An Investigation of Liability and the Oil Tanker Market

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Dedication

I would like to dedicate this paper to my wife Julie, whose endless patience with me during the writing of this dissertation was far beyond what I deserved.

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Abstract of Dissertation

An Investigation of Liability and the Oil Tanker Market

This dissertation consists of three essays on two separate but related topics pertaining to oil tankers. The first two essays focus on how the threat of liability for oil spills effects the organizational decisions of oil companies, while the third explores the drivers of oil tanker ownership across countries. The first essay presents a theoretical model of an oil company's decision to use its own tanker to transport its oil, as opposed to contracting with a shipping company. The model was motivated by the fact that the current theoretical models of liability in the economic literature omit many of the important elements of the liability regime for oil spills. Several testable predictions are derived from the model. The second essay empirically tests two of the predictions of the theoretical model using data on US port-calls by oil tankers and exploiting the variation in oil spill liability laws across US states. The results of these empirical tests suggest that tankers owned by major oil companies are more likely than other tankers to call on ports that extend liability for oil spills from the owners of the tankers to the owners of the cargo, as predicted by the theoretical model. This empirical finding contributes to the economic literature on liability by providing evidence that the imposition of extended liability can cause large firms to undertake potentially hazardous activities internally, where they can, in principle, directly control the level of preventative care.

The third essay provides an analysis of the ownership structure of the international tanker fleet and how it has changed since the passage of the Oil Pollution Act of 1990. The empirical findings of the third essay suggest that the drivers of tanker

ownership at the national level are strongly influenced by the government's role in the sector.

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Chapter 1:

Introduction

The Deepwater Horizon oil spill in 2010 has renewed public interest in the environmental and economic damages that can result from large oil spills in US coastal waters. Liability for oil spills has long been seen as a way to both reduce the number of spills and to ensure that injured parties are fully compensated for their losses, but the question of who should be held liable for a spill is still a point of discussion. Under US law, only the owners and operators of tankers are explicitly liable for the damages resulting from an oil spill. The owners of the spilled oil (the cargo-owners, which are typically oil companies) face no explicit liability under federal law, but several coastal states have passed laws that extend liability to cargo-owners. After both the Exxon Valdez and the Deepwater Horizon oil spills, the imposition of cargo-owner liability at the federal level was debated as a policy option. In both cases, Congress ultimately decided against it. This paper hopes to contribute to that policy discussion by providing a theoretical framework for examining oil spill liability as well as conducting an empirical investigation of the issue.

These issues are also part of a much larger academic discussion on the economics of liability. There are two main strands of economic literature that are relevant to oil spill liability. The first strand relates to "judgment-proof" firms – firms that may not have sufficient assets to compensate victims in the event of a major accident. This literature has shown that large firms with deep pockets have an incentive to contract with smaller

firms to undertake hazardous activities to limit their exposure to liability. This area of research is clearly relevant to the oil tanker market where the major oil companies are many times larger than the shipping companies they use, and a single large oil spill could inflict billions of dollars in damages on individuals, businesses, and fisheries. The second relevant strand of economic literature explores the issue of "extended liability" in which companies that do business with the polluting firm could be held "vicariously liable" for damages caused by their business partner. The threat of extended liability is relevant to the relationship between oil companies and shipping companies, and is central to the models presented in Chapters 3 and 4.

While there is a relatively large theoretical literature on the economics of liability, the existing models omit many important elements of the liability regime dealing with oil spills. Chapter 3 contributes to the economic literature on liability by capturing the unique elements of oil spill liability laws in a theoretical model. That model describes an oil company's decision to either transport its oil on its own tankers or contract with a shipping company to charter a tanker. The model presented in Chapter 3 uses a principal-agent framework to describe the relationship between an oil company and a shipping company when liability for the spill is extended to cargo owners. Separating equilibrium analysis is then used to determine the conditions under which an oil company would be indifferent as to whether to use its own tankers or charter a tanker from a shipping company. Five testable predictions result from the analysis:

Proposition 1: An increase in *official* liability limits for oil spills will increase chartering if oil companies believe their liability is not limited in practice.

Proposition 2: Oil tankers that operate in jurisdictions that extended liability to cargo owners are more likely to be owned by oil companies than tankers that operate in jurisdictions that do not extend liability to cargo owners.

Proposition 3: An increase in charter rates will have less of a negative effect on chartering (possibly a positive effect) in jurisdictions that impose extended liability.

Proposition 4: An increase in the expected damages from an oil spill based on location, such as an increase coastal land values, will have less of a positive effect on chartering (and possibly a negative effect) in jurisdictions that impose extended liability.

Proposition 5: An oil company will charter higher quality tankers when operating in a jurisdiction that imposes extended liability for oil spills.

Chapter 4 contributes to the economic literature on liability by providing an empirical analysis of the shipping decisions of major oil companies in light of differences in oil spill liability laws across US states. Despite the relatively large theoretical literature on the economics of liability, there has been surprisingly little empirical research on the issue. In fact, I could find only one published paper on extended liability for environmental damages that contained an empirical analysis (Brooks 2002). The empirical analysis presented in Chapter 4 exploits the variation in oil spill liability laws across US coastal states to test Propositions 2 and 5 from Chapter 3 (as listed above). Data were not available to test the other propositions. A model of port calls by major-owned tankers is developed and estimated to determine if the imposition of cargo-owner liability at a port is associated with a higher number of port calls by tankers that are owned by major oil companies, as predicted by the theoretical model in Chapter 3. As a

robustness check, a separate model is developed and estimated to determine whether tankers that are owned by oil companies are more likely to call on ports that impose extended liability. More than 30,000 US port calls by oil tankers between 2006 and 2009 are used in the analysis.

The empirical results obtained indicate that oil companies are indeed more likely to use their own tankers when operating in jurisdictions that extend liability to cargo owners, as predicted by the theoretical model. This empirical finding supports the notion that the imposition of extended liability can cause large firms to undertake potentially hazardous activities internally, where they can, in principle, directly control the level of preventative care. The results also indicate that tankers visiting ports that extend liability to cargo owners tended to be newer and were more likely to be double hulled, which is consistent with Proposition 5 of the theoretical model.

The ultimate decision of where a tanker operates is made by the tanker's owner, which raises the question: who owns the tankers? Chapter 5 provides an analysis of the ownership structure of the international tanker fleet and how it has changed since the passage of OPA-90. Two hypotheses for the observed changes in country-level oil tanker ownership between 1993 and 2009 are tested. The first hypothesis is that the volume of a nation's oil trade drives oil tanker ownership in that nation. The second hypothesis is that the size of a country's shipping industry drives oil tanker ownership in that nation. The empirical results show that both factors are important drivers, but for different sets of countries. A nation's level of oil trade is only a significant driver of tankers ownership in countries where the government owns some or all of the of nation's tankers. Conversely, the size of a nation's shipping industry (as measured by non-tanker vessel ownership) is

only a significant indicator of tanker ownership in countries where the government owns no oil tankers. These findings suggest that the drivers of tanker ownership at the national level are strongly influenced by the government's role in the sector. Chapter 5 differs from most studies of vessel ownership in that it focuses on the ultimate owners of the tankers (also known as the beneficial owners), not the registered owners, which are often single-vessel firms that exist only on paper.

Chapter 2:

Background Information

I. The market for tanker services

Eighty six million barrels of crude oil were produced on average each day in 2012, and 55 million of those barrels were traded internationally. Two thirds of the traded barrels were transported on oil tankers, according to data from the United Nations Conference on Trade and Development's latest Review of Maritime Transport. Much of that oil is transported on tankers a second time as refined petroleum products, such as gasoline and diesel. Oil tankers constitute roughly one third of the world's vessels in volume terms and about the same share of all seaborne trade.

Like oil itself, the services of oil tankers are traded on an open market. Any oil company, refinery, or trader that wishes to charter an oil tanker can do so at the going market rate for a particular route. There are two primary segments of the charter market – *spot charters* and *time charters*. In the spot market, tankers are chartered for a single voyage to deliver a specific volume of oil from point A to point B at an agreed price. In the time-charter market, tankers are chartered for a specified number of days, months or even years. A less common arrangement is a *bareboat charter,* where a tanker is chartered with no crew or other provisions. Bareboat charters are different than spot and time charters, where the owner of the tanker maintains operational control of the vessel and its crew. Since the early 1980s, the spot market has been much larger than the time charter market. In early 2010, around half of the world's tankers were employed on the

spot market compared to 30 percent on time charters. The remaining 20 percent of tankers were not available for charter.

More than 2,500 oil tankers larger than 50,000 dead weight tons (dwt) were in operation in 2009, the final year of data used in this dissertation.[1] These large tankers are responsible for the vast majority of the international trade in oil. Roughly 80 percent of those tankers transport crude oil, with the rest carrying refined petroleum products. As of 2009, the age profile of the tanker fleet was the youngest it had been in 30 years due to a building boom in the 2000s and the mandatory retirement of older single-hulled tankers under both US and international law. The size profile of the current tanker fleet has also changed, with crude oil tankers growing in size to take advantage of economies of scale for long voyages. Better communications and integrated global markets for chartering and insuring tankers have also increased the efficiency of the global tanker fleet over the last several decades.

II. Liability in shipping

The legal foundation for limited liability in the US shipping industry can be traced to the Limited Liability Act of 1851, which limited the liability of ship owners operating in US waters to the value of the vessel involved in the accident. The law was passed in response to U.S. shippers' complaints that foreign vessels were at a competitive advantage when operating in US waters because they had fewer attachable assets in the US and therefore faced less risk of legal action in the event of an accident. The Limited

[1] All of the numbers presented in this paper refer to tankers that are greater than 50,000 dwt.

Liability Act of 1851was the primary legal regime in the U.S. for more than one hundred years.

A large oil spill by the Torrey Canyon oil tanker off the coast of England in 1967 led to a public outcry on both sides of the Atlantic about the inadequacy of laws that regulated the operation of oil tankers.[2] The UN's Convention on Civil Liability for Oil Pollution (CLC) was adopted in 1969 and came into force for signatory countries in 1975.[3] The CLC set liability limits at about $20 million for the largest tankers and for the first time imposed strict liability on tanker owners. The US never signed or ratified the CLC or its later conventions, preferring to address shipping liability issues through domestic legislation. The US Federal Water Pollution Control Act (FWPCA) was passed in 1970, and imposed strict liability on the owners of tankers operating in US waters, but limited that liability to $150 per ton or about $20 million for a the largest tankers at that time. To ensure vessels owners could cover damages, both CLC and FWPCA required tanker owners to provide evidence of financial responsibility up to the liability limit. Other laws were enacted that dealt with individual aspects of liability for oil spills, such as the Trans-Alaskan Pipeline Act of 1973 and the Deepwater Ports Act of 1974. By the late 1980s, Congress had been attempting to pass a unified oil pollution law for a number of years but had been unable to agree on several important issues. The question of whether to extend liability to cargo-owners (the owners of the oil – typically an oil company) was actively debated. Some lawmakers also wanted to remove all liability

[2] In 1967 the Torrey Canyon, which was owned by a US oil company, spilled 29 million gallons of crude oil off the coast of England. The resulting lawsuit against the tanker company was tried in a US court. Citing the 1851 law, the judge initially awarded the injured parties just $50 -- the estimated value of the one remaining life raft.

[3] The UN committee that was formed to write the law would later become the International Maritime Organization (IMO).

limits for oil spills. The Exxon Valdez oil spill in March of 1989 increased the pressure on Congress to resolve their differences. The Oil Pollution Act of 1990 (OPA-90) passed 17 months later in August of 1990.[4]

OPA-90 uses both direct regulation and increased liability to reduce the risk of oil spills in US waters. Among its many provisions, the law increased liability limits eight-fold for large oil tankers to $1,200 per ton of oil. The three broad categories of liability under OPA-90 include cleanup costs, damages to private property, and damages to natural resources.[5] In 2006, the liability limit in US waters was raised further to $1,900 per ton for double hull tankers and $3,000 per ton for single hull tankers. However, under OPA-90, liability is not limited if the oil spill is caused by negligence on the part of the tanker operator, if the operator does not fully cooperate with the spill cleanup, or if any federal laws or regulations were breached in the operation of the tanker. Given the large number of relevant laws and regulations, the potential liability created by OPA-90 is only limited by the size of the company in most cases.[6] OPA-90 also allows individual US States to set their own liability standards and most coastal states have chosen against limiting liability.[7, 8] Industry press from the early 1990s suggests the threat of unlimited liability under OPA-90 was a major concern of tanker owners.[9,10]

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[4] Ramseur, Jonathan L. Oil Spills in US Coastal Waters: Background, Governance, and Issues for Congress. DIANE Publishing, 2010.
[5] Boyd, James. Global Compensation for Oil Pollution Damages: The Innovations of the American Oil Pollution Act. Resources for the Future, 2004.
[6] Kim, Inho. "Financial Responsibility Rules Under the Oil Pollution Act of 1990." Natural Resources Journal 42.3 (2002): 565-98.
[7] Brooks, Richard R. W. "Liability and Organizational Choice." Journal of Law and Economics 45.1 (2002): 91-125.
[8] Etkin, Dagmar Schmidt, and Cortlandt Manor. "A Worldwide Review of Marine Oil Spill Fines and Penalties." Environmental Research Consulting (2003). Retrieved from http://www.environmentalresearch.com/erc_papers/ERC_paper_10.pdf.
[9] Stokes, Peter. "Pollution Act a Misconceived Piece of US Legislation ." Lloyds List. December 31 1990.
[10] Grey, Michael. "A Sinister Threat to Shipping." Lloyds List April, 18 1991.

International law followed with the 1992 Protocol to the CLC. International liability limits were raised and, like OPA-90, owners and operators face unlimited liability in cases of negligence. It is generally considered more difficult to "break" liability limits under CLC than under OPA 90, so the risk of unlimited liability was (and is) considered higher under U.S. law than under international law.[11] After the Deepwater Horizon oil spill in the Gulf of Mexico in 2010, BP could have sought to limit its liability for economic damages to removal costs plus $75 million under OPA-90[12], but chose not to do so, which suggests that companies with sufficient assets will be expected to pay the full economic damages in the event of a major oil spill in US waters, regardless of the official liability limits.

Under both OPA-90 and international law, there is no liability for cargo-owners but seven US coastal states have explicitly stated that cargo-owners are financially liable (jointly with the tanker owner) for any oil spills along their coasts. Those states are Alaska, California, Maryland, New Jersey, North Carolina, Oregon, and Washington. Even before the enactment of OPA-90, the division of liability between cargo owners and vessel owners was a point of contention between the two groups.[13] In 2010, liability for oil spills was extended to cargo-owners under OPA-90 for the first time, but only for single-hull tankers, and cargo-owner liability does not apply to tankers calling on offshore loading terminals more than 60 miles from shore.

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[11] US Department of Transportation, Coast Guard, Regulatory Impact Analysis: Financial Responsibility for Water Pollution from Vessels. June 1994

[12] OPA-90 section 1004 states "Except as otherwise provided in this section, the total of the liability of a responsible party under section 1002 and any removal costs incurred by, or on behalf of, the responsible party, with respect to each incident shall not exceed… for an offshore facility except a deep-water port, the total of all removal costs plus $75,000,000."

[13] "Ship owners, cargo-owners appear far from reaching oil spill liability accord." Platts Oilgram News, May 12, 1986.

Both OPA-90 and CLC-92 require tanker owners to maintain evidence of financial responsibility up to their respective liability limit. Surety bonds, letters of credit, and self-insurance are can be used to meet this requirement, but the vast majority of tanker owners use their insurance coverage to provide evidence of financial responsibility.[14] Protection and indemnity (P&I) clubs are the primary source of liability insurance for ship owners against third party claims.[15] The P&I clubs are non-profit mutual insurance societies that require their members (the tanker owners) to make annual payments into a common fund to cover liability claims against any member. The 13 largest P&I clubs constitute the International Group of P&I clubs, which cover more than 90 percent of the oil tankers in operation today. These 13 members provide maximum insurance coverage of $9 million per incident. Claims of $9 to $30 million are covered by the International Group through a pooling of resources among the 13 clubs. Claims of $30 to approximately $7.5 billion are covered by the International Group through markets.[16] [17]

[14] Tusiani, Michael D. The Petroleum Shipping Industry: A Nontechnical Overview. Vol. 1. PennWell Books, 1996.p235.
[15] By contrast, hull insurance and cargo insurance are generally handled through marine insurance companies.
[16] Stopford, Martin. "Maritime Economics." London ; New York: Routledge, 2009. 306-307.P 231
[17] International Group of P&I Clubs. "The Pooling Agreement." Retrieved from: http://www.igpandi.org/Group+Agreements/The+Pooling+Agreement.

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Chapter 3:

Liability Rules and the Organization of Production:

A Model of Liability in the Oil Tanker Market

Abstract:

This essay investigates how potentially polluting firms reorganize their production processes when faced with increased liability for environmental damages. While there is a relatively large economic literature dealing with both the judgment-proof problem and the subject of extending liability to other firms (such as banks) that interact with the injuring firm, the existing models omit many important elements of the liability regime dealing with oil spills. Most importantly, the existing literature largely ignores the fact that a large firm often has the option of undertaking the hazardous activity internally. This essay will contribute to the existing literature by capturing the unique elements of oil spill liability in a theoretical model of an oil company's decision to either transport its oil on its own tankers or contract with another company to ship its oil.

This essay investigates how potentially polluting firms reorganize their production processes when faced with increased liability for environmental damages. The decision facing such a firm is whether the benefits of vertical integration outweigh the expected liability for undertaking the hazardous activity internally. I develop a theoretical model of a firm's decision to outsource a hazardous activity that is part of its production process. The model is intended to replicate in a simple manner the decision of

an oil company in choosing whether to own and operate its own tankers or to charter tankers from independent tanker companies.

While there is a large economic literature on the general issue of firm-level liability for accidents, few papers have focused on the unique features of liability in shipping. The available literature in this area has not captured many of the important elements of the liability regime dealing with oil spills. For example, under both US and international maritime law, liability for the owners of oil tankers is strict but limited, and tanker owners are required to maintain evidence of financial responsibility for potential environmental damages. The existing literature has also largely failed to explore the decision facing a large company that has the option of undertaking the hazardous activity internally or outsourcing it to reduce its exposure to liability. This essay will contribute to the existing literature by capturing these elements in a theoretical model. Section I reviews the relevant literature. Section II lays out a theoretical model that describes the decision of an oil company to charter or own an oil tanker in light of liability risks.

I. Literature Review

There are two main strands of economic literature that are relevant to liability in the oil tanker market. The first strand relates to "judgment-proof" firms that may not have sufficient assets to compensate victims in the event of a major accident. These papers are clearly relevant to the oil tanker market, where a single major spill could inflict billions of dollars in damages on individuals, businesses, and fisheries. The second strand explores the issue of "extended liability" in which companies that do business with the polluting firm could be held "vicariously liable" for the damages caused by their

business partner. The threat of extended liability is relevant to the business relationship between oil companies and tanker companies, and is central to the analysis presented in this essay.

Judgment Proof Literature

One policy goal of liability laws is to induce potential polluters to internalize the expected external damages that could result from their activities. But if the potential polluter does not have sufficient assets to fully compensate injured parties, the incentives to undertake an efficient level of care are reduced. In the economics and legal literature this issue is called the "judgment proof" problem.

Shavell (1986), Beard (1990), and Larson (1996) develop liability models of a firm that may cause damages in excess of its assets. All three models demonstrate that the possibility of bankruptcy truncates the expected payout of the firm if there is an accident, which reduces the incentives to take an efficient level of care. Shavel (1986) concludes that strict liability alone is insufficient to induce a judgment-proof firm to take an efficient level of care. He also shows that the incentives to purchase insurance are limited when a firm has a low level of assets. Shavell goes on to show that mandatory insurance requirements will lead to an efficient level of care, but only if the insurer can effectively monitor the firm. The financial responsibility requirements under OPA-90 and international maritime law are equivalent to a mandatory insurance requirement, so Shavell's analysis suggests that tanker owners should exercise an efficient level of care, assuming the maritime insurers can monitor firm-level care.

Several other papers have explored more deeply the issue of mandatory insurance and asset requirements for firms that undertake potentially polluting activities. In the

legal literature, Jost (1996) and Polborn (1998) argue that mandatory insurance effectively solves the judgment-proof problem by eliminating from the market firms that could not cover the expected damaged from an accident. Shavell (2005) also finds that a minimum asset requirement or compulsory liability insurance alleviate the judgment-proof problem, but this "solution" has the negative effect of discouraging some firms (those with limited assets and a high level of risk aversion) from engaging in the activity, even if the expected social benefits from undertaking the hazardous activity exceed the expected social harm. This result is potentially relevant to the oil tanker market in that the requirement for tanker owners to demonstrate higher levels of financial responsibility after OPA-90 likely caused some tanker companies (those that could not obtain insurance) to exit the market.

Extended Liability Literature

In the above literature, liability is exclusive to the party that caused the harm. A related body of literature extends the analysis to include the prospect of "extended" or "vicarious" liability in which some entity that transacts with the polluting firm is held partly or jointly liable for damages. Extended liability is intended to address the judgment-proof problem and to force all firms that profit from the potentially hazardous activity to internalize the expected damages. Examples of extended liability include liability for lenders to polluting firms, retailers of defective products, and oil companies that charter accident-prone tankers.

For instance, in 2008 a French court held the French oil major Total liable for an oil spill that did not involve one of Total's tankers. In the first ruling of its kind in Europe, the

French court ruled that Total was negligent in allowing its oil to be transported on an unsafe tanker.[18]

Sykes (1984) used a principal-agent framework to show that when the level of care taken by the agent is "cheaply observable" the principal can reduce the threat of extended liability by simply making the contract contingent on the level of care taken by the agent. If the care level is not cheaply observable, the principle must make the payment contingent on outcomes, employing penalties or rewards. Sykes argues that the economic benefits of extended liability are greater when there are repeated interactions between the principal and agent, because the principal has additional punishment tools if the agent causes an accident, which is clearly the case in oil tanker markets.

One of the most commonly cited theoretical papers in the extended liability literature is Pitchford (1995), who builds a model where liability is extended to a lender. In Pitchford's model, the potentially polluting firm has limited assets and must externally finance some or all of its business. The owner-managers of the firm would like to finance as much of the project as possible to limit the amount of their own assets exposed to a tort claim in the event of an accident. If the owners are able to replace debt for equity, it reduces their incentive to take preventative care since they only stand to lose their equity in the firm if there is a major accident. The imposition of lender liability initially reduces the probability of an accident because the lender will force the owners to hold more equity in the firm, which in turn induces them to take more preventative care. But if the lender's potential liability is greater than the owners' level of assets, the lender will increase the interest rate of the loan to compensate for the additional risk of extended

[18] Carvajal, Doreen. "Oil Company Total Ruled Liable in 1999 Spill Off French Coast." New York Times January 16 2008.

liability. The fundamental insight of Pitchford is that those increased loan payments reduce the expected payoff to the owners in a no-accident state of the world, but do not change the owners' expected payoff if there is an accident, since the owners can only lose their equity in the firm. Increasing lender liability can therefore reduce the owners' incentive to avoid an accident. Pitchford's bottom line is that extended liability does not necessarily lead to a reduction in polluting events. The corollary to Pitchford's argument for tankers is that higher liability limits could lead to higher insurance premiums for tanker companies, which will reduce the payoff to the tanker company if there is no accident and therefore reduce its incentives to take the optimal level of preventative care.

Liability in the Shipping Literature

A relatively small body of literature looks specifically at the issue of liability for oil spills from ships. Segerson (1987) explores alternative policies for controlling stochastic pollution including marine pollution. She find that liability limits can address the policy goal of limiting risk to potential polluters who are risk averse, but concludes that the liability caps used in marine liability are less efficient than a system that would impose full liability for small spills (assuming ship-owners are risk-neutral for small spills) and partial liability for large spills. Jin and Kite-Powell (1999) build on Segerson's work and find that when the shipping market is competitive, unlimited liability is desirable, regardless of the risk preferences of the shipping firms and society. Neither Segerson nor Jin and Kite-Powell consider the issue of extended liability.

Brooks (2002) directly addresses the issue of liability and oil tankers. He argues that much of the literature on judgment-proof firms has ignored the issue of extended liability when arguing that large firms will simply contract out hazardous activities to

avoid liability. Brooks asserts that extended liability includes reputational damage to an oil company if it charters a sub-standard tanker that spills oil. Brooks presents a simple numerical model of an oil company's decision to own or charter a tanker to demonstrate that contracting with potentially insolvent firms can generate higher expected liability because judgment-proof independent tanker companies have a lower incentive to exercise proper care. Brooks' model does not include any mention of government-set liability limits or mandatory evidence of financial responsibility, which are two major features of the liability regime created under OPA-90. In the model presented in his paper, tanker companies are assumed to have the financial means to cover any accident up to the government-set liability limit.

In the empirical portion of his paper, Brooks uses data from the Army Corps of Engineers on oil shipments between US ports to shows that the 20 largest oil companies and their subsidiaries substantially *increased* the amount of oil shipped on their own tankers after the introduction of OPA-90. He compares that trend with domestic oil shipments within the United Kingdom, which did not experience a change in liability regulation and did not see a change in the contracting behavior of the largest oil companies. He concludes that oil companies decided to transport more oil on their own vessels because of the potential of extended liability under OPA-90.

II. The Theoretical Model

This section will present a general model of an oil company's decision to charter a tanker. Following the example of Sykes (1984) I use a principle-agent framework to model the interactions of an oil company (the principal) and a tanker company (the agent)

in the presence of extended liability. The first model captures all of the major features of oil tanker liability laws. In order to obtain some results analytically, a simplified version of the model will then be solved. In these models, the oil company has a choice to use its own tanker or to charter a tanker on the open market. The oil company will compare the total cost (including expected liability) of each option in making its decision. Table 1 describes the variables used in the model.

The oil company uses its own tanker

For an oil company, the transportation of oil entails a cost that it seeks to minimize. If the oil company decides to own a tanker, it must decide on the quality of the tanker and what level of care to devote to preventing a spill. The profit maximization problem of the oil company is given by:

$$\max_{x,q} \{(1 - p(x,q))v_o - \ p(x,q)\{E[l^o|q,\delta,L] + E[D|q,\delta]R + v_t\} - c(x) - r(q)\} \qquad (1)$$

Where $p(x,q)$ is the probability of an accident, given the level of preventative care (x) and the quality of the tanker (q). Spending on care reduces the probability of an accident with diminishing returns ($p_x < 0$, $p_{xx} > 0$) and the same is true for spending on quality of the tanker ($p_q < 0$, $p_{qq} > 0$). For any given voyage, the oil company must pay the cost of care $c(x)$ and the rental rate of the tanker $r(q)$, which is a function of the tanker's quality. If there is no accident, the oil company receives the value of having the oil delivered (v_o). If there is an accident, the oil company expects to pay liability damages $E[l^o|q,\delta,L]$ as well as a reputational cost that is proportional to the

damage $E[D|q,\delta]R$. This reputational cost is meant to capture any lost profits an oil company might incur as a result of customers avoiding its product after a spill.

Table 1: Variables Used in the Analysis

x	The level of care taken by the tanker owner
x_s	Standard level of care mandated by the regulation
x^o	The level of care chosen by the oil company when using its own tanker
x^t	The non-contractible level of care chosen by the tanker company.
q	Quality of the tanker (age, hull type, etc.)
p(x,q)	Probability of an oil spill given the level of care and quality of the tanker
c(x)	Cost of care
r(q)	Rental rate for a tanker as a function of the tanker's quality
δ	Parameter that captures the expected damage of an oil spill based on its location
$E[D\|q,\delta]$	Expected damages resulting from an accident as a function of the quality of the tanker and the location of the spill
$E[l^o\|q,\delta,L]$	Expected liability of the oil company when using its own tankers as a function of the tanker's quality and location, which impact the level of damages, as well as the liability limit
A	Total assets of the tanker company
$E[l^t\|q,\delta,A]$	Expected liability of the tanker company as a function of the tanker's quality, location, and assets of the tanker company
$f(D;q,\delta)$	Probability distribution of damages given the quality of the tanker and its location
L	Legal limit to liability for the tanker owner
$F(D;q,\delta,L)$	Probability that the damage from given oil spill is less than the liability limit, where $F(D;q,\delta,L) \equiv \int_0^L Df(D;q,\delta)dD$
R	Reputational cost multiplier for the oil company
v_t	Value of damage to tanker and cargo in the event of an accident
v_o	Value to the oil company of having the oil delivered to its refinery
α	Probability that the oil company will face extended liability
β	Fraction by which reputational cost to the oil company is reduced if a spill is on a chartered tanker instead of the oil company's tanker
m	Demand parameter for tanker services
y(q,m)	Charter rate for a given tanker as a function of the quality of the tanker and the market demand for tanker services[19]

[19] The possibility that the asset level of the tanker company could influence the charter rate is explored in section III C as part of the discussion of equation (15).

In the event of an accident, the oil company also loses the value of the damage to the tanker as well as the value of the spilled oil (v_t), which could be significant. When oil prices peaked at $147 per barrel in 2008, one very large crude carrier (VLCC) could carry about $300 million of oil. By comparison, the liability limit for oil spills at the time was $1,900 per barrel or about $3.8 billion for a VLCC.

The expected damage function for a given spill is:

$$E[D|q,\delta] = \int_0^\infty Df(D;q,\delta)dD \tag{2}$$

The distribution of damages is a function of the quality of the tanker, so an increase in q shifts the distribution of damages to the left, hence $\frac{dE[D|q,\delta]}{dq} < 0$. For instance, tankers with double hulls are likely to spill less oil after an accident. The distribution of damages is also function of the location of the spill, which is captured by the parameter δ. An increase in δ shifts the distribution of damages to the right, hence $\frac{dE[D|q,\delta]}{d\delta} > 0$. For instance, an oil spill on a popular beach area (high δ) is likely to cause more economic damages than a spill along a sparsely populated coast line (low δ). As is standard in the literature, the distribution of damages is not influenced by the level of preventative care, which only influences the probability of an oil spill. The common approach in the literature is to assume a fixed level of damage if there is an accident (Shavell 1986, Larson 1996) or to assume a fixed distribution of damages (Beard 1990). However, these simplifying assumptions would not capture the physical realities of an oil spill where the

quality of the tanker and the location of spill clearly have an impact on the size of the economic damages. The expected liability function for an oil company is:

$$E[l^o|q,\delta,L] = \begin{cases} \int_0^L Df(D;q,\delta)dD + L\big(1 - F(D;q,\delta,L)\big) \quad if \quad x \geq x_s \\ \\ E[D|q,\delta] \quad if \quad x < x_s \end{cases} \tag{3}$$

The oil company's liability will be capped at L if it meets the regulatory standard of care ($x \geq x_s$).[20] With probability $\big(1 - F(D;q,\delta,L)\big)$ damages will be greater than the liability limit, in which case the company would still only pay L in damages. But if x < x_s, the oil company would be liable for the full extent of the damages $E[D|q,\delta]$. For simplicity, it is assumed that oil companies are large enough to cover any damage that results from a spill. The same assumption will not be made for a tanker company. Referring back to equation (1), an assumption of the model is that the liability cap does not limit the reputational cost to an oil company if a spill occurs. R is always greater than zero. If R > 1 the reputational cost of a spill is greater than the actual damages.

The oil company charters a tanker

There are two important differences in the cost minimization problem when the oil company chooses to charter. First, the oil company does not choose the level of care. The tanker company chooses a level of care that maximizes its own profits. (This is

[20] Recall that OPA-90 and CLC-92 impose unlimited liability for an oil spill if the tanker company is found to have been negligent in its operation of the tanker.

similar to the incentive compatibility constraint in a standard principle-agent model.) The oil company, therefore, cannot make the charter rate contingent on the level of care taken by the tanker company, but (as is common in principal-agent models) the oil company is assumed to know the other parameters of the model and can determine the level of care (x^t) that solves the tanker company's profit maximization problem:

$$\max_x \ \big(1 - p(x,q)\big)y(q,m) + p(x,q)(-E[l^t|q,\delta,A] - v_t) - c(x) - r(q) \qquad (4)$$

With probability $\big(1 - p(x,q)\big)$ an accident does not occur and the oil company pays the tanker company *y(q,m)*, which is a function of the quality of the tanker (q) and the market demand for tanker services (m). The demand for tanker services is included here to capture the fact that charter rates are set by the global tanker market, which is exogenous to this model. The cost of chartering a tanker is increasing with the demand for tanker services ($y_m > 0$). The cost of chartering a tanker is assumed to increase with the quality of the tanker, but at a decreasing rate ($y_q > 0$, $y_{qq} < 0$).

With probability *p(x,q)* there is an accident and the tanker company faces liability $E[l^t|q,\delta,A]$ and the loss in value of its tanker and value of the spilled oil (v_t). The cost of care $c(x)$ is always paid. The tanker company is assumed to rent the tanker for rate $r(q)$, which is also always paid.

The expected liability for a tanker company is:

$$E[l^t|q,\delta,A] = \begin{cases} \int_0^L Df(D;q,\delta)dD + L\big(1-F(q,\delta,L)\big) & if \quad x \geq x_s \\ \int_0^A Df(D;q,\delta)dD + A\big(1-F(q,\delta,A)\big) & if \quad x < x_s \end{cases} \tag{5}$$

If the tanker company meets the regulated standard of care ($x \geq x_s$) its liability is the same as the oil company's in equation (3). But if the regulator determines that the tanker company did not meet the regulated standard of care ($x < x_s$), the tanker company's damages will be limited to its assets (*A*). The financial responsibility requirement for tanker owners is included in this model as an assumption that $A \geq L$. But expected damages can still be larger than A. The potential inability of the tanker company to pay for a very large spill when $x < x_s$ is the source of the judgment-proof problem.

The second important difference for the oil company between using its own tanker and chartering a tanker is that, with probability α, the oil company is held vicariously liable for an oil spill caused by the tanker company.[21] Following the example of Brooks (2002), extended liability is captured in this model by assuming the oil company (as the cargo-owner) is responsible for any liability that is greater than the assets of the tanker company it hired to transport oil.

Assuming, for the moment, that the tanker company chooses a level of care $x^t \geq x_s$, the tanker company's liability is limited to L and there is no risk of extended liability for the oil company. In this case, the problem for the oil company when chartering is:

[21] For example, the value α of would be higher in the U.S. states that impose cargo-owner liability.

$$\max_{q} \{(1 - p(x^t, q))(v_o - y(q, m)) - p(x^t, q)(\beta E[D|q, \delta]R)\} \quad (6)$$

With probability $(1 - p(x^t, q))$ there is no accident, and the oil company receives the value of having the oil delivered to its refinery (v_o) and pays the tanker company $y(q, m)$.[22] With probability $p(x^t, q)$ there is an accident and the oil company's expected payout is only the reputational cost of a spill($\beta E[D|q, \delta]R$). The reputational cost to the oil company is discounted in equation (6) by a factor β ($0 < \beta < 1$) because the reputational cost of a spill is assumed to be smaller if the spilled oil did not come from the oil company's own tanker.

If, however, the tanker company fails to meet the standard level of care $(x^t < x_s)$, its liability is not limited, which introduces the threat of extended liability for the oil company. For this second case, the profit maximization problem for the oil company becomes:

$$\max_{q} \ (1 - p(x^t, q))(v_o - y(q, m)) - p(x^t, q)\{\alpha(\max(0, E[D|q, \delta] - A)) + \beta E[D|q, \delta]R\} \quad (7)$$

With probability $(1 - p(x^t, q))$ there is no accident, and the oil company gains the value of having the oil delivered to its refinery (v_o) and pays the tanker

[22] Note that the oil company must know the level of care the tanker company will choose (x^t) when comparing the cost of chartering to the cost of using its own tanker. While x^t is not contractible, the oil company can determine it by solving equation (4) using the other parameters of the model, which are assumed to be readily observable. This is a common feature of principal-agent models.

company $y(q,m)$, as in equation (6). With probability $p(x^t,q)$ there is an accident, and the oil company still bears the reputational cost of a spill, but may also be held liable for any damages in excess of the assets of the tanker company. This extended liability is captured by the term $\alpha\big(\max(0,E[D|q,\delta]-A)\big)$, where α is the probability of being subject to extended liability, given the jurisdiction where the spill occurred.

Figure 1: Oil Company's Liability Scenarios and Table 2 capture the possible outcomes from the point of view of the oil company if there is a spill from a tanker that it has chartered:

Figure 1: Oil Company's Liability Scenarios

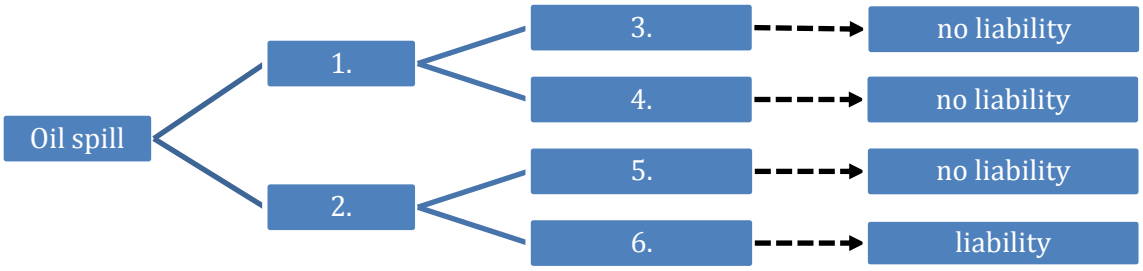


Table 2: Oil Company's Liability Scenarios

End node	Level of care by tanker company	Expected Damages	Oil company's liability	Tanker company's liability
3	$x^t \geq x_s$	$E[D\|q,\delta] \leq L$	0	$E[D\|q,\delta]$
4	$x^t \geq x_s$	$E[D\|q,\delta] > L$	0	L
5	$x^t < x_s$	$E[D\|q,\delta] \leq A$	0	$E[D\|q,\delta]$
6	$x^t < x_s$	$E[D\|q,\delta] > A$	$\alpha(E[D\|q,\delta]-A)$	A

In the event of a spill, the tanker company will either be found by the regulator to have taken at least the standard level of care (node 1) or less than the standard level of care (node 2). At node 1 the tanker company's liability is limited to L, while at node 2 liability is unlimited. At node 3 expected damages are less than or equal to the official liability limit, so the oil company faces no liability and the tanker company pays the full cost of damages. At node 4 expected damages are in excess of the liability limit, but the tanker company's liability is limited to L because it took at least the standard level of care. Again, the oil company faces no liability because the tanker company's is required to have sufficient assets (or insurance) to cover damages up to the liability limit. At nodes 5 and 6 liability limits do not apply because the tanker company took less than the standard level of care. At node 5 expected damages are less than or equal to the asset level of the tanker company, so the oil company faces no liability and the tanker company pays the full cost of damages. At node 6 expected damages are greater than the assets of the tanker company, and the oil company is potentially liable for damages in excess of the tanker company's assets, depending on whether the jurisdiction where the spill occurred imposes extended liability for oil spills (α).

Simplified model with non-contractible care

To obtain analytical results, a simplified version of the above model is presented here and solved. Reputational costs (R), the tanker market demand parameter (m), and tanker quality (q) are dropped from the model. The following analysis solves for the effects of variation in the parameters of the model given q, R, and m. The effects of variation in q and m given the level of preventative care (x) are considered later.

Another simplifying assumption is that liability is assumed to be unlimited. This assumption is easily justified for tankers operating in US waters because OPA-90 allows individual states to set their own liability limits, and most coastal states have chosen to impose unlimited liability for oil spills. Moreover, as stated previously, liability is not limited under OPA-90 if any federal laws or regulations were breached in the operation of the tanker. Given the large number of relevant laws and regulations governing maritime operations, tanker owners must assume that liability will be unlimited in most cases. [23,24,25]

The final simplifying assumption is that oil companies are assumed to have sufficient assets to cover the damages from spills, while tanker companies will only be able to pay for damages less than or equal to their level of assets (A). In light of these assumptions, equations (3) and (5) reduce to:

$$E[l^o|\delta] = E[D|\delta] = \int_0^\infty Df(D,\delta)dD \tag{8}$$

$$E[l^t|\delta, A] = \int_0^A Df(D,\delta)dD + A\big(1 - F(A,\delta)\big) \tag{9}$$

Equation (9) shows the expected liability function for a tanker company. For potential damages up to A, the tanker company's expected liability is equal to the damage

[23] This assumption if further supported by the empirical results in Chapter 4, which find that the imposition of unlimited liability at a US port is not a significant indicator of how many major-owned oil tankers call on that port.
[24] Kim, Inho. "Financial Responsibility Rules Under the Oil Pollution Act of 1990." Natural Resources Journal 42.3 (2002): 565-98.
[25] Jin, Di, and Hauke L. Kite-Powell. "On the Optimal Environmental Liability Limit for Marine Oil Transport." Transportation Research Part E: Logistics and Transportation Review 35.2 (1999): 77-100.

function (the first term on the right hand side), which is the same as the oil company's expected liability in equation (8). But with probability $\big(1 - F(A, \delta)\big)$, damages will be greater than A, and the tanker company's liability will be limited to A (the second term on the right hand side).

The simplified profits equation for the oil company in using its own tankers is now given by:

$$\pi^o = \big\{\big(1 - p(x)\big)v_o - p(x)(E[D|\delta] + v_t) - c(x)\big\} \tag{10}$$

The first-order condition for the oil company's optimal level of care, x^o is:

$$p'(x^o)(E[D|\delta] + v_o + v_t) = -c'(x^o) \tag{11}$$

So the oil company will choose a level of care that equates marginal cost of care with its marginal expected losses. As is easily established:

$$\frac{\partial x^o}{\partial E[D|\delta]} > 0, \quad \frac{\partial x^o}{\partial \delta} > 0, \quad \frac{\partial x^o}{\partial v_o} > 0, \quad \frac{\partial x^o}{\partial v_t} > 0$$

The oil company will spend more on care as expected damages ($E[D|\delta]$) increase, as the value of the tanker and cargo (v_t) increase, and the value of having the oil delivered to its refinery (v_o) increase.

When chartering a tanker, the profit function for the oil company is:

$$\pi^c = \big(1 - p(x^t)\big)(\, v_o - y) - p(x^t)\big(\alpha\big[E[D|\delta] - E[l^t|\delta, A]\big]\big) \tag{12}$$

where x^t is the non-contractible level of care chosen by the tanker company to maximize its own profits. The tanker company's simplified profit function is:

$$\max_x \big(1 - p(x)\big)y - p(x)(E[l^t|\delta, A] + v_t) - c(x) \tag{13}$$

The first-order condition for the tanker company's choice of care is:

$$p'(x^t)(E[l^t|\delta, A] + y + v_t) = -c'(x^t), \tag{14}$$

with $\dfrac{\partial x^t}{\partial E[l^t|\delta, A]} > 0$, $\dfrac{\partial x^t}{\partial y} > 0$, $\dfrac{\partial x^t}{\partial v_t} > 0$

So the tanker company will choose a level of care that equates the marginal cost of care with its marginal expected losses if there is an accident. The tanker company will spend more on care as its expected liability increases and as the value of its tanker (v_t) and its payment for delivering the oil (y) increase.

The oil company will choose to charter only if the expected profits from doing so are greater than the profits from using its own tanker: $\pi^c > \pi^o$. One way to look at the decision facing an oil company is to consider a separating equilibrium in terms of the asset level of the tanker company (A). Given that tanker companies differ in A, there is some $\bar{A}$ at which a representative oil company will be indifferent between chartering and using its own tanker. The profit functions in Figure 2: demonstrate the relationship between oil company profits and the assets of the tanker company. To obtain Figure 2:, I

first take the derivative of the oil company's profit function when chartering (12) with respect to A:[26]

$$\frac{d\pi^c}{dA} = p'(x^t)\left(\frac{dx^t}{dA}\right)(y - v_o - \alpha\{E[D|\delta] - E[l^t|\delta, A]\}) \tag{15}$$
$$+ p(x^t)\alpha\left(\frac{\partial E[l^t|\delta, A]}{\partial A}\right) > 0$$

The profits of the oil company when chartering are increasing in A for two reasons. As A increases, the tanker company has more to lose from an accident and therefore chooses a higher level of care, which reduces the probability of and accident and the risk of extended liability for the oil company (the first term in (15)). The sign of equation (15) is based on the assumption that the cost of chartering a tanker (y) is less than the sum of expected extended liability and the value of having the oil delivered $\left(y < v_o + \alpha\left[E[D|\delta] - E[l^t|\delta, A]\right]\right)$. An increase in A also reduces the expected payout by the oil company if there is a spill, because the tanker company will be able to cover a higher fraction of expected damages (the second term in (15)).[27]

This result could have important policy implications. Recall that OPA-90 requires tanker owners to maintain evidence of financial responsibility up to the liability limit. Raising the liability limit, therefore, forces tanker companies to have more assets or purchase more insurance, which reduces the threat of extended liability for the oil

[26] This derivative makes use of the envelope theorem, as do other derivatives further below of (maximized) profits with respect to a model parameter.

[27] One implication of the result from equation (15) is that oil companies may be willing to pay a higher charter rate to tanker companies with a high level of assets. For simplicity, this partial-equilibrium analysis assumes that effect is small enough to be ignored.

company when chartering. If oil companies do not believe that their liability is actually limited under OPA-90, then an increase in the official liability limits only serves to increase the asset requirements for tanker owners, which should lead to more chartering according to the result in equation (15).

Proposition 1: An increase in *official* liability limits will increase chartering if oil companies believe their liability is not limited in practice.

Taking the second derivative of the oil company's profit equation with respect to A^t gives:

$$\begin{aligned}\frac{d^2\pi^c}{dA^2} = {} & p''(x^t)\left(\frac{dx^t}{dA}\right)^2 (y - v_o - \alpha[E[D|\delta] - E[l^t|\delta, A]]) \\ & + p'(x^t)\left(\frac{d^2x^t}{dA^2}\right)(y - v_o - \alpha)[E[D|\delta] - E[l^t|\delta, A]] \\ & + p'(x^t)\left(\frac{dx^t}{dE[l^t|\delta, A]}\frac{\partial E[l^t|\delta, A]}{\partial A}\right)\alpha\left(\frac{\partial E[l^t|\delta, A]}{\partial A}\right) \\ & + p'(x^t)\alpha\left(\frac{\partial^2 E[l^t|\delta, A]}{\partial A^2}\right) < 0\end{aligned} \tag{16}$$

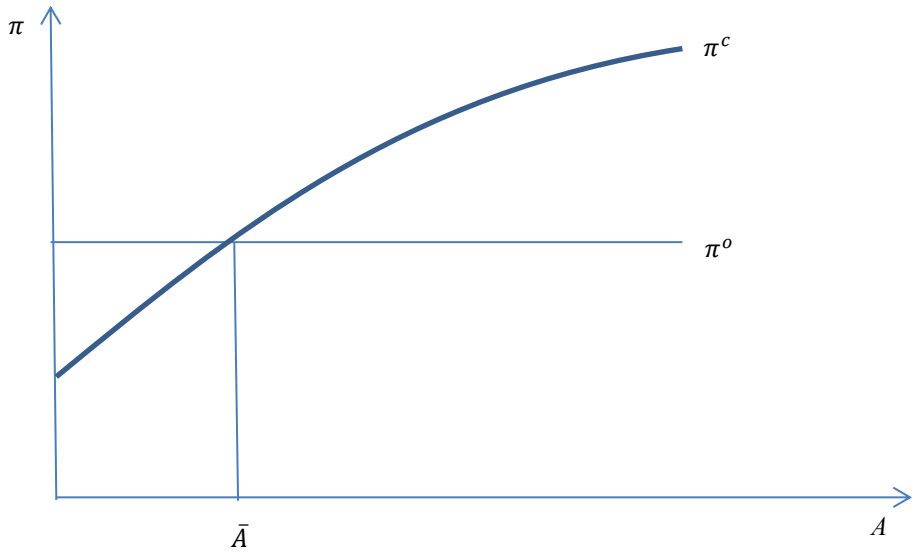
The sign of equation (16) is based on the same assumptions as for equation (15) $\left(y < v_o + \alpha\left[E[D|\delta] - E[l^t|\delta, A]\right]\right)$ and the additional assumption that the tanker company's liability is increasing in assets, but at a declining rate. More formally, the second derivative of the tanker company's expected liability with respect to A is negative $\left[\left(\frac{\partial^2 E[l^t|\delta, A]}{\partial A^2}\right) < 0\right]$. Intuitively, an increase in assets by a small tanker company

will increase its expected liability more than an equivalent increase by a very large tanker company.

Thus the π^c curve is upward sloping in A but at a declining rate. The π^o curve is horizontal because π^o is not a function of A (see equation (10)). The two curves are depicted in Figure 2:.

Figure 2:

Separating Equilibrium Based on Tanker Company Assets (A)



Oil companies will choose to charter only when $A > \bar{A}$. Therefore, a change in the parameters of the model that that shifts $\bar{A}^t$ to the right will reduce the amount of chartering by oil companies and a change in the parameters of the model that that shifts $\bar{A}$ to the left will increase the amount of chartering. Since π^o is not a function of α or y, the change in $\bar{A}$ for these two parameters can be assessed by determining how π^c shifts when one of these parameters changes:

$$\frac{d\pi^c}{d\alpha} = -p(x^t)(E[D|\delta] - E[l^t|\delta, A]) < 0 \tag{17}$$

$$\frac{d\pi^c}{dy} = -\left(1 - p(x^t)\right) - p'(x^t)\alpha\{E[D|\delta] - E[l^t|\delta, A] - y\}\left(\frac{dx^t}{dy}\right) \tag{18}$$

An increase in α lowers π^c and shifts $\bar{A}$ to the right making chartering less profitable for oil companies relative to using their own tankers. This result is the basis for the second proposition of the model:

Proposition 2: Oil tankers that operate in jurisdictions that impose extended liability are more likely to be owned by oil companies than tankers that operate in jurisdictions that do not impose extended liability.

Alternatively, tanker companies that operate in jurisdictions that impose extended liability will tend to have a higher level of assets (or insurance) than tanker companies that operate in jurisdictions that do not impose extended liability.

Equation (18) captures the effect of a change in the charter rate (y) on the profitability of chartering. The first term in (18) simply shows the direct effect that higher charter rates have increasing costs and on reducing oil company profits. The second term indicates that higher charter rates will induce a higher level of care from the tanker company, thus reducing the threat of extended liability for the oil company and increasing the profitability of chartering. The model does not specify which effect dominates. Taken together, these two effects represent the third proposition of the model.

Proposition 3: An increase in charter rates will have less of a negative effect on chartering (and possibly a positive effect) in jurisdictions that impose extended liability.

In the absence of extended liability ($\alpha = 0$), the second term is zero and higher charter rates lead directly to less chartering.

The impact of a change in δ on the profitability of chartering is more difficult to assess because it impacts both $\pi^o$and π^c through $E[D|\delta]$ and $E[l^t|\delta, A]$. Taking the derivative of oil company profits with respect to δ when using their own tankers (10) or chartering (12) give the following results.

$$\frac{d\pi^o}{d\delta} = -p(x^o)\left(\frac{\partial E[D|\delta]}{\partial \delta}\right) < 0 \tag{19}$$

$$\begin{aligned}\frac{d\pi^c}{d\delta} = & -p'(x^t)\left(\frac{dx^t}{d\delta}\right)(y - v_o - \alpha[E[D|\delta] - E[l^t|\delta, A]]) \\ & - p(x^t)\alpha\left(\frac{\partial E[D|\delta]}{\partial \delta} - \frac{\partial E[l^t|\delta, A]}{\partial \delta}\right)\end{aligned} \tag{20}$$

The impact of a change in δ on π^o is clearly negative (19). Increasing δ raises expected damages, which reduces the profitability for the oil company when using its own tankers. In the absence of extended liability ($\alpha = 0$) the impact of δ on π^c is positive; assuming the value to the oil company of having the oil delivered to its refinery is greater than the charter rate.[28, 29] In terms of Figure 2:, a positive change in δ shifts the

[28] This assumption simply requires rationality on the part of the oil company. If the oil company did not value the delivery by at least the charter rate, it would not have chartered a tanker.

[29] Including reputational costs would show a larger positive effect on the profitability of chartering for an increase in δ. The higher level of care by the tanker company induced by the higher δ would reduce the probability of a spill and therefore reduce the expected reputational cost to the oil company.

π^o curve down and the π^c curve up (when $\alpha = 0$), which reduces A and leads to an increase in chartering.

$$\frac{d\pi^c}{d\delta} = -p'(x^t)\left(\frac{dx^t}{dE[l^t|\delta, A]}\frac{\partial E[l^t|\delta, A]}{\partial \delta}\right)(y - v_o) > 0 \quad \text{(when } \alpha = 0) \tag{21}$$

When $\alpha > 0$, the impact of a change in δ on π^c is ambiguous because there are offsetting effects. The first term in equation (20) is positive and indicates that a higher δ will induce greater care from the tanker company thus reducing the probability of an accident and the threat of extended liability. The second term in (20) is negative because $E[l^t|\delta, A]$ is truncated at A, so an increase in δ will have a larger impact on expected damages than on the tanker company's expected liability $\left(\frac{\partial E[D|\delta]}{\partial \delta} > \frac{\partial E[l^t|\delta, A]}{\partial \delta}\right)$. The model does not specify which effect dominates. This result is the basis for the fourth proposition of the model:

Proposition 4: An increase in δ will have less of a negative effect on chartering (and possibly a positive effect) in jurisdictions that impose extended liability.

It is possible, of course, to have a corner solution where the oil company will always choose to charter or never choose to charter, depending on the parameters of the model. In other words, the two curves in Figure 2: may not cross. From equation (12), the two lines will cross if and only if:

$$\big(1-p(x^t)\big)(\,v_o-y)-p(x^t)\alpha E[D|\delta]<\ \pi^o$$

$$\pi^o<\big(1-p(x^t)\big)(\,v_o-y) \tag{22}$$

$$\text{where}\quad \pi^o=\big\{\big(1-p(x)\big)v_o-p(x)(E[D|\delta]-v_t)-c(x)\big\}$$

The lines will only cross if $\pi^c < \pi^o$ when A = 0 (the first inequality in (22)), and $\pi^o < \pi^c$ when A^t is very large (the second inequality in (22)). The opposite sense of the first inequality in (22) defines the corner solution where the oil company always chooses to charter. The opposite sense of the second inequality defines the corner solution where the oil company never chooses to charter.

Intuitively, when A equals zero, the tanker company has very little to lose in the event of a spill and will choose a low level of care, which translates to a high probability of an accident. So the threat of extended liability will be high for the oil company and π^c will be very low (assuming $\alpha > 0$). As A goes to ∞, $E[l^t|\delta, A]$ approaches $E[D|\delta]$, so the tanker company has as much to lose as the oil company if there is a spill. The tanker company's level of care will therefore approach the high level of care that would be chosen by the oil company if the level of care were observable. The threat of extended liability will therefore approach zero as A goes to ∞.

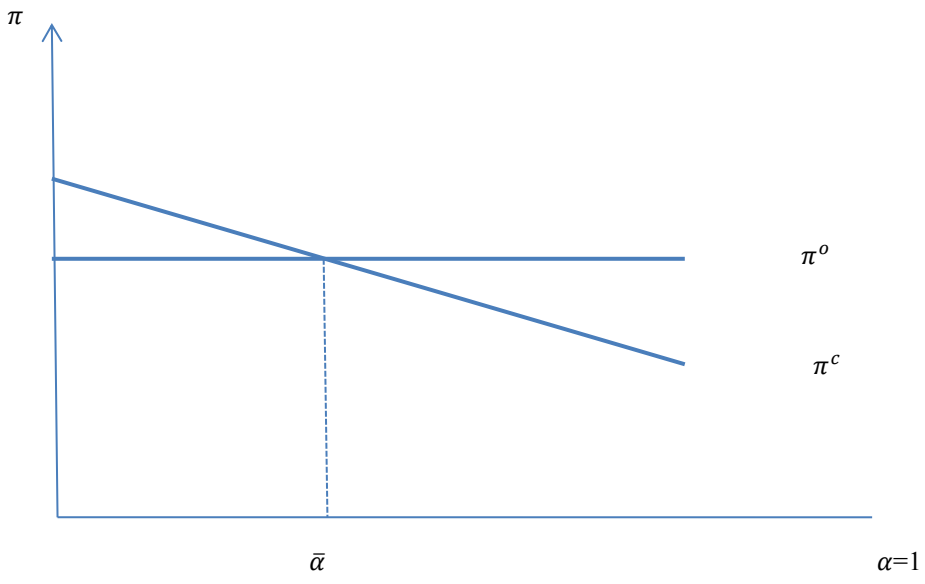
Another way to look at the decision facing an oil company is to consider a separating equilibrium in terms of the risk of extended liability (α). From equations (12) and (13) joint profits under a charter arrangement ($\pi^c + \pi^t$) are decreasing in α, which reduces the scope for a mutually beneficial contractual arrangement between the two companies. This is further indication that we should observe less chartering in jurisdictions that impose extended liability. As described above, different jurisdictions

impose different liability regimes. For instance, the threat of extended liability under OPA-90 in the US is considered higher than in countries where CLC-92 is the relevant liability regime. Given that expected liability differs across ports, and that the profits of chartering are decreasing in α (see equation (17)) there is some $\bar{\alpha}$ at which an oil company will be indifferent between chartering and using its own tanker when visiting a given port. Setting $\pi^o = \pi^c$ and solving for the separating equilibrium $\bar{\alpha}$ gives:

$$\bar{\alpha} = \frac{p(x^o)(E[D|\delta] + v_o + v_t) + c(x^o) + \big(1 - p(x^t)\big)(-y) + p(x^t)v_o}{p(x^t)(E[D|\delta] - E[l^t|\delta, A])} \tag{23}$$

Figure 3:

Separating Equilibrium Based on Probability of Extended Liability (α)



When the probability of extended liability is less than the separating equilibrium ($\alpha < \bar{\alpha}$) in a particular jurisdiction, the oil company will choose to charter. When $\alpha > \bar{\alpha}$, the oil company will choose to use its own tankers. The profit functions in Figure 3

demonstrate the relationship between profits and extended liability for an oil company that must choose between chartering and using its own tanker. The oil company's profit equation when using its own tanker (see equation 10) is not a function of α, so the π^ocurve is horizontal. Taking the derivative of the oil company's profit equation when chartering (12) with respect to α:

$$\frac{d\pi^c}{d\alpha} = -p(x^t)(E[D|q,\delta] - E[l^t|\delta,A]) < 0 \tag{24}$$

$$\frac{d^2\pi^c}{d\alpha^2} = 0 \tag{25}$$

So π^c is decreasing in α, and at a constant rate. The obvious implication of Figure 3 is that chartering becomes less profitable (in expected terms) as the threat of extended liability increases. A change in the parameters of the model that shifts $\bar{\alpha}$ to the right will reduce the amount of chartering by oil companies overall. Since π^o is not a function of A or y, the change in $\bar{\alpha}$ can be assessed by determining how π^c shifts when one of these two parameters changes. As shown in equation (15), an increase in A has a positive effect on π^c, which shifts $\bar{\alpha}$ to the right and increases chartering by oil companies. As shown in equation (18), the impact on π^c of an increase in y is ambiguous because it has two opposing effects. The direct cost of chartering a tanker increases (π^c shifts down and $\bar{\alpha}$ shifts left), but it also increases the incentives for the tanker company to take a higher level of care, which reduces the probability of an accident (π^c shifts up and $\bar{\alpha}$ shifts right).

As with Figure 2, it is possible to have a corner solution where the two profit curves in Figure 3 do not cross. The lines will cross if and only if $\pi^c > \pi^o$ when $\alpha = 0$, and $\pi^o > \pi^c$ when $\alpha = 1$. Plugging these values of α into equation (12), the two lines will cross if and only if:

$$\big(1 - p(x^t)\big)(\, v_o - y) > \; \pi^o \tag{26}$$

$$\pi^o > \big(1 - p(x^t)\big)(\, v_o - y) - p(x^t)\big[E[D|\delta] - E[l^t|\delta, A]\big]$$

The opposite sense of the first inequality in (26) defines the corner solution where the oil company always chooses to charter. The opposite sense of the second inequality in (26) defines the corner solution where the oil company never chooses to charter. Intuitively, if the oil company is unwilling to charter a tanker ($\pi^o > \pi^c$) when there is no threat of extended liability (α=0), then it will also be unwilling to charter as the threat of extended liability increases. Similarly, if the tanker company chooses to charter a tanker ($\pi^o < \pi^c$) even when extended liability is explicit in the law (α=1) it will also choose to charter when the threat of extended liability is less.

Simplified model with contractible care (quality of tankers)

While the level of care taken by a tanker company is not contractible for the oil company, the age and other physical properties of the tanker company are directly observable and can therefore be contracted. The analysis changes somewhat if the quality of the tanker (q) is used instead of care (x) as the choice variable. Since the

quality of a tanker is contractible, the oil company simply chooses the quality of tanker that maximizes profits. The profit equation the oil company seeks to maximize when chartering becomes:

$$\pi^c = \big(1 - p(q)\big)\big(\, v_o - y(q,m)\big) - p(q)\alpha\{E[D|q,\delta] - E[l^t|q,\delta,A]\} \qquad (27)$$

Note that the charter rate of the tanker $y(q,m)$ is a function of the quality of that tanker as well as a demand parameter for tanker service (m). The first-order condition for the oil company is:

$$\begin{aligned}\Big(1 - \big(p(q)\big)\Big)\Big(y_q(q,m)\Big) &\\ &= p'(q)\,\big(\, v_o - y(q,m)\big)\\ &- p'(q)\alpha(E[D|q,\delta] - E[l^t|q,\delta,A])\\ &- p(q)\alpha\left(\frac{\partial E[D|q,\delta]}{\partial q} - \frac{\partial E[l^t|q,\delta,A]}{\partial q}\right)\end{aligned} \qquad (28)$$

So the oil company will choose a quality of tanker to charter such that the marginal cost of quality is equal to the marginal change in expected costs to the oil company (including extended liability) if there is an accident. In the absence of extended liability ($\alpha = 0$) the second and third terms on the right hand side of the equation are zero and the oil company will choose to charter a lower quality tanker to minimize chartering costs. But when $\alpha > 0$ the oil company will charter a higher quality tanker to minimize its exposure to extended liability. This result is the fifth proposition of the model.

Proposition 5: An oil company will charter higher quality tankers when operating in jurisdictions that impose extended liability.

To determine how changes in the parameters of the parameters of the model impact the profitability of chartering a tanker, I take the derivative of the oil company's profit function when chartering (29) with respect to α, A, and m.

$$\frac{d\pi^c}{d\alpha} = -p(q)(E[D|q,\delta] - E[l^t|q,\delta,A]) < 0 \tag{29}$$

$$\frac{d\pi^c}{dA^t} = p(q)\alpha\left(\frac{\partial E[l^t|q,\delta,A]}{\partial A}\right) > 0 \tag{30}$$

$$\frac{d\pi^c}{dm} = -y_m(q,m)\big(1 - p(q)\big) < 0 \tag{31}$$

As in the case of non-contractible care, equation (29) shows that an increase in α will unambiguously increase expected chartering costs for an oil company relative to using its own tanker. Comparing equation (30) with equation (15) shows that that, as in the previous model, a higher level of tanker company assets (*A*) increases the oil company's profitability of chartering by reducing the oil company's expected extended liability if there is an accident. But unlike equation (15), increasing the expected liability for the tanker company does not help to "align the interests" of the oil company and tanker company by reducing the probability of a spill, because care, as captured by tanker quality, is contractible and therefore optimal for the oil company.

Since the profitability of an oil company for chartering a tanker is increasing in both the quality of the tanker and the level of assets of the tanker company, these two variables are effectively substitutes for the oil company. A tanker company with a low level of assets, for instance, would have to compensate the oil company by using high quality tankers, while a company with a high level of assets could reduce its costs by using lower quality tankers.

Unlike the case of non-contractible care, in equation (31) the impact of charter rates (induced by higher market demand) is unambiguous. A higher charter rate reduces the profitability of chartering a tanker and does not have the effect of generating a higher level of care from the tanker company, since care is observable.

This model would become somewhat more complicated if risk aversion were introduced into the objective function of the tanker company in equation (13). A risk-averse tanker company would choose a higher level of x^t than a risk-neutral tanker company to reduce the probability of incurring the losses associated with an oil spill. In the simplified model presented here, the higher x^t would only serve to increase the profits to the oil company when chartering (π^c) in a jurisdiction where the threat of extended liability is greater than zero ($\alpha > 0$). It would not change the results of the analysis because x^t is not observable by the oil company and the charter rate (y) is exogenous to the model. In practice, however, if tanker companies were risk averse, their increased spending on preventative could lead to a higher charter rate (assuming a competitive market), which would increase the cost to oil companies of chartering a tanker relative to using their own tankers. Risk-averse tanker companies could, in theory, choose higher levels of preventative care than risk-neutral oil companies would prefer.

III. Propositions and implications of the model

The model presented in sections III.C and III.D is intended to capturing the major elements of the current liability regime for oil spills from tankers. The results of the model are used to analyze the incentives facing oil companies and tanker owners in the market for tanker services. The model yields the following predictions:

1. An increase in *official* liability limits will increase chartering if oil companies believe their liability is not limited in practice. As official liability limits increase, tanker companies will be forced to maintain a higher level of assets (or insurance), which reduces the threat of extended liability to the oil company. (Proposition 1)
2. Oil tankers that operate in jurisdiction that impose extended liability are more likely to be owned by oil companies than tankers that operate in jurisdictions that do not impose extended liability. (Proposition 2)
3. An increase in charter rates will have less of a negative effect on chartering (possibly a positive effect) in jurisdictions that impose extended liability. (Proposition 3)
4. An increase in the expected damages from an oil spill based on location, such as an increase coastal land values, will have less of a positive effect on chartering (and possibly a negative effect) in jurisdictions that impose extended liability. (Proposition 4)
5. An oil company will charter a higher quality tanker when operating in a jurisdiction that imposes extended liability for oil spills (Proposition 5).

The first prediction of the model is meant to address the current liability regime in the United States with respect to unlimited liability. If oil companies do not believe that their liability is actually limited under OPA-90, then an increase in the *official* liability limits only serves to increase the asset requirements for tanker owners, which reduces the threat of extended liability for the oil company. As stated previously, tanker owners must maintain evidence of financial responsibility up to the liability limit. The 2010 Deepwater Horizon oil spill in the Gulf of Mexico is a good example of why oil companies may not believe their liability is actually limited under OPA-90. As stated previously, BP's actual liability limit in that case was $75 million, but they have paid billions of dollars in damages. So increasing liability limits for tanker owners may benefit oil companies by forcing tanker companies to maintain a higher level of assets, which reduces the threat of extended liability for the oil companies that charter their tankers. If this proposition is correct, we might expect to see an increase in chartering activity by the major oil companies to US ports when liability limits are increased. This happened 2006 when the liability limits under OPA-90 were increased from $1,200 to $3,000 per ton for single hull tankers and from $1,200 to $1,900 for double hull tankers.

The second proposition suggests that tankers that regularly call on ports that impose extended liability are more likely to be owned by an oil company than tankers that do not call on ports that impose extended liability. As noted in section one, OPA-90 gives individual states the right to set their own liability laws, and at least ten states have chosen to impose cargo-owner liability. If this prediction is correct, we would expect to see a larger percentage of oil company owned tankers calling on ports in these states compared to the states that do not imposed cargo-owner liability.

Propositions 3 and 4 are somewhat counter intuitive. One might assume that increased charter rates would unambiguously reduce chartering activity, but the model suggests that higher charter rates also have the effect of inducing tanker owners to take a higher level of care in the operation of their ships, which reduces the threat of extended liability for oil companies. If true, we may see oil companies paying above market rates during periods of particularly low tanker charter rates to induce tanker owners to exercise a greater level of care.

Proposition 4 suggests that oil companies may be more likely to use their own tankers in jurisdiction where an oil spill would create particularly high economic damages. One might assume that an oil company would be extremely reluctant to use its own tanker to deliver oil to a place like Long Beach California, where there are several refineries, because the economic damages from a spill along the California coast would be significant. But the model suggests that the threat of extended liability for very large damages has an opposing effect, which could reduce chartering. The result also suggests that when the potential damages are high, oil companies will only be willing to charter from tanker companies that have a high level of assets.

The fifth proposition suggests that when tanker companies choose to charter a tanker, they will charter higher quality tankers to ports that impose extended liability. Quality, however, can be difficult to measure, since it includes the quality of the operator of the tanker as well as the tanker's physical properties.

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Chapter 4:

Liability Rules and the Organization of Production: Evidence from the Oil Tanker Market

Abstract:

This essay contributes to the economic literature on extended liability by providing an empirical analysis of the shipping decisions of major oil companies in light of differences in oil-spill liability laws across US states. It tests two key predictions of the theoretical model presented in Chapter 3. The first prediction tested is that oil companies are more likely to use their own tankers – as opposed to chartering a tanker – when operating in jurisdictions that extend liability for oil spills from the tanker owner to the owner of the oil (typically the oil company). More than 30,000 US port calls by oil tankers between 2006 and 2009 are included in the analysis. The results suggest that oil companies are indeed more likely to use their own tankers when operating in jurisdictions that extend liability to cargo-owners, as predicted by the theoretical model. These empirical findings support the notion that the imposition of extended liability motivates large firms to undertake potentially hazardous activities internally, where they can, in principle, directly control the level of preventative care. A second finding of this essay is that the tankers visiting ports in states that extend liability to cargo-owners tended to be newer and were more likely to be double hulled, as predicted by the theoretical model.

I. Background

The Deepwater Horizon oil spill in 2010 has renewed public interest in the environmental and economic damages that can result from major oil spills in US coastal waters. Over the four years since the spill, many legal and policy papers have been written about the US laws dealing with oil spill liability.[30, 31, 32] These papers have tended to focus on the patchwork of federal and state laws that constitute the US liability system for oil spills. They typically reference the economic literature on the liability for economic damages, but that body of literature is almost entirely based on theoretical models. This chapter contributes to the economic literature by providing an empirical analysis of the shipping decisions of oil companies in light of differences in oil spill liability laws across US states.

One of the key predictions of the theoretical model in Chapter 3 is the following: "*Oil tankers that operate in jurisdictions that impose extended liability are more likely to be owned by oil companies than tankers that operate in jurisdictions that do not impose extended liability*." Extended liability, in this context, means holding the owners of the oil (the cargo-owners) liable for an oil spill, even if they did not own or operate the oil tanker that spilled the oil. The policy objective of cargo-owner liability is to incentivize oil companies to use reputable shipping companies that operate safe tankers. The theoretical model suggests that cargo-owner liability increases the incentives for the

[30] Rameur, Jonathan. Oil Spills in US Coastal Waters: Background and Governance. Congressional Research Service. January 2012.
[31] Cohen, Mark. Deepwater Drilling: Law, Policy, and Economics of Firm Organization and Safety. Vanderbilt Law Review. November 2011.
[32] Perry, Ronen. The Deepwater Horizon Oil Spill and the Limits of Civil Liability. Washington Law Review. 2011.

major oil companies to use their own tankers, as opposed to chartering a tanker, because they can, in principle, ensure that an optimal level of preventative care is being applied.

For the purposes of this essay, I define a major oil company as any oil company that owned large tankers that visited US ports between 2006 and 2009.[33] Those companies are BP, ExxonMobil, Chevron, and ConocoPhillips. Fortunately, that group of companies lines up well with the general usage of the term "major oil company."[34] As noted in the Chapter 2, the major oil companies are many times larger than other tanker owners, and therefore have much more to lose in the event of a large oil spill. For instance, the largest single tanker owner in the data in 2009 was the Japanese shipping company Mitsui O.S.K., which owned 73 tankers larger than 50,000 dead weight tons in 2009. Mitsui's market capitalization currently is about $4 billion. ConocoPhillips, the smallest of the major oil companies, has a market capitalization of about $100 billion.

The relevant US laws

The primary US law dealing with oil spills is the Oil Pollution Act of 1990 (OPA-90). In addition to the many technical mandates of OPA-90 (double-hulled tankers, spill-response authorities, etc.), the law overhauled the liability regime for oil spills in US waters. Under OPA-90, oil tanker owners and operators were defined as the "responsible parties" for any oil spill. Cargo-owners and charterers were assigned no explicit liability

[33] I define "large tankers" as tankers larger than 50,000 dead weight tons. This definition includes Panamax, Aframax, Suezmax, and very large crude carriers (VLCCs).
[34] Shell and Total S.A. are also included in the list of "majors" or "super majors" in industry reporting. Shell and Total owned tankers during this time, but those tankers did not call on US ports. The so-called "mid-majors," like Marathon, Occidental, Anadarko are also much larger than the shipping companies, but owned no large tankers from 2006 – 2009.

for spills.[35] Liability remained strict but limited, as it had been under the Clean Water Act. Liability limits for each tanker were increased from $150 to $1,200 per dead weight ton. Tanker owners were required to file a certificate of financial responsibility (COFR) with the US Coast Guard, which certified that the owner of each tanker than entered US waters had sufficient insurance or financial assets to cover the maximum level of liability for their tanker.

Importantly for this essay, OPA-90 did not supersede the oil spill liability laws of individual US states. The result has been a new patchwork of state-level laws. As of 2008, 16 coastal states had enacted laws that impose unlimited liability on tanker owners for oil spills in their waters. Seven states have enacted laws that explicitly extended liability to cargo-owners. This essay uses this variation in oil spill liability laws across US coastal states to see how oil companies respond to differences in liability laws.

Table 3 shows the relevant liability laws for the coastal states as of 2008. For the purposes of this essay, "unlimited liability" applies only to clean-up costs for third-party claims. For the other main category of liability, natural resource damage, all but three coastal states (New Jersey, Texas, and Virginia) impose unlimited liability.

[35] When an oil company charters a tanker, the owner and operator of the tanker maintains control of the vessel and its crew. The exception is a bareboat charter, where no crew or other provisions are provided. Under OPA-90, a bareboat charterer is jointly liable with the tanker owner for damages resulting from a spill.

Table 3: State Liability Laws for Oil Spill (2008)

	Unlimited Liability	Cargo-owner	Separate COFR
Alabama	X		
Alaska	X	X	X
California	X	X	X
Connecticut	X		
Delaware			
Florida			
Georgia	X		
Hawaii	X		
Louisiana			X
Maine	X		
Maryland	X	X	
Massachusetts	X		
Mississippi	X		
New Jersey		X	
New York			
North Carolina	X	X	
Oregon	X	X	X
Pennsylvania	X		
Rhode Island	X		
South Carolina	X		
Texas			X
Virginia			X
Washington	X	X	X

Source: De la Rue, Colin M., and Charles B. Anderson. "Shipping and the Environment: Law and Practice." 2nd ed. Informa Law, 2009. 1163-1181.

Alaska, California, Maryland, New Jersey, North Carolina, Oregon and Washington explicitly impose liability on cargo-owners. Cargo-owners are also *potentially* liable in a number of other states whose liability laws include broad language that is open to interpretation. In Georgia, for instance, cargo-owners do not have explicit liability for oil spills, but liability can be assigned to "any person who caused a spill," which could include cargo-owners in some cases.[36] As noted in Chapter 1, the reason to

[36] De La Rue, Colin. Shipping and the Environment. 2nd ed. Lloyds Shipping Law Library. 1168. 2009.

impose cargo-owner liability is to increase the oil company's incentive to charter high-quality tankers that are operated by reputable shipping companies.

Certain states require a separate certificate of financial responsibility (COFR) in addition to the COFRs that tanker owners must file at the federal level with the US Coast Guard. COFRs clearly define the guarantor of financial responsibility in the event of a spill, which allows state governments and third parties to more quickly in pursuing financial settlements under state law. The requirement for a separate COFR may, therefore, increase liability risk for tanker owners and will be included in the empirical analysis.

II. Literature Review

There is a relatively large theoretical literature on the economics of liability, as outlined in Chapter 3, but there has been surprisingly little empirical research on the issue. In fact there has been almost no empirical research on the connection between extended liability and environmental damage. The most widely cited empirical study of industry reorganization in response to liability is by Ringleb and Wiggins (1990). Their paper tested the assertion that some companies in hazardous industrial sectors were exposing their employees to serious health risks, then avoiding liability by simply going out of business before long-term impacts to employee health were known. The research used data on the rate of small-firm entry into 19 sectors of the US economy between 1967 and 1980, which was the period when changes in U.S. liability law made it easier for workers to seek compensation for injuries. Their measure of potential liability in each sector was the number of workers exposed to carcinogens from 1972-1974. After

controlling for other factors that could explain the entry of small firms into a given industrial sector, they found that the small-firm entry rate was significantly higher in sectors with high rates of exposer to carcinogens. That finding suggested that small firms were specializing in hazardous activities and then going out business to avoid liability for latent damages. The authors ultimately concluded "expected liability costs seem to outweigh the returns to internal organization for these hazardous activities." The obvious policy implication was that liability laws alone might not be an effective tool if the full extent of damages are not known immediately.

Other papers have considered the effectiveness of liability laws in preventing environmental accidents. Alberini and Austin (2002) use data on chemical spills in the US to determine if strict liability is associated with fewer chemical spills. Like this essay, their analysis exploits differences in liability laws across US states, but they do not consider the impact of extended liability. They found that strict liability reduces the frequency and severity of pollution releases, but that the effect varied with firm size. They also found that smaller firms are responsible for more pollution in states that impose strict liability, suggesting that strict liability may encourage firms with less assets to specialize in risky activities.

The empirical section of Brooks (2002) is the only economic paper I have found that empirically investigates the question of extended liability for environmental damages, though it does so with aggregate data and without using econometric analysis. Brooks presents data on oil shipments between US ports to show that large oil companies and their subsidiaries substantially *increased* the amount of oil they shipped on their own vessels after the passage of OPA-90, which is surprising given that OPA-90 assigned

increased liability to the owners of the tankers. He compares that trend with domestic oil shipments within the United Kingdom, which did not experience a change in liability regulation, and shows that the UK did not experience a change in the chartering behavior of the largest oil companies. After considering and dismissing several alterative explanations, he concludes that the increased threat of extended liability under OPA-90 caused the oil companies to transport more oil on their own vessels.

Unfortunately, Brooks only had access to aggregated shipping data and was therefore unable to control for differences in cargo-owner liability laws across states or ports. In fact, his paper presented no econometric analysis and relied entirely on trends in the data over time. He concludes his paper with the following statement:

> "Either heightened vicarious liability[37] or increases in the magnitude of liability[38] can render contracting out undesirable. Unfortunately for this analysis, both were ratcheted up following the Exxon Valdez oil spill. Clearly both played a role in the outcome, but it is not possible to directly attribute the impact of each. Efforts of attribution are necessarily relegated to future research."

Advances in vessel tracking technology make it possible to answer the question that Brooks left to future research. By combining data on tanker movements with the

[37] Vicarious liability is an alternate term for extended liability. Both terms are used in the economic and legal literature.
[38] The "magnitude of liability" is a reference to the increase in liability limits under OPA-90.

variation in liability laws across states, I am able to separately control for the impacts of unlimited and extended liability. Unfortunately, the current system for tracking vessel movements was not fully implemented until 2002, so data on ship movements in the years immediately following the passage of OPA-90 are not readily available.

III. The data

Sources of the data:

This essay analyzes data on more than 30,000 US port calls made by large oil tankers from 2006 to 2009. The port-call data came from IHS Sea-Web, a proprietary online vessel tracking service.[39] Sea-Web uses the global Automatic Identification System (AIS) to track each vessel's movements by electronically exchanging data with other vessels, land-based AIS receivers, and satellites. For each port call, the data include the name of the port as well as the arrival and departure times. The data also include the tanker's size, age, flag state, and type (crude oil tanker, refined product tanker, chemical tanker, etc.).

Annual ownership information for each tanker came from Lloyds List Intelligence (LLI). Like the IHS port-call data, the LLI tanker data include information about each tanker, including the size, age, flag state, and type. Using the IMO number for each tanker, I was able to link ownership data from Lloyds List Intelligence to the port call

[39] IHS Sea-Web Online Database: http://www.sea-web.com

data from IHS Sea Web.[40] I compared the two data sets and found them highly consistent. The minor inconsistencies were resolved straightforwardly.[41]

To control for the possibility that oil companies are more likely to use their own tankers when delivering oil to refineries they own, I built a dataset that links major-owned refineries to individual ports. The list of major-owned refineries came from the Energy Information Administration's annual *Refinery Capacity Report*, which included the location and owner of every petroleum refinery in the US each year. I used three different sources to link each coastal refinery to a particular port: the oil company web sites, the port authority web sites, and the EIA's energy infrastructure profile of the United States. The refinery data was consistent from 2006 to 2009, with no oil companies selling or purchasing refineries during that period. The major oil companies owned about half of the total refining capacity in the US during the period of this analysis.

Limitations of the data:

While the port-call data contain a great deal of useful information, they do not include the purpose of each port call. So I do not know, for instance, if the tanker loaded oil, discharged oil, made repairs, or undertook some other activity. More importantly for this essay, I cannot distinguish a tanker that is empty from a tanker that is fully laden. Given this lack of information, I treat all port calls equally, with two important exceptions. First, all "port calls" to anchorage areas and lightering zones were excluded

[40] All ships are assigned a unique and permanent identification number (IMO number) when launched. IHS Fairplay assigns the numbers on behalf of the International Maritime Organization. Each tanker will maintain that number until it is broken up, even if it changes its name, owner, registration, or flag state.
[41] The primary inconsistency between the two sources dealt with the tanker type. The IHS data included about a dozen "crude/oil products" tankers that LLI listed as "crude oil" tankers. Those tankers were included in my dataset as crude oil tankers.

from the data because they do not represent independent observations.[42] If a tanker has to wait at anchor before entering a port, for instance, its visit to the anchorage zone would count as a second observation of what is essentially the same port call. Second, I removed port calls that were impossibly short in duration, which I define as less than four hours. The port-call data is based on the AIS ship tracking system, so a tanker simply passing a port can be counted as a port call. These very short "port calls" are clearly not independent observations and were dropped from the data.

Perhaps the biggest shortcoming of the data is that it covers a period (2006-2009) when there were no major changes in state-level liability laws. I was unable to find any instance of a US state enacting or retracting cargo-owner liability or unlimited liability during that period.[43] Without a change in liability laws within individual states, I am unable use difference-in–difference or fixed-effects analysis to determine how oil companies reacted to a changes in liability laws. The regression analysis, therefore, exploits the variation in liability laws across states to assess the relationship between liability and the shipping decisions of oil companies

Descriptive Statistics:

The 36,896 port calls in the data set included 641 different tankers making calls to 45 different ports in 17 coastal states. That works out to an average of 32.9 port calls per port per year and 6.7 port call per tanker per year. Table 4 shows the number of port calls

[42] A lightering zone is a designated area where large tankers can transfer oil between tankers. Several major US ports have designated lightering zones where large tankers can transfer oil to smaller tanker for delivery to the port.

[43] I checked Lexis Nexis as well as the leading shipping industry publication, Lloyds List, from 2005 to 2009.

each year by all tankers and the number of port calls by major-owned tanker. Not surprisingly, the share of port calls by major-owned tankers is relatively small compared to the total, but it is actually larger than their share of the international fleet. In 2006 the majors owned 6% of the global tanker capacity, according to the data from Lloyds List Intelligence. By 2009 that figure had dropped to just 4%.[44] The total number of port calls by all tankers grew each year from 2006 to 2009, while the number of port calls by major-owned tankers peaked in 2008, according to the IHS data. Given these year-to-year differences, it will be important to control for yearly effects in the regression analysis.

Table 4: US Port-Calls by Major-Owned Oil Tankers

year	total port calls by all tankers	port calls by major-owned tankers	major-owned tanker share of port calls
2006	11,326	956	8.4%
2007	15,687	1,171	7.5%
2008	16,322	1,333	8.2%
2009	17,347	1,064	6.1%

Source: IHS Sea Web (sea-web.com)

The tankers in the data set vary widely by age and size. As can be seen in Table 5, the major-owned tankers tend to be older and larger than the rest of the fleet that calls on US ports, and nearly all of the tankers owned by major oil companies are crude oil tankers.

[44] The number of tankers owned by the major oil companies barely changed from 2006 to 2009, but the rest of the international tanker fleet grew significantly.

Table 5:

Physical Properties of Tankers (Weighted by Number of Port Calls)

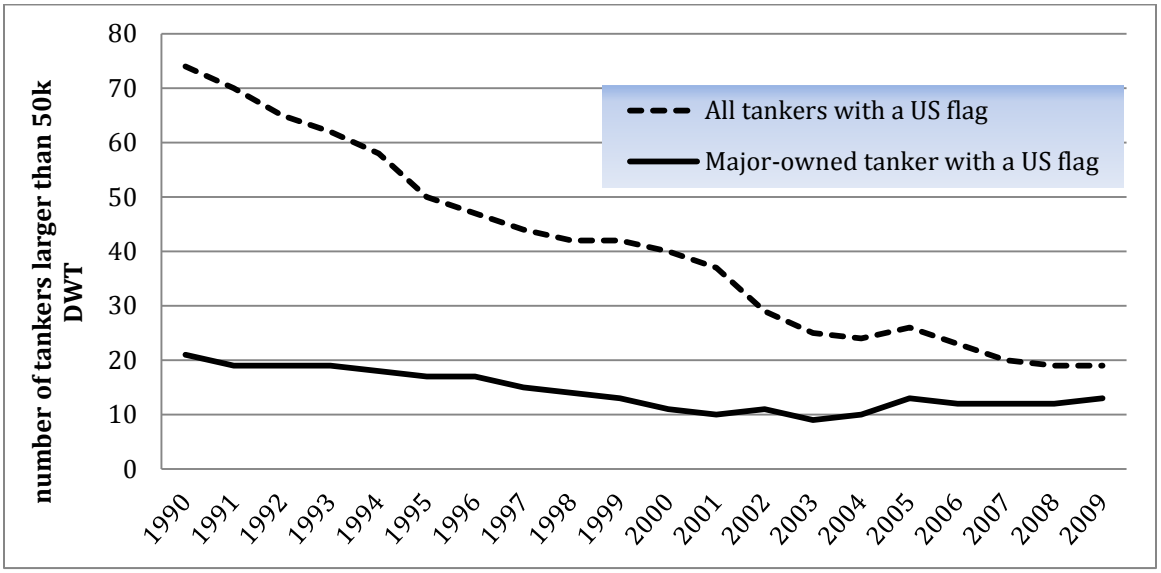
Owner type	major oil company	other
average age (years)	9.4002	7.2496
average size (million dwt)	0.1384	0.0996
percentage that are crude oil tankers	99%	74%

Source: IHS Sea Web (sea-web.com)

The tankers also vary in their flag state, with US flagged tankers accounting for only 10% of the total port calls (3,790 of 36,896) during the four-year period. Under the Merchant Marine Act of 1920 (also known as the Jones Act), tankers that operate between US ports must be US flagged, US built, US owned, and US crewed.[45] The total number of US flagged tankers was in steady decline from 1990 through 2009 (Figure 4). By 2006 there were only 23 tankers larger than 50,000 dead weight tons operating under a US flag. The number of major-owned US-flagged tankers also declined in the 1990s, but was generally stable from 2000 through 2009. As a result of these trends, the major oil company's share of large US-flagged tankers increased significantly (Figure 5). By 2006, 52% of large US-flagged tankers were owned by major oil companies. By 2009, that figure had increased to 68%.

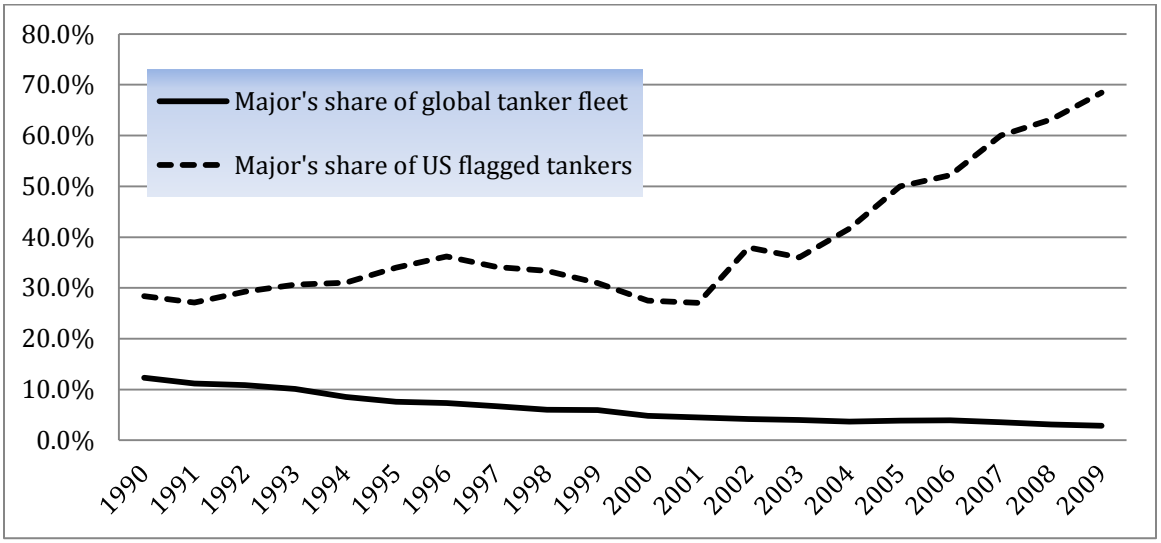
[45] The act was implemented to support and maintain a US shipbuilding capability and the domestic shipping industry. Industry press indicates that building a tanker in the US is three to four times more expensive than in Asia. Charter rates for US flagged tankers are significantly higher than similar routes in other markets.

Figure 4: US Flagged Tankers (1990 – 2009)



Source: IHS Sea Web (sea-web.com)

Figure 5: Major's Share of US-Flagged Tankers (1990 – 2009)



Source: IHS Sea Web (sea-web.com)

The threat of extended liability to cargo-owners is considered higher in the US than in other countries because several states have chosen to impose cargo-owner

liability.[46] The limitations imposed by the Jones Act mean that US-flagged tankers operate almost exclusively in US waters and therefore have the greatest exposure to the US liability system for oil spills. The fact that the major oil companies maintained ownership of the US-flagged tankers after the passage of OPA-90 is consistent with the notion that the major oil companies saw vertical integration in the shipping of their oil as the best way to limit their exposure to extended liability under OPA-90.

Table 6 shows the total number of port calls and the number of port calls by major-owned tankers for each coastal state. As one can see from the data, the major oil companies are very active in the west coast trade, which primarily consists of moving Alaskan crude to west coast refineries.

[46] The liability regime for the rest of the world is the 1992 Convention on Civil Liability for Oil Spills (CLC-92). Every major economy other than the United States has joined the convention. CLC-92 does not extend liability to cargo-owners.

Table 6: Port calls by State

State	Total port calls	Major-owned tanker port calls	Major-owned tanker share of port calls
Alaska	915	837	91.5%
Alabama	299	2	0.7%
California	4,701	905	19.3%
Connecticut	12	0	0.0%
Delaware	432	3	0.7%
Florida	485	27	5.6%
Georgia	182	0	0.0%
Hawaii	353	35	9.9%
Louisiana	8,840	234	2.6%
Massachusetts	57	0	0.0%
Maryland	72	0	0.0%
Maine	333	13	3.9%
Mississippi	64	0	0.0%
North Carolina	14	0	0.0%
New Jersey	398	4	1.0%
New York	2,336	7	0.3%
Oregon	38	18	47.4%
Pennsylvania	1,607	4	0.2%
Rhode Island	40	0	0.0%
South Carolina	92	0	0.0%
Texas	10,866	236	2.2%
Virginia	213	6	2.8%
Washington	2,267	1,755	77.4%

Source: IHS Sea Web (sea-web.com)

IV. Econometric models

Analysis by port: Model 1

To estimate the relationship between major-owned tanker usage and cargo-owner liability, I develop an empirical model of port calls by major-owned oil tankers. Let the *number* of port calls by major-owned tankers at port *i* in year *t* be defined as:

$$\begin{aligned} \mathrm{MPC}_{i,t} = \beta_0 + \beta_1 COL_i + \beta_2 UL_i + \beta_3 COFR_i + \beta_4 TPC_{i,t} + \beta_5 crude_share_{i,t} \\ + \beta_6 size_{i,t} + \beta_7 age_{i,t} + \beta_8 MOR_i + \beta_9 2007 + \beta_{10} 2008 \\ + \beta_{11} 2009 + \epsilon_{i,t} \end{aligned} \quad (1)$$

where COL_i (the primary variable of interest) is a dummy variable that is equal to one if port *i* is located in a state that imposes cargo-owner liability. (The variables are described in Table 7.) If the major oil companies are more likely to use their own tankers when sending their oil to ports that impose cargo-owner liability, as predicted by the theoretical model, I should observe a positive coefficient on COL_i. The other independent variables fall into three general categories: other liability issues, commercial factors, and physical constraints at port i.

Cargo-owner liability (COL_i) is not the only liability issue oil companies must face when choosing whether or not to use their own tankers to ship oil to a given port. As noted previously, the threat of unlimited liability and the requirement to file a state-level COFR can also influence the liability risk for the tanker owner. Dummy variables for unlimited liability (UL_i) and a state-level COFR requirement ($COFR_i$) are therefore included (based on the state where port *i* is located) to control for the possibility that these other liability issues are influencing the decisions of the major oil companies to send their tankers to port i. These laws did not change during the period of observation (2006 – 2009), so there is no to *t* subscript on the liability variables.

The commercial factors include port specific information that could impact an oil company's desire to load or discharge oil at a given port. Some ports are simply not heavily involved in the oil trade and are therefore unlikely to receive many port calls by large oil tankers, to include major-owned tankers. I do not have a direct measure of the

quantity of oil that is handled by each port, but the port-call data allow me to count the number of tankers that called on each port each year. So the total number of port calls ($TPC_{i,t}$) is included in the model to control for the fact that some ports simply handle more oil that other port.

Table 7: Variables for Analysis (by Port) with Descriptive Statistics

Variable	Description	Mean	S.D
$MPC_{i,t}$	Major port calls – the number of port calls by tankers owned by major oil companies (major-owned tankers) to port *i* in year *t*	10.42	32.70
$fracMPC_{i,t}$	Fraction of major port calls – the fraction of tanker port calls at port *i* in year t by major-owned oil tankers	0.12	0.25
COL_i	Cargo-owner liability - dummy equal to 1 if port *i* is in a state with cargo-owner liability. This is the variable of interest and is the measure of extended liability from the theoretical model.	0.33	0.47
UL_i	Unlimited liability - dummy equal to 1 if port *i* is in a state with unlimited liability	0.53	0.50
$COFR_i$	Certificate of financial responsibility - dummy equal to 1 if port *i* is in a state that requires a COFR (separate than the federal COFR)	0.60	0.49
$TPC_{i,t}$	Total port calls – the total number of port calls at port *i* in year *t* by all tankers	98.13	216.90
$crudeshare_{i,t}$	Fraction of tankers at port *i* in year *t* that are crude oil tankers	0.50	0.32
$size_{i,t}$	The average size in millions of dead weight tons of tanker calling at port *i* in year *t*	0.10	0.04
$age_{i,t}$	The average age in years of tanker calling at port *i* in year *t*	7.87	6.24
MOR_i	Major-owned refinery - dummy equal to 1 if port *i* serves a refinery owned by a major	0.23	0.42

Another commercial factor that could influence an oil company's decision to use its own tanker is whether the port serves a refinery it owns. As noted previously, one would expect ports that are co-located with major-owned refineries to receive more port calls from major-owned tankers, so a dummy is included that is equal to one if port *i* serves a major-owned refinery (MOR_i).

A third commercial factor deals with the type of oil handled at each port. As noted previously, nearly all of the major-owned tankers in the data are crude oil tankers, as opposed to refined fuel tankers. So ports that primarily handle refined fuels like gasoline and diesel are unlikely to receive many, if any, port calls by major-owned tankers. I do not have a breakdown of the relative quantities of crude oil and refined fuels at each port, but the port-call data includes the tanker type for each port call, which allowed me to calculate the percentage of port calls by crude oil tankers at each port each year, which is included as a variable in the model ($crude_share_{i,t}$).

The physical properties of each port could also impact the ability of the major oil companies to use their own tankers. The major-owned tanker fleet is larger and older than the rest of the fleet of tankers that called on US ports between 2006 and 2009. So a port that cannot handle large tankers, for instance, is less likely to have port calls by major-owned tankers. To control for these effects, the average size ($size_{i,t}$) and age ($age_{i,t}$) of the tankers that called on each port each year are included in the model. Yearly dummy variables for 2007, 2008, and 2009 are included in the analysis to allow for separate intercept terms for each year. 2006 is the base year in the analysis.

A potential problem with using a pooled OLS regression is that COL_i might be correlated with other factors that could affect $MPC_{i,t}$. It seems likely, for instance, that the

Exxon Valdez oil spill was an important factor in prompting the West Coast states to impose cargo-owner liability. It is less clear, however, how past oil spills would directly affect the decision of tanker companies to use their own tankers at certain ports, if not through the resulting change in liability laws. Nevertheless, I cannot rule out the possibility that COL_i is correlated with other factors that are affecting $MPC_{i,t}$. As noted previously, there were no changes in state-level liability laws during sample period (2006-2009) that would allow me to use a panel data techniques to address individual port (or state) fixed effects. In fact, all seven of the states that imposed cargo owner liability in 2008 (Table 3) had already imposed cargo-owner liability by the early 1990s.[47]

Analysis by Port: Model 2

Model 2 differs from the previous analysis in that the dependent variable is the *fraction* of total ports calls (as opposed to the *number*) by major-owned tankers to port *i* in year *t*. This alternative formulation is included in the analysis as a robustness check on Model 1. Let the fraction of port calls by major-owned tankers at a port *i* in year *t* be defined as:

[47] Petroleum Industry Research Foundation. "Transporting U.S. Oil Imports: The Impact of Oil Spill Legislation on the Tanker Market." Report prepared for the U.S. Department of Energy. Washington D.C. June 1992. Appendix II, Details of State Statues.

$$\begin{aligned}\text{fracMPC}_{i,t} = {} & \beta_0 + \beta_1 COL_i + \beta_2 UL_i + \beta_3 COFR_i + \beta_4 crude_share_{i,t} \\ & + \beta_5 size_{i,t} + \beta_6 age_{i,t} + \beta_7 MOR_i + \beta_8 2007 + \beta_9 2008 \\ & + \beta_{10} 2009 + \epsilon_{i,t}\end{aligned} \tag{2}$$

where COL_i (the primary variable of interest) is a dummy variable that is equal to one if port *i* is located in a state that imposes cargo-owner liability. Model 2 has the same independent variables as Model 1, with one exception – total port calls ($TPC_{i,t}$) is not included in the model because the dependent variable ($fracTPC_{i,t}$) is a function of TPC_i ($fracTPC_{i,t} = MPC_{i,t}/TPC_{i,t}$). Another difference with Model 2 is that the independent variable is now constrained to be a number between zero and one, which should reduce heteroskedasticity and result in much smaller coefficient estimates.

Analysis by Tanker: Model 3

In the previous models, the units of observation were ports. In the following models, the units of observation are tankers. One advantage of using tankers as the unit of observation is that it increases the number of observations from 45 ports to 641 tankers. Let the number of port calls by tanker *j* in year *t* to ports with cargo-owner liability ($PC_COL_{j,t}$) be given by:

$$\begin{aligned}\text{PC_COL}_{j,t} = {} & \beta_0 + \beta_1 MOT_j + \beta_2 TPC_{j,t} + \beta_3 crude_j + \beta_4 size_j + \beta_5 age_j \\ & + \beta_6 DH_j + \beta_7 US_j + \beta_8 2007 + \beta_9 2008 + \beta_{10} 2009 + \epsilon_{j,t}\end{aligned} \tag{3}$$

where MOT_j (the variable of interest) is a dummy variable that is equal to one if tanker *j* is owned by a major oil company. (The variables are described in Table 8.) If the major oil companies are more likely to use their own tankers when sending their oil to ports that impose cargo-owner liability, as predicted by the theoretical model, I should observe a positive relationship between MOT_j and $PC_COL_{j,t}$.

The set of other factors that could affect the number of calls that tanker *j* makes to ports with cargo-owner liability is similar to the previous model, but those controls now reflect the properties of the tanker, not the port. The total number of port calls ($TPC_{i,t}$) by tanker *j* in year *t* is included, to control for the fact that some tanker simply make more port calls to US ports than other tankers, and are therefore more likely to make more port calls to ports with cargo-owner liability.

Including variables for the age of the tanker (age_j) and whether it is double hulled (DH_j) allows me to test a second prediction of the theoretical model – that oil companies will charter higher quality tankers when that tanker will operate in a jurisdiction that imposes cargo-owner liability. Unlike the level of preventative care taken by a shipping company, the quality of the tanker is readily observable to the oil company. Since the oil company is jointly liable for an oil spill when operating in a jurisdiction that imposes cargo-owner liability, it has a strong incentive to charter high-quality tankers that are less likely to be involved in a major oil spill.

A dummy variable for crude oil tankers ($crude_i$) is included to capture the fact that crude oil is a more persistent pollutant that refined petroleum products like gasoline and diesel, which evaporate much more quickly than crude oil. Crude oil is therefore more likely to wash up on shore after a major spill. I would therefore expect a negative

relationship between crude oil tankers and port calls to ports that impose cargo-owner liability. The size of the tanker ($size_i$) is included to capture any limitations that may be specific to ports with cargo-owners liability.

The limitations of the Jones Act make US flagged tankers more likely to visit ports that impose cargo-owner liability. As stated previously, any tanker that carries a cargo from one US port to another US port must have a US flag. The West Coast states that impose cargo-owner liability for oil spills also receive much of their crude oil from Alaska, which must be transported on US-flagged tankers, thus increasing the number of port calls by US-flagged tankers to ports that impose cargo-owner liability.[48] To control for the possibility that US-flagged tankers are the primary driver of the results, the regression model in the next section is run with and without U-flagged tankers.

[48] As of 1990, all three West Coast states imposed cargo-owner liability for oil spills. California was the last of the three to adopt cargo-owner liability with the Oil Spill Prevention Act of 1990, which was passed before OPA-90, but also in response to the Exxon Valdez oil spill.

Table 8: Variables for Analysis (by Tanker) with Descriptive Statistics

Variable name	Description	Mean	S.D
$PC_COL_{j,t}$	Total port calls to ports in states that impose extended liability by tanker *j* in year *t*.	2.66	10.13
$frac PC_COL_{j,t}$	Fraction of total port calls by tanker *j* in year *t* to ports in states that impose extended liability. $fracTPC_{j,t} = PC_COL_{j,t}/TPC_{j,t}$	0.20	0.34
MOT_j	Major-owned tanker - dummy equal to 1 if the tanker *j* is owned by a major oil company	0.05	0.22
$TPC_{j,t}$	Total port calls– the total number of port calls by tanker *j* in year *t*	11.18	14.97
$crude_j$	Crude oil tanker - dummy equal to 1 if tanker *j* is a crude oil tanker	0.77	0.42
$size_j$	The size of tanker *j*, in millions of dead weight tons	0.12	0.06
age_j	The age of tanker *j* as of January 1, 2006 in years	7.61	5.36
DH_j	Double dull - Dummy equal to one of the tanker has a double hull	0.98	0.14
US_j	US flag – Dummy equal to one of the tanker has a US flag	0.02	0.15
2007-2009	Dummy equal to one for port calls in the year *t*		

Analysis by Tanker: Model 4

Model 4 differs from Model 3 in that the dependent variable is the *fraction* (as opposed to the *number*) of ports calls by tanker *j* that were to ports with cargo-owner liability. This alternative formulation is included in the analysis as a robustness check on Model 3. Let the fraction of port calls by major-owned tankers at port *i* in year *t* be given by:

$$\text{fracPC_COL}_{j,t} = \beta_0 + \beta_1\, MOT_j + \beta_2\, crude_j + \beta_3\, size_j + \beta_4\, age_j + \beta_5\, DH_j + \beta_6\, US_j + \beta_7\, 2007 + \beta_8\, 2008 + \beta_9\, 2009 + \epsilon_{j,t} \quad (4)$$

where MOT_j (the primary variable of interest) is a dummy variable that is equal to one if tanker *j* is owned by a major oil company. Model 4 has the same independent variables as Model 3, with one exception – total port calls ($TPC_{j,t}$) is not included because the dependent variable ($fracTPC_{j,t}$) is a function of TPC_j ($fracPC_COL_{j,t} = PC_COL_{j,t}/TPC_{j,t}$). Another difference with Model 4 is that the independent variable is now constrained to be a number between zero and one, which should reduce heteroskedasticity and result in much smaller coefficient estimates.

V. Results

Results for Models 1: Analysis by port

In Model 1, the dependent variable is the number of port calls by major-owned tankers to port *i* in year *t* ($MPC_{i,t}$). The key variable of interest is COL_i, which is a dummy variable that is equal to one if port *i* is in a state that imposes cargo-owner liability. If the theoretical model is correct, I should observe a positive relationship between port calls by major-owned tankers and ports that impose cargo-owner liability. The results of Model 1 are in Table 9below.

Table 9: Results for Analysis by Port (Model 1)

Dependent Variable ($MPC_{i,t}$): Port Calls by Major-owned Tankers to Port *i* in Year *t*

	MPC (1)	MPC (2)	MPC (3)	MPC (4)
			excludes US-flagged tankers	excludes US-flagged tankers
	robust SE	robust SE clustered by state	robust SE	robust SE clustered by state
COL	44.00***	44.00***	6.030***	6.030**
	(5.74)	(3.08)	(3.16)	(2.62)
UL	7.889	7.889	0.638	0.638
	(1.46)	(0.77)	(0.61)	(0.36)
COFR	2.219	2.219	1.842*	1.842
	(0.46)	(0.23)	(1.79)	(0.93)
TPC	0.0348***	0.0348**	0.0134***	0.0134***
	(5.24)	(2.39)	(5.90)	(5.88)
crude_share	48.26***	48.26**	8.139**	8.139
	(3.15)	(2.18)	(2.16)	(1.37)
size	94.73	94.73	-1.798	-1.798
	(1.04)	(0.57)	(-0.08)	(-0.05)
age	2.419***	2.419**	0.337	0.337
	(3.22)	(2.57)	(1.12)	(0.59)
MOR	-4.672	-4.672	2.960**	2.960***
	(-0.83)	(-0.49)	(2.38)	(2.94)
2007	2.966	2.966	-0.0210	-0.0210
	(0.46)	(0.85)	(-0.01)	(-0.01)
2008	6.499	6.499	0.804	0.804
	(0.99)	(1.74)	(0.43)	(0.35)
2009	3.251	3.251	-0.709	-0.709
	(0.49)	(0.89)	(-0.42)	(-0.33)
_cons	-60.49***	-60.49**	-8.383***	-8.383*
	(-4.99)	(-2.73)	(-2.99)	(-1.78)
N	180	180	168[49]	168
R-sq	0.522	0.522	0.377	0.377

* p<0.10 ** p<0.05 *** p<0.010"
t statistics in parentheses

[49] The number of observations declined from 180 to 168 in the third and fourth regressions because several ports did not have a sufficient number of port calls to be included in the analysis after US tankers were dropped from the data. See Table 12 in the appendix for more information.

To account for the possibility that US-flagged tankers are driving the result, the third and fourth regressions in Table 9 exclude port calls by tankers with a US flag. Robust standard errors are used in all four regressions. The standard errors for the second and fourth regressions are also clustered by the state where port *i* is located, as indicated in the table. Clustering of standard errors allows for the possibility that observations for ports within states are correlated, but assumes observations are uncorrelated between states. Dummy variables are included for 2007, 2008, and 2009, leaving 2006 as the base year.

The results support the major prediction of the theoretical model. The variable of interest – cargo-owner liability (COL) – is significant and of the expected sign. The imposition of cargo-owner liability is associated with 44 additional port calls per year by major-owned oil tankers. This is a large figure, given that each port in the data set received an average of 32.9 port calls per year. The magnitude of the result drops dramatically when US-flagged tankers are excluded from the data. The imposition of cargo-owner liability is associated with only six additional port calls per year by major-owned oil tankers that do not have a US flag. While the magnitude of the coefficient is much smaller in the third and fourth regressions in Table 9, the results are still highly significant.

This drop in the size of the coefficient on COL is not surprising because the average US flagged tanker makes many more port calls per year than the other tankers. Since they operate between US ports, US-flagged tankers will have two US port calls for each cargo movement (the load port and the delivery port), while tankers delivering oil from other countries to the US will have only one US port call. The routes between US

ports are also generally much shorter than the international routes, allowing a US-flagged tanker to make many more port calls per year than a non-US-flagged tanker. For instance, it takes less than a week to make the trip from Alaska to anywhere along the US west coast. The trip from the Persian Gulf to the US coast takes about 40 days in each direction.

Unlimited liability (UL) is positively associated with port calls by major-owned tankers, but the result is not significant. This finding is consistent with the notion that the major oil companies consider their liability unlimited in practice in the US. The state-level requirements for a separate COFR has a small impact on the number of port calls by major-owned tankers in all four regressions, and is only significant in the third regression in Table 9.

The total number of port calls (TPC) has a seemingly small impact on the number of port calls by major-owned tankers, but the result is highly significant. When all tankers are included in the regression, one hundred additional port call by non-major-owned tankers at a given port is associated with a 3.47 additional port calls by major-owned tankers. When the US flagged tankers are removed, that figure drops to 1.34. The small magnitude of this effect is not surprising considering that major-owned tankers constituted between 6.1 and 8.4 % of the total number of port calls in the data (Table 4).

The positive coefficient on size in the first two regressions in Table 9 suggests that, as expected, ports that take larger tanker are also more likely to have port calls by major-owned tankers, but the result is not statistically significant and disappears when US-flagged tankers are excluded from the data. The average age of tankers that call on a given port is positively associated with port calls by major-owned tanker, but that result

seems to be largely driven by the presence of US-flagged tanker. When the US-flagged tankers are removed from the data, the effect of age (both in magnitude and significance) on the number of port calls by major-owned tankers largely disappears. The fact that US flagged tankers are, on average, considerably older than rest of the international fleet, explains that finding.

Somewhat surprisingly, the presence of a major-owned refinery (MOR) at a port is not associated with additional port calls by major-owned tankers, except when the US flagged tankers are removed from the data. This suggests that the major oil companies are more likely to use their own tankers when delivering oil to their own refineries, but only with their internationally-flagged tankers. One possible explanation for this result is the large share of the US-flagged tanker fleet that is owned by the major oil companies. Given that Alaskan crude can only move on US flagged tankers, the major oil companies may have no choice but to use their own tankers to transport Alaskan crude to west coast refineries that are owned by other companies.

The overall fit of model declined from an R^2 score of 0.522 to 0.377 when the US flagged tankers were removed from the analysis. Clustering the errors by state increased the size of the standard errors, which is not surprising given that there are 45 different ports in the data set, but only 17 different coastal states in the data set.

It is also worth noting that none of the yearly dummy variables are significant, which suggests the yearly differences noted in Table 4 did not have a large impact on the number of port calls by major-owned tankers, nor did the large swings in the global oil price between 2006 and 2009.

Results for Models 2: Analysis by port

In Model 2, the dependent variable is the fraction (as opposed to the number) of port calls by tanker *j* that were to ports in states that extend liability to cargo-owners ($fracMPC_{j,t}$). The key variable of interest is still COL_i. If the theoretical model is correct, I should observe a positive relationship between port calls by major-owned tankers and ports that impose cargo-owner liability. The results of Model 2 are in Table 10 below. As before, dummy variables are included for 2007, 2008, and 2009, leaving 2006 as the base year.

Again, the results largely support the prediction of the theoretical model. The variable of interest – cargo-owner liability (COL) – is significant and of the expected sign, but in only three of the four regressions. The imposition of cargo-owner liability is associated with a 24.7 % increase in the share of major port calls by major-owned oil tankers. As before, the coefficient on COL is much smaller when US flagged tankers are excluded from the data. The imposition of cargo-owner liability is associated with a 6.42% increase in the share of port calls by major-owned oil tankers that do not have US flags.

Table 10: Results for Analysis by Port (Model 2)

Dependent Variable ($fracMPC_{i,t}$): the fraction of port calls by major-owned tankers to port *i* in year *t*

	fracMPC (1)	**fracMPC (2)**	**fracMPC (3)**	**fracMPC (4)**
			excludes US-flagged tankers	excludes US-flagged tankers
	robust SE	robust SE clustered by state	robust SE	robust SE clustered by state
COL	0.247***	0.247**	0.0642**	0.0642
	(5.56)	(2.48)	(2.53)	(1.33)
UL	0.0534	0.0534	0.0157	0.0157
	(1.46)	(0.74)	(1.09)	(0.59)
COFR	0.0241	0.0241	0.00849	0.00849
	(0.72)	(0.39)	(0.65)	(0.37)
crude_share	0.473***	0.473**	0.189***	0.189
	(5.87)	(2.48)	(3.62)	(1.66)
size	-0.520	-0.520	-0.231	-0.231
	(-1.53)	(-0.93)	(-1.15)	(-0.79)
age	0.0134***	0.0134***	0.00307	0.00307
	(4.55)	(3.43)	(0.92)	(0.75)
MOR	-0.0674**	-0.0674*	-0.0117	-0.0117
	(-2.38)	(-1.90)	(-0.77)	(-0.64)
2007	0.000477	0.000477	-0.00397	-0.00397
	(0.01)	(0.03)	(-0.17)	(-0.35)
2008	0.0205	0.0205	-0.0108	-0.0108
	(0.60)	(0.76)	(-0.51)	(-0.58)
2009	0.0233	0.0233	-0.00766	-0.00766
	(0.64)	(0.78)	(-0.35)	(-0.48)
_cons	-0.282***	-0.282**	-0.0765**	-0.0765*
	(-5.19)	(-2.71)	(-2.28)	(-1.84)
N	180	180	168[50]	168
R-sq	0.605	0.605	0.273	0.273

* p<0.10 ** p<0.05 *** p<0.010"
t statistics in parentheses

[50] The number of observations declined from 180 to 168 in the third and fourth regressions because several ports did not have a sufficient number of port calls to be included in the analysis after US tankers were dropped from the data.

Results for Models 3 and 4: Analysis by tanker

For Models 3 and 4, the unit of analysis switches from ports to tankers. The dependent variable for Model 3 is the number of port calls by tanker *j* to ports with cargo-owner liability ($PC_COL_{j,t}$), while the dependent variable for Model 4 is the *fraction* of ports calls by tanker *j* that were to ports with cargo-owner liability ($fracPC_COL_{j,t}$). The key variable of interest for both models is MOT_j, which is a dummy variable that is equal to one if tanker *j* is owned by a major oil company. If the theoretical model is correct, I should observe more port calls by major-owned tankers at ports that impose cargo-owner liability compared to non-major-owned tanker.

The coefficient on MOT is significant and of the expected sign for both regressions. Major-owned tankers are indeed more likely than other tankers to call on ports that extend liability to cargo-owners, as predicted by the theoretical model. A tanker that is owned by a major oil company made 6.4 more calls to ports in states that impose extended liability than non-major-owned tankers. In percentage terms, being owned by a major oil company increases the fraction of port calls to ports with cargo-owner liability (fracPC_COL) by 15.5 %.

Table 11: Results for Analysis by Tanker (Models 3 and 4)

Dependent Variable for Model 3 (PC_COL): Port Call by Tanker j to Ports with Cargo-owner Liability

Dependent Variable for Model 4 (fracPC_COL): Fraction of Port Call by Tanker j to Ports with Cargo-owner Liability

	Model 3	**Model 4**
	PC_COL	**fracPC_COL**
	Robust SE	Robust SE
MOT	6.403***	0.155***
	(4.91)	(3.26)
TPC	0.243***	
	(7.35)	
crude	-1.326***	-0.0844***
	(-5.72)	(-5.53)
size	15.41***	0.846***
	(5.96)	(4.73)
age	-0.0910**	-0.00856***
	(-2.55)	(-6.49)
DH	9.902***	0.169***
	(4.15)	(3.46)
US	34.55***	0.689***
	(9.45)	(13.45)
2007	-0.166	0.0148
	(-0.43)	(0.75)
2008	-0.0240	0.000267
	(-0.07)	(0.01)
2009	-0.346	-0.0140
	(-0.92)	(-0.72)
_cons	-11.13***	0.0226
	(-4.38)	(0.40)
N	2564	2088 51
R-sq	0.595	0.149

* p<0.10 ** p<0.05 *** p<0.010
t statistics in parentheses

[51] The number of observations declined from 2,564 in Model 3 to 2,088 in Model 4 because the dependent variable could not be calculated for ports that had zero US port calls in a given year.

Tankers that called on ports with cargo-owner liability tended to be newer (age) and were more likely to be double hulled (DH). These results are statistically significant and are consistent with prediction five from the theoretical model, which states that oil companies are more likely to charter high-quality tankers when transporting their oil in jurisdictions that impose cargo-owner liability. A double-hulled tanker made nearly 10 more port calls per year to ports with cargo-owner liability than a single-hulled tanker, and being double hulled increased the fraction of port calls to ports with extended liability by 16.9 %.

The coefficient on total port calls (TPC) is significant and of the expected sign. A tanker that made 100 additional port calls could be expected to make 24.3 additional port calls to ports with cargo-owner liability. As expected, crude oil tankers are less likely to call on ports that impose cargo-owner liability. Crude oil tankers made 1.3 fewer port calls each year to ports with cargo-owner liability. The results also show a positive relationship between the size of the tanker and the number of port calls to ports with cargo-owner liability.

As expected, US-flagged tankers were much more likely to call on ports with cargo-owner liability than non-US-flagged tankers. As with the previous regression equations, the yearly dummy variables are not statistically significant.

VI. Conclusions

This essay contributes to the existing literature on the economics of liability by providing an empirical analysis of how oil companies respond to the imposition of extended liability. The analysis exploits the variation in oil spill liability laws across US

states to determine whether oil companies are more likely to use their own tankers – as opposed to chartering a tanker – when calling on a port that extends liability to cargo owners. This question was motivated by the theoretical model presented in Chapter 3, which shows that the imposition of cargo-owner liability reduces the expected profits to the oil company of chartering a tanker relative to using its own tanker.

This analysis examines this issue using two different approaches. The first approach uses data on 45 US ports to determine whether ports that extended liability to cargo-owners were more likely to be visited by tankers owned by major oil companies. The second approach uses data on 641 individual tankers to determine whether oil tankers owned by major oil companies were more likely to call on ports that impose cargo-owner liability.

For the first approach (analysis by port), seven of the eight regressions find that ports that imposed cargo-owner liability were indeed more likely than other ports to be visited by major-owned tankers. The eighth equation also finds a positive relationship, but it was not statistically significant. For the second approach (analysis by tanker) both the results from both models find that major-owned tankers are more likely to visit ports that extend liability to cargo-owners, and the results are highly significant. Taken together, these results strongly support the hypothesis that oil companies take liability laws into account when deciding where to use their own tankers. Within the larger economic context, these empirical findings support the hypothesis that the threat of extended liability motivates large firms with deep pockets to undertake potentially hazardous activities internally, where they can, in principle, directly control the level of preventative care.

Another prediction of the theoretical model is that oil companies will choose to charter high-quality tankers when visiting ports that impose cargo-owner liability. The regression results in Table 11 support that prediction. Tankers that visited ports with cargo-owner liability were newer and more likely to be double hulled than other tankers. These results suggest that oil companies attempted to minimize the risk of a spill by chartering higher quality tankers when operating at ports that imposes cargo-owner liability.

The results in Table 9 and Table 10 indicate that the imposition of unlimited liability at certain ports was not a significant determinant of whether a major oil company used its own tanker or chartered a tanker. That result is consistent with the notion that the major oil companies do not believe their liability is actually limited for any oil spill in US waters, which was a key assumption used in the simplified model presented in Chapter 3.

Opportunities for future research:

Additional data would allow for the testing of several other predictions from the theoretical model. Data on port calls before and after a particular state implemented cargo-owner liability, for instance, would allow one to apply fixed effects or difference-in-difference estimation techniques. The results presented here would be more convincing if the data showed an increase in port calls by major-owned tankers when cargo-owner liability was first introduced in a given state. The cargo-owner liability laws appear to have been in place for at least ten years before my data

Information on the asset levels of the shipping companies would also improve the analysis by allowing a test of another prediction of the theoretical model - that oil companies prefer to work with larger shipping companies that can absorb more of the cost of a spill and are less likely to have a spill in the first place because they have more assets to lose and are therefore more likely to choose a high level of preventative care.

This essay indicates that the imposition of cargo-owner liability is associated with more oil being transported on tankers owned by the major oil companies, it also finds that oil companies will charter higher quality tankers when operating at ports that impose cargo-owner liability. It does not, however, answer a fundamental question: does the imposition of cargo owner liability lead to fewer oil spills. That analysis would require data on oil spills over time.

VII. Appendix

Additional robustness tests:

The primary finding from the results in Table 9 is that the ports that impose cargo-owner liability (COL) have a significantly higher number of port calls by major-owned oil tankers (MPC) – even when US-flagged tankers are excluded from the analysis. But excluding US-flagged tankers reduces the number of observations in the analysis from 180 (45 ports over four years) to 168 (42 ports over four years). When the US-flagged tankers are excluded, three West Coast ports no longer had at least four tanker port calls each year, and were therefore dropped from the analysis.

To ensure consistency in the analysis, Table 12 replicates the results from Table 9, but the results in the first two columns are limited to the 42 ports (168 observations) that still had at least four port calls each year when US-flagged tankers were removed from the analysis. As with Table 9, the dependent variable ($MPC_{i,t}$) is the number of port calls by major-owned tankers at port *i* in year *t*, and the key variable of interest is a dummy variable that is equal to one if the port imposes cargo-owner liability (COL). The results in Table 12 indicate that the primary variable of interest (COL), continues to be significant and of the expected sign. The only significant change in the results is that the coefficient on *crude_share* is no longer significant when using standard errors that are clustered by state.

Table 12: Results for Analysis by Port (Model 1)

Dependent Variable ($MPC_{i,t}$)

	MPC (1)	**MPC (2)**	**MPC (3)**	**MPC (4)**
	robust SE	robust SE clustered by state	excludes US-flagged tankers robust SE	excludes US-flagged tankers robust SE clustered by state
COL	40.16***	40.16**	6.030***	6.030**
	(5.15)	(2.24)	(3.16)	(2.62)
UL	7.079	7.079	0.638	0.638
	(1.50)	(0.77)	(0.61)	(0.36)
COFR	2.885	2.885	1.842*	1.842
	(0.65)	(0.33)	(1.79)	(0.93)
TPC	0.0269***	0.0269**	0.0134***	0.0134***
	(5.44)	(2.60)	(5.90)	(5.88)
crude_share	41.36***	41.36	8.139**	8.139
	(2.69)	(1.24)	(2.16)	(1.37)
size	35.47	35.47	-1.798	-1.798
	(0.50)	(0.27)	(-0.08)	(-0.05)
age	2.101**	2.101***	0.337	0.337
	(2.39)	(3.40)	(1.12)	(0.59)
MOR	1.052	1.052	2.960**	2.960***
	(0.27)	(0.22)	(2.38)	(2.94)
y2007	2.222	2.222	-0.0210	-0.0210
	(0.39)	(0.76)	(-0.01)	(-0.01)
y2008	5.519	5.519	0.804	0.804
	(0.96)	(1.46)	(0.43)	(0.35)
y2009	1.619	1.619	-0.709	-0.709
	(0.29)	(0.45)	(-0.42)	(-0.33)
_cons	-48.85***	-48.85**	-8.383***	-8.383*
	(-4.81)	(-2.48)	(-2.99)	(-1.78)
N	168	168	168	168
R-sq	0.506	0.506	0.377	0.377

* p<0.10 ** p<0.05 *** p<0.010"
t statistics in parentheses

Table 13 and Table 14 below provide robustness checks of the results in Table 11 by including three additional explanatory variables. The variable age^2 is added to capture the possibility that there is a non-linear relationship between a tanker's age and the number of port calls it made to ports with cargo-owner liability. The interaction variable *MOT*age* is included to test the hypothesis that the relationship between *age* and *MPC* is the same for major-owned tankers as it is for non-major-owned tankers. The interaction variable *MOT*US* is included to test the hypothesis that the relationship between US-flagged tankers and *MPC* is the same for major-owned US-flagged tankers as it is for other US-flagged tankers. These additional variables are shown in bold in Table 13 and Table 14 below.

The results indicate that that the relationship between a tanker's age and the number of port calls it makes to ports with cargo-owner liability is indeed non-linear. The coefficient on age^2 is positive in every model, while the coefficient on *age* is negative in every model. The coefficient on age^2 is significant in the final model of Table 13 and in every model in Table 14. These results indicate that the number of port calls a tanker makes to ports with cargo-owner liability is declining in age, but that decline slows as the tanker's age continues to increase. The non-linearity of *age* is probably due to the fact that tankers stop calling on ports that impose cargo-owner liability after a certain age, and therefore do not continue to show additional declines as they get older. Unfortunately *age* and age^2 are strongly correlated, which probably explains why *age* is no longer significant in Models 3A and 3B in Table 13. The inclusion of age^2 also has almost no impact on the overall fit of Model 3A compared to Model 3.

The interaction variable *MOT*age* is not statistically significant in any of the results, so I cannot reject the hypothesis that the relationship between *age* and *MPC* is the same for major-owned tankers as it is for non-major-owned tankers. This result is not surprising when one considers that the oil companies are the primary charterers of oil tankers. The imposition of cargo-owner liability gives them a strong incentive to charter higher quality tankers, as predicted by Proposition 5 of the theoretical model.

The interaction variable *MOT*US* is strongly significant in Model 3C of Table 13. Tankers that are both US-flagged and are owned by a major oil company make 21.59 more port calls per year than non-major-owned US-flagged tankers to ports with extended liability. While this result appears to support Proposition 2 of the theoretical model, the variable *MOT*US* has very different result in Table 14, where the coefficient is relatively small (only a 9% increase in port calls) and is not statistically significant. The inconsistency of the results for *MOT*US* makes it difficult to draw any strong conclusions about the importance of this interactive affect.

Table 13: Results for Analysis by Tanker (Model 3)

Dependent Variable for Model 3 (PC_COL): Port Call by Tanker j to Ports with Cargo-owner Liability

	Model 3	**Model 3A**	**Model 3B**	**Model 3C**
	PC_COL	PC_COL	PC_COL	PC_COL
MOT	6.403***	6.456***	4.675**	4.418**
	(4.91)	(5.06)	(2.43)	(2.32)
TPC	0.243***	0.244***	0.243***	0.239***
	(7.35)	(7.29)	(7.31)	(7.04)
crude	-1.326***	-1.327***	-1.324***	-1.211***
	(-5.72)	(-5.73)	(-5.68)	(-5.28)
size	15.41***	15.71***	15.51***	14.95***
	(5.96)	(5.72)	(5.74)	(5.39)
age	-0.0910**	-0.137	-0.125	-0.362***
	(-2.55)	(-0.90)	(-0.86)	(-3.03)
DH	9.902***	9.984***	10.17***	9.015***
	(4.15)	(4.07)	(4.13)	(4.04)
US	34.55***	34.22***	34.26***	19.09***
	(9.45)	(8.96)	(9.03)	(3.15)
age^2		**0.00215**	**0.000897**	**0.0154****
		(0.26)	**(0.11)**	**(2.41)**
MOT*age			**0.223**	**-0.0323**
			(0.89)	**(-0.13)**
MOT*US				**21.59*****
				(3.03)
Y2007	-0.166	-0.151	-0.156	-0.0868
	(-0.43)	(-0.39)	(-0.41)	(-0.23)
y2008	-0.0240	0.00496	-0.00502	0.0867
	(-0.07)	(0.01)	(-0.01)	(0.24)
Y2009	-0.346	-0.308	-0.320	-0.230
	(-0.92)	(-0.80)	(-0.83)	(-0.62)
_cons	-11.13***	-11.11***	-11.24***	-9.441***
	(-4.38)	(-4.40)	(-4.42)	(-4.10)
N	2564	2564	2564	2564
R-sq	0.595	0.595	0.596	0.612

* p<0.10 ** p<0.05 *** p<0.010"
t statistics in parentheses

Table 14: Results for Analysis by Tanker (Model 4)

Dependent Variable for Model 4 (fracPC_COL): Fraction of Port Call by Tanker j to Ports with Cargo-owner Liability

	Model 4	**Model 4A**	**Model 4B**	**Model 4C**
	fracPC_COL	fracPC_COL	fracPC_COL	fracPC_COL
MOT	0.155***	0.168***	0.160**	0.161**
	(3.26)	(3.48)	(2.41)	(2.42)
crude	-0.0844***	-0.0836***	-0.0837***	-0.0832***
	(-5.53)	(-5.49)	(-5.49)	(-5.44)
size	0.846***	0.897***	0.896***	0.894***
	(4.73)	(4.93)	(4.93)	(4.91)
age	-0.00856***	-0.0178***	-0.0177***	-0.0191***
	(-6.49)	(-4.41)	(-4.23)	(-4.23)
DH	0.169***	0.187***	0.188***	0.179***
	(3.46)	(3.95)	(3.94)	(4.18)
US	0.689***	0.628***	0.629***	0.561***
	(13.45)	(12.06)	(11.88)	(4.78)
age2		**0.000453*** **	**0.000444** **	**0.000527** **
		(2.68)	**(2.40)**	**(2.52)**
MOT*age			**0.000925**	**-0.000509**
			(0.21)	**(-0.12)**
MOT*US				**0.0912**
				(0.72)
Y2007	0.0148	0.0181	0.0181	0.0185
	(0.75)	(0.91)	(0.91)	(0.93)
y2008	0.000267	0.00661	0.00654	0.00730
	(0.01)	(0.33)	(0.33)	(0.37)
Y2009	-0.0140	-0.00519	-0.00530	-0.00443
	(-0.72)	(-0.26)	(-0.27)	(-0.22)
_cons	0.0226	0.0273	0.0262	0.0383
	(0.40)	(0.50)	(0.47)	(0.76)
N	2088	2088	2088	2088
R-sq	0.149	0.150	0.150	0.151

* p<0.10** p<0.05 *** p<0.010"
t statistics in parentheses

References:

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Chapter 5: Oil Tanker Ownership Across Countries

Abstract

This essay uses panel data techniques to test two hypotheses to explain the changes in country-level oil tanker ownership between 1993 and 2009. The first hypothesis is that a nation's level of oil trade drives oil tanker ownership in that nation. The second hypothesis is that the size of a nation's shipping industry drives oil tanker ownership in that nation. The main finding of this essay is that both factors are significant indicators of tanker ownership, but for different sets of countries. A nation's level of oil trade is a significant indicator of tankers ownership, but only in countries where the government owns some or all of the of nation's tankers. Conversely, the size of a nation's shipping industry (as measured by non-tanker vessel ownership) is a significant indicator of tanker ownership, but only in countries where the government owns no oil tankers. These findings suggest that the drivers of tanker ownership at the national level are strongly influenced by the government's role in the sector. This essay is different than most studies of vessel ownership in that it focuses on the ultimate owners of the tankers, not the registered owners, which are often single-vessel firms that exist only on paper.

I. Background

This chapter uses panel data techniques to test two separate hypotheses for the dramatic changes observed in oil tanker ownership across countries between 1993 and 2009.[52] The first hypothesis tested is that a nation's level of oil trade drives oil tanker ownership by its firms. If true, we would expect countries that import or export large quantities of oil to own more tankers than countries that import or export very little oil. The second hypothesis tested is that nations with large shipping industries are more likely to own tankers. If true, we would expect countries with a high level of ownership of non-tanker vessels to also own many tankers. Finally, I explore the role of governments in tanker ownership by testing whether there is a difference in the determinants of tanker ownership between countries where the government owns oil tankers and countries where the government owns no tankers.

Most studies of oil tanker ownership have focused on the "registered" owners of tankers, which are the companies that maintain legal ownership of the vessels.[53] But the vast majority of registered owners are subsidiaries of larger companies that maintain ultimate control of the vessels. In 2009, 350 different companies owned the largest 2,500 tankers, but those companies had created more than 1,700 individual subsidiaries to legally own the tankers. These subsidiary companies tend to be based in countries with

[52] For expediency, I sometimes refer to countries as "owning tankers," which should be understood to mean that entities within a country own tankers. Those entities could be oil companies, shipping companies, or the government.

[53] IHS Fairplay gives the following definition of registered ownership: "The legal title of ownership of the vessel that appears on the ship's registration documents. It may be an Owner/Manager or a wholly-owned subsidiary in a larger shipping group; or a bank or one-ship company vehicle set up by the bank; or of course, it may be a "brass-plate" company created on paper to legally own a ship and possibly to limit liability for the "real" owners and/or benefit from off-shore tax laws. It may be a legal-requirement of the flag-state with whom the ship is registered for the legal owner to be a company registered in that country."

open registries like Panama, Liberia, and the Marshal Islands. This essay focuses exclusively on the ultimate owner of each tanker, which are often called the "beneficial owners," not the registered owners.

Energy Security as a potential driver of tanker ownership

The idea that tanker ownership enhances a nation's energy security has been advanced in the press and by the shipping industry itself.[54] But companies do not need to own tankers in order to maintain access to tanker services. Like oil itself, the services of oil tankers are traded on an open market. Any oil company, refinery, or commodity trader that wishes to charter an oil tanker can do so at the going market rate for a particular route. In 2010 roughly 80 percent of the world's tanker capacity was available for charter.

The energy security argument, however, is based on the notion that countries can better rely on their own tankers to deliver oil during times of crisis. In the U.S., for instance, defenders of the Jones Act say the law enhances US security by "ensuring the United States controls its essential transportation assets and the related infrastructure in both peacetime and wartime."[55] China's energy security concerns are cited to explain the increase in oil tanker ownership by its state-owned enterprises over the last decade. In their 2007 paper on China's energy security strategy, Erickson and Collins conclude that, "Anxiety over the security of maritime oil supply is one factor shaping decision-making

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54 Collins, Gabe. "China Seeks Oil Security with New Tanker Fleet." Oil & Gas Journal Oct 9, 2006 2006: 20,22,24-26.

55 The Transportation Institute is a lobbying organization for the US shipping industry. http://www.trans-inst.org/jones-act.html

as interested actors promote the development of a large Chinese tanker fleet and Beijing contemplates the construction of a blue water navy."[56]

Major oil exporters that rely on the resulting revenue to finance their government expenditures may feel the need to own tankers to guarantee their access to tanker services. US and EU sanctions against Iran, for instance, have made independent tanker owners reluctant to transport Iranian crude. The National Iranian Tanker Company has carried nearly all of Iran's crude oil exports since mid-2012.

There is a relatively large economic literature on the concept of energy security with a wide range of methodologies used to measure it.[57] [58] One simple metric for energy security that is relevant to the oil tanker market is the percentage of a nation's total energy consumption that is provided by imported oil. The benefit of this metric is that is captures a nation's dependence on imported oil as well as the importance of oil in its overall energy mix. For instance, some countries may import nearly all of their oil, but oil may represent a relatively small part of their energy consumption. The analysis presented in this essay will include this measure to test the notion that energy security is a significant driver of oil tanker ownership across countries.

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56 Andrew S. Erickson and Gabriel Collins, "Beijing's Energy Security Strategy: The Significance of a Chinese State-Owned Tanker Fleet," Orbis, Vol. 51, No. 4 (Fall 2007), pp. 665-84.

57 Masson, André, Bengt Johansson, and Lars J. Nilsson. "Assessing Energy Security: An Overview of Commonly used Methodologies." Energy 73 (2014): 1-14.

58 Cohen, Gail, Frederick Joutz, and Prakash Loungani. "Measuring Energy Security: Trends in the Diversification of Oil and Natural Gas Supplies." Energy Policy 39.9 (2011): 4860-9.

Liability for oil spills as a potential driver

Liability is thought to be an important driver of oil tanker ownership, as explained in Chapters 3 and 4. It is possible, therefore, that firms may choose to avoid oil tanker ownership based on the liability laws of the country were they reside. For most of the world, the relevant liability law for oil spills is the International Maritime Organization's Convention on Convention on Civil Liability for Oil Pollution Damages and its 1992 protocol.[59] CLC-92, as it is known, came into force in 1996 for the initial fourteen member states. Membership gradual increased over the next dozen years. By 2009, 64 of the 76 countries in my data had acceded to the convention.

Types of owners

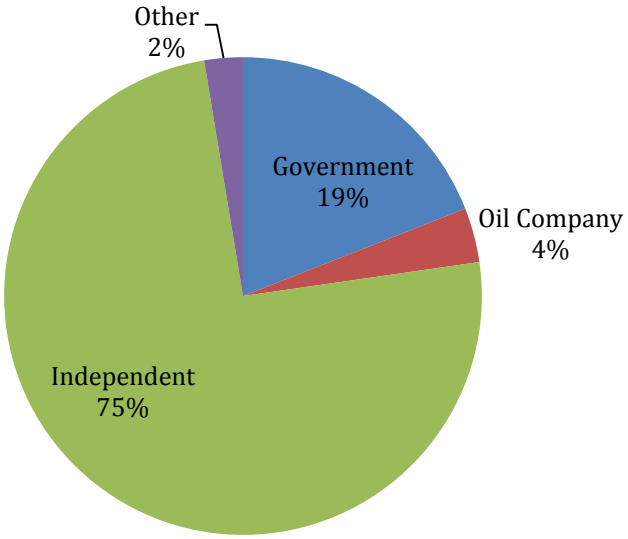
Figure 6 breaks down the ownership of large tankers into four broad types: independent shipping companies, governments, oil companies, and others. The *independent* category includes both publically traded and privately owned shipping companies. The *government* category includes both national shipping lines and national oil companies. The *oil company* category includes the major international oil companies like Exxon and BP. The *other* category includes non-traditional owners such as commodity traders and financial institutions.

Identifying which companies were ultimately owned by governments was not strait forward, since governments can be the majority shareholder in publically traded shipping companies. For instance, AET (formerly American Eagle Tankers) is not

[59] The Convention on Civil Liability was initially passed in 1969. There are more than 120 signatories the 1992 protocol to the convention, which substantially raised liability limits and required evidence of financial responsibility, among its many provisions.

typically considered a government shipping company, but the firm is wholly owned by the publically-traded Malaysian firm MISC Berhad, which is majority owned by the Malaysian oil company Petronas, which is in turn fully owned by the Malaysian government. I therefore include AET's oil tankers under the government category, since the government of Malaysia is ultimately the majority owner, though AET is generally considered independent shipping company.[60]

Figure 6: Tanker Ownership by Company Type in late 2010



Nineteen percent of worldwide tanker capacity was owned by governments in 2010.[61] While the available data does not allow for a historical analysis of government ownership, published reports by the International Organization of Independent Tanker

[60] International Organization of Independent Tanker Owners lists AET as an independent tanker company.

[61] When publically traded companies in which the government is the major shareholder are not counted as government-owned companies, the figure drops to 13 percent, which corresponds with the figure reported by the International Organization of Independent Tanker Owners in its 2009 Tanker Facts report.

Owners (Intertanko) suggest that the fraction of tankers owned by governments increased from 2006 to 2009. [62]

II. The data

Sources of the data:

The panel includes annual data on 75 different countries from 1990 to 2009. Lloyds List Intelligence, a shipping analysis firm based in London, provided ownership data on every operational vessel (not just oil tankers) larger than 50,000 dead weight tons from 1990 through 2009. The Lloyds List data include the name and nationality of both the registered owner and real owner of each vessel each year. The data also include the physical attributes of each tanker (age, size, hull type, etc.). Additional ownership information is from EA Gibbons Shipbrokers. The EA Gibsons data is unique in that it includes the "owner type" for each tanker, which was used to create Figure 6. Seventeen different owner types are included in the EA Gibsons data, which I combined into the four basic categories presented in Figure 6. The EA Gibsons data was obtained for the 2,505 oil tanker larger than 50,000 thousand deadweight ton that were in operation in late 2010. Unfortunately, I do not have access to information on ownership type for previous years. Data on oil imports and exports for each country in each year were obtained from the Energy Information Administration. Annual data on GDP for each country are from the World Bank.

62 Ranheim, Erik. "Tanker Facts" International Association of Independent Tanker Owners. 2007 - 2010. http://www.intertanko.com/upload/Publication

Adjustments to data:

The available data does not include every country in the world. The population of interest is the set of countries whose firms (or governments) could realistically expect to own oil tankers. I have therefore limited the list to countries that owned at least one large vessel (not necessarily a tanker) at some point between 1990 and 2009. Unfortunately comprehensive data was not available for every country. I had to drop the following, countries and territories from the data because important data was not available for much of the sample period: Aland Islands, Netherlands Antilles, Czechoslovakia, Cuba, Cayman Islands, Gibraltar, Isle of Man, Monaco, Marshall Islands, Burma, North Korea, Taiwan, St. Vincent & Grenadines, British Virgin Islands, and Yugoslavia. With the exception of Taiwan, tanker ownership in these countries was minimal.

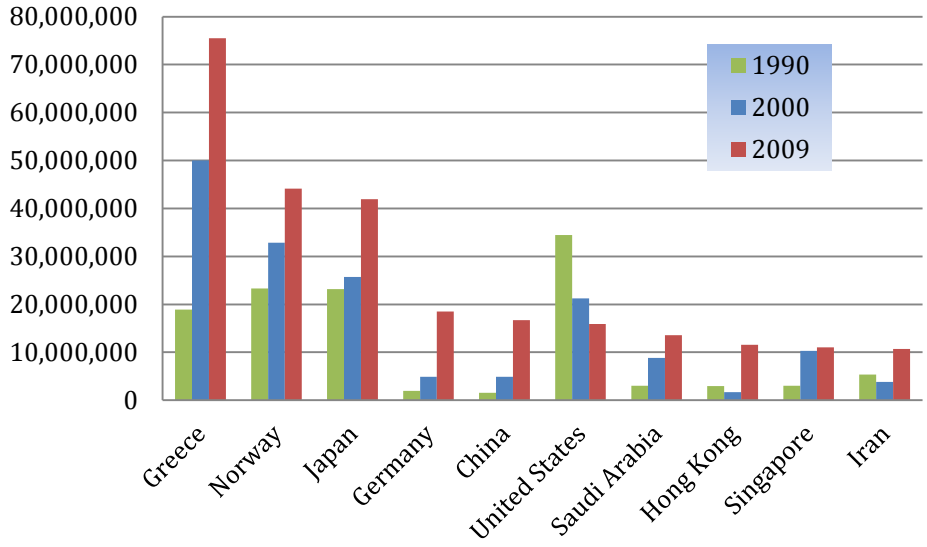
The years 1990 – 1992 were dropped because much of the data for the former Soviet republics – as well as Iraq and Kuwait – are incomplete for those years. These omitted countries are unlikely to represent a random sample, so those years are removed from the regression to avoid sampling bias in the regression results.

Descriptive statistics:

The ownership of the world's oil tankers changed significantly between 1990 and 2009. In 1990 U.S. based companies owned more tonnage of large oil tankers than any other nation.[63] By 2009, the US had fallen to sixth place and Greece had become, by far, the largest tanker-owning nation, with roughly a quarter of the international fleet of large oil tankers. (Figure 7)

[63] All statistics presented in this paper refer only to tankers greater than 50 thousand dead weight tons.

Figure 7: Tanker Tonnage by Country (1990, 2000, 2009)



Of the top ten tanker-owning countries in 2009, China and Germany experienced the greatest growth in tanker ownership between 1990 and 2009. Chinese and German firms owned just 16 and 6 large tankers respectively in 1990. By 2009, the Chinese-owned fleet had increased to 110 tankers and the German-owned fleet had increased to 130 tankers. While the two countries experience similar growth in their fleets, the apparent drivers were very different. Chinese growth appears to have been primarily driven by a government decision to support Chinese ownership of oil tankers, while the expansion of the German-owned fleet was driven by private investment in limited liability partnerships (KG funds) that emerged in Germany in the mid-1990s as investment vehicles for vessel ownership. [64] [65]

64 Andrew Erickson, Gabe Collins, Beijing's Energy Security Strategy: The Significance of a Chinese State-Owned Tanker Fleet, Orbis, Volume 51, Issue 4, 2007, Pages 665-684

65 Stopford, Martin. "Maritime Economics." London ; New York: Routledge, 2009. 306-307.

Figure 8:

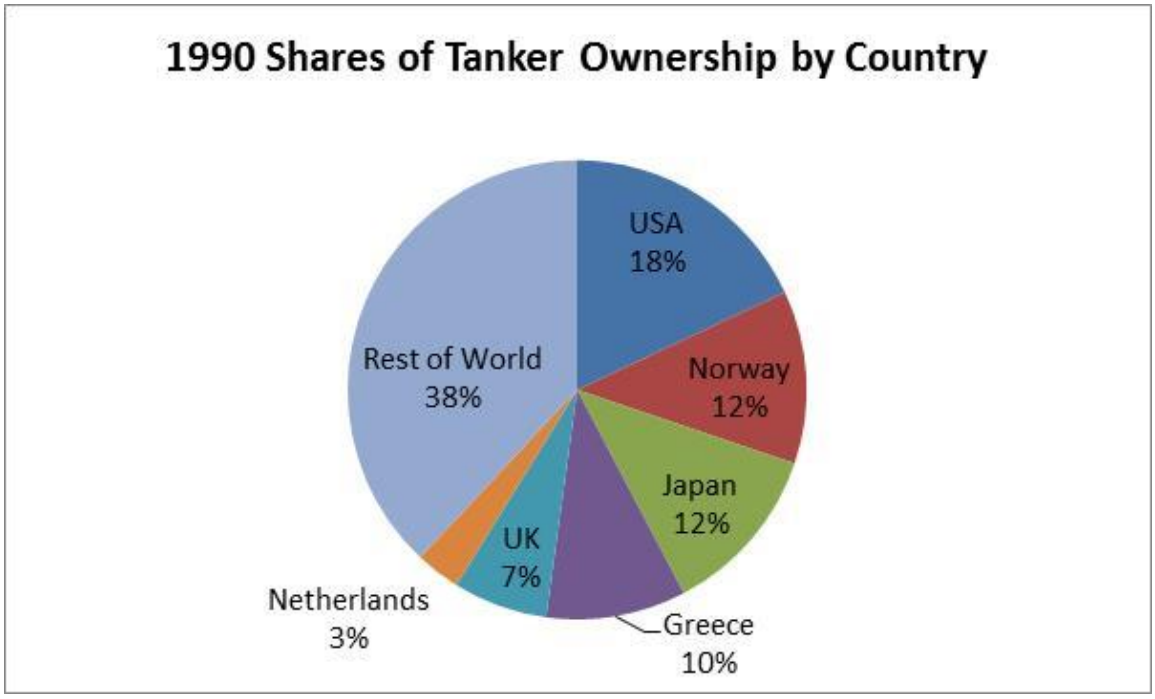
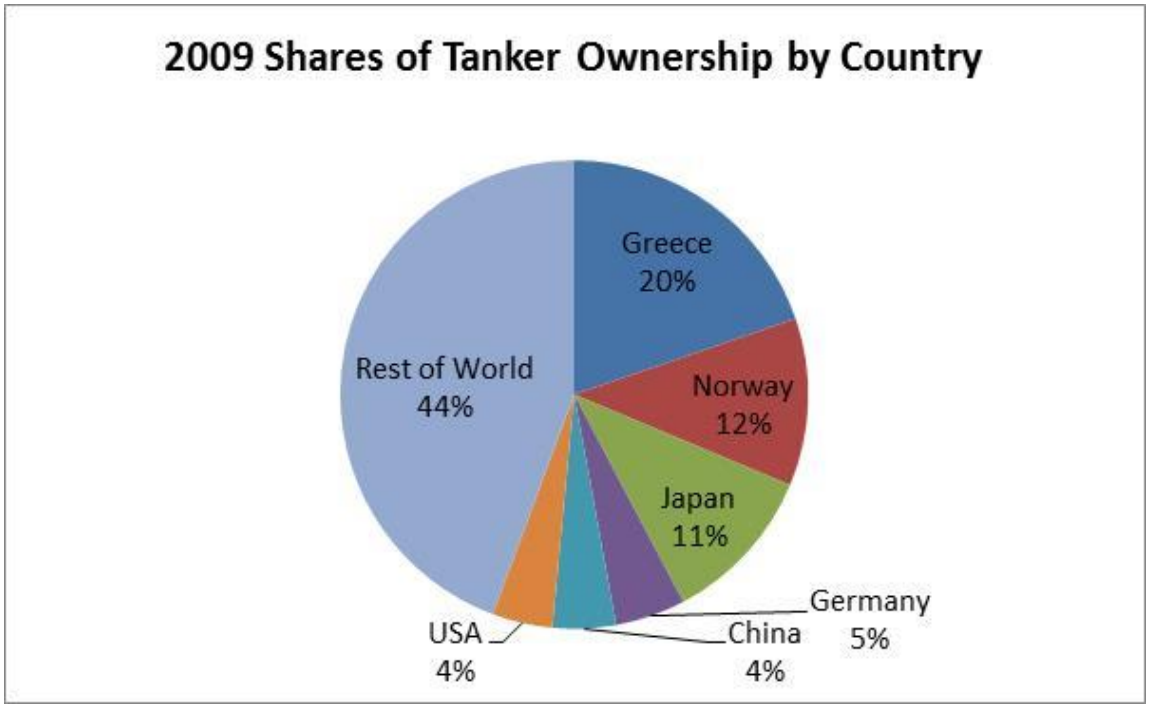


Figure 9



The drop in tanker ownership by US companies was both in total tonnage capacity and in the number of ships. In 1993 US based companies owned 218 large tankers, by 2000 that figure had dropped to 158 and by 2009 it had fallen to just 110 large tankers. Other countries that saw major drops in large tanker capacity include Spain, France, and the UK, all three of which were in the top ten in 1990 but not in 2009. The drop in tanker ownership by US companies followed the general decline in the ownership of oil tankers by the major oil companies.

More than 350 different companies in 50 different countries owned the 2,500 largest tankers in 2009. The largest single owner of large oil tankers is the independent Japanese shipping company Mitsui O.S.K., which owns 73 tankers larger than 50 thousand dead weight tons, which represents about four percent of the global fleet of large tanker.

Types of vessels

One possible explanation for the level of tanker ownership in a given country is the size of that nation's shipping industry. Table 15 presents data on vessel ownership levels in 1993 and 2009 for the three major categories of large ocean-going vessels: oil tankers, container ships, and bulk carriers. Container ships are cargo vessels that can carry thousands of 20- or 40-foot containers of various dry good. Bulk carriers are vessels that are designed to carry large quantities of unpackaged bulk cargo, such as coal and ore. These three vessel types constitute 95 percent of the total vessel tonnage in the data. Table 15 shows the level of vessel ownership of the 25 largest tanker owning nations in 2009.

A quick review of the data in Table 15 suggests that some of the largest tanker owing nations, like Greece, Germany, and Japan, are also large owners of bulk carriers and container ships. By comparison, the vessel owners in several of the major oil exporting countries, like Saudi Arabia, Kuwait, and Russia, maintain ownership of relatively few non-tanker vessels. Norway, which is both a major oil exporter and a large tanker owning nation, owned more than 8 million tons of bulk tanker tonnage in 2009, but that is relatively small compared to the tonnage of tankers owned by Norwegian firms.

Table 15: Vessel Ownership by Country (Top 25 Tankers Owners in 2009)

	tanker tons		container tons		bulk carrier tons	
	1993	2009	1993	2009	1993	2009
Greece	35,477,083	75,274,168	0	4,143,609	21,989,176	73,252,911
Norway	20,192,547	40,067,256	59,283	159,960	9,037,107	8,351,111
Japan	22,278,734	39,050,867	474,804	10,382,935	27,215,864	84,431,613
Germany	1,814,644	18,503,404	388,070	22,158,839	3,213,098	14,570,389
China	2,470,363	15,209,260	0	5,294,044	5,214,855	38,078,347
Saudi Arabia	2,168,745	13,560,385	0	0	77,996	63,261
United States	24,484,462	12,315,780	803,576	1,741,507	7,025,841	6,833,658
Hong Kong	8,686,631	11,810,151	0	2,396,431	8,682,635	16,449,269
Iran	5,060,649	10,707,811	0	366,278	0	2,097,865
Singapore	3,709,987	9,897,442	214,108	2,965,737	1,306,174	4,146,370
Russia	1,868,965	9,258,734	0	0	1,037,002	237,475
Belgium	317,095	8,628,337	0	53,511	1,659,887	2,925,138
Malaysia	174,176	7,905,079	65,535	268,918	408,809	421,335
Denmark	2,616,017	7,597,750	1,319,629	14,369,408	1,920,877	2,155,242
India	3,265,850	7,558,918	0	57,790	1,194,902	4,593,412
Korea	1,758,243	6,786,423	431,165	3,416,508	9,085,457	21,264,549
Italy	2,037,123	5,931,945	0	103,296	4,150,279	5,649,807
Israel	1,831,177	5,224,567	0	2,128,327	2,027,162	7,813,444
UK	3,516,661	5,158,530	229,499	515,386	3,727,333	1,138,657
UAE	249,179	4,031,302	0	0	64,657	2,407,456
Kuwait	3,462,378	3,103,559	0	727,425	0	0
Brazil	1,573,113	2,958,966	0	0	2,067,437	2,404,763
Turkey	1,380,108	2,906,186	0	0	1,426,438	4,620,520
Netherlands	4,393,805	2,090,889	202,480	0	151,038	559,289
Libya	1,028,305	1,725,917	0	0	0	0

Outliers in the data:

Four countries are identified as consistent outliers in data: Greece, Norway, Japan, and the US. (See Figure 10 to Figure 14 below.) Greece, Norway and Japan are the three largest tanker-owning nations, while the US is the largest oil-importing nation and was one of the largest tanker-owning nations throughout the 1990s. Figure 10 shows each nation's tanker tonnage against its oil imports in 2000. Figure 11 shows tanker tonnage against oil exports. Figure 12 and Figure 13 show tanker tonnage against bulk tonnage and container tonnage respectively, while Figure 14 shows tanker tonnage against per capita GDP. As the four largest tanker owning nations in 2000, Greece, Norway, Japan, and the US are well above the other countries in every graph. The US is also the largest oil importer, which places it well to the right of the other countries in Figure 10.

Given the scale of ownership in these four countries relative to the rest of the population, it is likely that they could have an outsized impact on the regression results. Each econometric model is therefore run with and without these four countries.

Figure 10: Scatter Plot of Oil Tanker Tonnage and Oil Imports in 2000

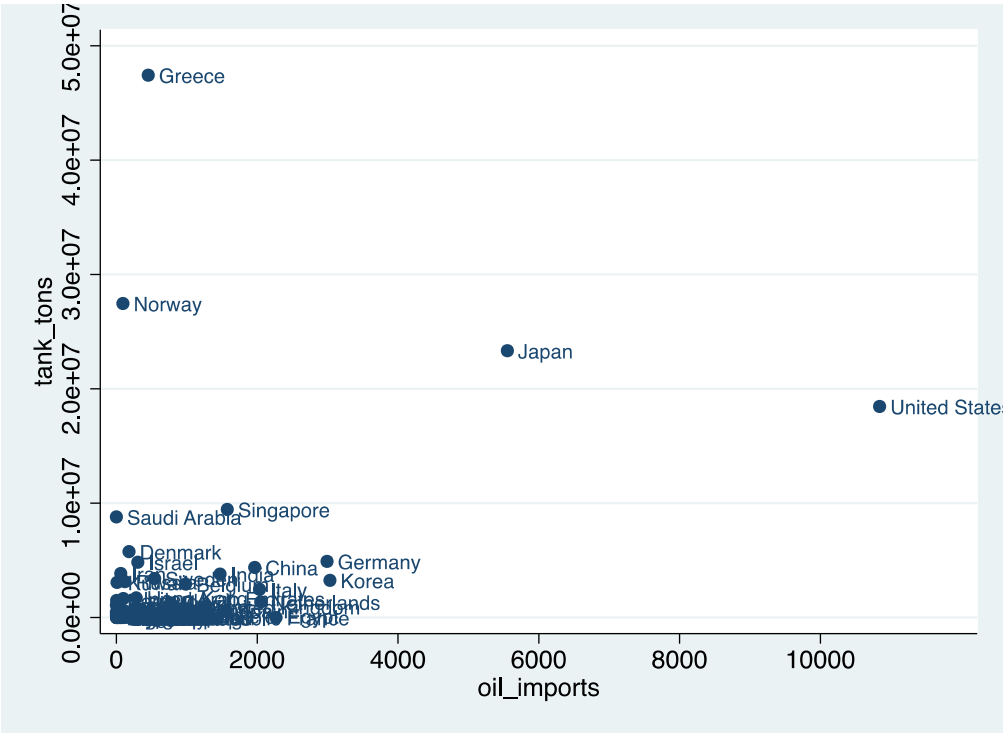


Figure 11: Scatter Plot of Oil Tanker Tonnage and Oil Exports in 2000

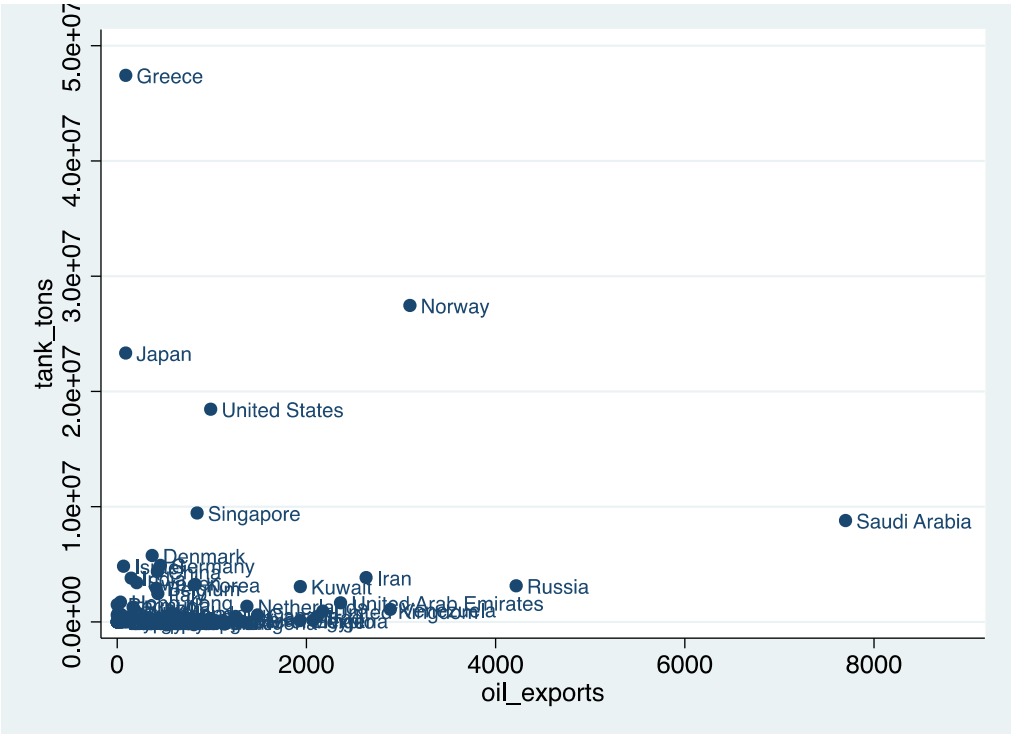


Figure 12: Scatter Plot of Oil Tanker Tonnage and Bulk Tonnage in 2000

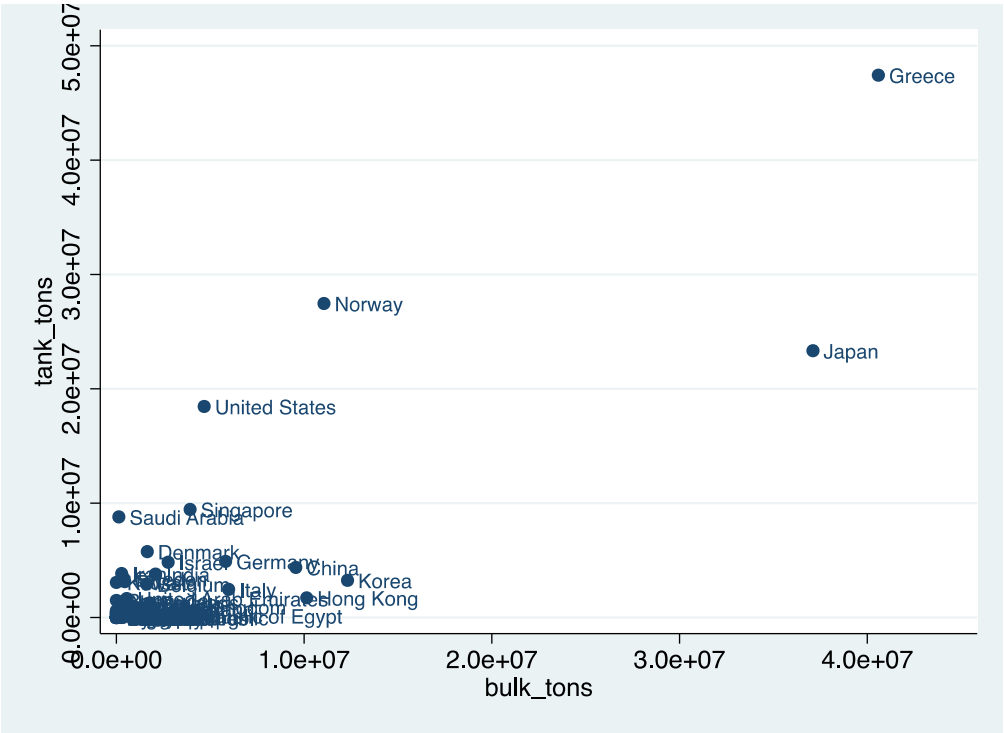


Figure 13: Scatter Plot of Oil Tanker Tonnage and Container Tonnage in 2000

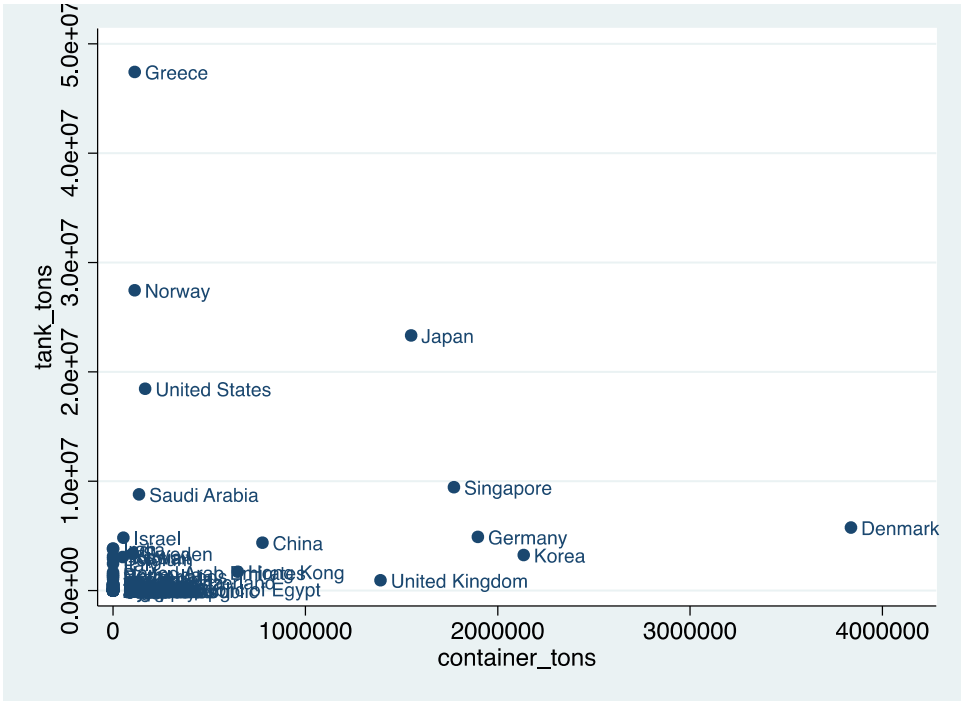
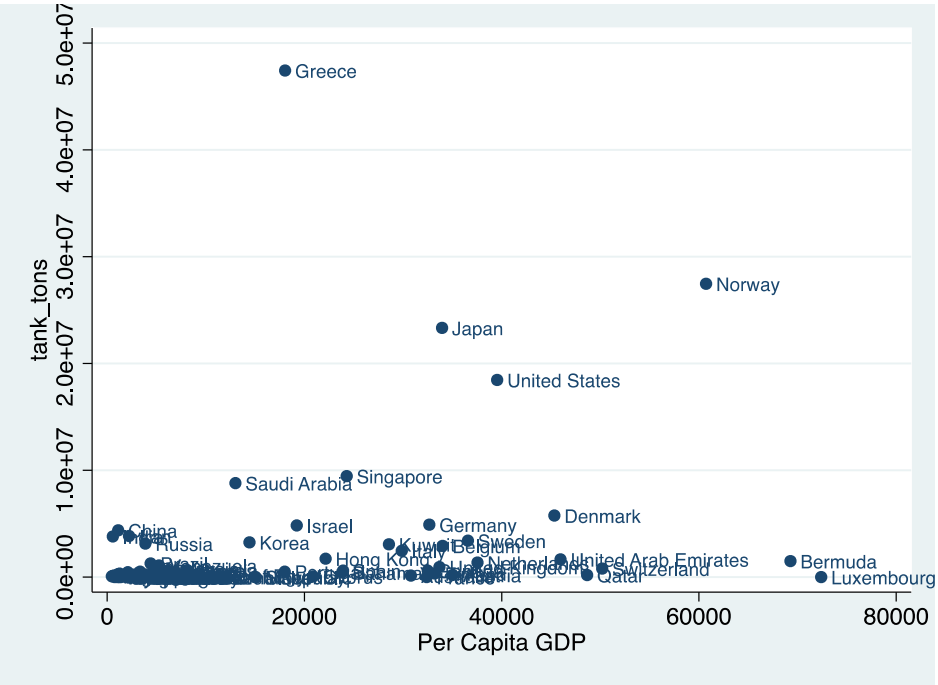


Figure 14: Scatter Plot of Oil Tanker Tonnage and Per-Capita GDP in 2000



III. Econometric Models

This essay uses two panel data techniques to assess the drivers of tanker ownership across countries. The first set of regressions uses pooled cross-sectional ordinary least squared (OLS) with yearly dummy variable. The second set of regressions uses fixed effects analysis. For each approach, separate regressions are run for countries where the government owns tankers and countries were the government owns no tankers. The models are also run with and without the outliers presented in the previous section.

Approach 1: Pooled OLS regressions

The first approach uses pooled cross-sectional OLS to determine the drivers of tanker ownership at the national level. Each country (*i*) is observed each year (*t*) from 1993 to 2009. The variables are described in Table 16.

$$tank_tons_{i,t} = oil_imports_{i,t} + oil_exports_{i,t} + bulk_tons_{i,t} + container_tons_{i,t} + oil_share_energy_{i,t} + pc_gdp_{i,t} + pc_gdp_{i,t}^2 + CLC_{i,t} + gov_owned_fleet_i + years_t + \epsilon_{i,t} \quad (1)$$

Table 16: Variables in the Analysis

Variable	Description	mean	S.D.
tank_tons$_{i,t}$	The total tonnage of tankers owned by entities in country *i* in year *t*	2,914,444	7,578,349
oil_imports$_{i,t}$	The average daily oil imports into country *i* in year *t* in thousands of barrels per day	655	1,469
oil_exports$_{i,t}$	The average total daily oil exports into country *i* in year *t* in thousands of barrels per day	690	1236
bulk_tons$_{i,t}$	The total tonnage of bulk carriers owned by entities in country *i* in year *t*	2,602,466	8,404,958
container_tons$_{i,t}$	The total tonnage of container ships owned by entities in country *i* in year *t*	367,833	1,540,815
oil_share_energy$_{i,t}$	The fraction energy consumption in country *i* in year *t* met by oil imports	0.428	0.442
pc_gdp$_{i,t}$	Per capita GDP for country *i* in year *t*	17,500	317
CLC$_{i,t}$	Dummy variable equal to one if country i is a member of the International Convention on Civil Liability for Oil Pollution Damage	0.502	0.500
gov_owned_fleet$_i$	Dummy variable equal to one if the government of country *i* owned any large tankers in 2010.	0.455	0.498

The level of oil tanker ownership in each country (*tank_tons*) is the dependent variable in the analysis. Oil imports and exports are included in the model as separate variables to determine if a nation's level of oil trade is a significant determinant of tanker ownership. The tonnage of bulk carriers and container ships are included to determine if specialization in shipping services is driving tanker ownership at the national level. Imported oil's share of total energy consumption is included to test the notion that energy security is a significant driver of tanker ownership across countries. The nation's per-capita GDP is included to control for the possibility that firms in wealthier nations are more likely to own tankers. The square of per-capita GDP is also included to control for the possibility that the relationship between national wealth and tanker ownership is non-linear. A dummy variable for membership in CLC-92 by country *i* in year *t* is included to control for the possibility that liability for oil spills is influencing the decisions of potential tanker owners in county *i*.

Models one through five vary only in the countries that are included in the analysis. The first model includes all countries, while the second model excludes the outliers (Greece, Norway, Japan, and the United States). The model is then run separately for countries where the government did, and did not, own tankers in 2010. The idea is to see if the drivers of tanker ownership where are the same in these two sets of countries. An underlying assumption of model is that that the factors that drove government ownership of tankers in 2010 were also present from 1993 to 2009.

Model three includes only observations of the 25 countries where the government owned some share of the tanker tonnage in 2010. Models four and five are restricted to the 30 countries where the government owned no share of the tanker tonnage in 2010.

Regression five is the same as regression four but excludes the outliers. There are 20 countries in the dataset that owned no tankers in 2009. I do not know whether the governments of those countries would have owned the nation's tankers, so those 20 countries are not included in models three, four, and five, but are included in models one and two.

Yearly dummy variables were included in each model, which allows for separate intercept terms for each year to account for the possibility that the population distribution could have changed over time. The standard errors are clustered by country under the assumption that the model's errors are uncorrelated across countries, but may be correlated across years for each country. The results of the pooled OLS regressions are shown in Table 17.

Table 17: Pooled OLS Results

dependent variable: tank_tons

	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**
	All countries		gov_owned_fleet =1	gov_owned_fleet = 0	
		outliers excluded			outliers excluded
	tank_tons	**tank_tons**	**tank_tons**	**tank_tons**	**tank_tons**
pc_gdp	3.725	17.25	28.39	-40.94	51.65*
	(0.06)	(0.74)	(0.40)	(-0.49)	(1.85)
pc_gdp2	0.000931	-0.000158	-0.00102	0.00133	-0.000565
	(0.67)	(-0.52)	(-0.71)	(0.97)	(-1.60)
oil_imports	289.8	50.11	1407.4*	93.56	-173.5
	(0.42)	(0.15)	(1.90)	(0.12)	(-0.63)
oil_exports	1276.8***	974.8***	1048.8***	3796.7**	460.3
	(4.95)	(7.56)	(7.95)	(2.10)	(1.06)
oil_share_energy	382080.0	784402.0*	235701.4	291772.2	808371.4
	(0.70)	(1.69)	(0.27)	(0.55)	(1.11)
bulk_tons	0.747***	0.346***	0.228	0.784***	0.352**
	(3.99)	(5.32)	(1.37)	(4.09)	(2.45)
container_tons	-0.170	0.535***	-0.328	-0.0672	0.561***
	(-0.44)	(6.65)	(-0.37)	(-0.19)	(5.21)
clc	-432098.5	-251690.2	-590943.3	-1264605.0*	-205024.5
	(-1.17)	(-1.63)	(-1.63)	(-1.86)	(-0.74)
_cons	-404213.0	-417205.6	-920980.0	185228.5	-511433.8
	(-1.02)	(-1.27)	(-1.40)	(0.16)	(-0.96)
N	1249	1181	411	500	432
adj. R-sq	0.751	0.665	0.692	0.762	0.632

* p<0.10 ** p<0.05 *** p<0.010
t statistic in parentheses

The results from model one, which includes all 75 countries in the data set, suggest that only two of the variables are significant indicators of tanker ownership: oil exports and bulk tonnage ownership. Both variables are strongly significant and the overall fit of the model is fairly good (adjusted $R^2 = 0.751$). When the outliers are removed in model two, the results generally hold, though there are some important differences. In model two, oil exports and bulk tonnage continue to be significant

indicators of oil tanker ownership, but container tonnage is now strongly significant as well, which suggests that the relationship between tanker tonnage and container tonnage is not as strong with the four outliers as it is with the rest of the countries in the analysis.

When the regression is restricted to the countries where the government owns some fraction the tanker fleet (Model 3), the results suggest that only oil exports and imports are significant indicators of tanker ownership. Bulk tonnage and container tonnage are not significant predictors of tanker ownership for these countries. This is an important result. It suggests that the presence of a shipping industry is not a significant indicator of tanker ownership in the countries where the government owns part of the tanker fleet.

When the regression is restricted instead to the countries where the government owns **no** tankers (Models 4 and 5), the results are very different. Oil imports are no longer significant but bulk tonnage is strongly significant. Oil exports are significant in model four, but not in model five, which excludes the outlier countries. Container tonnage is significant in Model 5, but not in Model 4. The fact that the results for Model 3 are significantly different than the results for Models 4 and 5 suggests that there are very different drivers of tanker ownership in countries where the government in involved in tanker ownership relative to countries where that is not the case. In particular, the level of oil trade is the primary predictor of tanker ownership in countries where the government owns tanker, while the size of the nation's shipping industry appears to be the primary driver of tanker ownership in countries where the government owns no tankers.

There are three other results worth noting. First, energy security (measured as imported oil's share of total energy consumption) is only significant in the second regression, providing minimal evidence that energy security is an important driver of tanker ownership across countries. Second, membership in CLC-92, which has is a negative coefficient in all of the models, is significant in Model 4 and is nearly significant in Models 2 and 3. This provides some evidence that the higher liability limits imposed by CLC-92 may have dissuaded oil tanker ownership by firms in member countries.

These results provide insights into the relationship between the level of oil tanker ownership and the independent variables. To understand how changes in these variables influence tanker ownership over time, the next section uses fixed effects estimation

Approach 2: Fixed Effects regressions

The second panel data approach uses fixed effects estimation to determine the drivers of tanker ownership at the national level. The advantage of fixed effect estimation is that omitted variables do not bias the estimates, assuming those omitted variables do not change significantly over time. For example, Greece has an ancient maritime history and is home to many family-owned businesses that have specialized in shipping for generations. Those factors have almost certainly had an influence on the level of Greek tanker ownership, but they did not change between 1993 and 2009 and therefore can be considered a country-specific fixed effect in this analysis. It would be difficult to capture all of the potential factors that drive tanker ownership at the national level in an empirical model.

The variables in the fixed effects models are the same as in the pooled OLS models. The level of tanker ownership (tank_tons) continues to be the dependent variable. The results are in Table 18. The results of the fixed effects regressions tell the same basic story as the pooled OLS regressions. Bulk tons and container tons are significant indicators of tanker ownership, except in countries where the government owned some or all of the tankers in 2010 (model eight). In those countries the level of oil exports appears to be the principle driver of tanker ownership. Unlike the pooled OLS models, oil imports are not a significant indicator of tanker ownership in any of the fixed effects regressions.

Table 18: Fixed Effects Results

Dependent Variable: tank_tons

	Model (6)	**Model (7)**	**Model (8)**	**Model (9)**	**Model (10)**
			gov_owned_ fleet =1	gov_owned_fleet =0	
		outliers excluded			outliers excluded
	tank_tons	**tank_tons**	**tank_tons**	**tank_tons**	**tank_tons**
pc_gdp	92.97	67.60	359.0	191.2	15.68
	(0.93)	(0.78)	(1.46)	(1.26)	(0.15)
pc_gdp2	-0.000869	-0.00126*	-0.00689*	-0.00150	-0.000700
	(-0.77)	(-1.86)	(-1.83)	(-1.20)	(-0.92)
oil_imports	-593.6	-698.9	709.1	-572.8	385.4
	(-1.24)	(-1.09)	(1.15)	(-0.93)	(0.48)
oil_exports	325.3	859.5**	861.1***	-4572.4***	-2223.8*
	(0.48)	(2.35)	(3.10)	(-2.98)	(-1.76)
oil_share_energy	93469.0	-85137.1	-1551610.3*	372514.0	-27707.7
	(0.31)	(-0.36)	(-1.85)	(0.67)	(-0.07)
bulk_tons	0.388***	0.468***	0.0715	0.392***	0.662***
	(4.10)	(4.36)	(0.24)	(3.90)	(3.94)
container_tons	0.426***	0.456***	1.011	0.463***	0.441***
	(2.98)	(4.46)	(0.76)	(3.24)	(4.90)
clc	296709.9	240407.8	514746.8	229426.1	81077.3
	(1.51)	(1.43)	(1.58)	(0.81)	(0.33)
_cons	743232.3	-41548.0	-1382649.1	2058393.3	1251920.2
	(0.57)	(-0.04)	(-1.48)	(0.64)	(0.56)
N	1249	1181	411	500	432
R-sq	0.554	0.509	0.529	0.636	0.636

* p<0.10 ** p<0.05 *** p<0.010
t statistic in parentheses

In Model 6, which includes all 75 countries in the data set, bulk tonnage and container tonnage are the only significant indicators of tanker tonnage. When the outliers are excluded from the regression (Model 7) oil exports become significant, and per capita

GDP squared also becomes significant, indicating that tanker ownership starts to decline as countries reach higher levels of per capita income.

One result from the fixed effects regression that is hard to explain is the negative relationship between oil exports and tanker ownership in countries where the government owns no tankers (Models 9 and 10). It is unclear why an increase in oil exports would drive down tanker ownership, or why a reduction in oil exports would increase tanker ownership. The presence of the outlier countries appears to be part of the explanation, because the coefficient and significance of the result is reduced substantially when the outliers are removed from the regression (Model 10).

IV. Conclusions

This essay uses panel data techniques to explore the dramatic changes observed in country-level oil tanker ownership between 1993 and 2009. The primary finding of this analysis is that there are different drivers of tanker ownership in countries where the government owns tankers relative to countries where the government owns no tankers. In countries where the government maintains some ownership of the national fleet, the nation's level of oil trade is the main driver of tanker ownership. In countries where the government does not own tankers, the size of the domestic shipping industry (as measured by the ownership of non-tanker vessels) appears to be the main driver.

This model does not explain why governments own tankers in some countries but not others. A quick review of the countries where the government owns tankers, however, indicates that vertical integration is likely an important driver. Table 19 shows that 16 of the 25 countries in which the government owns tankers are net oil exporters.

The presence of a state-controlled oil industry in most of these countries is almost certainly a contributing factor in their government's ownership of tankers, though more research would be needed clearly define that relationship.

Table 19: Countries with and without Government Ownership of Tankers

Government Owned Tankers	No Government Owned Tankers	No Tankers
Angola*	Argentina	Austria
UAE*	Australia	Bulgaria
Brazil	Belgium	Colombia*
Chile	Bahamas	Czech Republic
China	Bermuda	Estonia
Algeria*	Canada*	Gabon*
Ecuador*	Switzerland	Hong Kong
Spain	Cyprus	Lebanon
Croatia	Germany	Malta
Indonesia	Denmark	Mauritius
India	Egypt	Panama
Iran*	Finland	Peru
Iraq*	France	Philippines
Jordan	UK*	Poland
Kuwait*	Greece	Romania
Libya*	Israel	Slovenia
Mexico*	Italy	Syria
Malaysia*	Japan	Tunisia
Nigeria*	Korea	Ukraine
Oman*	Luxembourg	Uruguay
Pakistan	Latvia	Yemen
Russia*	Netherlands	
Saudi Arabia*	Norway*	
Venezuela*	Portugal	
Vietnam*	Qatar*	
	Singapore	
	Sweden	
	Thailand	
	Turkey	
	United States	

* net oil exporter

This analysis does not specifically address the causal direction of tanker ownership, but the direction is relatively clear for some variables. For instance, it is

highly unlikely that the ownership of oil tankers is driving a nation's oil import and export levels. Refineries and other consumers would not choose to import or export more oil simply because domestic entities owned tankers. It also highly unlikely, with the possible exception of Greece, that oil tanker ownership has a significant impact on a nation's per capita GDP. To the extent a relationship exists between per capita GDP and tanker ownership, the former almost certainly drives the latter.

The causal relationship between the ownership of tankers and other vessels is less clear. This model does not clarify whether oil tanker ownership precedes or follows the ownership of other large vessels. Instead, the model simply uses container ship ownership and bulk carrier ownership as measures of the size of the domestic shipping industry. CLC-92 membership is another example where causality could move in both directions. While it is certainly possible that CLC membership could impact the decision of potential tanker owners to buy or sell an oil tanker, shipping companies would probably seek to influence its government's decision to join CLC-92. That would be especially true in large tanker-owning nations such as Greece, Japan, and Norway. One should not assume, however, that shipping firms and tanker owners would uniformly be against joining the convention. The largest tanker owning companies may welcome the additional financial requirements under CLC-92, which could force some of the smaller tanker-owning companies out of the market.

A possible avenue for future analysis would be to explore more closely the impact of CLC-92 on oil tanker ownership in the member nations. The results of the analysis presented here are inconclusive on that question. This analysis exploits the fact that different countries ratified the protocol at different times between 1996 and 2006 to

determine whether joining the convention had a negative or positive impact on tanker ownership at the national level. Further analysis could explore the size of the firms that were affected by a nation's decision to join CLC-92. Given the asset requirements under CLC-92, one might expect smaller firms to exit the market upon its implementation, which is a testable hypothesis. The analysis would require a fully specified model of exit from the tanker market and a good measure of the asset level of small shipping companies, which may be difficult to find.

V. Appendix

For the pooled OLS results presented in Table 17, heteroskedasticity was corrected by using clustered robust standard errors, and the results were presented with and without the major outliers. As a robustness check, Table 20 below presents the results of weighted least squared (WLS) regressions using the same data. The four major outliers (Greece, Japan, Norway, and the United States) are included in the results presented in Table 20. While the exact form of heteroskedasticity is not known, Figure 15 and Figure 16 suggest that the variance of the error terms from an OLS regression are probably proportional to *bulk_tons* and *container_tons*. The WLS regressions in Table 20, therefore, combine these to variables and uses each country's non-tanker-tonnage (*bulk_tons* + *container_tons*) as the proportionality factor.

The results in Table 20 largely support the earlier findings. For countries where the government owns some or all of the tankers, the level of oil exports is the primary driver of oil tanker ownership. For countries where the government owns no tankers, the size of that countries shipping industry (as measured by its non-tanker-tonnage) appears to be the primary driver of tanker ownership. It is worth noting that the number of observations in Table 20 is smaller than Table 17, because some countries owned no bulk carriers or container ships during certain annual observations. Those observations were automatically dropped because Stata could not divide the regression equation by a proportionality factor of zero.

Figure 15

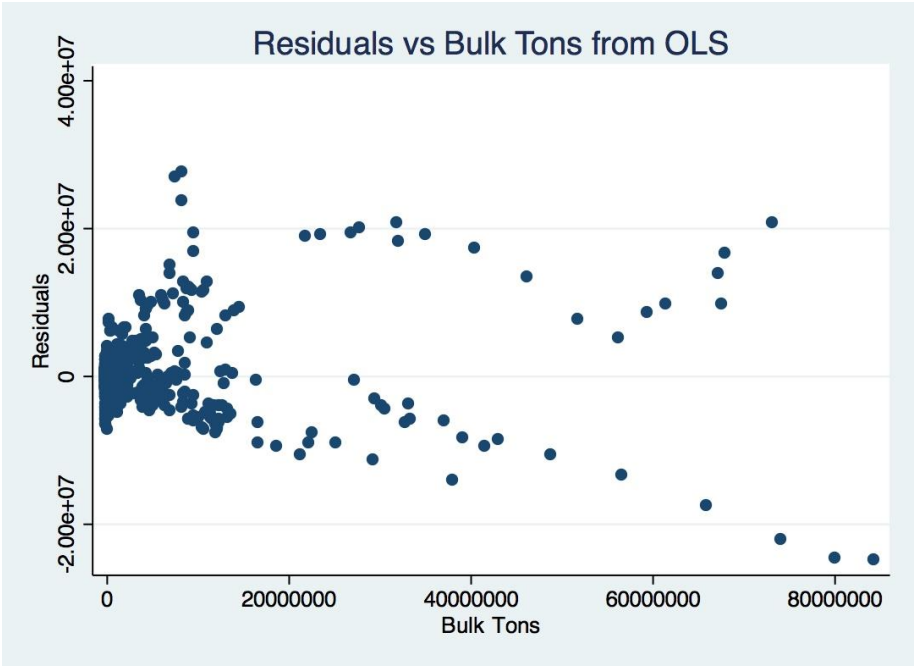


Figure 16

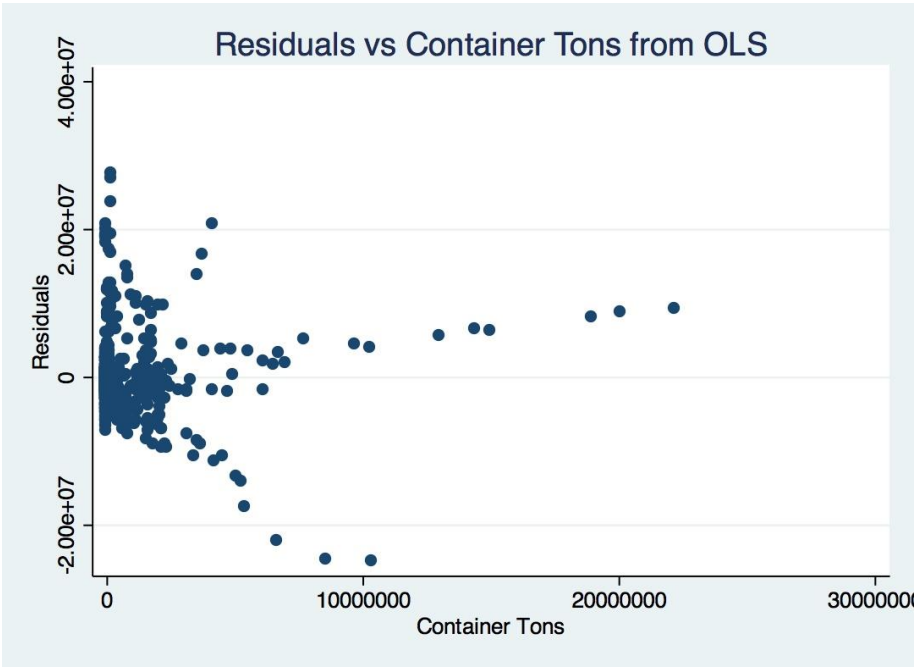


Table 20: Weighted Least Squared Results using Total Non-Tanker Tonnage as the Proportionality Factor

dependent variable: tank_tons

	Model (11)	**Model (12)**	**Model (13)**
	All countries	gov_owned_fleet = 1	gov_owned_fleet =0
	tank_tons	**tank_tons**	**tank_tons**
pc_gdp	10.55	163.7***	32.41*
	(0.49)	(2.91)	(1.77)
pc_gdp2	-0.000113	-0.00385***	-0.000277
	(-0.47)	(-3.22)	(-1.21)
oil_imports	389.8	1736.4	593.6
	(0.92)	(1.59)	(1.20)
oil_exports	1194.5***	1137.5***	228.9
	(13.23)	(15.88)	(0.29)
oil_imp_share_energy	530004.2*	321626.0	301329.3
	(1.88)	(0.45)	(1.30)
bulk_tons	0.745***	0.143	0.816***
	(4.47)	(0.51)	(3.90)
container_tons	0.0560	0.248	0.0408
	(0.22)	(0.14)	(0.16)
clc	-142028.7	-852300.5**	-3138.2
	(-0.71)	(-2.39)	(-0.02)
N	895	286	445
adj. R-sq	0.813	0.901	0.586

* p<0.10 ** p<0.05 *** p<0.010
t statistic in parentheses

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Chapter 6:

Conclusion:

This dissertation considers two separate but related topics pertaining to oil tankers. Chapters 3 and 4 focus on liability for oil spills, while Chapter 5 explores the drivers of tanker ownership across countries. The theoretical model developed in Chapter 3 contributes to the economic literature on liability by modeling an oil company's decision to use its own tanker as opposed to contracting with a shipping company to transport its oil. The model was motivated by the fact that the current theoretical models of liability in the economic literature omit many of the important elements of the liability regime for oil spills, which is somewhat surprising, given that few environmental risks get more public attention than large oil spills. Several testable predictions are derived from the model. Most importantly, the model shows how the imposition of cargo-owner liability affects the profits, and therefore the decision-making, of an oil company.

Chapter 4 continues the work of Chapter 3 by empirically testing two of the predictions of the theoretical model using shipping industry data on US port-calls by oil tankers, and exploiting the variation in oil spill liability laws across US states. The results of these empirical tests suggest that tankers owned by oil companies are indeed more likely than other tankers to call on ports that extend liability to cargo-owners, as predicted by the theoretical model. The empirical results also find that tankers calling on

ports that extend liability to cargo owners tended to be younger and were more likely to be double hulled, which is also consistent with findings of the theoretical model.

These theoretical and empirical results offer policy-relevant insights into the imposition of cargo-owner liability. States that choose to impose cargo-owner liability can expect to see an increase in port calls by major-owned tankers, which are likely to be operated with more preventative care than other tankers. States that imposes cargo-owner liability can also expect to see an increase in the quality of the tankers calling on their ports, relative to states that do not extend liability to cargo owners.

It is likely, however, that there are dynamic elements to these effects. If additional states were to impose cargo-owner liability, the analysis presented in this dissertation suggests that the overall level of chartering by oil companies would decline. The tanker companies would almost certainly respond to this decrease in demand for tanker services by attempting to make chartering more attractive to oil companies. Equation 15 from Chapter 3 suggests that the oil company's profits when chartering are increasing in the tanker company's level of assets (or insurance coverage), so one possible response by the tanker companies might be to increase their level of insurance coverage, which has actually happened in recent years. The International Group of P&I Clubs now covers third-party damages of up to $7.5 billion through its pooled reinsurance contracts – up from $4.25 billion in 2005. This dramatic increase in the level of insurance coverage is probably intended, in part, to assure oil companies that any vessel they charter will have sufficient insurance to cover third-party damages in the event of an oil spill, thus reducing (but not eliminating) their exposure to extended liability when chartering.

One area of potential future research is to investigate why some states have imposed cargo-owner liability and others have not. OPA-90 gives individual states the ability to pass their own oil-spill liability laws, yet only 7 of the 23 coastal states have explicitly extended liability to cargo owners. One must assume that the other 16 coastal states have decided that the cost of imposing cargo-owner liability outweighs the benefit. The models presented in Chapters 3 and 4 give some insights into the possible benefits of cargo-owner liability for individual states, as stated above. Unfortunately, the analysis does not provide insight into the expected costs to individual states of imposing cargo-owner liability. These costs may involve the expected response of oil companies (beyond the chartering decisions explored in Chapters 3 and 4) to a change in liability laws.

A full analysis of the expected costs to individual states of imposing cargo-owner liability would require an examination of the activities of oil companies and tanker companies before and after cargo-owner liability was imposed. Unfortunately, as stated previously, I was not able to find any instances of an individual state imposing cargo-owner liability since the early 1990s.[66] Given this lack of recent data, an analysis of the expected costs of imposing cargo-owner liability would likely be limited to an examination of the commercial, legal, and political debates of the issue within each state. The fact that the two largest oil-importing states – Texas and Louisiana – do not extend liability for oil spills to cargo owners suggests that the oil industry in those states may be influencing the political debate around this issue.

[66] Petroleum Industry Research Foundation. "Transporting U.S. Oil Imports: The Impact of Oil Spill Legislation on the Tanker Market." Report prepared for the U.S. Department of Energy. Washington D.C. June 1992. Appendix II, Details of State Statues.

Chapter 5 asks a separate but related question: why do some nations own more oil tankers than other nations? The empirical models in Chapter 5 uses panel data techniques to tests two hypotheses for the changes in oil tanker ownership at the national level observed between 1993 and 2009. The first hypothesis is that a nation's level of oil trade drives its level of tanker ownership. The second hypothesis is that the size of a nation's shipping sector (as measured by the number of non-tanker vessels) drives its tanker ownership. The results show that both factors are significant, but in different sets of countries. The level of oil trade is only a significant indicator of tanker ownership in countries were the government owns tankers, while the size of a nation's shipping sector is only a significant indicator of tanker ownership in countries where the government does not own tankers.

These results imply that the drivers of tanker ownership at the national level are strongly influenced by the government's role in the sector. In countries where the government is not involved in the shipping sector, the primary drivers of ownership of tankers are the same as the drivers of ownership of other vessels. But that is not the case in countries where the government owns some or all of the tanker fleet. Sixteen of the 25 countries with a government ownership of tanker are also net oil exporters. Many of those countries, including Saudi Arabia, Iran, and Iraq, have oil sectors that are dominated by the government, which suggests that vertical integration in their state-owned oil sectors is probably an important factor in the results.

Energy security, as measured by a nation's dependence on imported oil for its overall energy consumption, does not appear to be an important driver of tanker ownership at the national level across countries. That does not mean, however, that

energy security is not an important driver for certain countries. In China, for instance, there appears to be a genuine belief within some segments of the government that the ownership of oil tankers by Chinese companies helps to ensure China's access to the international oil market. The fact that some governments take a different view of energy security than other governments is not surprising, given the particular economic and historical context of each nation.