greater responsibility to check up on Halliburton, but still failed to do so (BP, 2010).

5.1.6 How can operating companies, such as BP, alter contracts with their employees to incentivize them to promote a safety culture while on the job?

Yet another set of principal-agent problems existed within the companies involved in the *Deepwater Horizon* disaster. There is evidence that BP employees did not have the proper incentives from corporate BP as their principal to promote a safety culture on board the rig. To the contrary, many decisions that were made in the events leading up to the blowout imply the promotion of a time- and money-saving culture, which is in opposition of a cautious one. For example, during well abandonment, there was an issue with the number of centralizers available versus how many the plans called for. After much deliberation and miscommunication between BP team members about replacing the missing centralizers with questionably substandard centralizers, only six centralizers were used—ten less than the plan called for. Although the BP Drilling Engineering Team Leader and a BP senior manager felt the differently designed centralizers should have been used to honor the abandonment plan's requirements, the BP Well Team Leader on board the rig stated their unconventional design would take too much time to install, and made the decision not to use them. His superiors did not contest his decision, implying this kind of timesaving-over-caution environment was approved of (National Commission, 2011).

Another example of timesaving behavior happened during a crucial step of the abandonment process: conversion of the float collars. Due to time constraints, when less flow was observed during conversion than anticipated, BP's team concluded that the pressure gauge was broken. Conversion was deemed successful, with no additional explanation or investigation (National Commission, 2011).

BP made several questionable decisions regarding cementing of the well, the failure of which is cited by all three investigations as one of the major causes of the blowout. A light nitrogen slurry cement design was chosen to reduce chances of cracking the delicate rock formation at the base of the well, but despite the unusual design, no extra care was taken to ensure its quality. In fact, BP experts were never given the opportunity to perform quality assurance tests on the cement before it was used, probably in the interest of saving time. The BP zonal isolation experts that would have performed the tests did not demand an opportunity to do so (National Commission, 2011) and thus lacked incentive to take care in their responsibilities.

After the primary cement job was pumped, lost returns were the only criteria for its success. When no flow-back was observed, BP crewmembers determined the cement job was a success. Schlumberger technicians were on board to conduct a cement evaluation test, but because this single criterion had been met, they were sent home. Rather than exercise caution by double-checking cement stability with a third party team of experts, BP crewmembers made the decision to save time and $128,000 (National Commission, 2011).

Evidence of BP's cost-saving culture is further evidenced by their decision to use unusual spacer fluid during the critical negative pressure test. The fluid used was made out of two different lost-circulation materials left over from previous well operations, which would have needed to be disposed of in a prescribed way onshore had it not been used in this way. Although the spacer was of unique composition, it was never thoroughly tested for its purpose (National Commission, 2011). Clearly, the BP employees on board *Deepwater Horizon* did not have the right incentives from corporate BP to be exercising caution in their decision-making. Even if regulations were in place to encourage avoidance of time- or cost-saving behaviors without careful consideration, these regulations were not enforced through incentives such as oversight.

5.1.7 How can subcontracted companies, such as Transocean, also alter contracts with their employees to incentivize them to promote a safety culture while on the job?

Transocean employees also made decisions that exhibited a lack of consideration for caution and safety concerns and implied principal-agent problems within the company. For example, the Transocean Well Control Handbook stipulated that wells should be monitored at all times, but did not explain how this should be done in special circumstances. Despite this stipulation, drillers and mudloggers, who were responsible for well monitoring, were not monitoring the well at all times during the events that occurred on April 20, 2010. Before the blowout occurred, Sperry Sun monitoring data was clearly indicating that the drill pipe pressure was continuously increasing, rather than staying the same or decreasing, as it should have been. However, no one was around to notice this. Had the crew detected this anomalous information when it became available, prevention or control of the blowout may have been possible (National Commission, 2011). Transocean was aware of the need for constant monitoring, but provided its employees with no incentive to abide by this.

Another decision made by Transocean crewmembers that went against Transocean's protocol was to divert mudflow through the mud gas diverter system, rather than overboard as the Handbook stated (BP, 2010). Diversion of the mud overboard would have saved the crew time, and chances of ignition on board the rig could have been reduced (National Commission, 2011). The crew clearly needed more incentive to follow Transocean Handbook procedures.

The failure of the blowout preventer, technology belonging to Transocean, is cited by all the investigations as a major cause of the blowout. There was no surface testing of this equipment before drilling began, yet after the explosion, two control pods were found to be dysfunctional. Testing of the equipment according to regulation would have detected these issues (National Commission, 2011). Transocean failed to incentivize its employees to take responsibility for equipment maintenance.

In December 2009, another Transocean rig had a similar incident in the North Sea. The incident was contained, but it cost Transocean both time and money. Despite learning some lessons about the need to provide more explicit instructions regarding procedures, such as negative pressure tests and well clean up operations, Transocean did not pass on the lessons to any of its employees outside the incident. The *Deepwater Horizon* crew never heard any of the advisements set forth by Transocean. The advisements included special instructions for when only a single mechanical barrier is present, which was the case on *Deepwater Horizon* at the time of the blowout (National Commission, 2011).

5.1.8 How can industries like offshore drilling be restructured in terms of regulation to incentivize all parties to assume greater responsibility for their actions?

As it is currently structured, the offshore drilling industry involves many different agencies with many different roles and objectives. Both between and within the agencies, these conflicting objectives lead to principal-agent problems. Additionally, the way it is organized is complex and distorted. There is a thin distribution of responsibility that allows agencies and individuals to have a lesser sense of liability for potential damages and focus more strongly on their respective objectives, which are usually profit-driven. The complicated relationships between companies and regulators, companies and subcontractors, and companies and their employees lead not only to deferral of responsibility, but also to issues with communication.

5.2 Proposed Solutions

Using an investigation of the *Deepwater Horizon* disaster as an example of what can happen in an industry where there is a high risk for negative externalities, it proves impossible to realistically determine which companies and individuals can be held to blame for what went wrong. Complex relationships existed between the enforcer (MMS) and operator (BP); between the operator and its subcontractors (Transocean, Halliburton); and between companies and their employees on site. Additionally, from a literature review of related questions about industries with high risk for negative externalities, it is clear that far too many nuances, exceptions, and unpredictable elements exist in the real world to determine one optimal enforcement strategy for all these industries. Economists have recommended various options for the best way to regulate companies in industries like offshore oil drilling, but the assumptions they make in order to do so are unrealistic. Using the questions that arose in the identification of agency problems in Section 5.1 of this Chapter as a guide for what must be resolved, in conjunction with my evaluation of the events that led to the biggest accidental oil spill of all time, *Deepwater Horizon*, within the framework of the principal-agent model, I have composed a list of potential mechanisms for an optimal enforcement strategy. This strategy was created with the intention to promote a stronger safety culture in these industries by resolving principal-agent problems on all levels. Although certain adjustments should be made according to industry and scenario, it is a combination of these proposals that is recommended for creating an optimal enforcement strategy for industries with a high risk of negative externalities.

5.2.1 What kinds of incentives can the government have to choose to promote safety rather than place emphasis on making a profit?

A major flaw in the offshore drilling industry lay in the incentive scheme of MMS, the government agency in charge of enforcing a safety culture and protecting the environment from the operations of oil drilling. However, the conflicting responsibilities of collecting revenue from lease sales with enforcing regulations on lessees did not give MMS enough incentive to regulate strictly or effectively. In May 2010, almost immediately after the *Deepwater Horizon* disaster, MMS was dissolved ("The Reorganization," 2010). In its place, three separate agencies were created for regulation of the offshore drilling industry. The Bureau of Ocean Energy Management was created "to ensure the balanced and responsible development of energy resources on the Outer Continental Shelf" ("The Reorganization," 2010). Next, the Bureau of Safety and Environmental Enforcement was created to "[ensure] safe and environmentally responsible exploration and production and [enforce] applicable rules and regulations" ("The Reorganization," 2010). Third, the Office of Natural Resources Revenue was created to "[ensure] a fair return to the taxpayer from offshore royalty and revenue collection and disbursement activities" ("The Reorganization," 2010).

As no direct responsibility can be placed on the government for potential damages during offshore drilling operations, splitting MMS into these branches of responsibility was the only realistic way to promote incentive within the government to protect the environment. By removing lease sales and profit from the concerns of two of the branches, there will be more attention towards their respective resource development and protection responsibilities, and no more conflicting objectives. This reorganization was the most logical and effective step that could have been taken by the government to improve the safety culture in the offshore drilling industry, and have more optimal enforcement.

5.2.2 What incentives can be given for experts on the technicalities and safety concerns of industries with high risk for negative externalities, like offshore drilling, to want to work as enforcers and monitors in such industries?

Due to a lack of government financial resources, monetary incentives for federal employees of The Bureau of Ocean Energy Management or The Bureau of Safety and Environmental Enforcement are not an option. However, if other third party monitors are brought into the industry, they might have the resources necessary to attract more specialist employees. One option is to require third party insurance for offshore drilling operators, both to help cover potential damages and act as a monitor of operations. Since insurers would be responsible for covering damages should an incident occur, they would have incentive to enforce safe drilling operations. Private insurance companies have the resources available to pay higher salaries than government agencies, thus attracting more qualified experts to inspect and monitor all parts of the drilling process (Cohen, Gottlieb, Linn, & Richardson, 2011).

5.2.3 What incentives can be given to companies, as agents, within industries with high risk for negative externalities, such as the drilling industry, to make them act more cautiously?

The primary principal-agent relationship in the offshore drilling industry is that between the enforcer and the companies involved in drilling operations. In order to provide these companies with incentive for taking safety precautions, a strict liability standard rather than a negligence rule is preferable. Because of moral hazard in the industry, enforcers are unable to observe every decision made and action taken during drilling operations, as well as which company or individual is responsible for each. As discussed by Viscusi & Zeckhauser (2011), enforcement of a negligence rule requires the evaluation of actions against a due care standard (Viscusi & Zeckhauser, 2011). This is unrealistic in an industry with moral hazard. Even now, almost four years after the *Deepwater Horizon* disaster, BP is undergoing litigation proceedings to determine the degree of blame to which they can be held accountable. Endless litigation such as this wastes time, money, and resources that could be substantially cut back on if a strict liability standard is put in place. Additionally, strict liability further prevents companies from deferral of responsibility during operations, since companies will be held accountable for damages, regardless of the level of care they exhibited. Although some arguments for how a negligence rule could work exist, the logistics involve assumptions and rules that only serve to complicate relationships between a principal and agent. Strict liability standards are simple, straightforward, and usually less expensive to enforce than a negligence rule (Cohen, 1998).

With strict liability, a liability cap is important to set. A liability cap is the amount of damages a firm must be able to cover in order to engage in offshore drilling operations. The current liability cap for the offshore drilling industry in the United States is $75 million. Given that BP has already set aside $42 billion for covering damages from the *Deepwater Horizon* spill, it is clear that this liability cap needs to be raised significantly. If a firm is unable to cover the cost of potential damages they may cause, they should be prevented from conducting offshore drilling operations. This leads to a concern for smaller firms, which may not be able to afford a high cap. However, keeping small firms in the industry is beneficial in a competitive market, so there are several ways in which small firms can be assisted in meeting the liability cap standards. One suggestion is to set the cap as a percentage of a given firm's revenue. However, this does not ensure the firm will be able to cover damages incurred. Instead, some sort of tax or insurance should be required to help reach the liability cap and keep small firms competitive within the industry. Providing small companies are taxed or insured up to the cap, meaning damages will be covered, they will be permitted to drill (Cohen, Gottlieb, Linn, & Richardson, 2011). As previously discussed, third party insurance provides the additional benefit of an expert to monitor drilling operations, making it potentially preferable to a tax.

Another way to keep small companies involved is to assess liability caps on a project-by-project basis. This may prevent small companies from drilling in the more risky deepwater areas, as liability caps will likely be higher for these sites. However, it will promote the drilling of wells closer to shore with less risk of damages occurring, as well as keep small companies competitive (Cohen, Gottlieb, Linn, & Richardson, 2011).

Finally, there is an option for large companies, such as BP, to self-insure on projects. When they contract out to smaller companies, these companies could then provide part of the insurance. This scenario keeps all involved parties responsible for maintaining safe drilling operations, as well as provides a role for small companies to remain in the industry.

5.2.4 What kind of contract can be designed to incentivize safety interests within involved companies (operators and subcontractors), given the moral hazard existent in these industries?

Another principal-agent relationship existent in the offshore drilling industry is that within operating companies, which deal with moral hazard as well. On shore, corporate BP confronts moral hazard with its employees on board drilling rigs, and subcontractors suffer from the same. When devising a contract, the principal must take moral hazard into account and provide incentives to agents accordingly. One way to design such a contract is to allow for third party observability. Although an agent's actions are not observable, some kind of results can be required that will imply the agent's actions and effort level (Newman & Wright, 1992). These could include holding employees on board drilling rigs liable for specific failings on board the rig, dependent on their role.

With moral hazard, some degree of monitoring is necessary. It might be in the best interest of drilling companies to hire someone specifically for this role who would be present on board drilling rigs at all times, giving employees incentive to exercise their best efforts. Similar to Cohen's (1998) idea for holding certain employees liable for environmental damages and on a fixed wage contract, this monitor would not be responsible for making any decisions regarding drilling operations. He would not have incentive to perform operations in a timely or cost-saving manner, but only to prevent any employees from falling short of the expected standard of care, as this kind of shortcoming would reflect back on him (Cohen, 1998). This self-monitoring would be cheaper and more effective than third party monitoring, and would divert monitoring costs onto the operating company, rather than the government.

When devising incentive contracts, the question of positive or negative incentives arises. With properly designed incentives, employees will exert their best efforts, avoiding the problems that come with moral hazard. In industries where level of production is key, bonus contracts are more efficient than penalty contracts. As discussed by Lazear (1998), under bonus schemes a critical level of effort must be reached, and reducing effort below a certain point has no cost. Additionally, individuals are psychologically more attracted to bonuses for extra effort than penalties for not reaching a certain standard (Lazear, 1998). Miller & Whitford (2007) propose a pure incentive contract providing a flat wage high enough for the agent to accept, plus a bonus when high levels of effort are displayed. They believe these kinds of incentives will promote the alignment of self-interested behavior with efficient allocation in principal-agent relationships. According to Miller & Whitford (2007), when the actions of agents have a large effect on the outcome of the final product, a principal is more likely to provide a bonus high enough to incentivize the agent to exert sufficient effort (Miller & Whitford, 2007). In the case of the offshore drilling industry, the actions of workers on board drilling rigs are critical for production, and thus a contract providing a bonus would be the optimal choice. Monitors on board drilling rigs could be responsible for assigning bonuses.

5.2.5 What kind of contract can an operator, like BP, draw up with its contracted subsidiaries to hold them more accountable for performing their duties with due care?

A third principal-agent relationship that exists in the offshore drilling industry is that between drilling site operators and their subcontracted companies. If BP had been held strictly liable for all potential damages at the Macondo well site, they would have had incentive to contract out responsibility for parts of this liability to subcontractors as they hired them. With this kind of top-down incentive scheme, each involved company would feel responsible for their actions and avoid making decisions that might lead to a scenario in which they would need to make large damage payments. The government would hold operators responsible, and in turn, operators would hold subcontractors partially responsible. Issues with damage payments and cleanup costs would be determined between an operator and its subcontractors, rather than through the government, again internalizing these extra costs.

5.2.6 How can industries like offshore drilling be restructured in terms of regulation to incentivize all parties to assume greater responsibility for their actions?

As it now exists, the offshore oil drilling industry is full of complex, multi-layered relationships that allow for deferral of responsibility and a lack of accountability. To build an optimal enforcement strategy, the industry must be restructured through simplifying the scenario. The relationships between involved parties must be clearly defined from the outset, with contracts stipulating exactly what each party is responsible for on a given project. In these contracts, there are two potential liability schemes that will disallow parties from evading responsibility for their actions.

First, one firm could be held strictly liable for all potential damages from the outset. In the case of *Deepwater Horizon*, this would have meant BP signing a contract with MMS when their lease for the Macondo well site was granted, accepting full liability for any damages incurred, no matter who the company felt was internally at fault (Viscusi & Zeckhauser, 2011). For example, BP would not have been able to blame Halliburton for the failure of their cement to seal the well. Through their initial contract with MMS, BP would have been held responsible for this as they made the decision to contract Halliburton and approved the cement design and installation. Since drilling companies would probably be wary of such a strict liability contract, they would have the option to defer certain responsibilities to subcontractors in their respective contracts. Although MMS would hold BP strictly liable for the damages of the Macondo well blowout, if BP had specified which parts of operations its subcontractors, such as Transocean and Halliburton, would be held accountable for should an accident occur, BP could subsequently hold these companies liable for helping to cover parts of their cleanup and penalty costs from MMS. For example, BP could stipulate that if the cement provided by Halliburton failed to effectively seal the well, Halliburton would be responsible for covering a percentage of damage costs incurred.

An alternate liability scheme that could be implemented would be to hold all firms involved in a project equally liable for damages. This would still require an initial operator to take on liability responsibilities when it was leased a site by the government, but as the operator subcontracted responsibilities to various corporations, these companies would also need to sign liability contracts with the government. Should an accident occur, each company would pay the damages in full, meaning each would feel fully liable for their actions (Segerson, 1988). Without the ability to defer responsibility, each company would promote safe behavior. Because some firms are involved on a very small level with a project, it could be at the discretion of the initial operator to determine which subcontractors should be held fully liable.

5.2.7 Can these strategies be applied to industries with high risk for negative externalities outside the offshore drilling industry?

Although this search for the optimal enforcement strategy has been conducted in regards to the offshore drilling industry, and specifically, the *Deepwater Horizon* disaster, proposals for the resolution of principal-agent problems in this industry can be applied to other industries with high risk for negative externalities. Different strategies will work better than others, subject to the exact structure of the industry and the companies within that industry. However, the basic roles of enforcers, operators, and subcontractors, as well as the issue of moral hazard in principal-agent relationships are general concepts that exist in many industries.

Enforcement agencies for any industry can be divided into entities with separate responsibilities regarding safety and profits, strengthening incentives for and attention towards enforcement of safety regulations. In order to incentivize companies within risky industries to avoid negative externalities, there must be a liability scheme in place. Proposals such as raising the liability cap and holding companies responsible for damages up to this amount would serve as strong incentive for cautious behavior and decision-making across industries. As in the drilling industry, many industries involve the subcontracting of various services, so holding one company strictly liable for a project helps provide greater incentive for safe operations. Additionally, this cuts back drastically on litigation costs following accidents. While strict liability is preferable to a negligence rule in the drilling industry, there may be some industries with negative externalities that could be better served by a negligence rule. However, most of these industries have issues with moral hazard, and would thus be well suited to strict liability.

Suggestions for resolution of moral hazard in the drilling industry are also applicable outside the industry, with options including third party observability and self-monitoring effective for most industries with moral hazard problems. The decision of whether to use positive or negative incentives in contracts is one that is more dependent on industry. However, in any industry that has emphasis on production, like the drilling industry, bonus schemes would be preferable.

Due to the risks involved in operations in these industries, third party insurance could be required, or at least offered, as a way to cover liability for companies with insubstantial internal resources. Third party insurance has the additional benefit of providing an expert third party monitor in conjunction with monitoring by the enforcement agency for an industry.

Overall, the majority of proposals submitted to form an optimal enforcement strategy for the drilling industry can be applied generally across industries with high risk for negative externalities.

Chapter VI

Conclusion

The world is full of uncertainty—no one can predict a future in which unprecedented events occur regularly. As the world and humankind continue to develop and grow, there will always be unusual circumstances and happenings that go beyond the wildest imaginings. Unfortunately, it is often these extraordinary circumstances or catastrophic events that move people to action. Rather than preempt the worst-case scenario, people have a tendency to slip into a comfortable carelessness until the worst occurs.

It is common knowledge that offshore drilling is a risky practice, especially with its recent shift to deeper and less-charted waters. Appropriately, from protecting the environment to protecting the lives of those working on rigs, the government and the drilling industry alike have always had extensive rules and protocols in place. Major oil spills have occurred in the past, but as time puts distance between such disasters and the present, the tendency to skimp on the fine print of regulations emerges. Both government regulators and drilling industry companies suffer from becoming too comfortable—as years go by without incident, attention to detail deteriorates, and some steps in ensuring safety are skipped.

The events surrounding the *Deepwater Horizon* disaster are an example of this tendency. Through an investigation of the disaster, it became clear that fault lay with every level of the industry: from the enforcing government agency, MMS; to the operator on the site, BP; to its subcontractors, Transocean and Halliburton; to individual employees of the companies. With a lack of attention to safety protocol and regulations within the industry, all parties were to blame for the disaster. The worst-case scenario occurred, spurring the need for reform. As much as is realistically possible, an event like this must be prevented from happening again.

Analysis of the principal-agent model proved extremely helpful in providing a framework for examining the flaws within the offshore drilling industry. Problems with contractual relationships, incentives, and asymmetrical information became evident on every level of the offshore drilling industry, and specifically in the *Deepwater Horizon* incident. However, due to the complicated nature of the industry and the various relationships involved in any given drilling project, applications of typical resolutions for principal-agent problems were not straightforward. The problems needed to be resolved, but in the context of the circumstances unique to the offshore drilling industry. This included the need for the enforcing agency, MMS, to incentivize a safety culture amongst its agents. In principal-agent literature, it is assumed that a principal will be motivated to produce the socially optimal outcome. However, this was not the case for MMS, a principal without a true financial stake in the industry, charged with regulating, but not owning or profiting in the enterprise. Royalties collected by MMS went into the National Treasury, benefiting the government, but not directly profiting their agency.

Additional review of relevant literature on this model as applied to industries with high risk for negative externalities and with potential for moral hazard helped in piecing together the optimal set of incentives for the offshore drilling industry.

Because the *Deepwater Horizon* disaster is a contemporary event, little literature yet exists dealing with it from this perspective. However, there is literature on topics such as moral hazard within the offshore drilling industry, and on the principal-agent model applied to Coast Guard regulation of oilrig transfers in coastal waters. No literature yet suggests the set of incentives that would be an optimal enforcement strategy for the offshore drilling industry, but by taking pertinent information and research from various sources, application of strategies to the industry became possible.

Since the industry and the relationships of agencies within it are by their very nature complex, suggestions for components of an optimal enforcement strategy must account for intricate layers of authority. The relationships must be simplified by specifically defining responsibilities from the outset of any project. Beginning at the top, this means providing the enforcing agency with incentive to enforce regulations. Following the *Deepwater Horizon* disaster, MMS was broken up into three branches to resolve its conflicting objectives of profit and regulation, providing the first step toward necessary reform. Additionally, the government's role as an enforcer is hampered by a lack of resources to attract the most qualified employees for enforcing regulations and reviewing the proposals submitted by drilling companies. To resolve this, third party insurance is suggested to provide a third party monitor with ample means to employ experts in the field. On the next rung of authority are companies that act as chief operators for drilling sites. In order to incentivize these companies to promote a culture of safety among their agents, the government should hold them strictly liable for all damages. Strict liability is less costly to enforce than a negligence rule, and avoids the problems with moral hazard in the industry that a negligence rule would face. If an operator is held strictly liable, they will have incentive to devise contracts with their subsidiaries that will hold them accountable as well. With this incentive to follow protocol, companies involved in drilling projects must then incentivize their employees by making them feel liable. Devising a contract that allows for third party oversight of agents' efforts assists with resolving moral hazard issues, as well as provides a kind of self-monitor. Additionally, for industries such as this in which production is key, a pure incentive contract with a sufficient flat wage plus a bonus for higher levels of effort is efficient. Only in conjunction with each other can these various layers of incentives have the potential to compose an optimal enforcement strategy for the offshore drilling industry.

After an examination of the characteristics of the offshore drilling industry that required different aspects of enforcement, more general conclusions were determined. As an industry with high risk for negative externalities, issues with principal-agent relationships, issues with moral hazard, and an inherent conflict between promotion of a safety culture and profit-maximization, the offshore drilling industry has much in common with many other industries. Thus, the possible pieces of the optimal enforcement strategy proposed by this thesis can be transferred and applied, either wholly or in part, to industries with similar characteristics to those listed above.

In reality, every industry, company, and individual project is unique. In order to make suggestions for an optimal enforcement strategy for industries with high risk for negative externalities, research criteria had to be narrowed. The *Deepwater Horizon* case study was chosen because the offshore drilling industry is a prominent example of this kind of industry, and *Deepwater Horizon* is a prominent example of a worst-case scenario within this industry. The enforcement strategy devised inherently has a bias towards applying to this incident and industry. Given more time, this thesis could be expanded to include additional case studies from both the offshore drilling industry and other industries with high risk for negative externalities. Through comparison within and across industries, more universally applicable components for an optimal enforcement strategy could be developed. However, due to differences between industries, there can be some benefit to devising an enforcement strategy on a smaller scale such as this.

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