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Promoting Private Risk Management in Offshore Drilling

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Abstract: This paper critically examines existing policies for regulating offshore drilling. I argue that historical regulations based on requiring significant redundancy in safety systems—"belts and suspenders"—is ineffective because the risks of safety system failures are not independent. New regulations require detailed safety and environmental planning and can be broadly classified as management-based regulations (MBR). The paper evaluates the theory of management-based regulations as it applies to offshore drilling and presents the existing evidence on MBR effectiveness. The results indicate that MBR is theoretically well suited to regulate offshore drilling, but there is limited empirical evidence of the effectiveness of MBR in regulating low-probability, high-consequence events. The paper ends with a proposal for an alternative regulation called a deposit-discount-refund system that is designed to better promote private risk management by creating incentives for both the creation of and the implementation of risk management plans.

JEL Codes: Q48, K32

Key Words: Macondo, Deepwater Horizon, regulatory reform, management-based regulation, deposit-refund, safety case

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1. Introduction

On April 20, 2010, 11 workers were killed in an explosion on the Deepwater Horizon rig in the process of drilling the Macondo well off the Gulf of Mexico. The blowout resulted in between 4 and 5 million barrels of oil leaking into the Gulf of Mexico. Early estimates of the damages from the oil spill are in the range of $20 billion with an addition $17 billion in fines (The Economist 2010). There are many entities at blame for the significant human and environmental disaster in the gulf and regulators have not escaped unscathed. Regulators at the Minerals Management Service (MMS), the federal agency charged with issuing permits and overseeing safety of offshore oil drilling, appeared compromised by conflicts of interest and unqualified to ensure safety in operations (CNN 2010; Leonnig 2010; U.S. Department of the Interior 2010). The magnitude of the damages from the Gulf oil spill, combined with perceptions of regulatory capture at MMS, has brought into question the sufficiency of current regulatory approaches to offshore oil drilling.

Prior to the Gulf oil spill the primary form of regulation of offshore oil drilling was a set of highly prescriptive command-and-control regulations requiring significant redundancy in safety systems; an approach I call "belts and suspenders." The belts and suspenders regulations were coupled with a strict liability regime where the operating company (BP in this case) was strictly liable for damages up to $75 million with additional damages covered from a government pool of funds generated through taxes on oil (Hargreaves 2010). Arguably, this coupling of regulatory systems should have created the right incentives for companies to manage risks. The safety technologies are required to be in place and if you are financially liable for damages you should have the right incentives to ensure that all these systems are working properly. Nonetheless, a disaster occurred.

This chapter examines three alternatives for regulation of offshore drilling in the United States. The first approach is the belts and suspenders approach used prior to the Gulf oil spill and also used as a response to this oil spill. I argue that the belts and suspenders approach is flawed because it fails to account for the inherent dependence in risk derived from human control of those technologies. The belts-and-suspenders approach may even encourage risk-taking by creating the impression that multiple safety systems will catch any errors before a significant accident occurs.

The second alternative examined is management-based regulation, which has been used to regulate offshore drilling in other countries and has been adopted by the United States in response to the Gulf oil spill. This approach requires drilling operators to develop detailed safety and risk management plans. This chapter examines the theoretical and empirical literature on management-based regulation to evaluate its suitability and likely effectiveness for regulating offshore drilling.

A potential disadvantage of management-based approaches to regulating offshore drilling is while risk management planning may occur under the regulation, there is little to ensure that risk management plans are fully implemented. The third alternative examined in this chapter is a proposal for promoting risk management for offshore drilling. This new approach, which I call a deposit-discount-refund system, requires upfront establishment of a project-level "safety deposit." Operators can earn "discounts" on the size of their safety deposit by earning high grades on independent third-party assessments of their safety management plans. Upon successful completion of the project the safety deposit is refunded to the company.

The chapter is organized as follows. Section 2 contains a brief overview of the Deepwater Horizon/Macondo accident focusing on the multiple failures in redundant safety systems that occurred. The history of the belts and suspenders approached and its application to offshore drilling is discussed in Section 3. Section 4 discusses management-based regulation (MBR) and the advantages and disadvantages of using such regulation for offshore oil drilling. Section 5 presents the deposit-discount-refund alternative and argues that this approach may provide stronger incentives for private risk management on offshore drilling platforms. The final section offers some concluding thoughts and directions for future research.

2. The Blowout at Deepwater Horizon/Macondo

A full description of all the components that contributed to the oil spill in the Gulf is beyond the scope of this paper and is available elsewhere (U.S. Chemical Safety and Hazard Investigation Board 2010; U.S. Department of the Interior 2010; BOEMRE 2011; National Commission on the BP Deepwater Horizon Oil

Spill and Offshore Drilling 2011). However, a brief narrative of key decisions that contributed to the disaster is necessary to understand the potential effectiveness of alternative regulatory responses.

The blowout at the Macondo well occurred while the well was being prepared for temporary abandonment. The well had been drilled and evidence suggested the well had reached a pool of hydrocarbons that warranted preparing the well for future production. Once prepared, the well is sealed off and temporarily abandoned until extraction operations begin at the site (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).

To prepare the well, a steel casing is lowered from the wellhead on the seafloor to the hydrocarbon pool. Cement is then pumped down the casing and back up the sides. The cured cement then isolates the hydrocarbons from the well (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).

The key failure at the Macondo well was that the cement job failed to properly seal the hydrocarbons from the well. There are at least three major changes in the engineering design of the well that occurred in the period prior to the disaster that may have contributed to the failure. More failures are described in the National Commission Report (2011), but here I highlight three important ones.

- Production Casing Design—There was disagreement about the design of the production casing. Results from different engineering models, used by BP and its contractor, Halliburton, argued for different types of casings. BP engineers decided to stick with the original design despite concerns about its suitability (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011). There is not universal agreement that the production casing design was a proximate cause of the blowout (U.S. Department of the Interior 2010).

- Number of Centralizers—There was disagreement on how many "centralizers" were required to keep the casing centered in the well. If the casing is not perfectly centered in the well, the cement will not flow evenly up all sides of the casing and risks of hydrocarbon intrusion into the well increase. BPs original design included 16 centralizers. At the time the casing was to be lowered into the well only 6 centralizers were available. Despite model results suggesting that up to 21 centralizers were required, only 6 centralizers were used (U.S. Department of the Interior 2010; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).
- Cement Slurry—The exact formulation of the cement slurry depends on the characteristics of the individual well. At the Macondo well there was concern about the fragility of the rock formation and a decision was made to use cement that had been "levened with tiny bubbles of nitrogen gas" (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011). In addition, BP and Halliburton made changes to

the pressure at which the cement was pumped and the way in which the well was prepared before cementing. All these changes were designed to reduce the risk of fracturing the rock formation which could lead to hydrocarbon leakage (U.S. Department of the Interior 2010; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).

These three decisions increased the risk of a blowout at the Macondo well. However, there were several systems in place that should have detected hydrocarbon leakage into the well before the situation became dire. These signals included laboratory analysis of the nitrogen foam cement slurry, visual tests of fluid flow, and two negative pressure tests on the well (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011). These tests were performed and each had abnormal results, yet these abnormalities were dismissed or rationalized (U.S. Department of the Interior 2010; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).

In addition, there were multiple safety systems in place to minimize the size of the blowout should one occur, in particular, the blowout preventer (BOP) which contains blind shear rams that cut through the well and seal it off. The BOP should have been activated manually when staff on the rig triggered the emergency disconnect system. When that failed it should have activated automatically using the deadman system. Neither system activated the blind shear rams and the well remained opened, resulting in a massive oil spill

(National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).

It is tempting to write off the sequence of failures at Macondo as a rare occurrence; the result of a perfect storm of carelessness and bad luck that is unlikely to occur again. Indeed before the Macondo blowout, the view was that safety of deepwater drilling had progressed far enough that the risk of a major oil spill was zero. In a speech on the economy in Charlotte, NC on April 2, 2010 (a mere 18 days before the catastrophe), President Barack Obama said:

> "I don't agree with the notion that we shouldn't do anything. It turns out, by the way, that oil rigs today generally don't cause spills. They are technologically very advanced. Even during Katrina, the spills didn't come from the oil rigs, they came from the refineries onshore."
>
> (The White House April 2, 2010)

But this optimistic view is inherently based on the belief in the independence of safety-system failure probabilities. Under these conditions, we can observe a situation like Macondo, but only very rarely. However, as the accounts of the events leading up to the Macondo blowout illustrate, the probabilities of multiple failures are not independent precisely because the same set of people are managing all of these systems.

3. Belts and Suspenders

Risks of environmental catastrophes, be they from nuclear power, offshore oil drilling, or shale gas drilling, are frequently viewed as technological risks. The primary regulatory approach to preventing systemic technological failures, and their resulting catastrophic damages, has been to require significant redundancy in safety systems; an approach I call "belts and suspenders."

Belts and suspenders regulations were the primary form of regulating offshore drilling in the United States before the Gulf oil spill. Even after the oil spill, when MMS was reorganized and the new Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), one of BOEMRE's first actions was to enact the Drilling Safety Rule (DSR) which contains a additional set of belts and suspenders regulations designed to reduce the chance of a blowout on a deepwater oil rig. These regulations include:

- requirements to control potential flows during well construction,
- certification of casings and cement by a professional engineer,
- two independent barriers across the flow path,
- ensuring proper installation of casings and liners,
- third-party verification that the blind-shear rams can cut drill pipe at anticipated pressures,
- requirements for a blow-out preventer (BOP) that can be controlled by a remotely operated vehicle (ROV)
- an ROV that is capable closing the pipe rams, the blind-shear rams, and unlatching the Lower Marine Riser,
- requirements for autoshear and deadman systems,

- training and documentation requirements (Bureau of Ocean Energy Management 2010).

This extensive set of prescriptive requirements is a classic example of the "belt and suspenders" approach to regulating technological risks. Significant redundancy in safety systems are required with the idea that all of the systems are unlikely to fail at the same time. This approach seems further motivated by the idea that with sufficient technological redundancies the "human" element in catastrophes, which cannot be directly regulated, is minimized. The particular laundry list of regulations in the DSR is also directly responsive to the particular series of technological and human failures at the Macondo well.

There are several problems with the belt and suspenders approach. First, this command-and-control approach is costly. In order to provide sufficient safety systems in a manner that will be applicable to all drilling operations significant amounts of redundancy are built in. These redundancies are costly ways of maintaining safety.

But perhaps more importantly, there is concern that these prescriptive approaches do not work as intended. The key assumption underlying the belts and suspenders approach to risk regulation is that the probabilities of safety-system failures are independent. That is, the failure of one system does not affect the probability of failures in other systems. From a purely technological standpoint this assumption is often reasonable. What is missing from this technological view is the human dimension of risk. On a given deepwater oil rig, a nuclear power plant, or a shale gas drilling operation, the technologies are operated and maintained by the same company—the same people. Human errors that interfere with the successful operation of one safety-system may well predict similar problems at other safety-systems. The human dimension makes the risk of system failures dependent. If the risks are not independent, then the probability of catastrophic failure of all systems does not approach zero rapidly. There remains a non-trivial probability of a large-scale failure—a fat-tail risk.

Furthermore, the requirements of multiple safety systems may actually encourage risk taking. If we assume that decision-makers are profit maximizers, then at each decision point with potential safety or environmental consequences, the decision maker must weigh the expected costs of taking a conservative, safety-focused approach with the expected costs of more aggressive decisions. The expected costs of the safety approach may be time spent waiting for a second opinion, further analysis, or additional materials and equipment. The expected costs more aggressive decisions are some expectation of the fines from any accident resulting from the decision as well as private costs including lives lost, property damage, and so forth. The cost of waiting for the second opinion, analysis, or materials may be quite salient. The costs of more aggressive decisions involve an estimation of the likelihood of an accident, the likely magnitude of the accident, and the resulting fines and damages.

Accidents are rare and large accidents even rarer, so the likelihood that any one short cut leads to an accident is also very low. This is particularly true if you believe that if the short-cut you take is erroneous another safety system will catch that mistake before a significant accident occurs. In essence, the probability of an accident from any one decision is small, and the conditional probability of an accident from that decision given other safety systems may be viewed as close to zero. Of course, if everyone making decisions views the problem this way then things can go very wrong.

A specific example from the Macondo well was the decision to use only six centralizers on the well despite models suggesting that up to 21 centralizers were required. The decision to use six centralizers was complex, but based in part on the additional time required (and the additional costs associated with that time) to use more centralizers. In retrospect, the correct decision would have been to use more centralizers or, at minimum, spend more time determining the safety if only six centralizers were used. But from the view of the BP decision-makers, the risk might be worth taking. If the cementing job was not sufficient with six centralizers there should have been other signals. In particular, the negative pressure test should have revealed that fluids were leaking back into the well. The negative pressure tests did reveal anomalies, but these anomalies were overlooked or misinterpreted. The presence of multiple belts-and-suspenders can lead to a sense of overconfidence in the safety of the whole system, which encourages risk taking.

4. Management-Based Approaches

Given the failure of multiple safety systems at the Macondo well and the lack of qualified government personnel to review permits and inspect wells, the National Commission and others have argued, convincingly, that long-term improvements in safety and environmental protection from deepwater drilling must come from within industry. Several policies have been proposed to try to promote a culture of safety among offshore energy companies. The most widely discussed policy is a form of management-based regulation (MBR).

MBR does not mandate specific means to achieving regulatory ends, but instead mandates that firms engage in systematic planning efforts designed to better achieve the regulatory end (Coglianese and Lazer 2003). A stylized model of MBR is provided in Figure 1. In this model, the regulatory requirements are on the front-end—firms are required to engage in systematic safety or environmental planning. These plans are designed to connect to certain actions and activities, however the actions and activities themselves are unobserved (at least most of the time) and unregulated. Finally, the actions and activities can lead to outcomes, which if negative are typically associated with fines and penalties.

The umbrella of policies that can be considered "management-based" is quite large. All of the following could be considered management-based regulations:

- Regulated firms must consider options to promote the regulatory end and issue a public statement that outlines their plans.
- In addition to the requirements above, regulated firms must review their production process, identify alternative production techniques or input mixes that would achieve the public goal, evaluate the feasibility of these alternatives and report on these evaluations (Bennear 2007).
- In addition to the requirements above, regulated firms must review supply chains and distribution chains including all subcontractors, identify changes in all operations that could promote the public goal, evaluate the feasibility of these alternatives and report on these evaluations.
- In addition to the requirements above, regulated firms must obtain periodic third-party review and certification of their management plans and evaluations.

Variants of management-based regulations are already in use to regulated food safety, pollution prevention and occupational health and safety. In the area of food safety, the Hazard Analysis and Critical Control Point (HACCP) system has been used to control pathogen contamination in the food supply since 1990s. The HACCP program requires food processors evaluate their production process and identify potential sources of food contamination, develop systems to eliminate or reduce those risks, and develop detailed records of their safety activities (Bennear 2007). The Occupational Safety and Health Administration adopted a set of regulations that required firms to implement management systems to assess the risk from chemical accidents, and develop rules and procedures to reduce those risks. Fourteen states have also adopted MBR to reduce toxic chemical use and release from manufacturing. For example, the Massachusetts Toxics Use Reduction Act (TURA) requires that manufacturing facilities develop detailed pollution prevention plans the examine the use of toxic chemicals throughout the production process, identify alternatives for reducing toxics chemical use, and evaluate those alternatives in terms of economic feasibility (Bennear 2006, 2007).

Indeed, MBR is already in use to regulate offshore drilling in other countries, particularly the UK, Norway and Canada. The Safety Case in the UK is an example of MBR for offshore drilling. The exact requirements for each safety case vary slightly by the type of drilling facility; there is separate set of requirements for fixed, mobile, and combined operations. However, all of the safety case regulations contain the same basic set of requirements. Each drilling installation must provide:

- Basic narrative description of the ways in which the installation was designed and will be operated to minimize risk.
- Descriptions and diagrams of the installation and all connections and wells that are planned for the installation.

- Information on the meteorological and oceanographic conditions as well as geologic conditions of the seabed.
- Descriptions of the types of operations and the number of people onboard the installation.
- Description of methods to control pressure, prevent leaks and blowouts, and minimize the effects on the subsea beds.
- A description of any pipeline capable of causing an accident with information on the dimensions and layout, the evacuation plan and location of temporary refuge for workers.
- A completed risk assessment with respect to the prior bullet.
- For operations, the safety case also contains plans for detection of toxic and flammable gases and plans to detect, mitigate and prevent fires.

Similar regulations were proposed by MMS in July 1991 as the Safety and Environmental Management Program (SEMP), but under pressure from industry these regulations were postponed. After the Deepwater Horizon spill these regulations were finally promulgated. The remainder of this section examines the theory of MBR and assess the degree to which offshore drilling risks are likely to be adequately management by these regulations.

4.1. Theory of MBR

Theory suggests that MBR is best suited to policy domains with significant heterogeneity in the sources or risk and the methods of mitigating that risk (Coglianese and Lazer 2003). The costs of command-and-control regulations increase with heterogeneity (Newell and Stavins 2003). However, if heterogeneity is the only concern, then MBR is not the only policy choice. Several policy instruments are well-suited to handling heterogeneity and achieving cost effective risk reductions that are site or entity-specific. These include market-based instruments, such as cap-and-trade or taxes, as well as performance standards (Stavins 2003). But all three of these approaches require some measure of policy outcomes—some measure of performance.

MBR, in contrast, can accommodate significant heterogeneity among regulated entities and can also be used when there are no measures (or poor measures) of policy outcomes (Coglianese and Lazer 2003). The regulated entities ultimately must construct some measure of performance, but this can be site-specific or context-specific and does not need to be monitored by regulators. It is largely for this reason that we observe adoption of MBR in cases where outcomes—for example, safety—are difficult measure because the absence of these outcomes—for example, a major accident—happens infrequently. Observing that a plant has no accidents does not necessarily reveal much about the safety of the plants underlying operations if accidents are infrequent events.

Given these two conditions, heterogeneity and absence of outcomes data, MBR does seem well-suited to regulating offshore drilling risk. But this begs the questions, in the absence of outcome data, and even outcome mandates, can MBR actually deliver improvements in heath and environmental safety?

Referring back to Figure 1, how does MBR actually motivate better actions/activities to lead to better outcomes?

The first way MBR may improve environmental quality or safety is through changes in internal decision-making at the regulated entities. In order for MBR to be effective through this channel it must be the case that the businesses are not already (voluntarily) engaged in the level of environmental management proscribed by the regulation and that there is a strong complementarity between management effort and planning and environmental quality (Bennear 2006). Here I use the economic meaning of the word "complement" which requires that increased consumption of one good/service either increases the marginal benefits or decreases the marginal costs of consuming the complementary good. This means that additional expenditures on safety planning, either increase the marginal benefits of expenditures on safety (by better targeting these efforts) or decrease the marginal costs of safety expenditures (by revealing lower cost alternatives), or both. The key is that once the firms engage in the planning, on average they discover opportunities for improvement that are in their own best interest to undertake. Thus, once planning is required, the improvements in actions/activities and outcomes are entirely voluntary and only occur if in the profit-maximizing or cost-minimizing interest of the firm.

The second way MBR may be effective is through information sharing between the regulated entities and the regulator. The information generated through the development of required plans may reveal something important to regulators about the costs and benefits of safety improvements. Information sharing can also allow for comparison across regulated entities which can, in turn, improve performance through targeted inspections or technical assistance (Karkkainen 2001; Bennear 2006).

4.2. Has Well Has MBR Worked?

While theory suggests that MBR may be a good regulatory tool for offshore drilling. Given the catastrophic consequences of safety failures in offshore drilling operations, it seems reasonable to evaluate how well MBR has actually performed in practice. This raises an interesting analytic dilemma. How does one evaluate the success or failure of a policy designed to regulate risks that are not directly measurable? In typical program evaluations (also called impact evaluations), the outcomes of the "treated" group are compared to the outcomes of a comparable "control" group. But all of these methods require detailed and comprehensive data on outcomes.

The U.S. Chemical Safety Board, an independent government agency tasked with investigating all chemical accidents in the United States, convened a public hearing on regulatory approaches to offshore oil drilling. At the hearing, there was a panel of representatives from the UK, Norway and Australia that discussed the use of the Safety Case in those countries. Without exception the representatives believed that the Safety Case had improved safety and reduced the likelihood of a large-scale disaster in their countries. But almost equally without exception these views were based on anecdotes and some limited (and not fully disclosed) analysis of near-miss data (U.S. Chemical Safety and Hazard Investigation Board 2010). More detailed research, perhaps using international data on near-misses, could help illuminate the impact of the safety case on offshore drilling risk.

In the meantime, empirical analysis of MBR has focused primarily on state pollution prevention programs (Coglianese and Lazer 2003; Bennear 2006; Bennear 2007) because of the existence of a time-series of data on toxic chemical releases from the Toxics Release Inventory (TRI). The cumulative evidence from these analyses is that MBR can lead to significant reductions in toxic chemical releases (Natan, Miller et al. 1996; Keenan, Kanner et al. 1997; Bennear 2006; Bennear 2007). Bennear (2007) uses panel data analysis to compare toxic chemical releases, source reduction activities and numbers of chemicals reported among plants subject to MBR and those not subject to MBR controlling for a number of other plant and location characteristics. Firms subject to MBR had statistically significantly larger reduction in toxic chemical releases, engaged in more source reduction activities, but did not report for fewer chemicals relative to their non-MBR counterparts. However, the gains from MBR appeared primarily in the earlier years of a program, with no statistically significant differences detected more than six years after program implementation (Bennear 2007). Other research has demonstrated that smaller firms are less likely to see environmental benefits from the planning effort (Natan, Miller et al. 1996;

Keenan, Kanner et al. 1997).

Because of infrequent outcomes data, there is very limited evidence on the impact of HAACP standards on reducing incidence of food-borne illness or on OSHA standards in reducing workplace accidents. Several studies have investigated the economics of HAACP standards, but these studies tend to focus on costs and simulate estimation on the benefits using assumptions of the decrease in pathogen count between 10 and 100 percent (Crutchfield, Buzby et al. 1997; Unnevehr and Jensen 1999). When estimating benefits, assuming a 50% reduction in pathogen count from the HAACP standards, the benefits of the standards outweigh the costs (Crutchfield, Buzby et al. 1997). However, concerns have been raised that the large upfront costs of HAACP regulations may result in consolidation in the industry as HAACP standards are too costly for small producers.

The take-home message from the empirical literature is that in cases that most resemble off-shore drilling, we have anecdotal evidence suggesting that these regulation may reduce risk, but no rigorous empirical evidence of effectiveness. In large part, this absence of evidence is due to absence of outcomes data, which also means we have no evidence on success or failure of alternative regulatory mechanisms either. In the one case where MBR was used when outcomes were observable there is some evidence of success. However, some reasonable concerns may remain about the ability of MBR to translate regulation of management effort and planning into systematic changes in actions/activities that reduce risk of rare, but catastrophic events.

The largest concern about the use of MBR under these conditions is that it relies quite heavily on industry safety planning *and* proper execution of plans. It also requires sustained attention over time to safety even when costs may be lower by not following the safety plan. In short, there is concern that MBR may not provide adequate incentives for operators to manage risk over the long term.

But MBR is not the only regulatory approach to offshore oil drilling. MBR for oil drilling is embedded in a broader regulatory regime that include the "belts and suspenders" command-and-control regulations, inspections and fines, and strict liability (up to a cap) on damages. One might argue that adding MBR to this regulatory mix is sufficient to prevent future safety failures of the magnitude of the blowout at the Macondo well.

Certainly inspections and fines could increase compliance, but that relies on level of expertise in inspections that was shown lacking at MMS and likely remains in short supply at BOEMRE. A combination of MBR and strict liability for damages should also increases the expected costs of failure to adhere to safety and environmental guidelines. Significant concerns have been raised about the existing cap on liability and the disincentive for safety implied by the cap. But these discussions typically imply that if the cap is raised or eliminated, industry should have the correct incentives to make better choices. And MBR just makes those "better choices" easier to make by documenting them and planning for multiple contingencies.

The fact is that whether MBR, in combination with other regulations, is sufficient is an empirical question, and it is an empirical question that will be nearly impossible to answer well. However, there is some reason to continue to be concerned about the ability of MBR combined with strict liability and belts-and-suspenders regulations to change the decision calculus on the drilling rig.

5. Alternative Risk Management Strategies

How can the calculus of these many individual decisions be reframed to provide appropriate weight to environmental and safety risks? In the high-paced and dynamic environment of the drilling well, how can we better ensure that the careful safety and environmental planning is actually executed? I argue that strict liability is insufficient over the long term to properly incentivize these individual choices. In the fairly immediate aftermath of a large scale accident, we are likely to see more attention to safety, but over time, as the memory of those costs fades, the cost savings calculus remains stacked against safety and the environment. If we want to encourage private risk management—execution of a environmental and safety management plan—then we need the costs of not following the plan to be more immediate in two ways, the costs need to be moved up front and there need to be consequences for mistakes that do not result in accidents.

In thinking of how one might design a regulatory system with those incentives, I was reminded of another market based instrument that is frequently used when the costs of mitigating damage after it occurs are high. This instrument is the deposit-refund system. The idea behind a deposit-refund system is that the regulated entity (consumer, firm, etc) pays an upfront deposit that is refunded, if and only if, the entity follows through on required actions. Deposit-refund systems are frequently used in waste disposal to help ensure proper disposal of consumer products that present environmental hazards in landfills.

The theory behind the deposit-refund system is well developed. It is frequently used when there are many regulated entities, so enforcement of standards is expensive and when costs of mitigating damage are high, (e.g., getting lead out of the aquifer after the lead batteries decompose in landfill). For economic efficiency the deposit is set equal to the marginal social costs of improper disposal (Bohm 1981; Russell 1988; Macauley, Bowes et al. 1992). In a context that more resembles offshore drilling, safety bonds have been proposed to hold companies accountable for the quality and safety of goods they import (Baker 2009). An example would be requiring a toy manufacture to provide a safety bond as insurance that imported toys do not contain lead.

In the context of offshore drilling, the deposit-refund system would involve an upfront "safety deposit" for all permitted well operations. The deposit is refunded, when the well drilling is complete and a safety inspection has occurred. Assuming the safety deposit is set at a magnitude equal to the expected costs of a significant accident, this system is not terribly different from a strict liability system. In theory, the incentives created by it should be the same.

However, there is significant research in behavioral economics that suggests that responses to these two strategies may be quite different. In a series of studies, Dan Ariely (2008) examined cheating behavior as a function of whether participants where asked to think about ethical behavior (either by recalling the ten commandments or by signing an honor code) *in advance* of their testing. The results of these experiments provide strong evidence that making ethics salient *at the onset* of an activity significantly reduces cheating. This research suggests that shifting the payment of the safety deposit upfront makes safety more salient and may result in increased attention to safety even if the monetary costs are not changed.

The second modification of the classic deposit-refund system is designed to make the consequences of every day decisions seem more substantial by rewarding consistent execution of the safety plan. This modification involves granting a "discount" on the safety deposit to operations who are certified by an independent third-party auditor as consistently executing their safety plan. The notion of an independent third-party audit of safety plan execution was also proposed by the National Commission as a key aspect of their proposals for increasing safety of offshore drilling. This plan provides a direct monetary reward for consistent successful audits. Firms whose audits receive high marks can earn a discount on the size of their safety deposit. In theory, firms with consistently high marks on safety audits could be required to offer no safety deposit, leaving them no worse off than under the current system.

An additional advantage of the deposit-rebate-refund system is that it can create incentives for private risk management and even empower other market actors to inspect and enforce this risk management (Baker 2009; Bamberger and Guzman 2009). One might expect insurance and bonding companies to become sources of capital for safety deposits, but they also have a financial stake in ensuring that operations they have bonded are safe. Under these conditions, the need for specific government mandates for risk and safety planning are reduced and, perhaps eliminated. The American Petroleum Institute (API) has had recommendations for safety planning similar to the SEMS since 2004 (2004) The problem has not been that industry is unaware of how to engage in risk and safety management planning, the problem has been that some parts of the industry have not felt sufficiently motivated to undertake this activity voluntarily. By creating a set of market-based incentives for risk management through the deposit-rebate-refund system, direct government mandates for risk planning may be unnecessary.

6. Conclusions

The disaster onboard the Deepwater Horizon and the subsequent environmental and economic losses highlight the problems with the current regulatory approach to offshore drilling. At the same time, the importance of oil for the U.S. economy and the importance of this industry in certain parts of the country, including the Gulf Coast, make permanent banning of offshore drilling unlikely and even undesirable. What is required is sufficient regulation of this industry to balance the benefits it provides with the low-probability, but high-consequence risk that it creates. This chapter explored three alternatives for regulating offshore drilling.

The first regulatory approach is the "belts and suspenders" approach where multiple redundant safety systems are proscribed by the regulator. This has been the primary approach used in the United States. I argue that this approach only works if probabilities of failure of any one system are independent. However, on an offshore oil rig, probabilities of failures are linked by the humans that operate them. Furthermore, the presence of multiple redundant systems can encourage risk-taking because any one short-cut is perceived to be very low risk given other safety systems that are in place.

The second regulatory approach is management-based regulation that requires detailed upfront environmental and safety planning that is unique to each drilling operation. MBR has been used in other countries, but evidence of success is nascent. This is largely due to the fact that accidents are rare events so it is difficult to statistically analyze whether any regulatory system results in lower accident frequency. Anecdotal evidence from countries that use MBR combined with evidence of MBR's success in pollution prevention programs suggest that this may be a promising alternative. One concern with the MBR approach is that the environmental and safety plans may do little to ensure day-to-day operational decisions are safety-focused. In order to change the calculus of these individual decisions, MBR will need to be operationalized in a way that provides proper incentives to accounting for safety at each decision point.

A third alternative is the deposit-discount-refund system which requires an upfront safety bond that is refunded upon safe completion of the drilling activity. Firms can earn rebates on the amount of the safety bond by earning high scores on an independent third-party review of their operational practices. The deposit-discount-refund system is designed to promote private risk management by providing incentives for risk management in day-to-day operations and by empowering other market actors, including insurance companies and bonding companies, to help inspect and enforce safety activity.

Deciding how to address the regulatory failures that were partially responsible for the disaster at the Deepwater Horizon rig is critically important. As we have recently seen, failures in regulatory approaches carry large costs, but these costs may not manifest for many years. It is important to cast a broad net in considering future approaches and to focus particularly on approaches that are likely to provide incentives for better private risk management in day-to-day operations. Further theoretical and empirical research on the alternatives presented in the chapter would be of great value.

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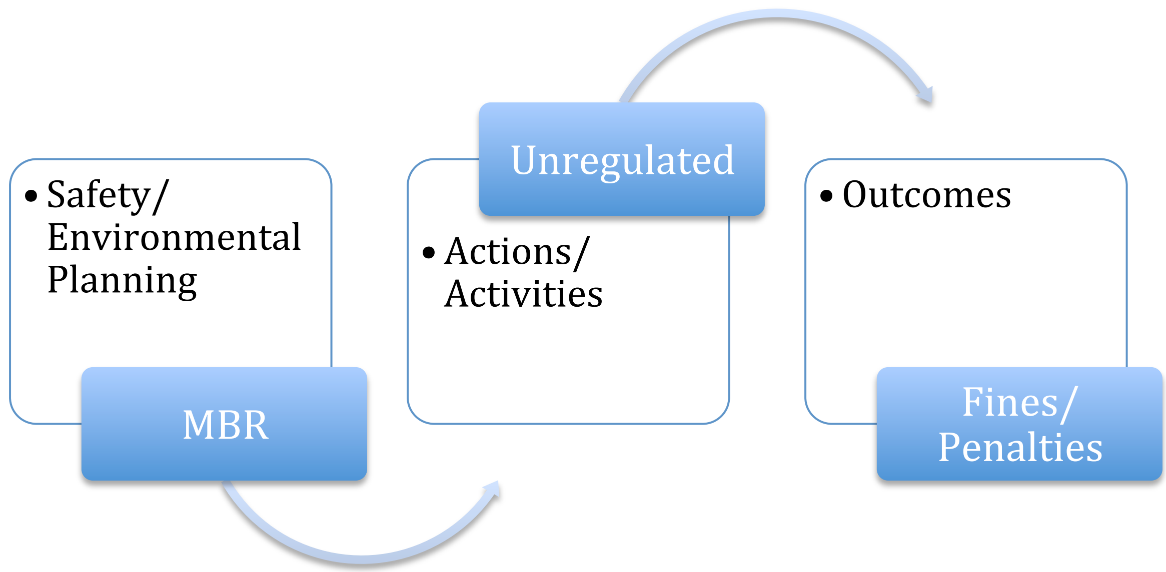

Figure 1: A Stylized Model of Management-Based Regulation