DISCUSSION PAPER

January 2011 ■ RFF DP 10-62

Understanding the Costs and Benefits of Deepwater Oil Drilling Regulation

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Abstract

The purpose of this paper is to provide a conceptual framework for understanding how analysis of costs and benefits might be incorporated into an assessment of regulatory policies affecting deepwater drilling. We begin by providing a framework for analyzing the life-cycle impacts of oil drilling and its alternatives, including onshore drilling and importing oil from abroad. We then provide background estimates of the different sources of oil supplied in the United States, look at how other oil supply sources might respond to regulations on deepwater drilling, and consider the economic costs of these regulations. After providing a comprehensive description of the potential costs and benefits from various types of drilling—including, when possible, estimates of the magnitude of these benefits and costs—we discuss the extent to which these costs and benefits may already be taken into account (or reinforced) through the legal, regulatory, and tax systems and through market mechanisms. We conclude by presenting a framework and simple example of how a cost–benefit analysis might be used to inform regulation of deepwater drilling, and sum up the policy implications of our work.

Key Words: catastrophic oil spill, cost–benefit analysis, government regulation, liability

Contents

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All findings, opinions, statements, and recommendations contained in this report are solely those of its authors. The report has been submitted to the staff of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, but the report is not the work product of the Commission or its staff, and should not be construed in any respect as the official or unofficial findings, opinions, statements, or recommendations of the Commission or its staff.

Executive Summary

The purpose of this paper is to provide a conceptual framework for understanding how costs and benefits might be incorporated into an assessment of regulatory policies affecting deepwater drilling, based on the principles of welfare economics. The paper provides background estimates of the different sources of oil supplied in the United States, looks at how other oil supply sources might respond to regulations on deepwater drilling, and considers the economic costs of such regulations. We also provide a comprehensive taxonomy of the potential costs and benefits from regulating deepwater drilling (as well as other sources of oil), and when possible, provide estimates of the magnitude of these benefits and costs.

Although we are primarily concerned with damages from deepwater drilling, we note that 62 percent of all oil found in waters off the North American coast is attributable to slow yet chronic releases from natural seeps in the seabed. The remaining 38 percent of oil resulting from anthropogenic activity is comprised of three types of activities: extraction (3 percent), transportation (10 percent), and consumption (87 percent). Extraction covers platform spills (such as the BP *Deepwater Horizon* spill), wastewater discharge, and atmospheric volatilization

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(resulting in volatile organic compounds in the air). Extraction activities in North American waters account for only 3 percent of anthropogenic oil spills to ocean waters (or 1.2 percent of all spills), with the bulk of this coming from wastewater discharge.

Despite the fact that in the aggregate, spill volume from drilling is a small percentage of total volume spilled, large spills of the size and location of the *Deepwater Horizon* incident can have a significant impact on ecosystems and the economy. For a significant spill in the deep water of the Gulf, much of the effects, particularly long-term effects, are unknown. Nonetheless, we can roughly identify categories of damages that are likely to carry the largest social damages. Based on previous experience with large spills, the largest single category is likely to be nonuse values for avoiding the ecological effects of spills, such as habitat damage and dead seabirds. The next-largest category is likely to be the avoidance of economic damages in markets affected by the spill; for example, lost revenues across the commercial fishing, hospitality, and recreation industries.

Next, we categorize each type of damage arising from a spill as being either private (e.g. the value of lost oil) or an “externality”—damage to third parties or the public (e.g. natural resource damages). We then examine which of these externalities under existing laws are internalized by responsible parties. To the extent that future drillers take into account (i.e., internalize) the possible future damages into their drilling decisions, then additional regulatory policies are not necessary. In the case of catastrophic spills, despite the large payments made to injured parties, it appears that significant externalities may not be internalized by our current laws and regulations. Government responses to the *Deepwater Horizon* spill may ultimately result in greater internalization.

The paper concludes by providing a framework for analyzing the costs and benefits of a ban or further regulation of deepwater drilling. Although we have attempted to place dollar values on both the benefits and the costs, we caution the reader that these figures are meant to be illustrative and are based on a simplistic empirical analysis. Three potential regulatory cases are considered in this analysis: 1) a permanent ban on drilling applicable to all deepwater and ultradeepwater areas; 2) a “high-cost intermediate regulation” that supposes that raising U.S. safety standards increases the costs of exploration, development, and production by 20 percent; and a “low-cost intermediate regulation,” where production costs rise by 10 percent. In 2035, the permanent ban, under which only shallow-water drilling is permissible, reduces U.S. offshore production by 79 percent, from 2.4 million barrels per day (“mmbd”) to just 0.5 mmbd. The intermediate regulation has a much more moderate effect, reducing offshore production by 4 percent (low-cost case) or 8 percent (high-cost case). The impacts on the world oil price are moderate to negligible.

The annual costs of a ban are $64 billion in welfare costs, plus $1 billion per year in losses to energy security ($65 billion). Assuming a ban would prevent a catastrophic spill from occurring once every 10 years and scaling up benefits estimates from research performed after the *Exxon Valdez* spill, the welfare benefits are $16.1 billion to $29.5 billion annually—considerably less than the annual costs of the ban. Given our assumptions, only if the ban prevented one catastrophic spill every four years or less would a ban on deepwater drilling be justified on a social cost–benefit basis.

In contrast to a ban, a regulation raising extraction costs by 20 percent would result in, at most, $22 billion in annual costs. Assuming that the regulation eliminates a catastrophic spill once every 10 years, it would pass a cost–benefit test only with the higher end of the benefits estimates—with costs of $22 billion annually and benefits up to $29.5 billion. Where costs rise only 10 percent, welfare costs are about $11 billion annually. Thus, even at the low estimate of welfare benefits ($16.1 billion annually), the regulation would pass a cost–benefit test.

In summary, this paper demonstrates a comprehensive framework to assess the costs and benefits of a ban or further regulation of deepwater oil drilling that also captures any negative benefits associated with substituting away from deepwater drilling toward other fuels, imported oil or oil from shallow water or land-based wells. Such a framework, if applied in a deliberate and comprehensive way that was beyond the scope of our paper, could help government agencies charged with regulating deepwater drilling produce more credible and comprehensive Regulatory Impact Analyses and, ultimately, better designed (e.g., more efficient) regulations.

Introduction

The recent accident at the BP *Deepwater Horizon* site was the largest accidental marine oil spill in world history, leaking, according to the U.S. scientific teams[1] appointed by Admiral Thad Allen, an estimated 205.8 million gallons[2] (4.9 million barrels) of oil into the Gulf of Mexico (DOI 2010a). That amount exceeds the annual average from 1990 to 1999 of oil spills and releases from both natural and anthropogenic sources, 197.4 million gallons annually (4.7 million barrels). The *Deepwater Horizon* spill was about 42 percent larger than that of the *Ixtoc*

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[1] The U.S. Scientific team is comprised of the National Incident Command's Flow Rate Technical Group (FRTG), led by United States Geological Survey (USGS) Director Marcia McNutt, and a team of Department of Energy (DOE) scientists and engineers, led by Energy Secretary Steven Chu (DOI 2010a).

[2] However, this estimate has been recently challenged by BP. The Oil Spill Commission and the Associated Press received a 10 page document from BP on December 3, 2010 claiming that the estimates produced by the U.S. Scientific Team are overstated by 20 to 50 percent (Cappiello 2010).

I, the next-largest offshore drilling spill off the U.S. coast, and about 19 times the size of the *Exxon Valdez,* the largest tanker spill off the U.S. coast.

Following the BP *Deepwater Horizon* disaster, the Obama administration announced a six-month moratorium on deepwater oil and gas drilling and the shutdown of deepwater exploratory wells already operating in U.S. waters until new safety requirements had been met. This moratorium has since been lifted, but in a new action, the administration has placed the Eastern Gulf of Mexico and the Mid and South Atlantic off limits for deepwater drilling for at least the next seven years (DOI 2010b). In the rest of the Western and Central Gulf, companies will be required to meet new regulatory safety standards before they are allowed to continue their operations, and lease sales in these areas are scheduled to begin in 12 months (DOI 2010b).

The purpose of this paper is to provide a conceptual framework for understanding how costs and benefits might be incorporated into an assessment of regulatory policies affecting deepwater drilling. We begin, in Section 1, with detailed definitions of the economic concepts used throughout this paper. We also provide a framework for analyzing the life-cycle impacts of oil drilling and its alternatives.

Section 2 provides background estimates of the different sources of oil supplied in the United States, looks at how other oil supply sources might respond to regulations on deepwater drilling, and considers the economic costs of these regulations. Section 3 provides a comprehensive taxonomy of the potential costs and benefits from deepwater drilling as well as alternative sources of oil. When possible, we provide estimates of the magnitude of these benefits and costs. Section 4 discusses to the extent to which these costs and benefits may already be taken into account (or reinforced) through the legal, regulatory, and tax systems and through market mechanisms. Section 5 presents a framework and simple example of how a cost–benefit analysis might be used to inform regulation of deepwater drilling. The final section sums up the implications for policy.

1. Theoretical Framework

This section presents underlying concepts and definitions for classifying and discussing the costs and benefits of policies directed to offshore drilling. First, we define the terms used throughout the rest of the paper (Box 1). We start with *welfare economics,* which is a coherent body of theory and applications that guides decisionmakers in measuring the effect of a given regulatory policy or other activity on society—through its effects on consumers, producers, and the government. Effects on consumers are measured by changes in consumer surplus (the difference between what households would be willing to pay for a product, reflecting their consumption benefits, and what they actually pay), effects on producers by changes in producer surplus (the revenue raised from selling a product less the costs of producing the product—basically, profits), and effects on government from changes in tax revenues (e.g., due to the loss of fuel tax revenue). Many of these effects are experienced through markets, but others, such as forgone damages to the environment or human health, are experienced outside markets. These are measured by society's willingness to pay to avoid such damages; several techniques exist for obtaining such estimates.

Cost–benefit analysis is a technique for accounting for all the positive and negative effects of a regulation in terms of their claim on our scarce resources. Such analyses are required by governments around the world to help determine whether society would be better off with a regulation than without it, or which design for a regulation would result in greater net benefits to society. These analyses divide effects into costs, or what we term regulatory costs, and benefits of the regulation.

In this paper, *regulatory costs* include direct costs imposed by a regulation on deepwater drilling as well as other costs of the regulation as captured by changes in markets. For instance, if regulation raises the costs of deepwater drilling, the price of oil may rise. Other things equal, this reduces consumer surplus through higher prices for oil products like transportation and heating fuels. It may also change industry profits. Section 2 and Appendix A cover these issues in more detail.

We follow conventional terminology in capturing effects of pollution on ecology, human health, and markets (see ORNL-RFF 1996 as an example), starting with the term *burden.* A burden is any release or spill of oil wherever it occurs, in any of the stages of economic activity (such as extraction, ocean transport, pipelines, tanker trucks, refining, and end use by consumers). Burdens enter the natural environment, where they interact with living things (plants, animals, humans) and other nonliving features of the environment that sustain life (such as sediments). The results of these interactions (such as fish mortality and petroleum concentrations in fish) are called *impacts*. These impacts then have effects on the economic system (such as reductions in the fish catch and lower profits in commercial fishing). Negative economic effects are termed *damages;* positive ones are termed *benefits* or *avoided damages.*

Note that these terms apply not only to avoided releases or spills but also to impacts caused by broader effects on supply and demand as regulations raise the cost of deepwater drilling: in particular, imported oil from overseas and land-based oil drilling may expand while overall oil consumption may fall. For example, if oil imports increase, there may be additional tanker spills or exacerbated effects on energy security. If land-based drilling increases, there may be more spills on land. If oil prices rise and consumption of oil and gasoline falls, the reduction in driving cuts air pollution and relieves congestion, with human health and time-saving benefits, respectively.

Another term to consider is *externalities.* These are effects on third parties that are not a part of a market transaction. To the extent that oil spills and releases from deepwater drilling harm marine ecosystems or coastal tourism, for example, they result in damages that are not borne (or not immediately borne) by the firm responsible for the spill. These are externalities. It is important to consider whether externalities are *internalized* into the behavior of those causing them, in which case the responsible parties take due care in their future decisions. If such externalities are already internalized prior to a proposed policy, then they do not count separately in the cost–benefit analysis conducted to assess the new policy.

How do externalities become internalized into a company's behavior? One way is through actions in markets. Fatal and nonfatal injury risk to rig workers (e.g., from fires or explosions) are generally viewed as internalized because jobs with relatively high accident risks tend to be compensated through higher wages and health and insurance benefits. The tort liability system is another way to induce due care. A third way is indirectly through taxes on their activities. A fourth way might be through changes in a company's stock prices when a disaster occurs. If a company's behavior with respect to risky activities fully takes into account the market, regulatory, legal, and financial environment in which it operates, as well as the probability and consequences of accidents, then one could argue that it has internalized the externalities. In practice, however, such judgments are extremely difficult to make.

Box 1. Definitions of Terms

burden—in this context, the release or spill of oil into the environment

impact—the effect of a burden (the release or spill) on ecosystems or humans

benefits or damages—the monetary effects of positive or negative impacts. These might include other harms associated with oil, such as energy security risk or traffic congestion.

regulatory cost—a measure of society's resources used up in responding to the regulation

cost–benefit analysis—a comparison of the benefits and regulatory costs of a proposed policy

externality—the effects on a third party (a party that is not a part of the underlying transaction)

uninternalized externality—an externality that is not taken into account in the behavior of those causing burdens. Only uninternalized externalities are included in a cost–benefit analysis.

In addition to their use in the cost–benefit calculus, *uninternalized externalities* are important because their existence implies that market behavior is inefficient, which potentially creates a role for government intervention to correct the inefficiency. For example, if firms do not bear the full societal risks associated with oil spills, they may underinvest (from society's perspective) in measures to prevent spills.

Figure 1 provides a schematic of the cost–benefit analysis components. A regulation on deepwater drilling imposes regulatory costs directly on this activity but might also increase oil supplied from other sources. For example, if the supply of oil from deepwater drilling is reduced as a result of regulation or moratoria, there may be a partially offsetting increase in supply from shallow-water drilling (e.g., in Alaskan waters), land drilling, pipeline imports (from Canada), or tanker imports from other countries. Each source of oil might have different transportation, refining, and distribution implications—each carrying its own risk of impacts—whether through oil spills, air or water pollution, or human accidents and fatalities. These impacts may lead to damages (the value of those impacts). Thus, any increase in damages from these other supply sources must be weighed against the benefits from reducing deepwater drilling. One particular concern is the negative national security and foreign policy implications of increased dependence on foreign oil as a result of reduced domestic production. Figure 1 also indicates that some of these damages are ultimately internalized by firms that cause harm, while others are not internalized and count in a cost–benefit analysis. Overall, after netting out all the benefits and costs associated with regulation, one has an estimate of the net welfare effects on society, a measure of how society's *utility,* or satisfaction, has changed as the result of a regulation.

2. Impact of Drilling Regulations on Sources of Oil Supply

Here we briefly present a picture of expected oil supply trends, prior to the recent oil drilling ban. Drawing from Brown (2010), we then indicate the potential effects of new regulations on deepwater drilling. Based on calculations presented in Appendix A, we estimate the economic welfare cost of these policies, prior to accounting for any externalities.

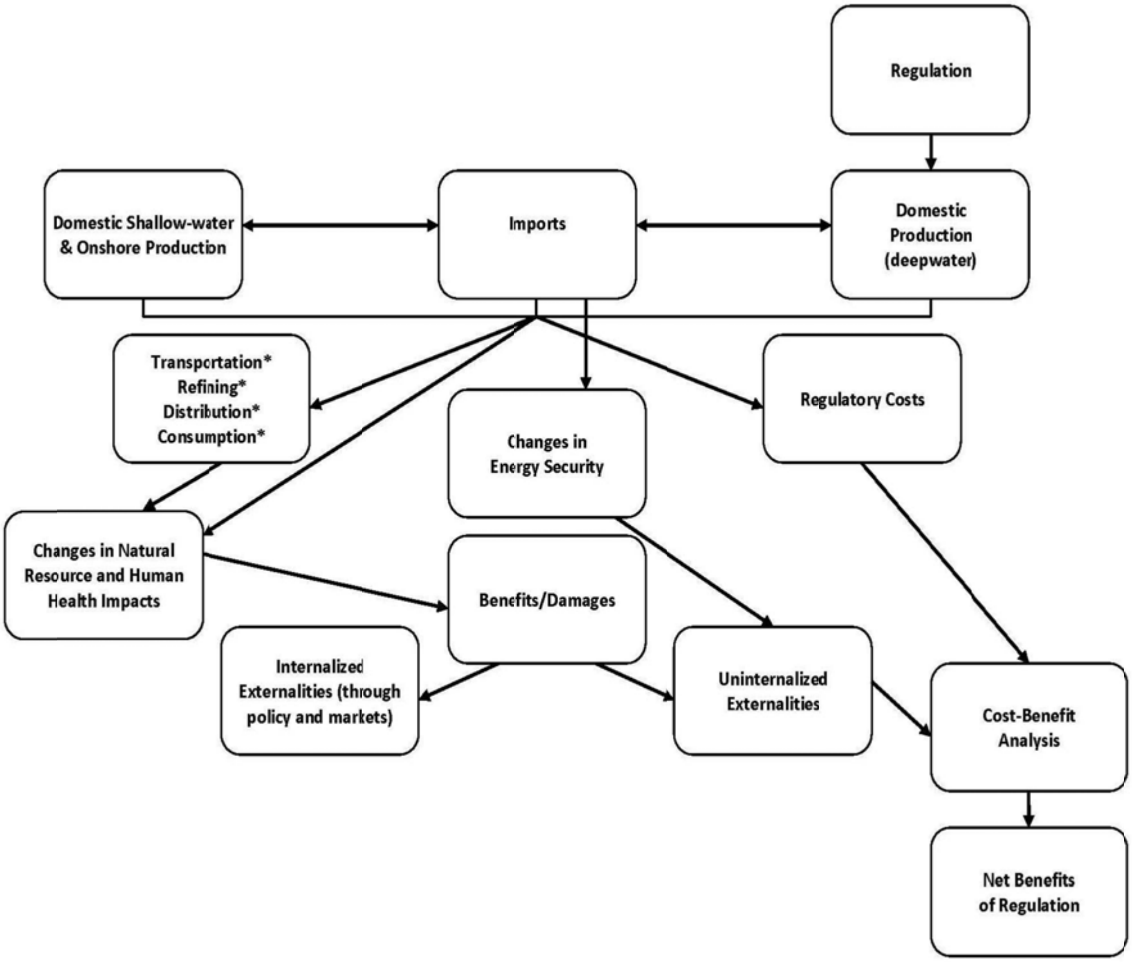
Supply Trends Prior to the Deepwater Drilling Ban

As shown in Figure 2, U.S. offshore oil production currently amounts to about 1.7 million barrels per day (mmbd), or 8.7 percent of total U.S. supply.

Prior to the drilling ban, U.S. offshore oil production was projected to rise steadily to 2.4 mmbd by 2035, or 10.7 percent of the country's total supply, with most of the growth from deepwater (water depth between 1,000 and 4,999 feet) or ultradeepwater (water depth greater than 4,999 feet) as opposed to shallow water (less than 1,000 feet). For example, in the Gulf of

Mexico, shallow-water production peaked in 1998, deepwater production peaked in 2004, but ultradeepwater has been expanding rapidly in recent years, reflecting proven reserves. In fact, deepwater now accounts for 80 percent of oil production in the Gulf of Mexico, and also 80 percent of proven reserves (Brown 2010, Table 1). The expected expansion of offshore production reflects relaxation of a previous moratorium on areas that could be drilled, as well as higher oil prices projected for the future. The Energy Information Administration (EIA 2010a), for example, projects world oil prices to rise from $70.30 per barrel in 2010, to $108.30 per barrel in 2020, and $123.50 per barrel in 2035 (prices in year 2008$).

Figure 1. Flowchart for Assessing Costs and Benefits of Drilling Regulations

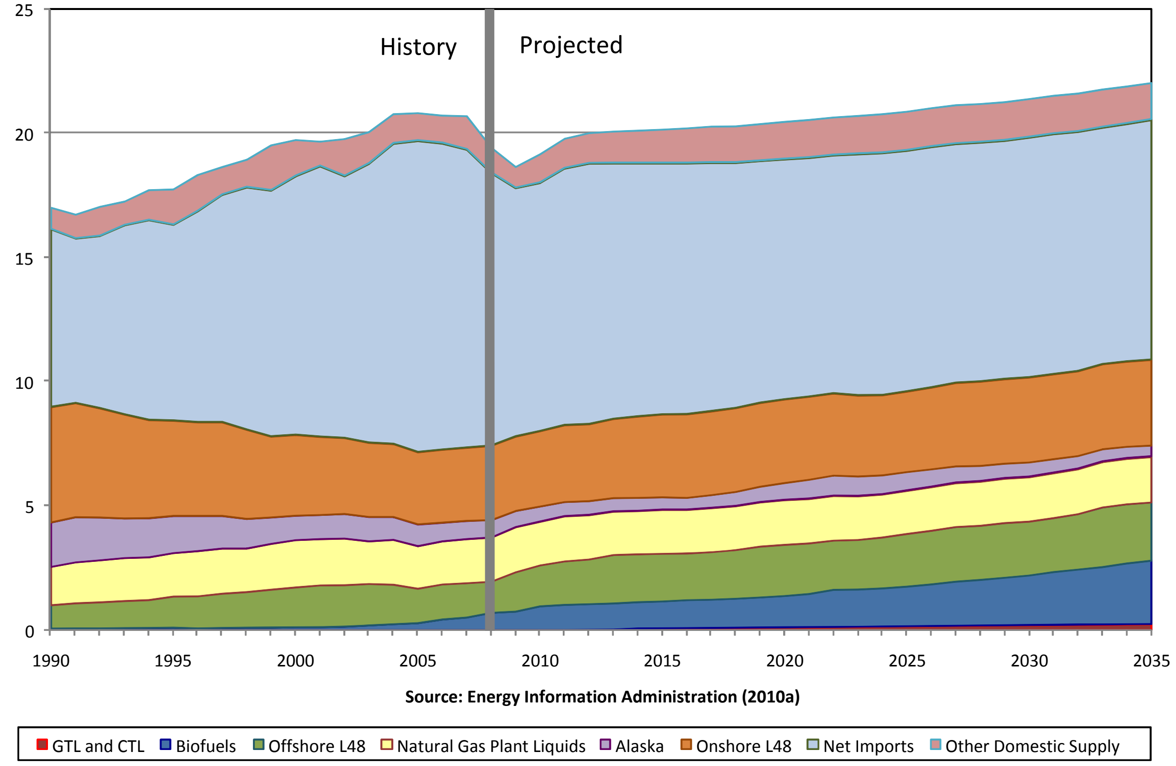


*These actions also lead to damages from conventional pollution, accidents, and congestion.

Potential Impacts of Drilling Restrictions

According to EIA (2010b), the recently imposed six-month ban on deepwater and ultradeepwater drilling will reduce domestic crude oil production by about 0.07 mmbd (about 0.36 percent of domestic oil consumption) in the first part of 2011. Brown (2010) considers two possibilities for a permanent tightening of deepwater drilling regulations and compares them with a business-as-usual case when oil supply trends revert to those in Figure 2 after the drilling ban is lifted. One bounding case looks at a permanent ban applicable to all deepwater and ultradeepwater areas. The other, which we call “high-cost intermediate regulation,” supposes that raising safety standards to those set in other countries, like Brazil, Canada, and the United Kingdom, increases the costs of exploration, development, and production by 20 percent. However, Brown (2010) also notes that industry sources suggest the costs of these safety standards could be lower. We therefore also consider a “low-cost intermediate regulation,” where production costs rise by 10 percent (i.e., price and quantity impacts are half as large as those in the high-cost case). We caution, however, that neither the 10 percent nor the 20 percent cost increase estimates are grounded in solid research. We use these figures for illustration and because they are, to our knowledge, the only estimates currently available.

Figure 2. US Petroleum Supply by Source, 1990-2035



Source: Energy Information Administration (2010a)

Table 1 summarizes the results for 2035, based on simulating a model of the U.S. oil market, benchmarked to the trends in Figure 2. The permanent ban, under which only shallow-water drilling is permissible, reduces U.S. offshore production by 79 percent, from 2.4 mmbd to just 0.5 mmbd. The intermediate regulation has a much more moderate effect, reducing offshore production by 4 percent (low-cost case) or 8 percent (high-cost case).

The impacts on the world oil price are moderate to negligible. The complete drilling ban raises the projected world oil price in 2035 about $4.10 per barrel, from $133.20 per barrel to $137.30 per barrel (3 percent), while the intermediate regulation raises the price by just $0.10 to $0.30 per barrel. These findings reflect the impact on world oil production— which falls by 1.5 percent and about 0.1 percent under the policies, respectively—and an assumption that withdrawing 1 percent of oil production from the market leads to a 2 percent increase in price over the longer haul.

About 23 percent of the reduction in offshore oil production under either policy is reflected in a reduction in domestic consumption. About 68 percent of the reduction is replaced by increased oil imports, while 5 to 8 percent of it is replaced by increased on-shore production.

Table 1. Projected Welfare Cost of Deepwater Drilling Regulations, 2035

	Baseline	Intermediate regulation		Permanent ban on deepwater and ultra-deepwater drilling
		low-cost	high-cost	
World oil price, 2008 $ per barrel	133.2	133.4	133.5	137.3
Production and consumption effects, mmbd				
World oil production	110.6	110.5	110.5	109.0
US consumption	22.00	22.0	21.97	21.59
US onshore production	7.42	7.43	7.43	7.52
US offshore production	2.36	2.30	2.23	0.50
US biofuels	2.56	2.56	2.56	2.65
Total US production	12.3	12.3	12.2	10.7
US net imports	9.66	9.71	9.75	10.9
Net economic welfare cost (ignoring externalities), $bn		0-11.4	0-22.4	>64.4

Source: Brown (2010), Table 3, and authors' calculations detailed in Appendix A.

Note. The low-cost intermediate regulation is interpolated from the high-cost intermediate regulation and the baseline scenarios in Brown (2010).

Regulatory Cost of Policies—Initial Assessment Ignoring Externalities

In Appendix A, we provide approximate calculations of the net regulatory costs of the regulatory scenarios, for 2035, using the price and production figures above. Our cost estimates are based on “economic welfare,” which measures the benefits to oil consumers from offshore oil production, less the costs to firms of supplying this crude oil.

For the intermediate regulation, the regulatory cost amounts to a maximum of $11.4 billion in the low-cost case and a maximum of $22.1 billion a year in 2035 (in 2008 dollars). There would be no cost to this regulation if firms had adopted safety technologies anyway, in the absence of regulation, perhaps as they revised upward their perceptions of spillage risks from existing technology in the wake of the BP *Deepwater* spill. At the other extreme, if they made no safety upgrades, costs would mainly reflect the (assumed) 10 or 20 percent increase in production costs due to meeting the regulation. For the years between now and 2035, the annualized costs of regulation would be smaller, but only moderately so, given that the level of offshore oil production in the business-as-usual case is not that different in the intervening years, compared with 2035 (Figure 1).

As discussed in Appendix A, the regulatory costs of the complete offshore drilling ban are more speculative because we lack accurate information on the production costs that would be saved by shutting down all deepwater production. In Table 1, we report a lower-bound estimate of $64.4 billion a year for 2035; this may substantially understate the true regulatory cost (Appendix A). Again, our lower-bound estimate for the intervening years to 2035 would not be that different.

3. Assessing Damages from Deepwater Drilling and Its Alternatives

This section provides a comprehensive framework for assessing damages from deepwater oil drilling as well as alternatives (such as onshore drilling and importing oil from abroad). As described earlier, we distinguish between environmental burdens (oil spilled), impacts (harm caused by the oil), and damages (monetized value of impacts). This approach highlights the fact that the ultimate effect of oil spills depends on numerous factors—including the type and quality of oil, location of the spill, and current weather patterns. Our analysis follows a 1996 study on the social costs of generating electricity by burning oil (ORNL-RFF 1996) and a more recent report by the National Research Council (NRC 2010), which considered the social costs of energy, focusing primarily on air pollutants. Unlike alternative damage assessment approaches, this taxonomy can help detect which production activities, or “sources,” cause the greatest damage. For example, slow and chronic releases from human consumption of oil account for a large portion of oil-related pollution, yet these are easily absorbed by local ecosystems with little environmental damage. The taxonomy also serves as a checklist to help evaluate who ultimately bears the costs of oil pollution damages. Finally, it highlights the trade-offs inherent in any public policy decision. For example, a ban on deepwater drilling may increase demand for land

and shallow-water production. Although a ban on deepwater drilling may decrease oil spilled in the Gulf of Mexico, offsetting onshore drilling might affect the surface water quality, and ultimately groundwater, as well as marine life in surrounding areas.

The remainder of this section starts by listing the burdens, followed by the impacts, and finally damages. We also provide an assessment of the likely magnitude of damages from a catastrophic spill, with a relative ranking of damage categories. Finally, we discuss additional damages that may arise from deepwater oil drilling—or a ban on drilling—including damages caused by substitute methods of extraction, and the impacts of a reduction in oil consumption following any rise in the price of oil related to a ban on, or further regulation of, deepwater drilling.

Box 2. Job Losses, Economic Welfare, and Cost–Benefit Analysis

In our current recession, with significant unemployment, the issue of how deepwater drilling policy might affect jobs is of high political importance, as well as economically important to those directly or indirectly affected. Yet, in an analysis of the costs and benefits of alternative policies for better managing drilling activities, job losses associated with diminished drilling activity don't "count," in the sense that this is not a metric used in such analyses. In fact, to use it would involve redundancies and—with an important qualification noted below—take one outside the welfare economics paradigm that supports and gives shape to cost–benefit analysis.

Conceptually, in a free-market economy, where people can move from job to job quickly, job losses—like losses to a company's stock and premature scrapping or selling off equipment, bankruptcy, and the like—are surrogate expressions for problems in a company or sector. But they are not, strictly speaking, measures of welfare loss to an economy. These losses are measured by changes in producer surplus, already taken into account in our calculations of the economic welfare cost of drilling regulations. That is, savings in labor costs are part of the overall savings in producer costs as production levels fall in response to new regulations. This assumes, however that labor markets are frictionless—that there are no costs to society when workers lose their jobs. In practice, labor markets are potentially distorted, for two reasons.

The first reason that labor markets are unlikely to be frictionless is that labor income is subject to various taxes (e.g., federal and state income taxes, employer and employee payroll taxes) that drive a wedge between the gross wage paid by firms and the actual wage received by households. According to economic theory, the gross wage reflects the social benefit of extra work effort (the value of the additional output) while the net wage reflects the social cost of that effort (the value of the time given up that could instead have been used in leisure activities, childrearing, etc.). To the extent that new regulations result in overall reductions in work effort at the economywide level, they therefore have a net economic cost because the forgone benefits from lost work effort exceed the value of the extra time available for other activities.

Second, there might be other distortions or market failures in labor markets. One issue is whether workers can adequately insure themselves (or have adequate government insurance) against job loss. The government's unemployment insurance generally does not replace lost wages dollar for dollar. Self-insurance is also possible, but few people have it, and it is unlikely to cover a relatively unforeseen event, such as a moratorium on deepwater drilling. Thus, some might make a case for market failure in the labor market.

In principle, any additional costs from economywide reductions in employment should be factored into a cost–benefit analysis. However, this is beyond our scope, given the difficulty of gauging to what extent workers laid off from deepwater drilling are able to find jobs elsewhere, with little overall change in economywide employment levels. From a practical (rather than conceptual) perspective, tracking gross job losses might be relatively easy (although even here the oil industry may be shrinking or growing jobs, and this changing baseline needs to be taken into account). But tracking reemployment is nearly impossible. Local or even regional data would not capture the number of people who leave the area for new jobs, for instance. Whether these workers end up incurring significant costs associated with moving and whether they accept lower or higher wages are also hard to track. And then there are indirect effects of job loss in the deepwater drilling sector on local communities, which again are very hard to track and estimate.*

*See, as examples, http://southpoint.frbatlanta.org/southpoint/2010/06/the-gulf-spills-employment-effect-early-evidence.html and http://macroblog.typepad.com/macroblog/2010/05/estimating-the-oil-spills-impact-in-the-gulf.html.

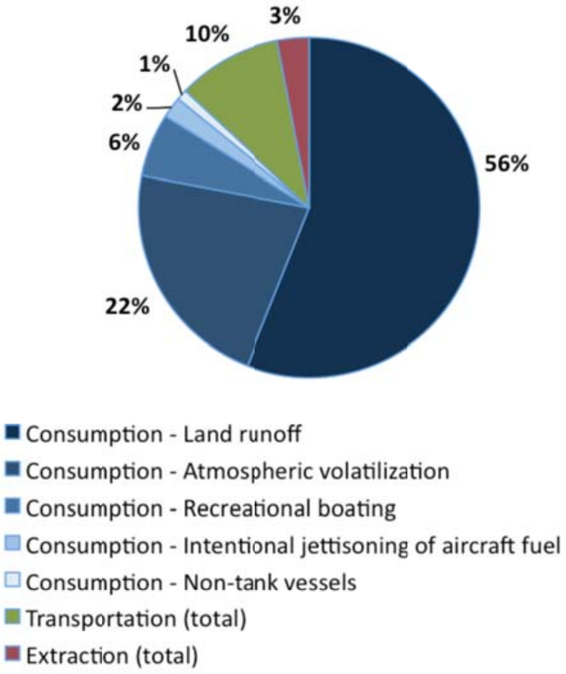
Burdens Assessment

Although we are primarily concerned with damages from deepwater drilling, 62 percent of all oil found in waters off the North American coast (within the 200-mile economic exclusion zone, EEZ) is attributable to slow yet chronic releases from natural seeps in the seabed.

To account for the remaining 38 percent of oil resulting from anthropogenic activity, we divide these activities into extraction (3 percent), transportation (10 percent), and consumption (87 percent), as shown in Figure 3 below. Extraction covers platform spills (such as the BP *Deepwater Horizon* spill), wastewater discharge, and atmospheric volatilization (resulting in volatile organic compounds in the air). Extraction is divided into deepwater and shallow water. Extraction activities in North American waters account for only 3 percent of anthropogenic oil spills to ocean waters (or 1.2 percent of all spills), with the bulk of this coming from wastewater discharge (NRC 2003).

Although episodic spills, such as those from large tankers or, most recently, from infrastructure breakdowns, draw public attention and scrutiny, it should be noted that oil spills from tankers account for approximately 8 percent of oil spills and other releases worldwide but only 2 percent in North America (NRC 2003). Transportation activities include tanker and pipeline spills, coastal facility spills, cargo washings, and atmospheric volatilization. Pipeline spills and leaks account for 2 percent of all anthropogenic oil releases to North American coastal waters, and tanker spills, 5 percent. The average spill size for pipelines is 26,450 barrels, whereas the average size of large tanker spills is 18,046 barrels. The frequency of pipeline spills is 0.67 spills per 1 billion barrels handled. For tankers, large spills (1,000 barrels or more) occur at a rate of 0.60 spills per billion barrels handled (ORNL-RFF 1996). Both the average spill volume and the frequency of transportation-related spills have dropped significantly over time, with consistent declines each decade since the 1970s, following passage of the Clean Water Act (1972), the Deepwater Port Act (1974), the Oil Pollution Act (1990), the Trans-Alaska Pipeline Authorization Act (1973), Outer Continental Shelf Lands Act Amendments (1978), and the National Oil and Hazardous Substances Pollution Contingency Plan. This decline is almost exclusively attributable to the reduced frequency of spills from tankers, barges, and trucks (Ramseur 2010).

Figure 3. Anthropogenic Releases of Oil



Oil releases due to consumption activities account for 33 percent of all oil-related pollution and 87 percent of anthropogenic sources. The largest source is runoff into coastal waters (representing 56 percent of total anthropogenic sources). Urban runoff is a function of coastal population growth, increasing with the number of cars, highways, and parking lots, plus municipal wastewater loads and improper use and disposal of petroleum products. Recreational marine boating accounts for 6 percent and atmospheric volatilization accounts for 22 percent of total anthropogenic sources of oil releases (NRC 2003).

Note that those data omit two major sources of oil spills: those from tankers beyond the 200-mile EEZ and those from land-based extraction activities. Nevertheless, we include land-based extraction as a category of oil spill because it might be affected by legislative or regulatory action directed at deepwater drilling.

Assessing Impacts

As discussed earlier, some oil releases (burdens) have little impact on ecological resources or human activity, but others might have a very significant and long-lasting impact. For example, 62 percent of the burden of oil releases is from natural seepage, but to the degree that they are understood, the impacts are thought to be relatively harmless. Most marine organisms exposed to oil from natural seeps have adapted to these releases over time and can metabolize the substance. For this reason, the oil released from natural seeps is not thought to pose an imminent threat to the natural ecosystems in the ocean (NRC 2003).

Table 2 summarizes the sources of oil spillage, release, and ultimate deposition into the ocean during extraction, transportation, and consumption and identifies all the potential impacts from each source. We classify impacts into effects on natural resources and effects on humans directly. Concerning natural resources, we recognize that because of our emphasis on monetary damages and externalities, the impact categories need to map as cleanly as possible into our categories of damages. Boyd and Krupnick (2009) argue that to avoid double-counting of damages, one should capture effects only on "top-level" or other species (such as shrimp, clams, and mussels) of value to humans, avoiding categories that include habitat supporting such species, or species and vegetation that support species of value. We take a more expansive view here to capture the many dimensions of impacts from oil spills.

The effects on flora and fauna can be of several types. Fish, plant life, and invertebrates can be killed on contact, their reproductive success can be impaired (both of which we classify as mortality resulting in lower populations), they can be deformed,[3] or their flesh or other body parts can become contaminated, leading not only to human health effects directly but also to bioaccumulation up the food chain. The classification also recognizes that mobile ocean species can avoid oil in the water. Such avoidance may disrupt economic activities as diverse as commercial fishing and bird-watching. We also recognize that, based on economic valuation

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[3] We categorize such effects under contamination, since sea life needs to be contaminated to experience morbidity effects.

studies, people place additional and separate values on marine birds and mammals that, through direct oil contact, can be killed or have their reproductive success reduced by oil contamination.

As for habitat impacts, we list five classes: effects on the water surface, effects on habitat below the surface in the water column or sediments, and effects on beaches and other land bordering the water body, plus effects on groundwater (which would be virtually zero for an ocean spill, but not for a spill on land) and on air quality (through volatilization).

Human health impacts are divided into mortality and morbidity. Injury, illness, or death can affect workers on rigs, those engaged in cleanup activities, and civilians through increased cancer risks from eating contaminated food or breathing contaminated air.[4] We capture additional impacts that affect economic activity, such as tarballs that drive tourists away from beaches, in the link between changes in beach quality and damages through recreation losses (discussed below).

In Table 2, impacts are classified as low (L), medium (M), high (H), or insufficient knowledge (I). A dash indicates little or no impact. For example, because the complex ecosystems in the deep sea are currently not well understood, the impact of oil pollution in deep water is currently unknown. These qualitative assessments of the magnitude of impact caused by oil production were determined largely by existing scientific research and historical precedent, specifically the findings of marine toxicologists who have worked on prior spills[5] and our own judgment based on reading the literature.

Our qualitative impact ratings are not based on aggregate national impacts and are not necessarily meant to represent a priority ranking of areas of concern. Instead, they represent an assessment of the magnitude of potential impacts for an oil spill or release of a given size. For example, unlike the slow and chronic releases from the seabed, which are unlikely to have a significant impact on marine ecosystems, an equivalent amount of oil spilled during an episodic blowout or a tanker accident can have immediate impacts on ecosystems and marine life. In such an event, we would also anticipate delayed impacts, such as degradation of air quality due to atmospheric volatilization of oil slicks and contamination of groundwater due to oil-ridden surface water.

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[4] There have already been increases in reports of nausea, dizziness, and headaches by Gulf residents and workers. Polycyclic aromatic hydrocarbons (PAHs) are proven carcinogens and neurotoxins, so the public health impacts of exposure to these pollutants could be severe albeit not immediately apparent. If not removed, PAHs persist much longer in sand and sediment than in water and could create a long-term environmental and health hazard along the Gulf coast.

[5] See, for example, Yardley (2010), Loureiro et al. (2006), Ramseur (2010), NRC (2003), and NOAA (2010).

The types of impacts and the magnitude of each depend on a variety of factors. For example, spills in cold water, like the *Exxon Valdez* tanker spill off the Alaska coast, generally have a relatively slower evaporation and dissolution rate. By contrast, spills that reach the surface of warm water dissolve and volatilize much more rapidly (NRC 2003). Spills from deepwater rigs or pipelines that are far below the ocean's surface undergo a weathering process, the duration of which is inversely correlated with the pressure levels and the velocity at which the oil escapes. The weathering process decomposes oil into microscopic droplets that then disperse and naturally degrade. In fact, an estimated 16 percent of the oil spilled by *Deepwater Horizon* has been removed through natural degradation (NOAA 2010).

Despite the volume of oil of the *Deepwater Horizon* incident, the impacts are much different from what they would have been had the spill occurred in shallow water, where the ecosystem is much more sensitive and the marine life is more concentrated and characterized by greater biodiversity (NRC 2003). Nevertheless, recent scientific studies have shown that some of the oil has blanketed the sea floor, where it has killed shrimp and other macroinvertebrates. The long-run impacts this will have on the ecosystem are unknown.

Table 2. Impacts from Oil Spillage or Releases: high (H), medium (M), low (L), insufficient knowledge (I), trace (—), not applicable (na)

	Natural resource impacts									**Human health impacts**		**Source (percentage of offshore releases)**	
Source	Fish and invertebrate displacement	Fish and invertebrate mortality	Seabird and marine mammal mortality	Contamination to fish and invertebrate populations	Shoreline contamination	Habitat loss or alteration	Surface water quality	Groundwater quality	Air quality	Mortality	Morbidity	**Anthropogenic (%)[6]**	**Total source (%)**
Natural seeps	I	I	—	I	—	I	—	—	—	—	—	—	**62.5**
Extraction (water)												**3.1**	**1.2**
Platform spills[7]												0.2	0.1
Wastewater discharge[8]												2.8	1.1
Atmospheric volatilization												0.1	—
Extraction (deepwater)	I	I	L	I	I	I	M	—	M	L	M		
Platform spills	I	I	I	I	I	I	M	—	—	L	M		
Wastewater discharge	I	I	I	I	I	I	M	—	—	—	—		
Atmospheric volatilization	—	—	—	—	—	—	—	—	M	—	—		
Extraction (shallow water) [9]	M	H	M	H	H	M	H	—	H	L	L		

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[6] Annual average estimates, 1990–1999.

[7] Includes accidental spills of crude oil, very rare occurrences of blowouts, as well as minor spills of refined products from equipment and vessels associated with platform operations.

[8] Residual water from reservoir pumped to the surface in oil production; although current industry practice is to treat "produced water" before discharging it, trace levels remain. The volume of produced water relative to production increases as oil reserves age. In general, shallow-water extraction sites are older than deepwater sites. It follows that the proportion of deepwater discharge to production is smaller relative to the ratio of shallow-water discharge to production.

[9] Studies of the harmful effects to coastal marine habitats of wastewater discharge from inshore facilities led to legislation in late 1990s prohibiting land facilities from discharging produced water into coastal waters.

	Natural resource impacts									Human health impacts		Source (percentage of offshore releases)	
Source	Fish and invertebrate displacement	Fish and invertebrate mortality	Seabird and marine mammal mortality	Contamination to fish and invertebrate populations	Shoreline contamination	Habitat loss or alteration	Surface water quality	Groundwater quality	Air quality	Mortality	Morbidity	**Anthropogenic (%)[6]**	**Total source (%)**
Platform spills[10]	M	H	M	H	H	H	H	M	H	L	L		
Wastewater discharge	M	H	M	H	H	H	H	—	—	—	—		
Atmospheric volatilization	—	—	L	—	—	—	—	—	H	—	—		
Extraction (land)	—	—	—	—	—	—	—	H	H	L	L	na	na
Platform spills	—	—	—	—	—	—	—	H	—	L	L	na	na
Wastewater discharge	I	I	—	—	—	—	—	H	—	—	—	na	na
Atmospheric volatilization	—	—	—	—	—	—	—	—	H	—	—	na	na
Transportation	H	H	H	H	H	H	H	M	—	L	L	**9.5**	**3.6**
Pipeline spills	H	H	H	H	H[11]	H	H[12]	M	—	L	L	2.0	0.8
Tanker spills[13]	H	H	H	H	H	H	H	—	—	L	L	5.5	2.0
Atmospheric volatilization	—	—	—	—	—	—	—	—	—	—	—	—	—
Cargo washings	—	—	—	—	—	—	—	—	—	—	—	na[14]	na
Coastal facility spills[15]	H	H	H	H	H	H	H	—	—	—	—	2.0	0.8

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[10] Platform spills into state waters account for 61 percent, whereas spills in the Outer Continental Shelf account for 39 percent of all platform spills; platform spills in the Gulf of Mexico account for 92 percent of total platform spills in North America.

[11] Most common in coastal waters, since the pipeline infrastructure is older (approaching 50 years old in many places) and more susceptible to accidents.

[12] Impacts depend on how far from surface the pipeline spill occurs. Pipeline spills occurring at low elevations undergo a longer weathering process, resulting in a more dispersed, less dense oil slick. Those occurring in shallow waters or closer to the surface result in oil slicks that are much denser, thicker, and less dispersed.

[13] Impacts vary depending on the location of spill with respect to the coast. Coastal spills such as the *Prestige* had very detrimental effects to coastal activity and ecosystems. Impacts also vary according to the size of the spill.

[14] Cargo washings are illegal in North America. Illegal discharges are reported as tanker spills.

	Natural resource impacts									Human health impacts		Source (percentage of offshore releases)	
Source	Fish and invertebrate displacement	Fish and invertebrate mortality	Seabird and marine mammal mortality	Contamination to fish and invertebrate populations	Shoreline contamination	Habitat loss or alteration	Surface water quality	Groundwater quality	Air quality	Mortality	Morbidity	**Anthropogenic (%)[6]**	**Total source (%)**
Consumption	L	L	L	M	L	M	M	—	M			**87.4**	**32.8**
Land-based sources (river and urban runoff)[16]	—	L	L	M	L	M[17]	M	—	—	—	—	56.2	21.1
Recreational marine boating	—	L	L	M	L	M	M	—	—	—	—	5.8	2.2
Nontank vessels[18]	L	L	—	L	—	L	L	—	—	—	—	1.2	0.5
Atmospheric volatilization	—	—	L	—	—	—	—	—	M	—	—	21.9	8.2
Intentional jettisoning of aircraft fuel[19]	—	—	L	L	L	M[20]	L	—	—	—	—	1.6	0.6
TOTAL[21]												**100.0**	**100.0**

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[15] Coastal location makes facility spills detrimental to the coastal environment, yielding significant impacts from both episodic and chronic releases.

[16] Urban runoff is a function of coastal population growth, increasing with the number of cars, asphalt highways and parking lots, municipal wastewater loads, and improper use and disposal of petroleum products. This estimate also captures petroleum refinery wastewater, municipal wastewaters, and nonrefining industrial wastes. Estimates have very high degree of uncertainty because the inputs as well as fates are not well understood.

[17] Urban runoff and recreational marine boating discharges are problematic in that they are chronic and often occur in sensitive coastal ecosystems.

[18] Spills from nontanker vessels are rare; however, operational discharges are large and include machinery space bilge oil, fuel sludges, and oily ballast. MARPOL 73/78 regulations have significantly reduced and in some cases eliminated discharge of oily and other pollutants into the sea.

[19] Reporting of releases is required but not at all monitored; jettisoning occurs mostly over lakes and coastal waters.

[20] Jet fuel is a light distillate, which has water-soluble fraction containing 2- and 3-ringed PAHs, which may affect marine life because they are highly bioavailable to seafood tissues, particularly fatty fish and shellfish, and particularly in relatively cold water. Light distillates are not adhesive, so they have minimal effect on shoreline habitats and beaches.

[21] Totals may not reflect exact summation due to rounding and elimination of trace effects.

Box 3. Issues in Estimating Damages from BP *Deepwater Horizon* Event

The *Deepwater Horizon* spill is unprecedented in size, location, and duration. Never before have deepwater ecosystems far below the surface been exposed to such large volumes of pollution for such an extended period of time. Because the complex ecosystems in the deep sea are not well understood, the impacts of deepwater oil pollution are currently unknown. In Table 2, the cells marked "I"—insufficient knowledge —are primarily for deepwater extraction. Marine toxicologists currently working in the Gulf admit that there is scant precedent or experimental research on which to base their work. In contrast with previous spill research, mere headcounts of oiled birds and dead fish washed ashore do not reveal the extent of the damage. Instead, long-term monitoring and assessment of marine life and activity in the vast area affected by the spill is needed (Winter 2010).

In August 2010, NOAA reported that approximately 26 percent of the spilled oil remained in the Gulf despite chemical dispersion and the natural dissolution and dispersion of oil due to weathering and evaporation (Lubchenco et al. 2010). The fate of this residual oil is yet to be determined. The specific type of oil, with its chemical properties and behavior in water, is one of the many variables that must be considered when predicting its ultimate fate, which is essential in evaluating the long-term impacts (those that persist or emerge at least two years after the initial spill date).

The oil released from the Macondo well is known as MS252. Compared with other crude oils, MS252 is sweet (i.e., low in sulfur), relatively low in polycyclic aromatic hydrocarbons (PAHs), and relatively high in alkanes, which means it has a below-average toxicity level and exhibits a higher bioavailability. In other words, it is the oil of choice for microorganisms that metabolize carbon, which will lead to higher rates of biodegradation. Other volatile organic compounds in MS252 are highly toxic, as in most other crude oils, but most of these evaporate quickly on reaching the surface (NOAA 2010). Because of the unprecedented volume and duration of *Deepwater Horizon* spill, the atmospheric volatilization of volatile organic compounds could lead to degraded air quality in areas surrounding the Gulf.

From Impacts to Damages

Table 3 links the impacts from Table 2 to various economic damage categories. Market-based damages (those that are experienced directly through market transactions) include losses to agriculture, aquaculture, commercial fishing, port and transportation services, private property, the hospitality industry (hotels, restaurants, and tourism) and related industries, and employee health. Nonmarket damages are classified as public health, public recreation, and nonuse values (i.e., the willingness of households to pay to avoid environmental damage even though they may never use the environmental amenity themselves). Public health damages in the form of mortality and morbidity can be experienced via three routes: (1) breathing the volatilized organic compounds (such as PAHs) from the oil; (2) coming into contact with oil, say at a beach, if this contact is not part of one's job; and (3) eating tainted seafood. Many estimates of the value to individuals of avoiding increased mortality risks, increased cancer risks, and increased injury or less severe morbidity risks exist in the economics literature and are used routinely in regulatory impact analyses by the U.S. Environmental Protection Agency and other agencies. See Box 4 for details on approaches to estimating damages.

Box 4. Estimating Monetary Values of Natural Resource Damages

There are two basic approaches to estimating damages consistent with welfare economics: revealed preference and stated preference. The revealed preference approach examines actual behavior, whether in markets or nonmarket activity, to infer the value that people place on avoiding impacts. In a market setting, such as that for fish, an oil spill can lead to a reduction in the supply of fish, which raises its price—and these things can be observed. The change affects both the suppliers of fish (up and down the supply chain) and consumers, summarized by changes in producer and consumer surplus. An example of nonmarket behavior is the effect of an oil spill on recreation—say, beach use. Economists have devised several ways to estimate the demand (or willingness to pay) for beach use, such as by measuring how far people will travel to use a particular beach and, when quality of that beach changes, what substitutes they seek out.

The stated preference approach is a survey-based set of methods, primarily contingent valuation and choice experiments, that pose hypothetical situations and then ask people their willingness to pay for avoiding specific damages to an ecosystem (or their own health) or ask them to make choices across outcomes that have multiple attributes, whose levels vary across such outcomes. For example, a survey might ask a respondent to choose one of three outcomes: the status quo, which carries no additional taxes or changes in energy costs; outcome A, which is described by attributes such as changes in fish and seabird populations and effects on local taxes or energy costs; or option B, which is characterized by the same attributes but offered at different levels. By observing these choices, researchers can estimate the willingness to pay for these different outcomes and even for changes in specific attributes.

Several alternative approaches have been taken to estimate the monetary effects of an oil spill, but these are not consistent with welfare economics (see Boyd 2010 for more details). The first is a restorative cost approach, by which the value of a good, service, or natural resource is determined by its replacement cost. This method was developed in part because of the difficulties of quantifying social damages caused by lost ecosystem goods and services. Instead of assessing lost wealth, it aims to measure the cost of replacing wealth.

Although this method is often favored by governmental organizations, including NOAA, for its simplicity and feasibility, the restorative approach has inherent limitations. The major shortcoming is that the costs of restoring an environmental asset and the forgone benefits that the asset delivers (or the damages it suffers) have no necessary relationship to one another. Since the aim is to tally forgone benefits (or damages), this restoration approach can be wildly inaccurate. If the restorative costs are too low, its use will not hold polluters accountable enough for their actions. If they are too high, there will be "too much" accountability. Furthermore, the restorative approach evades the important ecological and economic analysis necessary to advance research and knowledge of complex natural systems and the subsequent economic consequences of damages caused by oil spills and releases into the ocean.

Another alternative approach can be characterized as a legal approach; it determines compensation for economic "damages." Of the several differences between this approach and a welfare economics approach, the two most important are (1) that it is an *ex post* approach focusing on compensation, whereas the economic approach can be either *ex ante,* focused on designing better policy, or *ex post,* for estimating compensatory damages; and (2) that it is guided by the doctrine of proximate cause and the judge-and-jury process rather than welfare economics and use of an analytical process based on the preferences and behavior of actors in society at large. See Box 6 for further details.

In contrast to the *ex post* legal approach to estimating damages, the *ex ante* economic approach seeks to estimate expected damages and use them for cost–benefit analysis to help guide the design of policy that will lower the probability and size of future spills. The goal of the *ex ante* economic approach is to provide incentives for corporations to decide on the appropriate amount of due care to take in future drilling and related activities. This differs from an *ex post* damage analysis using welfare economics which would determine who (or what natural resources) has actually been damaged for purposes of determining appropriate compensation. Finally, while an economic welfare approach might be used to determine appropriate compensation, the legal approach to damages might differ as it might not fully compensate victims for reasons discussed in Box 6.

Nonuse values are the willingness of individuals to pay for avoiding damages to an ecosystem, apart from their use (if any) of that system. For example, the public may care about reduced fish populations, dead birds, and lost habitat beyond their pure economic value. Nonuse values, unlike those in the first two nonmarket categories, are not localized. In theory, anyone in the United States, indeed anyone in the world, could have such values for avoiding impacts in the Gulf. Thus, even if average nonuse values per person are only a few dollars, this category of damages can be a very large component of total damages.

Public recreation damage is any loss of utility associated with forgone recreation activities (such as swimming, boating, and beachcombing) or having to travel to recreation areas that are less desirable to the individual. There is a long history of studies that estimate how recreation activities in a population are affected by pollution, closures, fishing bans, or creation of new recreational areas, and from that information, how much people would be willing to pay to experience their preferred recreational activities.

Table 3. Economic Damages from Natural Resource and Human Health Impacts Resulting from Oil Spills and Releases

	Market									Nonmarket		
Natural resource and human health impacts	Agriculture*	Aquaculture*	Commercial fishing*	Water recreation[22]*	Port and transportation route closures	Private property loss or damage	Hospitality industry[23]*	Related industry[24]*	Employee health	Public health	Nonuse values	Public recreation[25]
Fish and invertebrate displacement			X	X			X	X				
Fish and invertebrate mortality/reproductive damage		X	X	X			X	X			X	
Seabird and marine mammal mortality				X				X[26]			X	
Contamination to fish and invertebrate populations[27]		X	X	X			X	X		X		X
Shoreline contamination		X		X	X	X	X				X	
Habitat loss or alteration[28]		X	X	X							X	X
Air quality									X	X	X	
Surface water quality	X	X	X	X	X	X	X	X		X	X	X
Groundwater quality	X					X				X	X	
Human mortality									X			
Human morbidity									X	X[29]		

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[22] Includes all paid water recreation, such as boating, fishing, scuba diving, and jet skiing.

[23] Includes restaurants, hotels, and other business that cater specifically, although not exclusively, to visitors.

[24] For example, canning and food-processing industries often slow or shut down operations because of lower inputs due to fishing losses.

[25] Includes all unpaid recreation, such as public beach use, swimming, and surfing.

[26] The fur seal pelt industry, for example, suffers losses as a result of any contamination or death of fur seals.

[27] Includes detectable contamination as well as more subtle contamination caused by pollution of sea sediments and biota that can result in bioaccumulation, the buildup of a chemical substance in an organism to levels that are higher than in the environment where the organism lives; PAHs are the compounds most likely to bioaccumulate in marine organisms, the degree to which varies by species and water temperature.

[28] Includes damages to such human activities as scuba diving.

[29] Volunteer cleanup crews may be exposed to carcinogenic compounds through direct contact or through the air. A study conducted on *Prestige* spill cleanup workers showed that two sets of volunteers working in March 2003 and April 2003, respectively, showed similar concentrations of volatile substances as the average for individuals living in highly polluted cities. A five-year follow-up study reported multiple cases of lung and cardiovascular disease among volunteers and cleanup personnel.

In Table 3, the cells designated with an X indicate which impacts map into which types of damages. More granular qualitative judgments are not possible, since the units of impacts (e.g., habitat losses and human injuries and deaths) differ dramatically across the categories. In some cases, one impact affects several economic endpoints, while others are more limited. Furthermore, some impacts are delayed. For example, the economic damages due to the loss of the herring industry in Prince William Sound were not fully realized until nearly a decade after the *Exxon Valdez* spill. The herring fisheries have gradually disappeared, at a cost of about $400 million (in discounted forgone profits) throughout the affected region (Yardley 2010).

Box 5. Impacts of Onshore Drilling

The federally mandated moratorium on offshore drilling, coupled with limited permits for shallow-water drilling, would in theory increase the demand for onshore production permits. In reality, onshore drilling has been on an upswing for the past few years: between July 2009 and July 2010, the number of active onshore rigs for natural gas and oil increased 76 percent (Klump 2010). The state governments of Wyoming, Nebraska, and Colorado have earned millions of dollars in recent months by auctioning off the rights to exploratory drilling on state land (Gruver 2010).

Onshore drilling is not without environmental risks and potential hazards to surrounding environments. The practice of hydraulic fracturing, dubbed fracking, for example, is a relatively new technology for extracting natural gas and oil through horizontal wells using a pressurized solution of water, chemicals, and sand. The practice has been suspected of leading to hazardous chemical and radioactive waste and pollution affecting the air and water quality in nearby communities. Risks to the water cycle are currently being investigated by the Environmental Protection Agency in a congressionally mandated study, expected to be released in 2012 (Harder 2010).

Even onshore oil rigs that do not use fracking release polluted “produced” water and oil into the environment, much as offshore rigs do into the ocean. These toxins are evaporated into the air and absorbed through land and can affect air, surface water, and groundwater quality.

Note that cleanup costs were not included in the taxonomy in Table 2 because these are *ex post* actions typically mandated by the government. They are not direct damages from the spill; instead, they are designed to mitigate some of the damages a spill might otherwise cause. In some cases, however, cleanup measures can exacerbate the damages caused by the spill itself. One common cleanup response is the release of chemicals into deep waters to accelerate the degradation process before the oil reaches the surface. This was done in response to *Deepwater Horizon*: 770,000 gallons of chemical dispersants were released at the Macondo wellhead, about one mile below the surface. Although this practice is hotly debated, since it may deplete oxygen levels and create “dead zones” in the ocean, the effort may significantly reduce impacts farther from the site. For example, a reported 8 percent of the original spill volume was chemically dispersed (NOAA 2010; Borenstein 2010).

Size of Damages from Deepwater Spills

Damages from a deepwater spill depend on factors such as distance to shoreline and water surface, water temperature, climate, spill volume, as well as the type and numbers of living things, property, and economic activity at risk. Because there have been very few large spills the size of the *Exxon Valdez* or the *Deepwater Horizon*, it is difficult to draw conclusions about the likely size of damages from analyzing past spills. However, a starting point is to look at the distribution of damages from earlier spills.

For a significant spill in the deep water of the Gulf, much of the effects, particularly long-term effects, are unknown. Nonetheless, we can roughly identify categories of damages that are likely to carry the largest and smallest social damages. Based on previous experience with large spills, the largest single category is likely to be nonuse values, where reports of habitat damage, dead seabirds, tarballs on beaches, beach closures and commercial fishing area closures would lead to widespread public support for avoiding another such ecological and economic catastrophe. As noted above, because these concerns touch so many people, the collective willingness to pay to prevent future spills can be very large.[30]

The next-largest categories are likely to be economic damages in markets affected by the spill. Table 4 provides data on total revenues from commercial fishing and from the coastal tourism and recreation industry for states affected by the *Deepwater Horizon* event (or that would be affected by any event in the Gulf). Tourism and recreation are far larger contributors to regional gross domestic product (GDP) than commercial fishing ($34 billion versus $700 million). Louisiana dominates fishing activities, whereas the west coast of Florida has by far the largest revenues at risk from tourism and recreation. To give some specificity, if 1 percent of commercial fishing were harmed, lost revenues would be $6 million, although likely distributed among a low-income population. One percent damage to tourism and recreation results in $340 million in lost revenues across the hospitality and recreation industries. Although these lost

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[30] We note that Helton and Penn (1999), discussed further below, indicate that natural resource damages constitute only about 26 percent of total damages for the spills they analyzed, with the largest category being response costs—about 50 percent of the total. However, Helton and Penn (1999) do not estimate actual natural resource damages, only the portion actually paid by the responsible parties. In addition, our analysis is concerned with the externalities of a spill—and most of the response costs are internalized to responsible parties. Thus, our analysis serves a different purpose from Helton and Penn (1999), who attempt to assess the out-of-pocket costs to responsible parties.

revenues hurt business owners and employees, economists do not consider them to be welfare effects to the extent that consumers have other recreational options and can obtain substitute seafood at little if any additional cost or loss in satisfaction. Instead, to the extent these substitutes are more costly or less preferred, there is a loss in consumer surplus (which would be considered welfare effects). From the producers' side, localized labor markets and widespread losses in demand mean that, at least in the short term, economic losses could be large and even approximate lost revenues (although they could be at least partly offset by programs that hire local labor in the cleanup effort). In the longer term, labor and entrepreneurial mobility limit losses, but with persistent ecological effects, "loss of one's way of life" may contribute to large economic losses.

Table 4. Annual Revenues, by Activity and State, $million (2008)

State	Commercial Fishing*	Coastal Tourism and Recreation**
Alabama	44	1,400
Florida (west coast)	123	20,000
Mississippi	44	2,000
Texas	176	7,200
Louisiana	274	3,600
TOTAL	**662**	**34,200**

***** http://www.st.nmfs.noaa.gov/st1/commercial/landings/gc_runc.html
**http://www.ustravel.org/sites/default/files/page/2009/11/Gulf_Oil_Spill_Analysis_Oxford_Economics_710.pdf

This leaves agriculture, aquaculture, port and transportation route closure, private property damage, and employee and nonemployee health effects. For a spill of large enough magnitude that gets close enough to shore, human health effects from contact with spill volatiles could amount to medium damage, since the population at risk could be large and people place high values on avoiding cancer and other types of health effects. Possible deaths or injuries to employees in the drilling industry are also part of damages, though (as we discussed elsewhere) not necessarily part of external damages. Aquaculture effects could be large where a fish farm is at risk. The other categories seem insignificant.

Natural Resource and Economic Damages from Catastrophic Spills

Although it is beyond the scope of this paper to determine the expected damages from a catastrophic deepwater oil spill, prior data on oil spills provide some information on the range and worst-case scenario for damages from such a spill. Cohen (1986) analyzed the U.S. Coast Guard's spill data from 1973 to estimate the fraction of oil spill volume that leads to a particular impact. For example, 59.7 percent of total spill volume was reported to have an effect on fish and the fishing industry (including fin fish, shellfish, sport fishing, commercial fisheries and hatcheries, and other marine biota), 51.5 percent was reported to have an effect on water supply (which includes municipal drinking water and water intake systems for municipalities, industry, and agriculture), 16.5 percent was reported to have an effect on birds, and 0.7 percent on recreation. Based on these data and estimates of the cost per gallon of each type of impact, Cohen (1986) estimated the average natural resource and economic damages of an oil spill to be $3.00 per gallon spilled in 1981, or $7.50 in 2010 dollars. This average value, however, tells us little about worst-case damages from a catastrophic spill.

Helton and Penn (1999) examined 30 large spills between 1984 and 1997 for which they could obtain natural resource damage payments as well as other measures of financial costs, including recovery costs, federal and state trustee costs, scientific assessment, litigation costs, third-party claims, and other costs such as "salvage and repair costs, delay and additional operating costs, and lost or damaged cargo costs" (Helton and Penn 1999). Although their measure of total financial costs is different from the definition of social damages used here (since many of these costs are private and internal to the responsible party), they report a range of costs from $1 to as much as $937 per gallon in 1990. They further report an average cost of $278 in 1990, or about $465 in 2009 dollars. The average natural resource damage payments for the 28 spills for which data on both spill size and natural resource damage payments were available was $40.36 per gallon in 1990 (with a range of $0.07 to $375), or about $66.20 in 2009 dollars.[31] These costs are not representative of all spills and instead represent a highly selected group based on the availability of natural resource damages (which Helton and Penn note are calculated in less than 1 percent of all spills).

Helton and Penn (1999) based their figures on actual dollars paid. The *Exxon Valdez* natural resource damage compensation was about $1.1 billion, making that spill only the third-largest natural resource damage estimate on a per-gallon basis. However, a major national survey done shortly after the spill (Carson et al. 2003) found that public willingness to pay to avoid a similar incident in the future was $2.8 billion to $7.2 billion in 1990, or $4.6 billion to $11.8 billion in 2009 dollars. Adding an estimated $600 million in economic damages paid to private parties (Cohen 2010a), or about $984 million in 2009 dollars, the externalities imposed by the *Exxon Valdez* are estimated to range from $5.6 billion to $12.8 billion, or $509 to $1,163 per gallon, in 2009 dollars. This would make the *Exxon Valdez* the most costly in terms of damage caused per gallon for a large spill off U.S. waters to date.

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[31] These figures are not reported in Helton and Penn (1999); instead, they are calculated from their Tables 1 and 2.

Based on Cohen's (1986) average spill damage figure, the natural resource damages from the 205.8 million gallons of oil spilled by the *Deepwater Horizon* would exceed $1.5 billion, but based on Helton and Penn (1999) would be $13.6 billion. These figures do not include cleanup costs or compensation to private parties that have incurred economic losses. Scaling the *Exxon Valdez* per gallon estimates to the *Deepwater Horizon* spill would give a damage estimate ranging from $105 billion to $239 billion—a figure that includes both natural resource damages and economic damages to private parties. This is considered a worst-case estimate of the damages caused by a catastrophic spill when we analyze the potential costs and benefits of deepwater drilling in Section 5. It is important to emphasize that this is an estimate of external social damages—it excludes the private cleanup and containment costs incurred by the industry. However, it includes an estimate of total natural resource damages, not just those that are ultimately paid for by the responsible parties.

Assessing Additional Damages

Although we have focused on oil spills because our central concern is the BP *Deepwater Horizon* event, it is important, perhaps vitally important, for policymakers to be aware of the full set of damages that could be affected by new legislative or regulatory actions following this event. We mentioned two in the beginning of this paper: (1) substitution to other types of extraction or oil supply activities if deepwater drilling is banned or made more expensive; and (2) reduction in oil consumption (following any rise in the price of oil) that would have positive effects, such as reducing air pollution, congestion, accidents, and other externalities from elsewhere in the fuel cycle. This latter class of effects would be no different from those arising from a tax placed on oil consumption or production that encourages users of oil (with effects on refiners, transporters, and those in other stages of the life cycle) to economize on its use. In elaborating on these two pathways below, we also want to consider the further implications of price changes on the production and use of alternative fuels to oil, such as natural gas and biofuels and, indirectly, even electric vehicles.

Benefits or Damages from Alternative Extraction Options

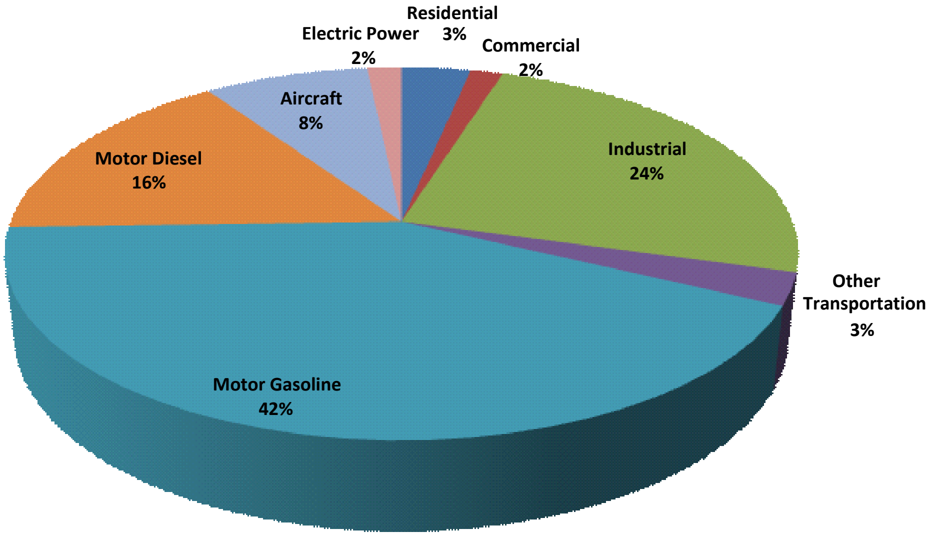
The nonspill-related damages associated with alternative extraction options and increasing oil imports can be easily described. Compared with damages from higher stages in the life cycle, such damages are trivial. The burning of gasoline, diesel, and other fuels on land in land-based extraction activities is probably more damaging to human populations than its use at sea, whether in shallow or deep water. Offsetting these effects is greater energy use in extraction activities in deepwater than in shallow-water wells or even wells on land. The largest difference in damages is found when comparing domestic extraction (whether on land or sea) with crude oil imports. Here the extracting country bears any damages from extraction and loading the oil onto tankers, the world at large bears the risk of air pollution during the ocean voyage (as well as spillage, but this is captured in Table 2), and the receiving country bears some damage once the tanker is near or at the coast.

Benefits or Damages from Changes in Oil Prices on Final Uses

If oil prices change as a result of regulating deepwater drilling, and these changes are passed on to gasoline and diesel fuel as well as other oil products, then this will have effects on pollution and, in the transportation sector, on congestion and accidents. In this section we detail these damages and, anticipating Section 4, we discuss the extent to which externalities are internalized. Basically, all the damages or benefits are considered externalities, but some adjustments are made for internalized externalities.

In 2007, gasoline use accounted for 45 percent of oil consumption, diesel fuel 16 percent, industrial uses 24 percent, aircraft 8 percent, and other uses (e.g., home heating fuels) 7 percent (see Figure 4). We take the main oil products in turn and briefly discuss damages associated with their use. The empirical literature on the price responsiveness of gasoline use is extensive (Small and van Dender 2006), but much less is known about the price responsiveness of other oil products. Nonetheless, it seems plausible to us that it would be similar to that for gasoline. In this case, we can infer damages for all oil use by adding estimates for the individual products and weighting by their share in oil consumption.

Figure 4. Oil Consumption by Use, 2007



Source: EIA (2008, Table 2)

Pollution. Studies of the social costs of oil use (or energy more generally) are an ideal place to find such estimates. ORNL-RFF (1996), for example, calculated the social "cost" of oil (what we term damages in this paper) used to generate electricity (which is only about 10 percent of the U.S. generation mix) in mills per kilowatt hour (mills/kWh). These damages are trivial.

The recent study by the National Research Council (NRC 2010) used two well-known models that together link transportation activities using oil (and other fuels) to a host of damages (GREET 2009; APEEP 2006). This study expressed such damages in cents per gallon, averaged over the United States, covering the effects of air pollutants on health, recreation (effects on visibility), and crops. These effects were attributable to different stages in the transportation life cycle, including feedstock (which includes extraction), fuel (which includes refining and transport), vehicle manufacturing, and vehicle operation. Differentiation was made by fuel type, covering natural gas, electricity, and biofuels of various types.

NRC (2010, Table 3.3), for 2005, put local pollution damages at 1.34 cents per gasoline vehicle mile (this includes a small contribution from upstream emissions leakage during fuel extraction, refining, and transportation, though this component is minor because of tight regulations). From NRC (2010, Table 3.4), local pollution damages from diesel trucks are 60 cents per gallon (in this case damages vary with fuel use rather than with miles driven).[32]

Turning to carbon dioxide (CO_2) emissions, each gallon of gasoline combusted produces 0.0088 ton of CO_2.[33] The value of the future global climate change damage associated with current CO_2 emissions is very contentious; for example, estimates are very sensitive to assumptions about the rate at which future damages should be discounted, how the risks of extreme climate change are modeled, how nonmarket effects (like species loss) are measured, and so on. NRC (2010) provided a very wide range for damages, from \$5 to \$100 per ton of CO_2. Probably the best discussion of the "social cost of carbon" is a recent interagency report (IAWG 2010). Based on synthesizing and updating evidence from different studies, that report recommended (in 2007 dollars) a central value of \$21.40 per ton of CO_2 for 2010 (with a range for sensitivity analysis of \$4.70 to \$64.90, depending on different scenarios for discount rates and future damages from global warming). We will use the \$21.40 figure, which amounts to 19 cents per gallon of gasoline. From Parry (2010), carbon damages for diesel are 16 percent higher per gallon than for gasoline.

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[32] Local pollution damages are projected to fall quite rapidly, however, because of regulations requiring reductions in particulates and SO_2 emissions.

[33] For the carbon content of fuels, see http://bioenergy.ornl.gov/papers/misc/energy_conv.html. Note that 1 ton of carbon is equivalent to 12/44 tons of CO_2 (given the relative molecular weights of carbon and CO_2).

Other oil products also have carbon and local pollution emissions, which we take to be about the same as for diesel, 60 cents per gallon, or $25 per barrel. Unlike highway fuels, other petroleum products are not subject to significant excise taxation. And although there are further damages associated with air travel, like flight delays, these have not been quantified but would likely make little difference to our calculations, given the modest share of aviation fuel in oil use.

Congestion, accidents, road damage. Automobiles also contribute to highway congestion, which represents another damage category (and also an externality because motorists do not account for their individual impact on adding to congestion and travel times for other drivers). Parry (2010) put the congestion damage at 4.5 cents per mile, averaged across regions of the United States and time of day.

For accidents, Parry (2010) used a value of 3.5 cents per automobile mile, after updating prior studies—for example, using the Department of Transportation's revised assumption about the value of a highway fatality ($5.8 million). These damages include injury risks to pedestrians, a large portion of medical and property damages borne by third parties, the tax revenue component of injury-induced workplace productivity losses, and so on. Other accident costs, like injury risks in single-vehicle collisions and forgone take-home wages from productivity losses, are viewed as externalities that have been internalized (see below) and so are not counted.

Unlike cars, heavy trucks also cause significant wear and tear on the road network, given that road damage is a rapidly rising function of the axle weight of a vehicle. On the other hand, trucks have a much lower fuel economy than cars, which implies a much smaller reduction in vehicle miles per gallon of saved fuel, which reduces the congestion and accident benefits. Without getting into the details, we simply summarize assumptions in Parry (2010): marginal congestion costs 9 cents per truck mile; accidents cost 3 cents per mile; road damage externalities cost 5.5 cents per mile.

Total damages and uninternalized externalities. Adding up the local pollution, congestion, and accident damages related to light-duty gasoline vehicles and multiplying by the average amount a passenger vehicle on the road is currently driven per gallon of gasoline—22 miles, according to the Bureau of Transportation Statistics (2008, Table 4.23)—gives a damage from these externalities equivalent to about $2.05 per gallon. Not all of the fuel reduction in response to higher prices will come from reduced driving, however. Instead, some will come from improvements in fuel economy, which to an approximation do not affect these damages, though this response will be weaker given the recent tightening of fuel economy standards. Based on Parry (2010), we will assume that two-thirds of any price-induced reduction in gasoline demand comes from reduced driving, implying a benefit of $1.37 per gallon.

Adding this benefit to the carbon benefit gives about $1.55 per gallon of gasoline reduced. However, from this figure we need to net out current fuel taxes, which effectively internalize some of these externalities in the price paid by motorists at the pump. Together, the federal and (average) state taxes currently amount to about 40 cents per gallon, leaving an (uninternalized) externality benefit of $1.15 per gallon of fuel saving, or about $48 on a barrel-of-oil equivalent basis.

Using assumptions (from Parry 2010) for fuel economy (6 miles per gallon), the fraction of the price-induced reduction in fuel use attributable to reduced truck driving (50 percent), and the current diesel tax (44 cents per gallon) gives an external benefit, net of the fuel tax, of about 70 cents per gallon of diesel, or $29 on a barrel-of-oil equivalent basis.

Externalities Related to Oil Import Dependence

So far we have been considering all the different damage categories and come up with specific estimates for them where possible. Just above, we also made adjustments where these damages, while externalities, were partly internalized. In discussing energy security, however, there logically is not a "damage" that is distinct from an externality. Therefore, in this section we use the term externalities and discuss whether they are internalized.

Various externalities have been associated with the amount of oil imports, as opposed to the overall level of domestic oil consumption, including market power, military spending, national security and foreign policy implications, and increased risk of macroeconomic disruptions. We look at each of these in turn.

Market power. It has long been recognized among trade economists that, up to a point, a country can make itself better off by restricting the imports of a particular product if that country has a degree of market or "monopsony" power—that is, ability to influence the world price of the imported commodity. In particular, by reducing imports, the country can induce a reduction in the world price, which lowers its import bill at the expense of revenues to foreign countries. In fact, there is an externality of sorts: in the absence of trade restrictions, imports of the commodity would be too high from the domestic country's perspective, because individual import buyers do not take into account their effect on adding to demand, and (incrementally) raising prices for other domestic importers. This price effect is complicated, since it depends on how consumers and producers of the product throughout the world respond to market pressure from changes in domestic consumption. This is especially true for oil because much of the supply comes from government-controlled entities. From Leiby (2007), Figure 3, an oil import tariff of about $8 per barrel for the United States might appear to be warranted.

Whether monopsony power really constitutes a valid “externality” that should be factored into an economic assessment of oil supply regulations is contentious, however. From a global perspective at least, there is no externality, and trade restrictions are harmful. There is no externality because as one domestic importer increases expenditures for other domestic importers through upward pressure on global prices, these extra expenditures are offset by a revenue gain to foreign oil suppliers. And even if a domestic perspective is taken, the issue is still murky because any domestic gains from a direct or indirect attempt to enact transfers from foreign suppliers to the domestic economy might be offset if it provokes retaliatory measures from oil-exporting countries. For these reasons, Brown and Huntington (2010) and NRC (2010) assume no externality from market power.

Military spending. It is sometimes argued that military spending to protect oil supplies from the Persian Gulf constitutes an additional external cost associated with U.S. oil imports. Measuring the amount of spending is not easy, however, because the Department of Defense budget is not itemized by region. Moreover, the U.S. military presence in the Middle East has other objectives, like promoting democracy and stability in the region, besides safeguarding oil production sites and transportation lanes. And to what extent such spending is a variable cost that would increase with more oil imports, as opposed to a fixed cost that would not, is also somewhat murky. One study by Delucchi and Murphy (2008) put the (variable) costs of oil supply protection at about $6 billion to $60 billion a year, or approximately $1.50 to $15 per barrel of (all) U.S. oil imports. For the most part, this estimate reflects peacetime spending, though it also includes an annualized average of U.S. military expenditures for the two Gulf wars.

Again, however, whether military spending is an externality is open to question. To the extent peacetime spending occurs to protect oil supplies, it effectively substitutes for spending that would likely have been incurred by private entities. In other words, there may be little, if any, net burden on the U.S. economy from oil-related military spending, at least in peacetime. NRC (2010, 333), for example, assumes no externality from military spending.

National security and foreign policy considerations. A frequently heard concern about U.S. dependence on foreign oil is that it helps fund governments of oil-exporting nations that are hostile to Western interests. Moreover, to the extent that oil profits ultimately end up in the hands of terrorist or other unsavory groups, dependence can threaten regional or U.S. national security by increasing the risk of terrorist activity (CFR 2006). And revenues may undermine efforts to promote good governance. For example, buoyant oil revenues may have made the Russian government less concerned about Western sanctions or withdrawal of assistance in response to its crackdown on democracy. However, in all these cases, the United States, acting unilaterally at least, has little influence over these revenue flows: even a 10 percent reduction in U.S. oil imports might reduce world oil prices on the order of perhaps 2 percent, which is very small when set against the rise in world oil prices over the last decade.[34]

Dependence on foreign oil suppliers may also constrain U.S. foreign policy if the government believes that oil-producing nations would disrupt the oil market in response to U.S. initiatives on, for example, human rights and democratic freedoms. In other words, oil dependence may make the United States more congenial to repressive regimes than it otherwise would be.

Although there is a general sense that the nation would be better off if it were less dependent on an oil market subject to political manipulation by hostile, autocratic regimes, placing some credible value on these benefits is extremely difficult. Therefore, we simply note that there is a positive security cost associated with oil imports, and it could be large (CFR 2006).

Macroeconomic vulnerability to oil price volatility. For a given total amount of U.S. oil consumption, an increase in the share of consumption coming from foreign oil, in response to a reduction in domestic oil supply, may increase the risk of oil price shocks because the increase boosts the share of world oil supply that comes from unstable regions. In turn, oil price shocks lead to losses in GDP. Of U.S. recessions since 1945, 10 of the 11 have been preceded by sharply increasing oil prices, and a long tradition of empirical work has found that sharply increasing oil prices have a harmful effect on U.S. GDP (see, e.g., discussions in Brown and Yücel 2002, Kilian 2008, and Hamilton 2009). As of 2008, approximately half of U.S. oil imports might be viewed as coming from unstable regions like Saudi Arabia, Venezuela, Iraq, Russia, and Africa (see Figure 5).

If oil consumers can anticipate the size and effects of oil supply disruptions and take them into account in inventory decisions, fuel choices, investment in energy conservation, and so on, the risk of GDP losses may be internalized. If, however, because of (say) limited information, oil consumers underestimate the risks of oil supply disruptions, they may underinvest in oil security protection, implying that some portion of oil-related GDP losses is external. Moreover, transfers from U.S. consumers to foreign suppliers from oil price shocks could also be viewed as an externality. A careful analysis by Brown and Huntington (2010), however, found that these

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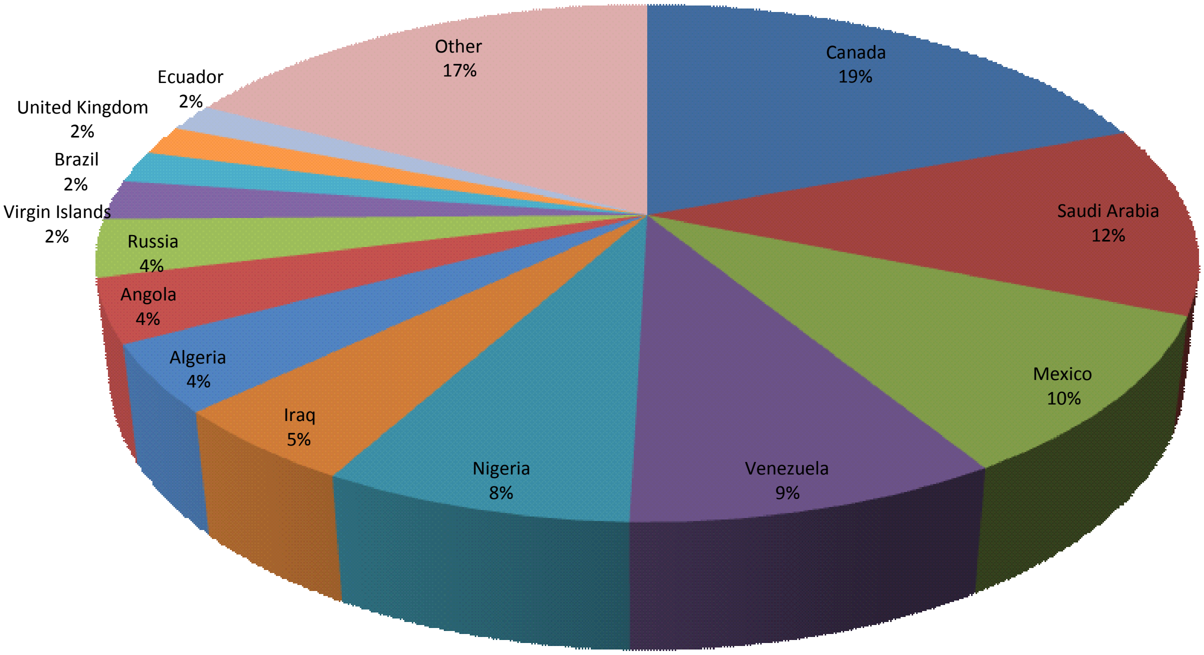
[34] The impact of changes in U.S. oil imports on world oil prices can be inferred from the inverse of the oil import supply elasticity, which measures the percentage change in U.S. imports in response to a 1 percent change in world oil prices. From Leiby (2007, Figure 3), a possible value for the oil import supply elasticity might be around 5, though accurately measuring this elasticity is problematic.

sources of external costs associated with marginal substitutions of oil imports for domestic oil supply were relatively modest, at $2.10 per barrel, with a plausible range of $0.90 to $5.70 per barrel (these estimates take into account that only about half of imports are from unstable regions.)

As noted above, each barrel reduction in offshore production increases oil imports by an estimated 0.68 barrel. The associated increase in (quantifiable) externalities due to macroeconomic vulnerability amounts to about $1.40 (= 0.68 × $2.10) per barrel of reduced offshore production.

Drilling restrictions and national security: a further look. There is a further strategic advantage to restricting deepwater drilling that is not considered here, given our focus on oil spills. In particular, leaving some oil in the ground could serve to reduce the impact of possible future oil price shocks due, for example, to a sudden cutoff in Persian Gulf supplies as a result of a radical takeover in Saudi Arabia. This is the reason for maintaining fuel supplies in the Strategic Petroleum Reserve. However, this reserve can address only short-term disruptions: the supplies could cover U.S. consumption for a few months at most. If, instead, a global oil price

Figure 5. US Oil Imports by Country of Origin, 2008



Source: EIA (2008)

shock were more prolonged, besides damaging the economy, it could also cause logistical problems for the military, which runs on oil.

An argument could therefore be made for leaving some oil reserves untapped in the Gulf of Mexico for use in these emergency situations. Unlike the reserves in the North Slope of Alaska, which would take years to exploit, given their remote location and the need for laying pipelines, oil in the continental shelf of the Gulf of Mexico could be tapped relatively quickly. (Oil deposits in the lower 48 states would have been even better, except that they have now been largely depleted.)

Externalities Related to Overall Oil Consumption

To the extent that reduced production from deepwater drilling leads to a fall in domestic oil consumption (as opposed to an increase in other sources of supply), there can be further externality benefits. Use of final petroleum products, particularly transportation fuels, is associated with additional externalities like pollution and highway congestion. These have already been discussed above. Changes in the amount of oil consumption itself can affect the overall vulnerability of the economy to oil price shocks, which we discuss below.

A reduction in domestic consumption (triggered by higher world oil prices) might be a positive externality because it would reduce the vulnerability of the U.S. economy to future oil price shocks. Again, however, Brown and Huntington (2010) have found the externality modest, at $2.80 per barrel of reduced consumption (with a plausible range of $0.20 to $8.70 per barrel).

Overall Effect

Now we add up the above estimates of pollution, congestion, and accident damages, labeling them externalities, making corrections for whether they are internalized, and adding in uninternalized energy security externalities, all on a per barrel basis. Then we weight the estimates for gasoline, diesel, and other fuels by their shares of oil use. This gives an overall external benefit of $35 per barrel of oil reduced. In turn, multiplying this by the estimated fraction (0.23) of reduced offshore production that comes from reduced consumption (as opposed to increased supply from other sources) gives an externality gain of $8 per barrel of reduced offshore production.

4. Are External Damages Internalized by Oil Firms?

Thus far, we have identified numerous damages associated with offshore drilling, many of which we have classified as externalities. However, existing liability laws impose on offshore oil drilling an expected sanction that equals the probability of causing and being liable for a spill, times the amount of all liability payments. The latter includes compensation paid to victims for the damages they incur as a result of the spill, payments for cleanup costs and natural resource damages, penalties paid to government agencies or courts, and legal costs borne by the firm. In effect, expected sanctions induce firms to take more care than they might otherwise to prevent spills, and in this sense the sanctions serve to internalize some of the external costs. Expected market responses may provide a further mechanism for internalization of external damages if a firm anticipates a decline in its stock market value if it causes an oil spill (e.g., as investors downgrade its performance relative to other firms in the drilling industry).

The implications of market responses are discussed in detail in Cohen et al. (2011). In this section, we provide some broad sense of the extent to which externalities associated with oil spills might be internalized through the existing liability system. To the extent they are internalized, existing policies are adequate for purposes of deterrence. On the other hand, to the extent external costs have not been internalized by responsible parties, firms do not have adequate incentives to take the socially desirable level of care in preventing future spills or other harmful effects of their drilling operations (Cohen 1992, 2010b). Before analyzing each damage category, three important caveats should be noted. First, the question of whether externalities are internalized by responsible parties is quite distinct from the question of whether injured parties are fully compensated for their losses. The first question pertains to *ex ante* incentive: do responsible parties expect to have to pay for all external damages they cause? The second question is one of *ex post* compensation, which may have little to do with external damages. For example, the government might settle natural resource damage claims with responsible parties for an amount significantly below the estimated damage in order to avoid a protracted legal battle, providing compensation payments that are less than the damages. Or local residents might settle their legitimate claims for less than their damages in order to avoid a lengthy legal battle, or a responsible party might compensate businesses or residents that were not damaged by the spill in order to reduce legal fees and/or to try to reestablish local goodwill.

Second, even in the (unlikely) event that *ex post* compensation payments just happen to roughly equate with external damages, as discussed at length in the Cohen et al. (2011), firms may still underinternalize or overinternalize spill risks. For example, companies may misperceive the probability of a catastrophic spill or the magnitude of harm such a spill might cause. Even if these risks are appropriately estimated, management might still take risks that are not in the best interest of shareholders because of the conflicting objectives of shareholders and managers. However, there are market pressures for firms operating in a competitive industry to understand the nature and extent of risks as accurately as possible and to maximize stockholder value. A further possibility (though not applicable to an industry giant like BP) is that, if a firm can declare bankruptcy and/or has inadequate resources to fully absorb all the damages it is responsible for under the law, it will not fully internalize these damages (Cohen 1987). This is particularly important in the case of catastrophic spills, where the damages can easily exceed the market value of firms involved in drilling operations (Muehlenbachs et al. 2011). Moreover, a firm might believe that because of complex contracts and drilling operations involving several major companies, blame will be shifted and some liability will (inappropriately) be apportioned to other firms.

Third, while responsible parties may pay significant monetary fines (whether imposed administratively or through a court system), these payments are a transfer of wealth from one party to another and do not directly represent internalized externalities. Nevertheless, as discussed below, oftentimes government agencies agree to settle with responsible parties for an amount based on natural resource damages. In many cases, the government will use those funds for ecosystem restoration—but the might simply go to the Treasury.

Table 5 identifies each of the component damages associated with a catastrophic oil spill and summarizes the extent to which these damages might ultimately be internalized. Once again, we need to stress the difference between a damage caused by a spill and an externality. Damages include all harms—whether they are borne directly by the responsible party, local residents, or the public at large. Externalities are only those damages that are borne by third parties who are not part of the underlying market transaction. Finally, as we discuss below, the liability system in the United States might or might not fully compensate for these externalities.

Lost Equipment and Oil

In the case of a catastrophic oil spill, the immediate consequences—including any harm caused to an oil rig, the value of lost oil, and so on—are likely to be borne directly by the responsible parties. These are private costs and not generally considered externalities. Although society cares about these damages because they are wasted resources and reduce economic welfare, they are fully internalized by those engaged in deepwater drilling. Thus, monetary sanctions (whether through government penalties or by tort actions) do not need to include these damages to deter spills (Cohen 1987).

Injuries and Deaths

In some cases, there might be injuries or loss of life to rig workers or third parties. The externality associated with such losses would include pecuniary burdens to third parties from medical costs (e.g., costs to insurance companies or the government under Medicaid) and lost productivity (e.g., the loss of tax revenue to the government as a result of forgone wages), as well as nonpecuniary burdens, such as pain, suffering, and reduced quality of life. To the extent tort law permits full compensation of both pecuniary and nonpecuniary losses, these damages are likely to be internalized by firms engaged in deepwater drilling.

Table 5. Portion of Oil Spill Externalities Internalized by Responsible Party

Harm	Portion likely to be internalized	Portion not internalized	Notes
Lost equipment and oil	100%	—	These are generally considered private costs
Workers or others injured or killed	100% for third parties; 100% for workers if labor markets are efficient	—	Compensation may be awarded to workers even if risks are internalized *ex ante.*
Cleanup and containment costs	100% if firm can afford	Any residual that firm cannot afford to pay.	Oil Spill Liability Trust Fund pays for costs (up to $1 billion per incident) that responsible party is unable (or unwilling) to pay, but this might not fully internalize costs;
Government costs related to the spill	Costs related to cleanup and containment are reimbursable by the responsible party under Oil Pollution Act (1990)	Most but perhaps not all government costs are reimbursable.	
Economic damages (lost tourism and fishing revenue, etc.)	Partial payment depending on liability cap and firm's willingness or ability to pay	Any residual unaccounted for through economic damage payments	Given uncertainties in documentation, economic damages may be under- or overcompensated;
Nonpecuniary losses to victims of the spill	None	100%	Courts have been reluctant to award nonpecuniary damages to economic victims of oil spills;
Public health damages	None	100%	Unlikely to be compensated given inability to show causal connection to individuals; see text
Residual damage to environment	Partial payment for natural resource damages, depending on legal standard, liability cap, scientific evidence, and firm's willingness or ability to pay	Any residual unaccounted for through natural resource damage payments	See text

Damage risks to deepwater drilling workers should, in principle, be taken into account by workers when they choose to work in oil drilling (which presumably pays higher wages to compensate for the higher risk of hazards) versus other occupations. Thus, to the extent labor markets are efficient, the risks to workers should be fully internalized *ex ante* and are not considered externalities. Of course, as discussed in Box 4, if labor markets are not efficient, we do not expect these risks to be fully internalized.[35]

Cleanup and Containment Costs

Once oil begins to spill, the firm is legally obligated under the Oil Pollution Act to try to contain it from further spillage as well as clean up as much as physically possible. There is no dollar cap on liability for cleanup. Efforts might include booms to prevent oil from spreading and/or capture it before it comes ashore, spraying chemical dispersants, mopping up beaches, and rehabilitating affected wildlife. However, if a firm is unable to pay for the cost of cleanup, funds from the Oil Pollution Liability Trust Fund are tapped (Richardson 2010).

Government Costs Related to the Spill

If the government steps in to assist, the responsible party is also required to reimburse the government's expenses. Most direct government expenses associated with the cleanup and containment activity are reimbursable, but there appear to be some expenses associated with spills that are not generally paid for by the responsible party.[36] As of October 12, 2010, the U.S. Coast Guard's National Pollution Funds Center is reported to have billed BP $581 million for recovery costs related to the *Deepwater Horizon* spill (GAO 2010). Although most if not all government costs associated with the cleanup efforts are thus likely internalized, legal investigatory costs and high-level management costs of government agencies (including the White House) would not be reimbursed.

Since not all oil from a large spill is likely to be contained or cleaned up fully, there will inevitably be residual harm that might affect both humans (businesses, property values, health, and so on) and natural resources (fish, beaches, ecosystems, and the like). Whether the residual harm caused by oil that was not cleaned is fully internalized by the responsible party is difficult to determine. We consider three separate categories of harm: economic, health, and natural resource damage impacts.

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[35] Paradoxically, to the extent labor markets are efficient and workers are compensated *ex post* for nonpecuniary damages, these payments may exceed any externalities and thus would tend to "overdeter" oil spills.

[36] See Oil Spill Cost and Reimbursement Factsheet http://www.restorethegulf.gov/release/2010/10/13/oil-spill-cost-and-reimbursement-fact-sheet, October 13, 2010.

Economic Damages to Businesses and Individuals Harmed by Spill

From a purely economic welfare perspective, lost profits are the appropriate measure of damages to any fishing and tourist industries that lose business following a spill. Whether these losses are actually compensated, however, will likely depend on the level of documentation and proof the injured parties can bring to the table, as well as any challenges to these claims by the responsible party. In fact, legal standards often make it difficult for victims to prove damages, and thus many will be undercompensated. For example, as discussed in Box 6, firms that are not located near a spill may not be able to establish legal damages even though economic theory would recognize their damages as an externality. However, it is also possible that some individuals are overcompensated. For example, is it appropriate to attribute all drop-off in business from 2009 to the BP spill, when the recession might have affected 2010 business in any event? Similarly, we know that there are always fraudulent claims following natural disasters, and there have been reports of such claims' being filed in the BP case. Even if many of these claims are weeded out and not paid, there is always an incentive to overstate losses, and some will inevitably be paid. On the other hand, the fact that such fraud exists might cause the responsible party to be overly strict in requiring documentation, leaving some legitimate claims unpaid.

A related concern is that despite the negative economic impacts in the region, there might be offsetting positive benefits elsewhere. For example, tourists who stay away from the Gulf area might instead vacation on the Atlantic coast, thereby increasing its economic activity. While the hotelier in the Gulf loses, a hotelier in another area gains new business. Further, while the responsible party must pay for the losses, it does not receive any credit for the offsetting benefit. From a pure "social welfare" standpoint, only direct harms count as welfare losses (unless there are distortions in the relevant markets). Thus, compensating those harmed for their losses is appropriate from the perspective of internalizing external harms. Said another way, netting out the benefits to others outside the Gulf would send an inappropriate signal to firms about their future level of care.

Finally, even if lost business profits are identified through the legal mechanisms discussed above, if the firm has reached a liability cap ($1 billion, as set by the Oil Pollution Act of 1990), it will not be responsible for compensating for these losses—and the externalities it causes will not have been internalized.

From an economic welfare perspective, if labor markets are efficient, lost income to workers laid off in the fishing and tourism industries would not be considered an economic damage. Instead, we would expect these workers to receive unemployment compensation and ultimately to find employment elsewhere. Nonetheless, workers directly affected in industries that may receive compensation for lost profits are generally entitled to compensation for lost wages.

Both workers who lose income and people who live near a spill site may suffer significant nonpecuniary damages in the form of mental anguish or more severe mental health consequences. These losses are not generally recognized by courts as being compensable by responsible parties. Thus, to the extent they occur, these externalities are not internalized.

Public Health and Nonpecuniary Victim Damages

Residents and/or cleanup workers might be subject to long-term health effects from breathing volatile organic compounds or coming into contact with oil. Others could become ill eating tainted seafood. If created by a spill, such harms are unlikely to be fully compensated for by the responsible party. It is virtually impossible in most cases to attribute a particular respiratory illness or cancer case to an oil spill, even if it can be shown that such illnesses are statistically likely. Thus, these harms are unlikely to be internalized by the responsible party.

Individuals who are economically harmed through job or business losses might also suffer emotionally. In fact, local community members who are not even economically harmed might suffer serious mental health issues following a catastrophic spill. There is evidence of such impacts in the case of the *Exxon Valdez* and other significant spills. However, in the case of oil spills, courts have been reluctant to compensate for either mental health care treatment or nonpecuniary damages to quality of life to those who are economically harmed or to other members of the community. Thus, this appears to be an area where victims are undercompensated, and this externality has not been internalized.

Residual Damage to the Environment

Finally, there are damages to natural resources themselves. As discussed earlier, damages may include both use (e.g., value to beachgoers or recreational anglers) and nonuse values to society (e.g., ecosystem). Economists have developed various techniques for estimating the monetary value of these nonmarket losses, which are discussed in detail in Box 3 (above). Although these methods have been upheld in court decisions and by expert panels of economists, they are not without controversy and uncertainties. Thus, inevitably, defense attorneys hire economists to argue for lower damages than those estimated by economists hired by the government trustees. For example, in the case of the *Exxon Valdez,* a government-funded study conducted around the time of the spill estimated that the lower-bound estimate of the public's willingness to pay to avoid the loss of wildlife from the *Valdez* spill was $2.8 billion (Carson et al. 2003) (see above), considerably more than estimated by Exxon's experts. Ultimately, the company and government settled for $1 billion in natural resource damages—a figure most likely lower than the true damage. In the case of the BP Gulf Oil spill, a significant portion of natural resource damages is likely to be unknown because they occur in deep water, where the impacts on the marine ecosystem are largely unknown (see above). Partly because of the difficulty, cost, and time to pursue litigation, the government oftentimes pursues "restoration costs" in place of valuing natural resource damages themselves. As discussed in Box 4, however, restoration costs are generally less than natural resource damages. Thus, in total, a significant portion of natural resource damages will likely be uncompensated through the legal process.

In the case of catastrophic spills, the bottom line is that despite the considerable uncertainty over the magnitude of any externalities that remain after the responsible party is charged for damages—and there are some areas in which it might pay more than the harm caused—overall, significant externalities may not be internalized through payments to injured parties. However, it is still possible that the full costs will be internalized if the government imposes civil and/or criminal penalties beyond the payments described above. In fact, under the Clean Water Act, penalties up to $1,100 per barrel— and $4,300 per barrel in the case of gross negligence or willful misconduct—may be assessed. For the BP Gulf oil spill, this could amount to $5 billion or $20 billion in fines, an amount that could more than offset any externalities not already internalized through the legal process. Note that there is no guarantee the government will seek that high a penalty— or succeed in imposing it.

Example: Damages from the Exxon Valdez *Spill*

Cohen (2010a) catalogued both the estimated damages caused by the *Exxon Valdez* spill and the publicly known costs Exxon incurred as a result of the spill. Including government penalties, civil settlements, punitive damages, and the cost of cleanup, Exxon paid approximately $4.3 billion to $4.4 billion (in 1980 dollars). Of this amount, about $2.1 billion went toward cleanup costs, $500 million to $600 million to pay for economic damages to private parties (e.g., fisheries), and $1 billion was paid toward natural resource restoration. However, since natural resource damages were estimated to range between $2.8 billion and $7.2 billion, the total damages caused by the *Exxon Valdez* were at least $5.5 billion to $9.5 billion—and might be higher if one adds additional public health damages and nonpecuniary losses (e.g., quality of life) to victims (e.g., cleanup workers, local residents). This is considerably less than Exxon ultimately paid. Thus, it appears that on balance, the external costs of the *Exxon Valdez* spill were not fully internalized.

We close this section by repeating an important caveat to our analysis. Even if the responsible party has fully paid for the harm caused by a catastrophic spill, not all injured parties may be fully compensated for their harm. Indeed, we have described various instances where such compensation is unlikely. Thus, for example, even if government penalties offset these uncompensated losses, the funds do not necessarily go to the injured parties. From the perspective of ensuring that the *ex ante* incentives of firms are aligned with taking due care, it does not matter who ultimately receives the proceeds of any monetary penalty assessed to responsible parties. But from a distributional equity perspective, it most certainly matters.

5. Cost–Benefit Analysis Framework and Its Application

In this section, we provide a framework for analyzing the costs and benefits of a ban or further regulation on deepwater drilling. A cost–benefit analysis considers not only the direct cost of the policy (e.g., higher production costs) and the direct benefits (e.g., fewer damages from deepwater spills) but also the indirect costs and benefits that are likely to accrue as the market adjusts to any ban or new regulation. Thus, we also consider the potential costs and benefits of a shift in the oil supply to onshore drilling or to oil shipped from outside the United States. Although we have attempted to place dollar values on both the benefits and the damages, we caution the reader that these figures are meant to be illustrative and are based on a simplistic empirical analysis. To conduct a rigorous cost–benefit analysis would require considerably more facts and data—something that is beyond the scope of this paper. Table 6 provides all the estimates of benefits and costs for the different scenarios and assumptions detailed below. Note that the damages and benefits taken from the discussions above are assumed to be uninternalized externalities, so we use the customary terms of benefits and costs.

Environmental Impacts and Damages from Spills

Although it was beyond our scope to measure actual damages from the *Deepwater Horizon* spill or speculate about damages from a future spill that regulations would prevent, we did set up a taxonomy for categories of impacts and how these impacts map to activities that generate or reduce economic value, termed damages. We learned that overall, spills from drilling account for very little of the oil found in coastal waters, with most coming from natural seeps and, of the anthropogenic sources, from oil-consuming activities (reaching the ocean from rivers and urban runoff. An impact that is perhaps surprising is human health effects from volatilization of oil. Information to identify the important impacts of deepwater drilling is insufficient, but for shallow-water drilling, impacts include fish and invertebrate mortality and contamination, as well as shoreline and habitat contamination. As for damages, historical assessments suggest that nonuse values are likely to be the largest damage category, followed by losses to society associated with seafood contamination, both real and perceived, and possibly the value of human health damages associated with breathing volatilized oil compounds. Recreational damages are likely to be small because people have other options. For commercial fishing, revenues in all affected states (including the west coast of Florida and Texas) are about $661 million annually, and coastal tourism and recreation bring in $34 billion. But only a small fraction of these revenues is affected, and lost revenues are not an appropriate measure of welfare costs. In general, welfare costs would be much lower.

For the purpose of our illustrative cost–benefit analysis, we will use the welfare estimates of damages per gallon of oil from the *Exxon Valdez,* scaled to the size of the *Deepwater Horizon* spill, which leads to estimates ranging from $509 to $1,163 per gallon, or $105 billion to $239 billion, in 2009 dollars.

Energy Security

Economic effects discussed in the literature include market power, military spending, and macroeconomic vulnerability to oil price volatility. Only the last is tagged as an external damage, at $1.40 per barrel of reduced offshore production (about $0.03 per gallon of oil). Under a ban, deepwater production of about 700 million barrels per year (in 2035) would be eliminated, with a total energy security externality of about $1 billion per year.

Changes in Overall Oil Consumption

If consumption of oil falls because the regulation of deepwater drilling drives up its cost, the regulation generates several benefits: reduced pollution, congestion, and road accidents, amounting to about $48 per barrel, or $1.15 per gallon of gasoline and about $0.70 per gallon of diesel, net of existing fuel taxes. Overall, external benefits are about $35 per barrel of oil reduced. With a 23 percent reduction in deepwater oil production and the consequent reduction in consumption, the externality benefit of regulation is about $8 per barrel of reduced offshore production, or a welfare benefit of about $5.6 billion per year.

Welfare Costs of Regulation (Regulatory Costs)

Earlier, we showed that a complete ban on deepwater drilling would result in welfare losses no less than $64 billion per year in 2035 but not much difference in intervening years. For the less stringent regulation, these costs could be anywhere from zero to $22 billion per year in 2035, depending on whether the industry would have adopted these technologies in the absence of regulation. These estimates for either policy capture minor effects on the world oil price, substitutions to imports (68 percent), reductions in domestic consumption (23 percent), and increased domestic production elsewhere (5 to 8 percent).

Net Benefits

A ban on deepwater drilling would reduce the risk of a catastrophic spill from ongoing drilling operations in deepwater to zero, but we do not know what effect tighter regulation would have on spill probabilities. RFF's analysis of spill data off the California and Gulf coasts shows only two spills in more than 40 years in the range of the *Exxon Valdez* (one-third the size or greater). So, counting the *Exxon Valdez* and *Deepwater Horizon* spills gives a probability of one very large spill in about 10 years. Of course, deepwater drilling is relatively new, and our longer history with large tanker operations and shallow water drilling may understate the probability of a major spill in deepwater. However, for purposes of illustration and to arrive at a ballpark estimate of the potential costs and benefits of increased regulation of deepwater drilling, we assume the base probability to be 1 in 10 years.

To estimate the benefits of a ban, we assume (1) catastrophic spills are the only type of spill we care about (say, because natural assimilative capacity would take care of most of a smaller spill); (2) all damages from these spills can be monetized using estimates based on the *Exxon Valdez* experience; (3) all further spills that a ban would prevent would come from deepwater drilling; and (4) these avoided spills would be about the size of the *Deepwater Horizon* spill. Given these assumptions, the ban would eliminate one *Deepwater Horizon*–type incident in 10 years. Thus, the annual expected benefit would be the value of avoiding the spill divided by 10. The annual benefits can then be compared with the annual costs (because the streams of benefits and costs are constant, no present-value calculations are needed).

The annual costs of a ban are $64 billion in welfare costs plus $1 billion per year in losses to energy security ($65 billion). The welfare benefits are $16.1 billion to $29.5 billion annually. Given the numbers for benefits provided above, it is immediately apparent that, the huge uncertainties of these estimates aside, a ban would not be economic at this probability (net benefits of at least *negative* $35.5 billion in the first year). On the other hand, if in the absence of further regulation, we expect one *Deepwater Horizon*–type spill every four years or less, then a ban on deepwater drilling would be justified on a social cost–benefit basis.

What about a less severe regulation? As noted, a regulation raising extraction costs by 20 percent would result in at most $22 billion of annual costs, plus an amount (less than $1 billion) for the energy security costs. In the best case, if we assume the regulation eliminates large spills (the same as a ban, given that we assume away the effect of small spills), then such a regulation would be economic only with the higher end of the benefits estimates—with costs of $22 billion annually and benefits up to $29.5 billion (but as low as $16.1 billion annually). Based on a compensation measure of damages, benefits would be only $5.8 billion per year, so further regulation would not be economic. Because the estimate of welfare costs of regulation is highly uncertain (the range above was the addition of 10 percent to 20 percent of the current costs of drilling), let us also consider the case where costs rise only 10 percent. In this case, welfare costs are about $11 billion annually (plus energy security costs of under $1 billion). Thus, even at the low estimate of welfare benefits ($16.1 billion annually), the regulation would be economic.

Now, let's assume that a regulation raising drilling costs by 20 percent still leaves some probability of a large spill. To go further, we would need to know the change in spill probability associated with this regulation, which we do not. One way to proceed is by using a breakeven analysis: we ask how much the probability of a spill would need to change for the benefits to equal the costs. Then we can say that any change in probability greater than this benchmark would make the regulation economic. The above low estimates of benefits and high estimate of costs ($22 billion annually) make it uneconomic even with the dramatic assumption that the ban and the less severe regulation have the same effect on spill probability (i.e., each eliminates it). Beyond this case, we focus first only on the highest estimate of benefits ($29.5 billion annually). In this case, if a 1 in 10 spill probability were reduced by 92 percent or more, the regulation would still be economic (have net benefits). If the costs are assumed to be only $11 billion instead of $22 billion annually, then the regulation would still be economic (at the highest benefit estimate) if the spill probability were reduced by only 50 percent or more. If the benefit estimate is very low ($16.1 billion), then this probability rises to about 70 percent or more. The bottom line is that to be economic, the regulation would need to drop the large spill probability substantially—by more than 50 percent. Needless to say, the results of a detailed study could be very different than these back-of-the-envelope calculations.

Table 6. Annual Net Welfare Benefits (in billion 2009 dollars per year) of Deepwater Drilling Regulation

				High benefit estimate			Low benefit estimate		
Regulation	**Regulatory cost uncertainty**	**Effectiveness of regulation**	**Welfare cost***	**Welfare benefits**	**Net benefits**	**Break-even effective-ness****	**Welfare benefits**	**Net benefits**	**Break-even effective-ness****
Complete ban	-	100%	$65	$29.5	-$35.5	NA	$16.1	-$48.9	NA
Increase costs of oil drilling and extraction	20% operating cost increase	Partial	$22	$22	0	92%	***	***	***
		100%	$22	$29.5	$7.5	NA	$16.1	-$5.9	NA
	10% operating cost increase	Partial	$11	$11	0	50%	$11	0	70%
		100%	$11	$29.5	$18.5	NA	$16.1	$5.1	NA

*Values are upper bounds per year. The actual cost depends on whether the industry would have adopted the risk-reduction technology absent the regulation.
**Defined as the minimum percentage decrease in spill probability from a base spill probability of 0.1 that would yield positive net benefits. For example, in the second row, the regulation has to be 92% effective, relative to a total ban, to have the same costs and benefits. Any effectiveness greater than 92 percent would result in positive net benefits.
*** Benefits are too low to equate to costs, even assuming 100% effectiveness relative to a ban.

Box 6. Legal versus Economic Approaches to Damage Compensation

This box contrasts the legal approach to compensation, as interpreted through the lens of Kenneth Feinberg's Gulf Coast Claims Facility (GCCF), with the economic approach, as interpreted through welfare economic theory. It abstracts from the debate about the motive for setting up such a compensation fund: does it simply mimic the expected court awards but faster and cheaper, or does it bypass some of the legal constraints and requirements to make awards based on its own view about the appropriate criteria for determining compensation?

Compensation under a Feinberg system and under a welfare-theoretic system is likely to be quite different, although the net difference in direction is unclear. In the former, the law drives compensation decisions, and the logic for legal damages may be inconsistent across cases and even judged by some to be unjust. In the other, economics would be an input into the decisions.

The GCCF is guided by the legal concept of proximate cause. GCCF protocols say the following:

> To help determine the proximate cause of an injury in negligence or other tort cases, courts have devised the "but for" or " sine qua non" rule, which considers whether the injury would not have occurred but for the defendant's negligent act. A finding that an injury would not have occurred but for a defendant's act establishes that the particular act or omission is the proximate cause of the harm, but it does not necessarily establish liability since a variety of other factors can come into play in tort actions (Gulf Coast Claims Facility 2010).

It would seem that the net compensation for damaged parties could be very inclusive, but legal theory and practice place a variety of limits on making claimants whole (see Farnsworth 2007 for accessible discussions, particularly chapters 6 and 31).

Proximate cause is similar in theory to concepts from welfare economics, but the former is narrower in practice. The “but for” interpretation of proximate cause fits in well with economic theory, where any expected utility change as a result of a spill should be counted as a damage. That any offsetting income (such as insurance settlements and wages earned by a cleanup worker) should be netted out from compensatory damages, as evidenced by the 9/11 Compensation Commission (Bornstein and Poser 2007), also fits well with welfare theory.

In practice, however, the limitations on the “but for” idea appear significant. Indeed, the qualifications in Feinberg’s protocol (Gulf Coast Claims Facility 2010) indicate that significant limitations to “but for” are operative—following the causation determinations in OPA and federal law.

Finally, beyond the protocols addressing proximate cause are two issues: how the amount of compensation is determined, and determining the categories of eligibility for compensation, as they inform the building of a conceptual framework for damages (below). The amount of compensation under the legal approach is not based on utility. The legal approach can include both compensatory damages and punitive damages, levied when “the defendant’s conduct is found to be intentional or willful or wanton or malicious” (Collin 1998). These awards are meant not only to punish the defendant but also to discourage future conduct of this type. Although plaintiffs may receive punitive damage awards, government agencies are more likely to be the recipients in the case of an oil spill.

In the Feinberg approach, compensatory damages appear to be based primarily on lost income, out-of-pocket expenses, and the value of damaged assets. None of these concepts match well with economic notions of making people indifferent with and without the spill. The most distinct example is for compensation for lost life. Here, the courts typically match compensation to lost income, perhaps adding multiples for punitive damage. Thus, compensation in the 9/11 case was larger for a person in a higher-paying job than in a lower paying job. This “human capital” approach has generally been regarded as much inferior to approaches using the value of statistical life, which is based on either revealed or stated preference valuations (see Box 4). In practice the human capital approach provides lower estimates of compensation than welfare-based approaches and makes less (or only an indirect) distinction based on income or wealth.

Once any of these values are introduced into the legal system, they can be much reduced or increased. As one commentator noted, the families of the workers killed on BP's *Deepwater Horizon* rig in the Gulf of Mexico might not receive a large damage settlement “because the Deepwater rig is legally considered an oceangoing vessel and was more than three nautical miles offshore at the time of the accident. As a result, the families of the dead workers can only sue BP and its contractors under a 90-year-old maritime law, the Death on the High Seas Act, which severely limits liability” (Mencimer 2010).

Another important difference between the legal and welfare economics approaches involves nonuse values, the amounts that people would pay to avoid a future injury to the environment, regardless of their use of the resource. Because utility is lost (i.e., willingness to pay is greater than zero), compensation should be paid under the welfare economics approach. Under a Feinberg approach, however, there might be no basis for making the compensation award, since by definition of “nonuse,” nothing tangible—income, property holdings, and so on—was affected.

One possible caveat would rest on the interpretation of terms like “mental anguish” and “loss of society.” The 9/11 Victim Compensation fund administered by Feinberg provided compensation for “noneconomic” damages, including pain and suffering, inconvenience, mental anguish, and “loss of society” (Bornstein and Poser 2007) . In practice, admitting that computing such damages was hard if not impossible, Feinberg paid all eligible claimants the same amount ($250K per victim, $100K per spouse and dependent child), saying he didn’t want to exercise “Solomonic judgment” in deciding who was more deserving of compensation for these types of losses.

Further insight into the conceptualization of noneconomic damages can be gained from Feinberg’s autobiography (Feinberg 2005), written after the Victim Compensation fund closed, in which he urged that future compensation funds be paid out more uniformly. From an ethical standpoint, he expressed distaste for valuing the life of a firefighter less than that of an accountant based on income, because it caused divisiveness among the grieving families and created an economic hierarchy, valuing the victims and their families according to their individual success. He also observed that the compensation process was incredibly time-consuming and undermined a primary motivation behind its creation—the expedient compensation to the families of victims in lieu of a lengthy court process. In a welfare economics approach, income need not have entered into the decision about compensation, and a value of statistical life estimate could have perhaps been used instead, with lower transaction costs.

Punitive damages can be consistent with welfare economics, in that the size of the damage award is meant to induce better, more careful behavior. But juries typically make such awards based on intentional, willful, or malicious behavior. In welfare economics, the idea is to encourage a socially appropriate amount of due care (not just better care) and to do so without regard to motivation, which is difficult to observe, subject to judgment, and in welfare economics, irrelevant. Whether BP is ultimately found liable for a punitive damage award will be up to judges and juries, and this determination might have little to do with concepts of economic welfare.

We conclude that there is no necessary relationship between legal and welfare economic damages.

5. Summary and Policy Implications

This paper has focused on building a framework for assessing the costs and benefits of further regulating and/or banning deepwater drilling and demonstrating the use of this approach for policy analysis. The costs and benefits of such regulation would be measured by the policy-induced change in the probability distribution of spills of various sizes, times the damages associated with such spills, plus any other benefits (or costs) arising from a reallocation of economic activity prompted by such regulation. In addition to environmental impacts associated with spills, we included impacts associated with oil price changes and substitution to other types of oil supplies, as well as energy security. Because the only damages that justify additional regulation are those not already internalized (by markets, liability laws, and policy), we have tried to sort out this issue. But we did not attempt to quantify the change in probability of an accident that any regulation would cause (except to reduce the baseline probability, which we assumed was 1 in 10, by 100 percent under a ban). Based on Brown (2010), we attempted to estimate the welfare costs to the economy of a ban on drilling or a regulation that increased deepwater drilling costs by either 10 or 20 percent.

Our analysis has implications for policies in two important ways. First, we have highlighted and provided a comprehensive list of the varied consequences of limiting deepwater drilling—some of them perverse. Second, we provided a framework for improving the future conduct of cost–benefit analysis to help decide on the policy design that maximizes net benefits to society, given that some regulatory action to limit deepwater drilling is to be taken.

We have argued that limiting deepwater drilling puts in place a chain of events in the economy that can offset or augment some of the environmental and other benefits—uninternalized externalities—associated with this activity. Raising the costs of deepwater drilling will make other approaches to obtaining oil (and meeting energy needs with other fuels) more attractive and may ultimately raise the price of oil and its products. However, these other energy sources have their own negative externalities, such as environmental and health implications and energy security implications. These negative externalities offset to some degree the corresponding benefits from reducing deepwater extraction. At the same time, any increase in oil prices reduces gasoline demand and other uses for oil, which lowers the considerable negative health and environmental externalities associated with these activities, reinforcing the social benefits of regulations to reduce deepwater drilling. In our view, this use-based reduction in negative externalities is the “tail wagging the deepwater drilling dog,” in that we are quite sure about the high price the American public pays for its use of oil in transportation and elsewhere and much less sure about the price paid for continuing deepwater drilling. We hesitate to add, however, that capturing the former benefits through an oil tax would be a far more efficient and effective way of reducing these externalities.

The foregoing points presume that there are uninternalized negative externalities that justify regulation. However, we have seen that this situation is not clear cut. Assuming that BP and other oil companies will behave differently, based on the *Deepwater Horizon* accident, a case can be made that most, if not all, oil spill damages are now being internalized. This internalization comes from the companies’ reassessment of the probabilities of various-sized spills, the basically unlimited liability they face for “covered” damages, and the effect of a big spill on a company’s stock price and borrowing ability. This assessment is not very strong, however: we noted (in Section IV) that some externalities do not appear to be internalized under existing liability laws, even as existing laws may provide compensation for some losses that are not externalities and thus go beyond deterrence.

Regarding the improvement in cost–benefit analyses of deepwater drilling regulation, this paper has developed a comprehensive and reasonably simple framework for capturing the economic costs and benefits of such regulations and demonstrated how it could be applied with some preliminary data. This framework is comprehensive enough to also capture any negative benefits associated with substituting away from the newly regulated deepwater oil drilling toward other fuels, imported oil, or oil from shallow-water or land-based wells. Such a framework, if applied in a deliberate and comprehensive way with more detailed data, could help government agencies charged with regulating deepwater drilling produce more credible and comprehensive regulatory impact analyses and ultimately, better, more efficient regulations.

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Appendix A. Estimating the Economic Welfare Cost of Deepwater Drilling Restrictions

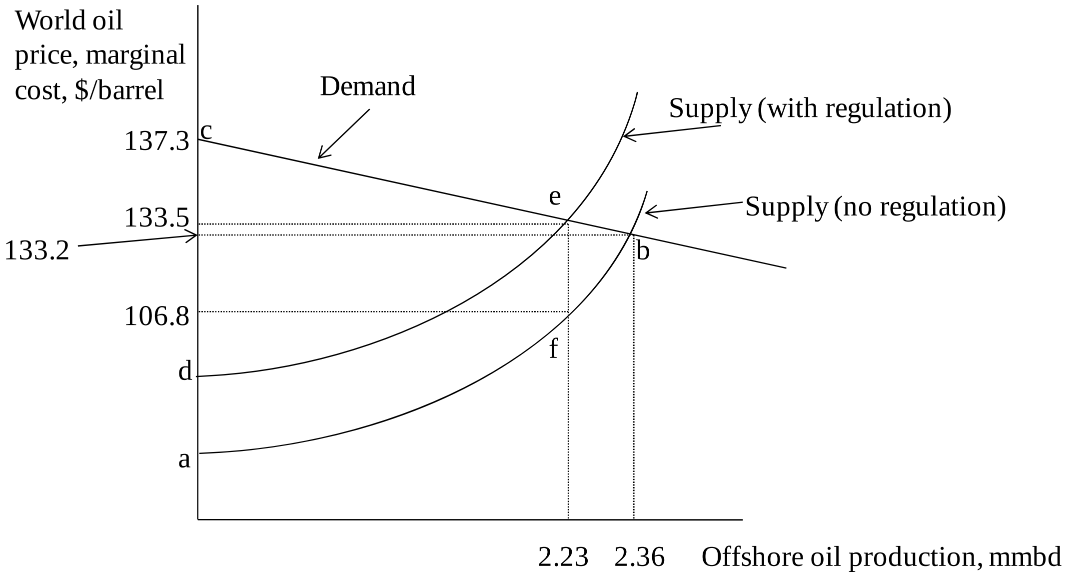
The economic welfare cost of drilling regulations is obtained from the standard tools used by economists. Consider Figure A1, which shows the supply and demand for offshore U.S. oil production.

The height of the supply curve at any given point represents to the costs to U.S. firms from producing an extra barrel of oil; that barrel will be produced as long as the prevailing market price at least covers this incremental cost. This curve is upward sloping because, in a given year, expanding oil production will utilize progressively more costly wells (e.g., rigs that are in ultradeepwater and longer distances from the coast). The area under the supply curve, between the origin and the amount of oil production, is total costs to firms incurred by supplying that level of crude oil output.

The height of the demand curve in Figure A1 reflects the benefit to domestic oil consumers from one extra barrel; that barrel will be sold as long as the price is at or below this incremental benefit. This curve is downward sloping, but only slightly, given that domestic consumption of offshore oil is small relative to world consumption and therefore has only modest implications for the world market price. The area under the demand curve, between the origin and the consumption of offshore oil, represents the total benefit to consumers from this oil.

The total net economic benefits from the business-as-usual level of offshore production in 2035 (2.36 mmbd)—that is, consumer benefits less supply costs—is indicated by the area between the demand and supply curves, or area *abc.*

Figure A1. Economic cost of oil drilling restrictions



Intermediate Regulation

Consider the high-cost, intermediate regulation that raises production costs by 20 percent. We take this cost increase as being the same for all units of production.

The supply curve with this regulation is indicated by the higher upward-sloping curve in Figure A1. Given the new equilibrium for the world price ($133.50 per barrel) and offshore oil output (2.23 mmbd), the net economic benefit falls to area *dec*—that is, the reduction in economic welfare is given by area *deba.* This consists of two components.

First are the extra production costs for the new level of output (compared with the costs of producing the same level of output without the regulation). This is the parallelogram *adef,* which has base 2.23 mmbd and height equal to 20 percent of the new equilibrium price ($133.50 per barrel), or $26.70 per barrel. Aggregating over a year, this cost is $21.7 billion (= 365 × 2.23 × 26.7 / 1000).

The second component is area *ebf.* This reflects the savings in production costs (at the new, higher level of cost), less forgone benefits to oil consumers, from the reduction in offshore oil production. To calculate this area, we make the (reasonable) approximation that the supply curve is linear over the range of oil reductions caused by regulations, implying area *ebf* is a (straight-sided) triangle. From Figure A1 this triangle has base 0.13 mmbd and height $26.70 and therefore area (after aggregating over a year) $0.6 billion (= .5 × 365 × 0.13 × 26.7 / 1000). Summing the two components gives a total economic welfare cost of $22.4 billion.

The low-cost intermediate regulation, which raises production costs by 10 percent, is calculated in the same way. Here we assume that all prices and quantities are midway between those in the baseline case and the case with a 20 percent increase in production costs. For this case, the increase in production costs corresponding to area *adef* has base 2.30 mmbd and height equal to 10 percent of the new equilibrium price ($133.40 per barrel), or $13.30 per barrel. Aggregating over a year, this cost is $11.2 billion (= 365 × 2.30 × 13.3 / 1000). The second component corresponding to area *ebf* has base 0.07 mmbd and height $13.30 and therefore area (after aggregating over a year) $0.2 billion (= .5 × 365 × 0.07 × 13.3 / 1000). Summing the components gives a (maximum) welfare cost of $11.4 billion.

In both cases, the above cost estimates should be viewed as upper bounds. This is because they assume no technology upgrades in the absence of regulation. In practice, firms are likely to improve safety procedures, at least to some extent, since expectations of spill risks have been revised upward following the *Deepwater Horizon* spill. To the extent such technology upgrades would have occurred anyway, the effectiveness and costs of new regulations are reduced.

Permanent Ban

We lack good data on the total costs of offshore oil production. In terms of Figure A1, this means that we do not know what the supply curve looks like well to the left of point *f*. To develop a lower-bound cost estimate, we assume that the supply curve is flat from the origin to point *f*—that is, unit costs are all $108.60 per barrel for the first 2.23 mmbd produced. Under this assumption, area *afec* is $63.7 billion (= 2.23 × .5 ((137.3 – 106.8) + (.2 × 113.5))). Adding the estimate of area *ebf* from above gives the total figure of $64.4 billion reported in Table 1.

This lower bound may substantially understate actual economic costs. Suppose, for example, that the first barrel of oil produced costs $53.4 per barrel, or half as much as just assumed, and costs per barrel rise linearly up to $108.6 per barrel at a production level of 2.23 mmbd. Repeating the above calculation, area *afec* would now amount to $123.3 billion (= 2.23 × .5 ((137.3 – 53.4) + (.2 × 113.5))).