Private Security and the Provision of International Public Goods[*]

Gregory DeAngelo[†]

Taylor Leland Smith[‡]

March 25, 2016

Abstract: Private solutions to property rights and personal protection evolve in environments that are weakly institutionalized, as well as regions with strong legal systems as well. In this work we examine the evolution and effect of private maritime security on international public safety – through the reduction of piracy - by analyzing International Maritime Organization vessel security data from 2007 - 2014. We find strong evidence that private security generates a strong direct effect on piracy prevention, significantly decreasing the likelihood that a privately secured vessel is boarded, experiences a hostage situation or suffers injuries or fatalities. Additionally, we observe an external effect of private security, whereby more privately secured vessels in the waterways significantly reduce the likelihood of an attack against unsecured vessels both contemporaneously and in the future. We conclude that the private provision of piracy prevention has been more efficiently and successfully provided than public attempts to generate the public good.

Key Words: Private Security, Criminal Deterrence, International Public Goods, Maritime Trade

JEL Code: K42, H41, F1

[*] We are grateful to Jacob Shapiro, Andrew Young, Alon Harel, Fernando Gomez, Rustam Romaniuc, Benjamin Powell, Bryan McCannon, Kaitlyn Harger, Alex Imas and participants at the MetaLawEcon Workshop at the University of Amsterdam, Western Economic Association, Public Choice Society Meetings, and Southern Economic Association Meetings for helpful comments on an earlier draft.
[†] West Virginia University, gregory.deangelo@gmail.com, corresponding author.
[‡] Texas Tech University, Taylor.L.Smith@ttu.edu

I. INTRODUCTION

The costs associated with maritime piracy are staggering. The World Bank (2013) estimates that Somali piracy alone imposed a considerable distortion on trade in 2010; the roughly US$1.62 trillion in global trade travelling along routes affected by piracy experienced between 0.75 to 1.49 percent increase in total ad valorem trade costs, amounting to an estimated US$12 to $24 billion annual cost to the global economy. Additionally, thousands of seafarers have been injured or taken hostage, and hundreds have lost their lives.[1] Moreover, maritime piracy is not a problem that is isolated to the region of Somalia, but rather an international problem, with pirates also operating in Southeast Asia, West Africa, the Arabian Sea, and South America.[2]

The provision of piracy prevention is a considerably difficult threshold public good to generate. Unlike the prevention of proscribed activities that have been examined in other analyses (e.g. Ayres and Levitt, 1998), piracy prevention faces several hurdles that make it uniquely different. First, piracy often occurs in international waterways, where property rights are not clearly established. Second, most piracy is prevalent near countries that are weakly institutionalized, decreasing the likelihood that local governments will be able to provide piracy prevention.[3] Third, international efforts to establish a centralized authority (e.g. intergovernmental naval forces) to generate piracy prevention will likely struggle with the vastness of the open waterways. Given these concerns, we explore whether private solutions – in the form of private security – can generate direct and external piracy prevention benefits.

The theory of the provision of public goods, which originated with the work of Samuelson (1954), is well established - see Kaul, Grunberg, & Stern (1999) and Kaulet al. (2003) for an overview of this literature. According to this theory, when private and social costs do not align in an international context an under-provision of international public goods will be the result. As Cornes and Sandler (1996) note: "it is very unlikely that an international public good could be provided only on a pure voluntary basis". Divergence between private and social costs result in a market failure: "social demand cannot be satisfied through market mechanisms since the social and private benefits cannot

---

[1] Perhaps more concerning than the economic costs of maritime piracy are the costs associated with injury and the loss of human life. As the World Bank (2013) notes: "As many as 3,741 crewmembers of 125 different nationalities have fallen prey to [Somali] pirates, with detention periods as long as 1,178 days. Reportedly, 82 to 97 seafarers have died either during the attacks, in detention after poor treatment, or during rescue operations". While these figures are specific to Somalia, they indicate very high human costs are associated with piracy. According to Oceans Beyond Piracy (2014), 3,654 seafarers were exposed to pirate attacks in Southeast Asia in 2014 alone. Of those attacks, 93% resulted in a successful boarding. Once a vessel is boarded, seafarers not only face a very high likelihood of death and/or kidnapping, but are also subject to frequent physical and psychological abuse. The prevention of maritime piracy not only carries considerable economic consequences, but also consequences for the vessel crews that facilitate roughly 90 percent of all global trade, with over 10 billion tons of world seaborne trade each year (Clarkson Research Services Limited, 2013).

[2] As Barker (2013) notes: "In recent years, the deployment of multinational forces in the waters around the Horn of Africa, particularly off the coast of Somalia, has created the perception that maritime piracy is exclusively a Somali problem. This is far from the case. Pirates also currently operate in places like Bangladesh, Indonesia, the Malacca Straits, the South China Sea, West Africa and South America." This also can be confirmed via the International Maritime Organization Global Integrated Shipping Information System; https://gisis.imo.org/Public/Default.aspx, and International Chamber of Commerce Commercial Crime Services International Maritime Bureau Piracy Reporting Center; https://icc-ccs.org/piracy-reporting-centre

[3] In fact, Somali pirates often view themselves as the "coast guard" in the absence of a formal coast guard, charged with preventing illegal fishing in Somali territorial waters (Bahadur, 2012).

converge" (Bellais, 2013). Therefore, the provision of international public goods through coordinated intergovernmental efforts is considered necessary.

However, a theory of the private provision of public goods has also been established by Bergstrom, Blume, & Varian (1986), Andreoni (1988), and Andreoni (1989).[4] Ostrom's (2010) contributions also discuss the conditions under which private solutions to commons problems can be expected. In all, these theories predict some amount of a crowd-out effect for private contributions that results from public contributions. Still, there are conditions under which public goods could be privately provided. However, Kotchen's (2006) extension of the theory of the private provision of public goods to green markets established that green markets can have beneficial or detrimental effects on environmental quality and social welfare. Applying this logic to piracy prevention, there could be cause for concern that private contributions to a public good, such as piracy prevention, might not yield greater safety.[5]

Examples of private contributions to public goods have been discussed, but these examples tend to be only descriptive. Coase (1974) offers an interesting discussion of the private and public provision of public goods, detailing that both private and public provisions of lighthouses existed. Additionally, Holcombe (1997) offers several real-world examples of the provision of public goods. His examples of privately provided public goods include microcomputer software, as well as television and radio broadcasting signals. Both of these works conclude that the provision of public goods not only can be provided privately, and perhaps even should.

Applying the theory of the private provision of public goods presents many of the same problems that are observed in these examples. When resources are allocated towards the prevention of maritime piracy there is a nonrival deterrence effect. If the allocation of those resources discourages piracy and decreases the number of pirates on the seas, all vessels nonrivalrously enjoy the decreased threat. Furthermore, because the number of pirates is decreased, if resources are allocated towards protecting certain vessels it is difficult to exclude other vessels from enjoying the safer environment. As such, the prevention of maritime piracy can be considered to be an international public good. Theory suggests that, all else equal, because private suppliers will find it difficult to obtain compensation from all vessels enjoying their services, there will be under-provision of piracy prevention. However, theory does not predict *no* private provision of piracy prevention, and the experimental literature suggests that positive levels might well be observed. Moreover, theory is also silent on the relative effectiveness of that private provision vis-à-vis some form of intergovernmental provision.

In this paper, we examine the private provision of piracy prevention using a data set of pirate attacks, which details whether private security was onboard. We then estimate the direct effect – in the form of reductions in the probability of being boarded, hijacked, injured, shot or killed – of

[4] International public goods have been extended specifically to maritime piracy by Bellais (2013).

[5] Empirical examinations of the theory of public goods also exist (Andreoni (1988), Laury & Holt (1998), Isaac, Walker, & Williams (1994)). In experimental settings where private contributions are the only form of public good production, free-riding is seldom observed in single-shot games, but becomes more prevalent in repeated games. Moreover, Andreoni (1993) establishes that incomplete crowding-out is observed in situations where subjects are taxed, providing evidence that people experience some private benefit from contributing to the public good.

private security on vessel safety as well as the external effect of private security on unsecured vessels. We find a strong deterrent effect of private security, significantly reducing the likelihood of being boarded, hijacked, or injured. Moreover, we find strong evidence that the presence of private security significantly reduced the overall number of attacks. We conduct a series of robustness checks in order to confirm that our observed effect is the true impact of private security on vessel and waterway safety.

In the next section, we provide an overview of modern piracy, while the following section discusses the potential for private and public enforcement in piracy prevention. In Section 4 we provide a discussion of the data used in the empirical analysis, which we conduct in Section 5. A series of robustness tests are run in Section 6, while Section 7 concludes.

II. AN OVERVIEW OF MODERN MARITIME PIRACY

The model of maritime piracy is relatively consistent. The start-up costs of a piracy operation are estimated to be as little as $500 (Chalk, 2010). Pirates operate from fishing vessels called "motherships" from which they detect potential targets. Once detected, pirates chase down vessels on skiffs (smaller boats with an outboard engine) and attempt to board the vessel using ladders and other climbing devices. If the pirates succeed at boarding the ship they seek to capture and make hostages of the crew while stealing high value loose valuables (money, watches, electronics, etc.). Depending on the situation, pirates often use the crew, rather than the vessel itself as collateral for ransoms. The pirates that actually carry out the attacks are often financed and/or commanded by more senior leaders on shore. Depending on the particular pirate organization, leaders will negotiate with shipping companies and/or insurance companies. During the negotiations, hostages are sometimes mistreated or tortured. In many instances, these hostages are seriously injured or killed. Occasionally hostages will be rescued by government navies or private security firms. More often than not, however, the negotiation ends with payment of the ransom. It is not uncommon for these ransoms to exceed US$5 million.

Piracy off the Coast of Somalia

While piracy is a nuisance in places other than Somalia, much of the discussion of maritime piracy is focused on Somalia due to its rapid surge and decline throughout the period of 2005 – 2013. Somalia, located on the tip of the Horn of Africa, is engulfed in a decade's long civil war, with tensions escalating throughout the 1990's and again since 2006. Since the fall of the Siad Barre Dictatorship in 1991, Somalia has lacked any unified, recognizable central government (The World Bank, 2013). Despite a long history of lawlessness, civil war and poverty, piracy off the Horn of Africa is a relatively new phenomenon, with the first successful hijacking in April 2005. The number of hijackings surged in 2005, declined briefly from 2006 to 2007, followed by an even more dramatic surge from 2008 to 2011.[6] During the time period 2011 - 2014 the number of attacks has declined by 54 percent, with only a handful of successful hijackings during this time frame.[7] Meanwhile, tensions within Somalia have not subsided and, to date, no end to the conflict is within sight.

[6] In fact, hijackings increased by 350 percent from 2005 to 2011.
[7] See (Pitney Jr. & Crocker, 2013) for an excellent and detailed history of Somali Piracy and the use of Private Maritime Security.

Piracy in the Gulf of Guinea

Maritime piracy on the Western side of Africa is also not a new phenomenon, with attempted hijackings occurring as early as 1995. West Africa piracy has become increasingly common since 2010, however, with attacks escalating from 4 hijackings in 2010 to 23 hijackings in 2013. It is estimated during the peak of West African piracy, vessels transiting in the Gulf of Guinea faced a probability of hijacking as high as 1/750. Assuming these estimates are accurate, the worst periods of Gulf of Guinea piracy were similar to those off the Horn of Africa. Very recently, West African piracy has declined to a minimal amount of activity. Coastal states surrounding the Gulf of Guinea have permitted the use of private military and security company's (PMSCs) until a very recent ban by the government of Nigeria.

Piracy in Southeast Asia

Maritime piracy has been a problem in Southeast Asia since at least the time of European colonization. A grey area has always exist between pirates, police, military and militia. A considerable proportion of international trade transits through the Malacca Straits, between Indonesia and Malaysia. In this region especially, maritime piracy has always thrived. This is becoming increasingly true as incidents of pirate attacks have become more frequent in the recent past. Additionally, PMSCs are forbidden by the governments of Indonesia and Malaysia, which is confirmed in the data we examine.[8] While we cannot utilize the data from Southeast Asia in the examination of the effectiveness of private security on vessel safety, we can utilize Southeast Asia as a sort of control group in the examination of private security on piracy prevention.

Motivations for Piracy

Though piracy exists in places outside of Somalia, many of the efforts to explain the motivations for maritime piracy are focused solely on the motivations of Somali pirates. The onset of Somali piracy is typically attributed to the failed state of Somalia, the persistent poverty, and the mere fact that Somalia constitutes the ideal environment for maritime piracy to thrive. This "anarchy and poverty narrative" is consistent throughout the literature on Somali piracy. As Roger Middleton of the UK-based Chatham House Institute observes: "With little functioning government, long, isolated sandy beaches and a population that is both desperate and used to war, Somalia is a perfect environment for piracy to thrive" (CNN, 2008). Savridis and LeBron (2011) note "[Piracy in the Horn of Africa] is the fruit of anarchy, extreme poverty, and the severe failure of the rule of law." The anarchy and poverty narrative falls considerably short, however. Somalia has lacked any universally recognizable form of government since the fall of the Mohammed Siad Barre Dictatorship in 1991. Moreover, Somalia has experienced poverty since at least the 1970's (Leeson, 2007a). The anarchy and poverty narrative does not explain why the sudden onset of Somali Piracy does not occur until 2005-2008. In fact, Somalia has experienced rapid economic growth since the fall of the Siad Barre Dictatorship

[8] The 1982 United Nations Convention on the Law of the Sea dictates, the legitimate monopoly over the use of force in matters of security lies with the State and not with ships passing through those waters. This leads Osnin (2006) to note that "the supply of such services by private companies can be viewed as impinging on the littoral states sovereignty [in the Straits of Malacca]." Moreover, in order to move into the China Sea, a vessel must pass through the Straits of Malacca, where PMSCs are not permitted.

(Powell, Ford, & Nowrasteh, 2008).[9] In other words, by this definition, Somalia has always been the ideal environment for piracy.

Most importantly, the anarchy and poverty narrative fails to explain the motivations for piracy in other locations around the world. Not only do places like Bangladesh, Indonesia, Malaysia, and Nigeria have functioning governments, they are also not as poor as Somalia (International Monetary Fund, 2015). Indeed, Bangladesh, Malaysia and Indonesia experienced 75%, 160% and 150% respective surges in the rate of piracy from 2010 to 2014. Meanwhile, Somalia experienced a 98% decrease in attempted hijackings during this same timeframe.[10] Therefore, we conclude that other factors must contribute to the prevalence of maritime piracy.

One explanation for the rise of Somali piracy is the decimation of Somali fisheries (The World Bank, 2013). Somali fishermen, in response to over-fishing by other countries, took to piracy in an attempt to protect their fishing interests. This narrative is supported by evidence that Somali pirates identify as more of a Coast Guard than a group of bandits (Bueger, 2013). It is also supported by the fact that many Somali pirates were or are also fishermen (Chalk, 2012). Moreover, fishing related disputes have also been used to explain the sudden surge of maritime piracy is Bangladesh and Nigeria (Oceans Beyond Piracy, 2014). These motivations may explain, at least in part, the prevalence of maritime piracy, but do not fully explain why Somali pirates, for example, have since ventured further into international waters to hijack oil tankers and other non-fishing commercial vessels that are not impacting fishing waters.

One likely explanation is that pirates were originally motivated by a variety of interests, including the decimation of fisheries, but that these interests change when pirates discovered the ease with which ransoms can be collected. Indeed, from 2005-2012 Somali pirates claimed ransoms between $339 and $413 million (The World Bank, 2013). These settlements reached a record average of US$5.04 million per ransom in 2011 (The World Bank, 2013).[11] All of this suggests that maritime piracy is most easily explained by the mere fact that it is both easy and highly lucrative.

III. MARITIME PIRACY PREVENTION: PUBLIC AND PRIVATE

The large costs associated with maritime piracy, along with the nonrival and nonexcludable characteristics of piracy prevention, have motivated intergovernmental efforts to provide such prevention services. However, there is little evidence to indicate that these efforts have been particularly effective. Alongside these intergovernmental efforts, private maritime security companies (PMSCs) have (where legal) have offered their services for profit. In this paper we are interested in evaluating the effectiveness of the PMSCs in providing international public good of maritime piracy prevention. Here we provide some background on both the provision of piracy prevention – both intergovernmental and private – an informally discuss the evidence regarding its effectiveness.

---

[9] Powell et al. (2008) find that Somalia's relative economic performance has improved during its period of statelessness. Leeson (2007a) also demonstrates how the people of Somalia are, in fact, better off stateless through a comparative analysis of Somalia before and after their government's collapse.

[10] There were 220 attempted hijackings in 2010 and only 3 in 2014.

[11] We were able to obtain ransom information from governmental reports, media accounts and occasionally from press releases by insurance companies. This resulted in that is released in 230 instances of ransom payments, with an average payout of US $3.3 million.

Intergovernmental Naval Efforts

One approach to overcoming piracy concerns would be to establish a navy, or divert naval resources to the fight against piracy. However, navies exist in all of the regions where maritime piracy is prevalent, yet in each of these regions naval efforts to prevent maritime piracy appear to have been largely ineffective. Very rarely are pirate attacks thwarted by (inter)government navies. The Indonesian navy, for example, is incapable of patrolling the vastly intricate system of islands that make up Indonesia. In the region of Somalia, intergovernmental naval forces have been deployed to prevent maritime piracy, leaving Somali waters perhaps more adequately patrolled than those of Southeastern Asia and West Africa.

The United Nations and European Union have both endorsed the use of force off Somalia, and substantial forces have been deployed (The World Bank, 2013).

"Three multinational maritime coalitions—the EU Operation Atalanta of the European Naval Force Somalia (EUNAVFOR), Operation Ocean Shield from the North Atlantic Treaty Organization (NATO), and the Combined Maritime Task Forces 151 (CFT-151)— are present to protect ships transiting off the Horn of Africa" (The World Bank, 2013).

In addition, at least seven countries acting individually have deployed ships or aircraft in the area. The international response to Somali piracy manifest in an intergovernmental naval occupation in Somali waters. European Union Operation Atalanta of the European Naval Force Somalia has operated since December 2008. EUNAVFOR claims legitimacy in the resolutions of the United Nations' Security Council.[12] The coalition is composed of more than 20 vessels and approximately 2,000 military forces. The coalition includes 26 countries.[13] U.S. Naval Forces Central Command, which covers the Persian Gulf, Gulf of Oman, Gulf of Aden, Red Sea, Arabian Sea, and Indian Ocean, established "Combined Task Force 151" in January 2009. The sole mission of Task Force 151 is to conduct anti-piracy operations in the region of Somalia. The task force is composed of two-dozen ships from 25 countries.[14] NATO also established Operation Allied Provider, which is composed of 30 vessels contributed by India, China, Russia, Pakistan, Saudi Arabia, the Netherlands, Malaysia, South Korea, Japan and the UAE. For the purposes of this paper, these three operations will be referred to as the intergovernmental naval occupation of Somali waters.

Private Military and Security Companies

As noted in Dixit (2007), while we might expect private solutions to property rights and personal protection to evolve in environments that are weakly institutionalized, they often exist in the shadow of the law in regions with strong legal systems as well. As growth in piracy and ransoms continued – especially in East Africa – solutions to the growing security concerns for vessels traversing these waterways were being considered. For example, vessels began utilizing avoidance measures, such as speeding their vessels up, using zig-zag maneuvers to create water wakes that smaller vessels could

---

[12] Resolutions 1814, 1816, 1838, 1846 (2008) and 1897 (2009) by the United Nations' Security Council.

[13] France, Spain, Germany, Greece, the Netherlands, Italy, the UK, Norway, Croatia, Montenegro, and the Ukraine among others.

[14] The United States, the UK, Canada, Denmark, France, Germany, Greece, Italy, the Netherlands, Pakistan, Saudi Arabia, Spain, South Korea, Turkey and Yemen, among others.

not traverse, sounding alarms/whistles, or even shooting a flare gun to attract attention to the attempted attack. Whether in response to these efforts not working, or not, some vessels began adopting more extreme measures by hiring PMSCs.

The Effectiveness of Enforcement

In order to provide safety from piracy in international waters, vessels must provide a credible deterrence mechanism to keep pirates from attacking the ship. In this way, our examination of the use of private security contributes to the economics and deterrence literature (see Becker (1968) for the seminal application of rational choice decision making to criminals). Fiorenti and Peltzmann (1997) provide a comprehensive collection of essays that consider the economics of criminal organization. [15] In short, economic models of crime suggest that increases in expected costs should reduce engagement in criminal activity. Therefore, measuring the effectiveness of enforcement is of great interest to economists. Ehrlich (1975) uses state-level data on variations in index crimes across the United States to identify the existence of a deterrent effect of law-enforcement activity on all crimes, providing some of the first estimates of the effectiveness of law enforcement in reducing crime. More recently, attempts to measure the effectiveness of enforcement are accomplished by relying on natural experiments in criminal enforcement. DeAngelo & Hansen (2014) estimate the causal effect of police on traffic fatalities and injuries by focusing on a mass layoff of Oregon State Police in February 2003. Their estimates, for example, suggest that a 35 percent reduction in police presence results in a roughly 10-20 percent increase in fatalities and injuries. McCormick and Tollison (1984) look at the effect of adding a third referee in professional basketball on the number of fouls omitted, while Levitt (1997) looks at random shocks to police forces due to electoral cycles on crime. Finally, Evans and Owens (2007) focus on the provision of federal grants allowing local agencies to employ additional police on criminal outcomes.

Measuring the effectiveness of private security is also of interest, however. Benson (1989) (1990), Ellickson (1994), Jones & Newburn (1998), Leeson (2007a) (2007b) and Stringham (2015) have all challenged the contention that private property and state-made law are inextricably intertwined. They have shown, collectively, that the commercial sector is capable of establishing and enforcing its own laws. [16] Private enforcement of private property rights is very common, as private efforts benefit from certain advantages over public efforts. Most notably, private efforts are often preemptive, as opposed to the typical after-the-fact efforts of public law enforcement. [17] For example, Ayres & Levitt (1998) show how Lojack devices provide a positive externality by greatly reducing social costs associated with car theft. In the case of Lojack, a public good is efficiently provided voluntarily as Lojack users deter car thieves from attempting a theft due to the uncertainty associated with being

---

[15] See also, e.g., Anderson (1979); Polinsky and Shavell (1979); Reuter (1983); Jennings (1984); Jankowski (1991); Dick (1995); Sherman, et. al., (1997); Konrad and Skaperdas (1998); Garoupa (2000); Skaperdas (2001); Imrohoroglu et al. (2004); Chang, Lu and Chen (2005); and Lee and McCrary (2009).

[16] Landes & Posner (1975), Cloninger (1975), Clotfelter (1978), Friedman (1984) and Benson (1989) provide the earliest accounts on the privatization of law enforcement in depth. In recent years, the literature on the effects of private security on public safety has grown. Examples of this literature include the role of private effort by bail bondsmen and bounty hunters Helland & Tabarrok (2004), business improvement districts Cook & MacDonald (2011), and individuals (Shavell (1991), Naysnerski and Tietenberg (1992), Hylton (1996) on public safety. See Friedman (1984), Kahan (1999) and Bohnet, Frey, & Huck (2001) for theoretical contributions on the role of private law enforcement and Sykes (2005) for a discussion of private versus public enforcement of international economic law.

[17] In the instance of maritime piracy, this is especially true. Intergovernmental navies that occupy waters off the Horn of Africa are rarely capable of responding to pirate attacks until undesirable outcomes have occurred. Much of the activities conducted by these navies are after-the-fact rescue efforts (Bellais, 2013).

caught in the act. Additionally, DeAngelo et al. (2015) show that fighting in the National Hockey League is up to twice as effective at reducing hits and egregious penalties when compared to penalties assessed by the league officials, showing further evidence of the effectiveness of private deterrence.

Efforts to measure the effectiveness of private law enforcement efforts, like those of Ayres & Levitt (1998) And DeAngelo et al. (2015), are quite difficult, however. A number of empirical hurdles exist; researchers typically rely on aggregated data and struggle to differentiate private efforts from other factors that affect the prevalence of crime (including public efforts). Without incident-based data where public enforcement is non-existent, it is difficult, if not impossible, to disentangle the deterrent effect of private versus public enforcement measures.

A study into the prevention of maritime piracy provides the unique combination of an incident-level experiment into private law enforcement efforts. Unlike most analyses, incident-level data coupled with the relative statelessness of international waters enables the direct measurement of a voluntary provision of international public goods. In the relative statelessness of international waters, maritime shipping companies rely on PMSCs to provide protection from pirates. In other regions, such as Southeast Asia, PMSCs cannot and are not utilized as they are illegal. Indeed, a very high proportion of Southeast Asian piracy takes place within coastal territorial waters, where PMSCs are patently forbidden. Using data from the International Maritime Organization (IMO) Global Integrated Shipping Information System (GISIS) database, we measure the effectiveness of PMSCs in reducing the likelihood of pirate attacks, boarding and hijackings. We also measure the spillover benefits of PMSC utilization to unsecured vessels and identify a statistically identifiable effect of PMSC on the provision of international public goods. Indeed, we find that private maritime security serves as a significant long-term deterrent of piracy. The paper proceeds with a discussion of the data that we will utilize in Section Two followed by a presentation of our result in Section Three. Finally, Section Four concludes the paper and provides a series of policy implications from empirical exercise.

IV. DATA

In order to analyze the effect of private security on the safety of vessels on the water, we gather information about every attack reported to the International Maritime Orgnization (IMO) for the period 2007-2014. Each incident report contains a large amount of information: date, ship name, ship type, IMO number, area, latitude/longitude, incident details, consequences of attack, action taken by the crew and the agency receiving the incident report. The most important pieces of information for the purposes of this research is the description of the incident details and consequences. This information provides a written description of the events surrounding the incident as recounted by the individuals who were attacked and/or first responders to the incident. Using google's *word2vec* extraction technique, we document information associated with each incident from the description and incident details provided to the IMO (Mikolov et al., 2013).[18]

[18] *Word2vec* has considerable advantages over regular expression extractions that we leverage in our data extractions. Simple regular expression extractions might falsely characterize data into categories that they do not belong. For example, a statement such as "no weapons were used during the attack" could easily be categorized as weapons being

Contained in our extractions are a series of outcomes (killed, injured, shots fired, boarded, hijacked and hostage), security (private security on board), weapons (knives, guns, grenades, sticks, pipes), action taken (increased the speed, meaneuvered the ship, deployed anti-piracy measures, drew attention to the ship, took evasive action, shot fire hoses at the attackers) [19] and the number of pirates involved in the attack. This information is combined with the type of vessel, and the location of the vessel at the time of the attack (international waters, territorial waters, in port).

For the puprposes of the main empirical analysis we will focus on the period 2007-2014, as this examines the time frame when piracy was at its height and when private security began appearing on vessels.[20] We report the monthly attacks and boardings over the 2007-2014 time frame for the six locations (Arabian Sea, China Sea, East Africa, West Africa, Indian Ocean and Malacca Straits) that are available in our data in Figure 1.[21] The largest number of attacks occured in the China Sea and East Africa with approximately 7.5 and 13.1 attacks and 0.47 and 2.60 boardings, respectively, per month. While monthly attacks fluctuate over time and locations, the number of boardings appear to be relatively low and stable over time.

---

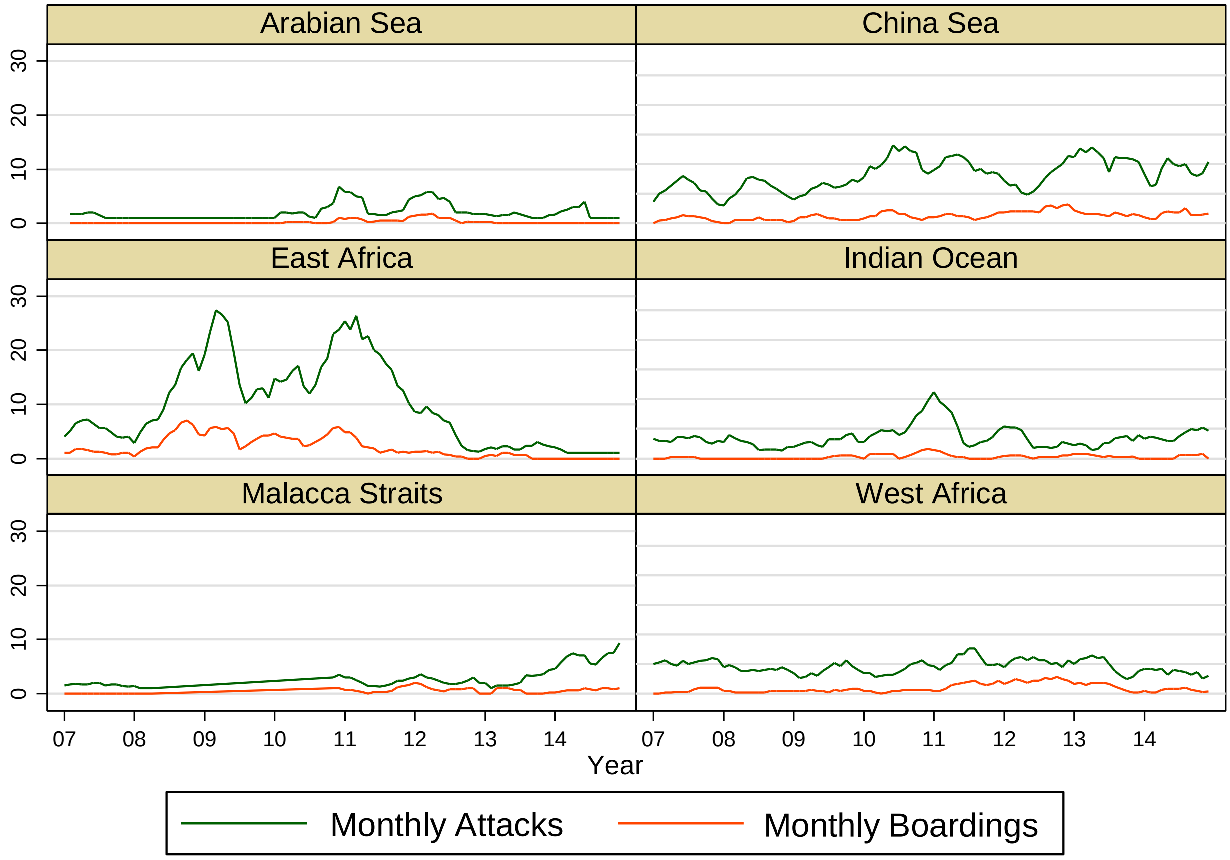
involved. Even if a series of qualifiers are used to ensure that such simple mistakes are not made, they will still underperform relative to an extraction that focuses on features rather than algorithms.

[19] Anti-piracy measures include removing all but needed crew from the deck and maintaining a close watch on all sides of the vessel, drawing attention to the ship entails blowing a whistle, sounding an alarm or illuminating the lights on the ship, while evasive action involves the ship taking one of the previously noted actions, but not explicitly stated in the incident details.

[20] The first documented instance of private security onboard a vessel in our data set is in 2009.

[21] The IMO gathered data from nine locations during this time frame, but we have dropped incidents from South America, the Mediterranean Sea and the North Atlantic Ocean from this analysis since these locations have very few attacks and are not geographically grouped near the locations that experienced a significant number of attacks.

Figure 1: Monthly Attacks and Boardings, 2007-2014



For expositional purposes we have divided our data into two larger areas: regions where it is legal (Arabian Sea, East Africa, Indian Ocean, and West Africa) versus illegal (China Sea and Malacca Straits) to have private security on vessels.[22] In Figures 2A and 2B we examine the probability of a successful boarding during our sample. Figure 2A examines only those regions where private security is legal. While the probability of a successful boarding is positive for many months when no private security is present, the likelihood of a successful boarding when private security is present is zero. Figure 2B displays the probability of a successful boarding for regions where it is illegal to have

[22] Private security predominately acts as a deterrent to pirates by issuing warning shots or returning fire when pirates initiate. In 82 percent of the private security observations in our data, the private security either shot a warning flare, warning shot, or returned fire. In the remaining 18 percent, the private security officers made their presence and weapons known in order to deter the pirates from attacking.

private security.

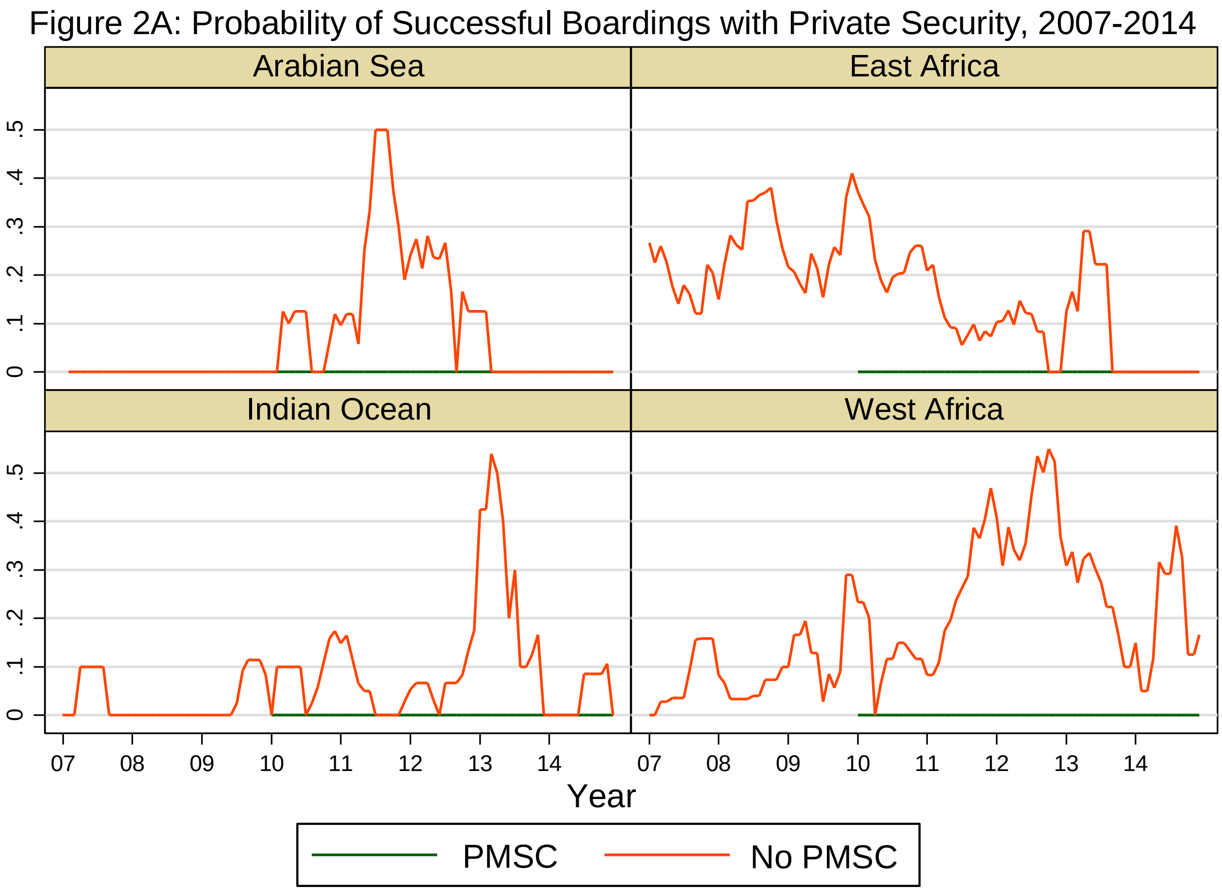
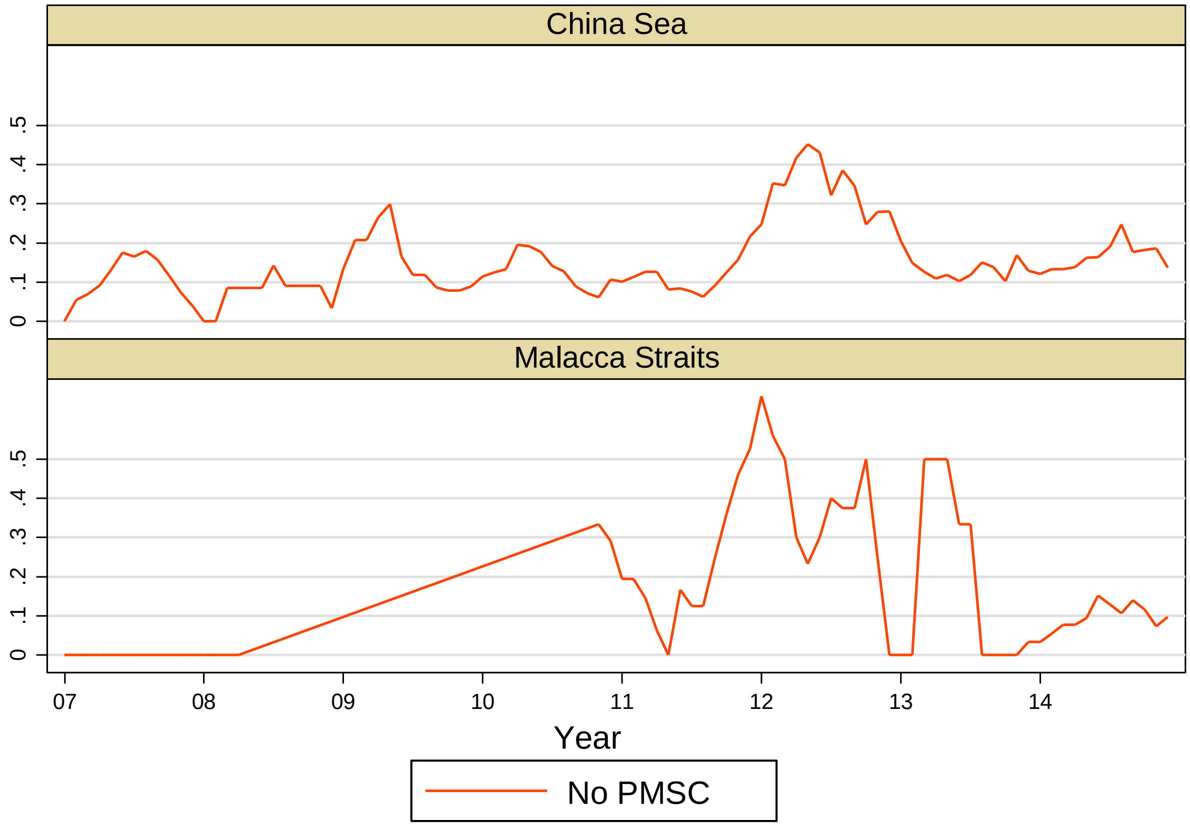


Figure 2B: Probability of Successful Boardings with Private Security, 2007-2014



Given that private security is not legal in the China Sea and Malacca Straits (and also never mentioned in the description of attack in the IMO reports), we narrow our analysis exclusively to locations where private security is legal. Within locations where private security is legal, approximately 90 percent of the attacks were directed at vessels that did not contain private security during the 2007-2014 time frame. Table 1 contains information about the outcome and explanatory variables in locations where private security is legal that we explore in our empirical analysis. Outcome variables are reported in Panel A and include whether a vessel was boarded, individuals were taken hostage, if the ship was hijacked, whether shots were fired, and whether injuries or deaths were experienced.[23]

A few observations are immediately apparent. First, there is not a single instance where a vessel was boarded, hostages were taken, or a vessel was hijacked when private security was reported onboard. Second, vessels without private security face a relatively high likelihood of an adverse outcome, as being boarded, taken hostage or hijacked occur approximately 20, 16, and 14 percent, respectively. Third, while the likelihood of a death is not significantly different on vessels with and without private security, the likelihood of injury is significantly higher on vessels without private security. This observation is despite the fact that the likelihood of shots being fired is considerably higher on vessels containing private security.

[23] Our measure of injuries and deaths include individuals both on the offensive and defensive sides of the attack.

Table 1: Summary Statistics for Outcome and Explanatory Variables

	Private Security onboard (n = 183)	No Private Security Onboard (n=1,606)	t-test
Panel A: Outcome Variables			
Boarding	0.000	0.200	6.771***
	(0.000)	(0.400)	
Hostage	0.000	0.156	5.819***
	(0.000)	(0.363)	
Hijacking	0.000	0.140	5.457***
	(0.000)	(0.347)	
Shot	0.525	0.050	-23.207***
	(0.501)	(0.219)	
Injury	0.055	0.138	3.196***
	(0.228)	(0.345)	
Death	0.011	0.013	0.244
	(0.104)	(0114)	
Panel B: Explanatory Variables			
Gun	0.683	0.529	-3.974***
	(0.467)	(0.499)	
Explosive	0.202	0.118	-3.238***
	(0.403)	(0.323)	
Implement	0.000	0.130	5.215***
	(0.000)	(0.336)	
Shots Fired	0.858	0.344	-14.207
	(0.350)	(0.475)	
Steal	0.016	0.377	10.015***
	(0.127)	(0.485)	
Number of pirates	3.492	3.240	-0.619
	(3.808)	(5.358)	
Barge	0.011	0.007	-0.615
	(0.104)	(0.083)	
Carrier	0.235	0.233	-0.045
	(0.425)	(0.423)	
Tanker	0.454	0.364	-2.369**
	(0.499)	(0.481)	
Container	0.093	0.151	2.126**
	(0.291)	(0.358)	
Cargo	0.120	0.138	0.672
	(0.326)	(0.345)	
Fishing	0.033	0.033	0.015
	(0.179)	(0.179)	
Yacht	0.005	0.014	0.987
	(0.074)	(0.119)	
Tug	0.016	0.016	-0.021
	(0.127)	(0.126)	
Speed maneuver	0.279	0.252	-0.780

	(0.450)	(0.434)	
Anti-piracy	0.087	0.078	-0.546
	(0.283)	(0.268)	
Attention	0.590	0.481	-2.811***
	(0.493)	(0.500)	
Evasive	0.301	0.262	-1.133
	(0.460)	(0.440)	
Hoses	0.055	0.057	0.112
	(0.228)	(0.231)	
International	0.896	0.613	-7.698***
	(0.306)	(0.487)	
Territorial	0.087	0.185	3.297***
	(0.283)	(0.388)	
Port	0.016	0.202	6.223***
	(0.127)	(0.402)	

*, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively. Standard errors reported in parenthesis.

Panel B of Table 1 includes the set of explanatory variables that we include in our analysis. The first three variables (*Gun*, *Explosives* and *Implement*) explain the weapon that pirates were utilizing in their attack. While *Gun* is self-explanatory, *Explosive* and *Implement* might not be. *Explosive* includes rockets, grenades and rocket propelled grenades. *Implement* includes knives, iron bars, sticks, or any other object that could be used as a weapon but that does not shoot or explode. *Steal* is an indicator variable for whether or not the pirates stole items from the ship, while *Number of pirates* is the number of recorded pirates that were attacking the ship. *Barge*, *Carrier*, *Tanker*, *Container*, *Cargo*, *Fishing*, *Yacht*, and *Tug* are indicator variables for the type of vessel. *Anti-piracy*, *Attention*, *Evasive* and *Hoses* are indicator variables for whether these actions were taken by the vessel under attack. *International*, *Territorial* and *Port* are indicator variables for the territorial location of the vessel at the time of the incident. Finally, we include indicators for the geographic location of the incident.

In the second and third columns of Table 1 we calculate the mean for each of the control variables when private security is and is not present, respectively. With the exception of *Number of pirates*, each of the control variables are indicator variables. *Guns* and *explosives* are much more present in attacks on privately secured vessels, while *implements* are used as weapons more frequently on unsecured vessels. Since boarding a vessel is less likely when private security is present, it is not surprising that stealing is more prevalent when private security is not present. The type of vessel and location of attacks are also different across secure and unsecured vessels, although a Kolmogorov-Smirnov test for equality of distributions is not rejected, implying that the distribution of attacks on secured and unsecured vessels are not different from one another.[24] Also, privately secured vessels are more likely to be attacked in international waters, presumably because private security is more present on vessels that are not in or near port.

In addition to the data obtained from the IMO reports, we gathered monthly information about the amount of vessel traffic in the four waterways (Arabian Sea, East Africa, Indian Ocean, and West Africa) that have been impacted by piracy. Through a research agreement with ExactEarth Ltd. we

[24] Appendix Figure 1 displays the distribution of attacks across secured and unsecured vessels.

were able to obtain, on a monthly-level, the total number of vessels that traversed each of these waterways using an Automatic Identification System (AIS) that has been adopted by nearly every vessel using international waterways.[25]

Table 2: Vessel Traffic by Locations

	Months with Attacks	Months without Attacks	t-stat
Arabian Sea	2,491.00	3106.97	-7.418***
	(1484.41)	(356.46)	
East Africa	1184.18	1459.33	-11.589***
	(121.63)	(120.57)	
Indian Ocean	987.10	1255.08	-5.007***
	(191.69)	(103.99)	
West Africa	636.89	886.00	-1.948**
	(337.87)	(40.15)	

*, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively. Standard errors reported in parenthesis.

Table 2 provides the average number of vessels in the waterways by location and across months where piracy does and does not occur. It is clear that the absence of attacks on vessels increases the amount of waterway traffic. In each location, there are, on average, 29 percent more vessels in months where attacks do not occur. Additionally, approximately 63 percent of the months in our data do not include an attack, but in the 37 percent that do experience an attack there is considerable variation in the number of attacks, which we explore in the following section.

V. RESULTS

To empirically examine the effect of PMSCs on vessel safety, we investigate our data in two stages. First, we examine the impact of our main explanatory variables on the probability of an attack occurring in order to ensure that pirates are not systematically avoiding vessels containing private security. Second, we analyze the data at the incident and monthly-level in order to determine the direct and external impact of private security on waterway safety.

III.1 Probability of Pirate Attack

We start by constructing the probability that an attack occurs, utilizing our location by month-level information about the number of attacks and vessel traffic, as $P_{jmy} = \frac{Attacks_{jmy}}{Vessels_{jmy}}$, where *j* denotes the location and *m* and *y* denote the specific month and year. We employ the following specification in examining the driving forces behind the likelihood of an attack:

$$\mathrm{P}_{ijmy} = \alpha_j + \gamma_m + \delta_y + \alpha_j.y + \beta_1 Private\ Security_{ijmy} + X_{ijmy} + \varepsilon_{ijmy} \quad (1)$$

[25] The 2002 IMO Safety of Life at Sea (SOLAS) agreement placed mandates on large passenger vessels and other transportation vessels (e.g. tankers) to utilize AIS technology. Although the AIS technology came online around 2002, the availability of our data did not start until 2010. Given this limitation, we use a linear interpolation to estimate the amount of vessel traffic for the years 2007-2009.

where α_j identifies location-specific effects, $\alpha_j.y$ identifies a location-specific linear time trend, γ_m accounts for month fixed effects, and δ_y accounts for year fixed effects. Additionally, $Private\ Security_{ijmy}$ identifies whether incident *i* involved a vessel with private security in location *j* in month *m* in year *y*. Finally, X_{ijmy} accounts for the incident-level details that vary by location, month and year, including the explanatory variables discussed in Table 1. The results of this estimation are reported in Table 3, where we include specifications at the incident and monthly-levels. Columns I and III estimate the fixed effects regression with controls for incident-level variation at both the incident and monthly-level. Columns II and IV are identical to columns I and III, except that they add a cubic polynomial in latitude and longitude in order to account for potential spatial dependence in pirate incidents (Dell, 2010). To estimate the monthly-level regressions we aggregate all explanatory variables (e.g. total number of vessels with private security onboard) to explain the probability that a vessel was attacked. We only report estimates of the effect of private security on the probability of an attack, noting that our point estimates are precisely estimated zeroes and that no statistically significant relationship exists.[26] We, therefore, conclude that pirates are not systematically targeting with or without private security.

Table 3: Incident- and Monthly-Level Estimates of the Probability of a Vessel being Attacked, 2007-2014

	Incident-Level Probability of Attack		Monthly-Level Probability of Attack	
	I	II	III	IV
Private Security	0.000 [0.001]	0.000 [0.001]	0.000 [0.001]	0.000 [0.001]
Region FE's	X	X	X	X
Month x Year FE's	X	X	X	X
Location-specific linear trend	X	X	X	X
Cubic Lat/Long		X		X
Controls	X	X	X	X
Adjusted R^2	0.808	0.795	0.654	0.658
Observations	1,789	1,517	388	388

This table reports incident and monthly-level estimates of the effect of the private security utilization on the probability of an attack. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), and actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.). Standard errors are clustered at the location level.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Given the results of Table 3, we proceed forward to examine the effect of private security on safety relaxing the concern that pirates are systematically attacking vessels with private security onboard. We examine each of the outcome variables outlined in Table 1 in logs using the same specification in Equation (1). Given that we are controlling for location- and time-specific variation as well as vessel type and other details of each incident (e.g. type of weapon used by pirates, other types of defense

[26] The results are nearly identical when we generate estimates that utilize only events that occurred in the open water (i.e. not while a vessel was in port).

used by vessel beyond private security, etc.), β_1 will identify the effect of private security within specific types of vessels in a specific location and time after controlling for all visible features and behavior of the vessel, crew and pirates.

III.2 Effect of Private Security on Vessel Safety

Table 4 reports the results of the incident-level estimates generated from running the estimation depicted in Equation (1), with clustering at the month-location level. This approach offers unbiased results of the effect of private security on vessel safety provided that the counterfactual group (vessels of the same type in the same location and month that do not have PMSCs onboard) shared common variation with the vessels that contained private security, with the exception of the introduction of PMSCs onboard vessels. While Table 3 shows that the decision to attack a vessel does not seem to be driven by the presence of private security, there might be reason to be concerned about the selection endogeneity associated with vessels that employ private security. For example, one might be inclined to believe that vessels that are carrying expensive cargo will have a higher likelihood of using private security because they have more at stake. However, as discussed above, the majority of the attacks are conducted in order to collect a ransom, not hijack the vessel. This would require that pirates are able to discern, prior to attack, which vessels within a class of ships (e.g. tankers) are more likely to pay a ransom.[27] Additionally, we account for as many observable features of the vessel in our results.

The estimates reported in Table 4 can be interpreted as semi-elasticities. As such, relative to vessels in a specific location and month that do not contain private security, those with PMSCs onboard are 10 percent less likely to be boarded, 6 percent less likely to be hijacked and approximately 6 percent less likely to experience a hostage situation. Moreover, vessels with private security are 4 percent less likely to experience injuries as a result of an attack. However, privately secured vessels are much more inclined – 25.9 percent more likely, in fact – to experience shots being fired during an attack. This could be the result of the vessel under attack firing on the attacking vessel, or vice versa. Unsurprisingly, we are not able to obtain a statistically precise estimate on deaths related to attacks given that they occur so infrequently.[28] In this first set of results, we present robust standard errors that are clustered at the location-month level in parenthesis. We also include spatially adjusted standard errors in brackets using the methods in Hsiang (2010) and Conley (2008).

Table 4: Incident-level Estimates of the Effect of Private Security on Vessel Safety, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
Private Security	-0.103*** (0.035) [0.037]	-0.061*** (0.009) [0.014]	0.259*** (0.016) [0.013]	-0.040* (0.023) [0.019]	-0.003 (0.008) [0.007]	-0.058*** (0.022) [0.019]
Region Fixed Effects	X	X	X	X	X	X
Month x Year FE's	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X

[27] Appendix Figure 1 examines the distribution of attacks for vessels that do and do not employ private security. A Kolmogorov-Smirnov test for equality of distributions is rejected at the 5 percent level, indicating that the composition of vessels attacked with private security is not different from those vessels that do not contain private security.

[28] Specifications using logit and Poisson estimation techniques yield results that are similar to these results.

Controls	X	X	X	X	X	X
Adjusted R^2	0.358	0.388	0.314	0.072	0.009	0.340
Observations	1,789	1,789	1,789	1,789	1,789	1,789

This table reports incident-level estimates of the effect of private security utilization on vessel and water safety. Additional controls include the type of vessel (see list in Table 1), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Robust standard errors are clustered at the location-month level are reported in parenthesis. Spatially adjusted standard errors are reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Our incident-level specification yields highly significant effects of private security on safety, but this specification could suffer from the fact that our outcome variables take on a zero value a large fraction of the time. We handle this in two ways. First, we aggregate our results to the monthly-level and utilize the same specification as in equation (1). Second, we examine two low-frequency events – deaths and injuries – in levels, rather than as indicator variables.

In Table 5 we present monthly-level estimates of the effect of private security on vessel safety. Our results are similar to those in Table 4, but are more precisely estimated with slightly larger point estimates. We continue to find support for the fact that private security onboard a vessel considerably reduces undesirable outcomes. Most notably, private security reduces the likelihood of a vessel being boarded by 24 percent, hijacked by 16 percent and a hostage being taken by 15 percent.[29] Unlike our incident-level estimates, when we aggregate to the monthly-level we find that deaths are significantly lower when private security is present, but we do not find the same support for injuries. While our point estimates are quite large, it is worth noting that, on average, there are 2.65 incidents involving private security per month, with a standard deviation of 2.68 attacks. Therefore, a one unit increase in vessels with private security is actually a rather large increase in the amount of privately secured vessels. While vessel and personal safety is increased in the presence of PMSCs, an arms race appears to be generated by vessels moving in the direction of private security. In fact, vessels with private security onboard are 38 percent more likely to either shoot at other vessels or be shot upon.

Table 5: Monthly-Level Estimates of the Effect of Private Security on Vessel Safety, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
	-0.241***	-0.156***	0.380***	-0.041	-0.021***	-0.146***
	(0.042)	(0.030)	(0.033)	(0.042)	(0.005)	(0.019)
Private Security	[0.055]	[0.031]	[0.044]	[0.045]	[0.005]	[0.024]
Region Fixed Effects	X	X	X	X	X	X
Month x Year FE's	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X
Controls	X	X	X	X	X	X
R^2	0.853	0.875	0.773	0.535	0.287	0.845

[29] It could be the case that increases in private security in the current month generate safety impacts on future months. To address this issue, we have aggregated the total number of attacks on vessels with PMSCs over the previous 1, 2, 3 months and examined the impact on safety in the following 1, 2, 3 months. The results are very similar to those reported in Tables 3 and 4 and are available from the authors upon request.

Observations	388	388	388	388	388	388

This table reports monthly-level estimates of the effect of the private security utilization on vessel and water safety. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Standard errors are clustered at the location level.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

While we observe a significant effect of private security on safety outcomes, we are aware that the use of private security on vessels is non-random. Vessels that are particularly vulnerable – often dubbed "low and slow" vessels – have a higher inclination to utilize private security, which could overestimate the effectiveness of private security. Two thoughts are worth noting, however. First, as we discussed above, piracy has proven more lucrative from obtaining hostages and demanding a ransom. In fact, interviews with pirates have found that most pirates do not even know how to operate larger vessels that contain valuable cargo, rendering the merchandise onboard relatively useless to the pirates. Second, the choice of who to attack is also non-random, as pirates learn signals about which vessels are less likely to be armed. If this effect overwhelms, then it is likely that our estimates are actually muted. Given that pirates cannot perfectly identify vessels with private safety onboard, externalities are likely borne from the presence of private security, a point that we will discuss in detail below.

III.3 External Effects of Private Security

In the above section we measured the effect of private security on the safety of vessels, finding that it had a significant direct impact on vessels that had PMSCs onboard. The presence of private security could also generate external effects by impacting unsecured vessels. In order to determine if an external effect is observed, we start by aggregating the total number of vessels containing private security in location j, month m and year y as our measure of the presence of private security. We also aggregate the total number of attacks in location j, month m and year y on unsecured vessels as our measure of piracy. Equation (2) details our first specification of the external effect of private security.

$$\ln(\textstyle\sum_i Attacks_{ijmy}) = \alpha_j + \gamma_m + \delta_y + \beta_1 \textstyle\sum_i Private\ Security_{ijmy} + X_{ijmy} + \varepsilon_{ijmy} \quad (2)$$

Table 6 presents three specifications of Equation (2). In column 1 we include location fixed effects as well as month by year fixed effects, in addition to the covariates that we have previously discussed. The results do not show a statistically significant relationship between monthly aggregate private security and the number of monthly attacks. When we add location by year fixed effects (column II) and a location-specific linear time trend to our estimation, however, the relationship between aggregate monthly private security and total monthly attacks share a negative and statistically significant relationship. Specifically, if one additional attacked vessel contains private security, this will decrease aggregate monthly attacks by 4.0-4.5 percent, or 2.5 fewer attacks per year.

Table 6: Monthly-Level Estimates of the Effect of Aggregate Private Security on Total Attacks, 2007-2014

	I	II	III
Σ(Private Security)	-0.010 [0.015]	-0.040*** [0.016]	-0.045*** [0.016]

Region Fixed Effects	X	X	X
Month x Year Fixed Effects	X	X	X
Location x Year Fixed Effects	-	X	X
Location-specific linear trend	-	-	X
Controls	X	X	X
R^2	0.998	0.998	0.998
Observations	388	388	388

This table reports monthly-level estimates of the effect of six month aggregate private security utilization on future vessel attacks. Additional controls include the type of vessel (see list in Table 1), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted robust standard errors are clustered at the month-location level and reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Given the significant effect of private security on the reduction of attacks, we further explore our data to determine if the presence of private security also reduced the violence associated with attacks. As noted in Iyengar (2008), there could be movement along the intensive margin of these attacks, where the violence associated with attacks rises despite fewer overall attacks. Alternatively, the number and intensity of attacks could decline. To measure these effects, we run the following specification for all vessels:

$$\ln(Outcome_{ijmy}) = \alpha_j + \gamma_m + \delta_y + \beta_1 Private\ Security_{ijmy} + \beta_2 \sum_i Private\ Security_{ijmy} + X_{ijmy} + \varepsilon_{ijmy} \quad (3)$$

Note that the specification in Equation (3) is very similar to Equation (1), with the exception that we now aggregate private security across all vessels in location *j* at the monthly-level. Specifically, $\sum_i Private\ Security_{ijmy}$ measures the total number of ships in location *j* in month *m* and year *y* that contained private security onboard the vessel. By including this aggregated measure of private security as well as the incident-level private security variable we are measuring both the direct and external impact that private security has on an unsecure vessel.

Table 7: Incident-Level Estimates of the Direct and External Effect of Private Security on Vessel Safety, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
Private Security	-0.099***	-0.061***	0.252***	-0.034*	0.005	-0.059***
	[0.030]	[0.008]	[0.023]	[0.020]	[0.011]	[0.022]
Σ(Private Security)	-0.003	-0.000	0.007**	-0.005	-0.002**	0.001
	[0.003]	[0.002]	[0.003]	[0.004]	[0.001]	[0.001]
Region Fixed Effects	X	X	X	X	X	X
Month x Year FE's	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X

Controls	X	X	X	X	X	X
Adjusted R^2	0.358	0.387	0.315	0.073	0.010	0.340
Observations	1,788	1,788	1,788	1,788	1,788	1,788

This table reports incident-level estimates of the effect of private security utilization on security of unsecured vessels. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted robust standard errors are clustered at the month-location level and reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Table 7 reports the direct and external effect of private security in a region on the safety of unsecured vessels. The first thing to note is that the estimates of the direct effect of private security on vessel safety are virtually identical to those presented in Table 4. Second, the external effect of private security on vessel safety is not statistically different from zero for most of our outcome measures, with the exception of shots fired and deaths. While estimates that are indistinguishable from zero might, on the surface, indicate infectivity of private security in generating safety on the waterways, this might not be the case. Given that the direct effect of private security is highly effective at deterring pirate attacks, we expect the external effect to be driven toward zero, which we observe in Figure 2A.

Additionally, given the small size of the external effect of private security that we observe, we note that although the increased presence of private security generated significantly more shots fired on unsecured vessels, the estimates yield only a 2 percent increase in overall shots fired. The reduction in the number of deaths due to increased overall private security in the waterways in a given month, however, is quite large. In fact, increases in the amount of private security decreases the likelihood of a fatality on an unsecured vessel by approximately 15 percent.

Given these baseline regressions, we now proceed to run multiple checks in order to determine how robust our estimates are to alternative specifications and measurement of the impact of private security on vessel safety.

VI. ROBUSTNESS CHECKS

Our results indicate that private security has a significant effect on vessel security, considerably reducing the likelihood of a vessel being boarded or hijacked while also reducing the number of hostages, injuries and deaths. Alternatively, we find that the presence of private security significantly increases the number of shots that are fired during (attempted) pirate attacks. In this section we present a series of robustness checks to our results. These include an examination of incidents exclusively in open water, the number of deaths and injuries (rather than dichotomous measures), other sources of deterrence beyond private security (e.g. use of evasive measures), spatial dependence and checks for the effect of unobserved variation on our estimates, a placebo test of our point estimates and the long-run impact of private security on waterway safety.

IV.1 Incidents Exclusively in International Waters

Given that approximately 18 percent of the attacks in our data set occur when a vessel is in port, one might be concerned that our estimates could be detecting the effect of onshore, public security foiling an attack. This could lead us to over-attribute the effectiveness of private security on deterring an undesirable outcome. To overcome this issue we remove all incidents that are reported when a vessel is in port and re-estimate Equations 1 and 3 with the same outcome variables. Appendix Tables 1 and 2 report the same estimation reported in Tables 4 and 7, with port incidents removed. The direct estimates of the effect of private security are nearly identical to those reported in Tables 4 and 7. The external effects of private security are similar to those reported in Table 7, with the notable exception that we now find that the likelihood of a boarding on a vessel that is unsecured is now reduced due to the increase in private security in the waterways. Thus, it does not appear that our results are being driven by the presence of naval forces or other onshore security, but rather by the private security that is onboard vessels.

IV.2 Levels of Deaths and Injuries

Our previous estimates find statistically significant results for relatively higher frequency events, such as boarding, hijacking, shots being fired and hostage situations. However, our estimates of lower frequency events (deaths and injuries) are not stable across different specifications. This is likely due to the infrequency of these events – deaths and injuries occur in approximately 1 and 6 percent of all incidents, respectively. To overcome this issue we examine the intensive margin of deaths and injuries by determining the number of injuries and fatalities associated with each incident and re-run Equations 1 and 3 with the natural log of the number of injuries/fatalities as our outcomes variable.

Appendix Table 3 shows incident and monthly-level estimate of the direct effect of private security on injuries and fatalities. Our monthly-level estimates show a negative and statistically significant effect of private security on deaths, which might be expected since fatalities occur so infrequently in our data. At the incident-level we find a negative and statistically significant effect of private security on injuries, however this result disappears when we aggregate to the monthly-level. Appendix Table 4 further explores the impact of private security by examining the direct and external effect of private security on deaths and fatalities. Columns I and III present estimates from the full sample while Columns II and IV examine incidents occurring only outside of a port (open waterways). While we still do not find evidence of the effect of private security on the reduction in fatalities, we do find weak support for the external effect of private security on fatalities, but this appears to be largely driven by incidents occurring in port. Injuries show a statistically significant relationship for both the direct and external effect of private security. Namely, having private security onboard a vessel decreases the number of fatalities by 4-6 percent. Additionally, one more vessel with private security sharing the waterways with an unsecured vessel reduces the likelihood of an injury by 1.6-1.8 percent. This effect appears to be driven by incidents occurring in open waterways.

IV.3 Interaction of Defensive Measures

A further concern about our estimate of the effect of private security on vessel safety could be that vessels do not make a choice to exclusively use private security. Instead, they could utilize a series of measures that could be employed to deter incoming attacks. We have included these as controls (e.g. evasive maneuvers, draw attention to vessel, use fire hoses on attackers, etc.) in the analysis, but it could be the case that these measures are taken in conjunction with employing private security. In Appendix Tables 5 we re-run Equation 1, but now include interactions between other deterrence measures (increasing speed, evasive maneuvers, use of water hoses, drawing attention to the vessel,

and anti-piracy measures) and private security. We report these estimates exclusively for incidents in the open waterways.

Even after controlling for interaction effects between private security and other measures of deterrence, we find strong evidence that private security reduces boardings, hijackings, fatalities and hostage situations. As we have seen in previous results, we cannot identify a statistically significant relationship between private security and injuries. Additionally, the presence of private security continues to drive up the amount of shots fired. Interestingly, the interaction between private security and increasing the speed of the vessel reduces undesirable outcomes in the same manner that we observe in our private security estimates, but with statistically smaller effects. Almost all other interactions, which typically involve the vessel not attempting to flee from the situation, result in increases in the undesired outcome. This is consistently true amongst our most prevalent outcome measures (boarded, hijack and hostage). Finally, our incident-level point estimates are larger when we include interaction effects, indicating that the effect of private security on vessels safety in Table 4 might have been muted as the additional deterrence controls captured part of the effect of private security on vessel safety.

IV.4 Spatial-Dependence

As discussed in our main specification, Dell (2010) provides a method of accounting for potential spatial dependence. Given that we have information about the latitude and longitude of incidents for over 85 percent of our data, we allow for incidents to share a spatial dependence in our specification, whereby attacks might be clustered near each other if they are being carried out by a single operation or spread apart if rival pirates are operating in the waterways.

Appendix Tables 6 displays the results of the estimation with a cubic polynomial in latitude and longitude included in the specification in Equation 1. The coefficient estimates on private security do not differ greatly from the estimates reported in Table 4. To determine if unobservable variation is driving our results, we follow the lead of Altonji et al. (2005), Bellows and Miguel (2008), and Nunn and Wantchekon (2011), by examining the ratio of the coefficient on private security in the full regression model (the specification that includes a cubic polynomial in latitude and longitude) to the difference in the coefficient estimates in the restricted model (the specification utilized in Table 4). If the difference between the coefficients in the restricted and full model is small, then the coefficient estimate is less affected by selection on observables, and selection on unobservables relative to observables needs to be stronger to explain away this effect. Moreover, if the coefficient estimate on private security in the full model is larger, the greater is the effect that needs to be explained away by selection on unobservables. So, by examining this ratio, we are identifying the relative magnitude of the ratio of selection on unobservables to observables in order for our OLS estimates to be chalked up to selection effects. On average, this ratio across all of our estimates for private security is 7.376, meaning that to attribute the entire OLS estimate to selection effects, the selection on unobservables would have to be, on average, 7.367 times greater than the selection on observables. Therefore, we conclude that it is unlikely that the estimated effect of private security is being driven by unobservable effects.

IV.5 Placebo Results

In all of the previous sections we continue to identify a large direct effect of private security on vessel safety. To further establish that this effect is specific to the waterways containing private

security, we conduct a placebo test of the effect of private security on vessel safety. Specifically, we examine incidents occurring only in locations where private security is not legal – the China Sea and Malacca Straits. We then randomly assign private security to 10 percent of the attacks in the locations where private security is not legal and re-conduct the analysis presented in Table 4, but only using the data from the China Sea and Malacca Straits.[30] The results, which are reported in Appendix Table 8, find no direct effect of private security on vessel safety. In fact, the randomly assigned private security that we identify in the China Sea and Malacca Straits has no statistically significant relationship with the outcome variables, regardless of the specification that we employ.[31]

To further reinforce our findings, we randomly assign private security to vessels that do not have private security onboard in our main sample of locations. Following the lead in Bertrand et al. (2004), we run a set of 100 permutations and report the 95 percent confidence intervals for the direct and external effect of private security on vessel safety in Appendix Table 7. For all but one of the coefficient estimates that we report in Table 7, our coefficient estimates fall outside of the 95 percent confidence intervals generated from our permutations, leading us to conclude that we are identifying the true direct and external impact of private security on vessel and waterway safety.

IV.6 Long-Term Effects of Private Security

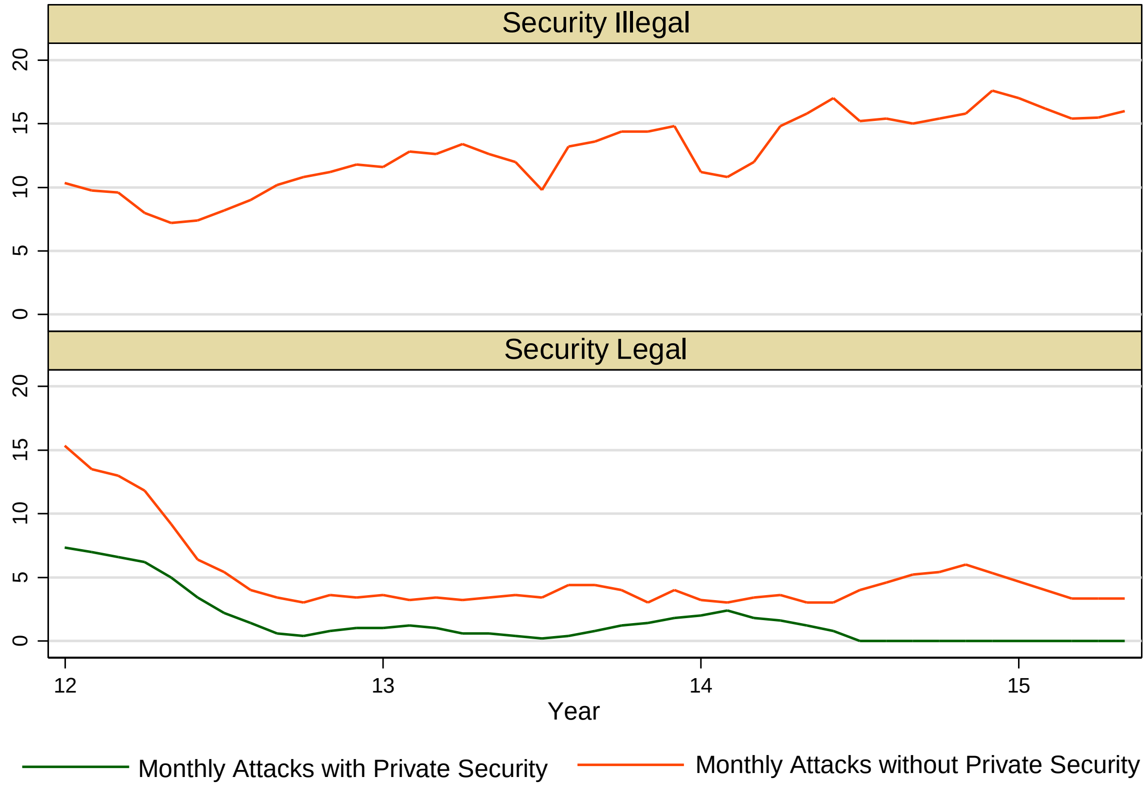
The effect of private security appears to be longer lasting than the current period. Interestingly, the number of attacks in regions where security is legal continue to dwindle, approaching and even reaching zero attacks per month in some locations. Figure 3 displays the number of monthly attacks in regions where security is both illegal and legal. It is evident over this time frame that the number of attacks (on secure and unsecure vessels) are declining in regions where security is legal, while they are increasing in regions where onboard security is not legal.

We run a set of monthly-level regressions that examine the direct effect of private security on the number of attacks in the next, 1, 3 and 6 months. Specifically, we examine the effect of the aggregate total number of vessels that are attacked with PMSCs onboard during the previous six-month time period on the number of future attacks. These regression results are reported in Appendix Table 8. Although the effect of private security on the number of attacks one month in the future is not significant, it appears that private security does have a longer term effect by the third to sixth months. Specifically, one additional attack on a vessel with private security onboard reduces monthly attacks by approximately 3 percent in the next 3-6 months. Thus, we find an external effect of private security not just for unsecure ships contemporaneously, but for both secure and unsecure vessels in future periods.

---

[30] We arrived at the 10 percent figure by dividing the number of incidents involving private security (183) by the total number of incidents (1,789) in locations where private security is legal. We also take care to assign the false private security in the locations where private security is not legal so that the distribution mirrors the temporal distribution of private security in locations where it is permissible.
[31] Probit, logit, Poisson and negative binomial specifications all yield the same, insignificant effects.

Figure 3: Monthly Attacks, 2012-2015



IV. POLICY IMPLICATIONS AND DISCUSSION

The theory of the private provision of public goods identifies a concern that free-riding could prevail given the nonrival and nonexcludable nature of the provided good. Moreover, there are concerns that the private provision could be crowded out by public/government attempts to provide such goods. We directly examine this concern in a framework where public provision of a public good – piracy prevention – has consistently struggled to achieve the goal of eliminating (or at least minimizing) pirate attacks. Given the prevalence of piracy in both weakly and less weakly institutionalized environments, we consider whether a private solution (private security) can more effectively reduce piracy. We find that private security has significant direct benefits on public safety by reducing the likelihood that a vessel with private security is boarded, hijacked or that hostages are taken by pirates. Additionally, we find weak evidence that unsecured vessels that are traveling in the same waterways as vessels with private onboard security experience external benefits from private security. We then present a battery of robustness and falsification tests to show that our results persist.

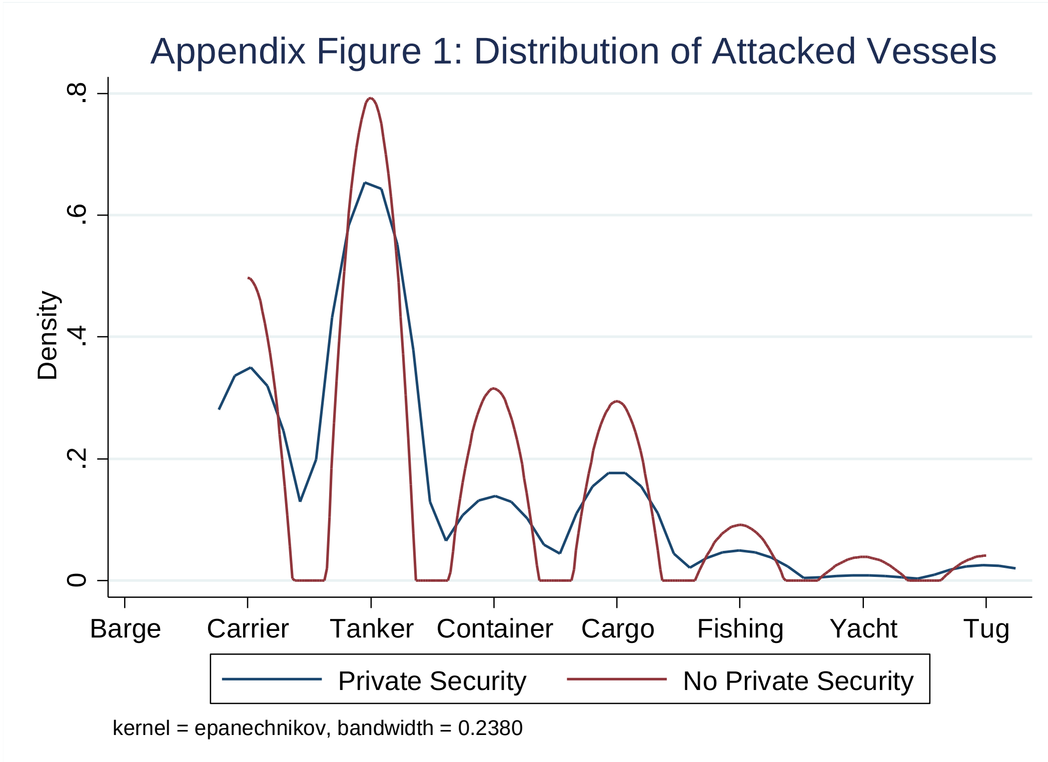
Although private security had both direct and external benefits by reducing the likelihood of a boarding/hijacking and the injuries/fatalities that could be associated with these outcomes, private security also reduced safety on the open waterways. Specifically, the likelihood that shots were fired and that guns or explosives were present during an attack significantly increased as private security

became more prevalent.[32] While this arms race did not result in greater fatalities or injuries it certainly affected the shipping patterns, as 7 percent of all ships and 50 percent of "low and slow" ships re-routed (Oceans Beyond Piracy, 2012).

Given that piracy has a major impact on commerce and welfare, we explored whether the private provision to a global public good would be successful in ensuring piracy prevention. It appears that the uncertainty of attacking vessels in waterways known to have private security provides enough of a disincentive to pirates to deter them from continuing to attack vessels. Ultimately, in regions where private security is legal, it appears that as little as 10 percent of attacked vessels containing private security is enough to deter, in the short and long run, piracy. Thus, our research contributes to the literature on the private provision of (international) public goods by displaying the effectiveness of private security in directly and externally reducing pirate attacks both contemporaneously and for future time periods.

[32] The likelihood that a gun was present increased by 10 percent while the likelihood that an explosive was present increased by 16 percent.

APPENDIX



Appendix Table 1: Incident-level Estimates of the Effect of Private Security on Vessel Safety in Open Waters, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
Private Security	-0.091*** (0.035) [0.036]	-0.058*** (0.009) [0.015]	0.270*** (0.004) [0.011]	-0.033* (0.013) [0.020]	-0.001 (0.003) [0.005]	-0.055*** (0.019) [0.020]
Year Fixed Effects	X	X	X	X	X	X
Month x Location FEs	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X
Controls	X	X	X	X	X	X
Adjusted R^2	0.409	0.416	0.303	0.075	0.053	0.389
Observations	1,447	1,447	1,447	1,447	1,447	1,447

This table reports incident-level estimates of the effect of private security utilization on vessel and water safety. Additional controls include the type of vessel (see list in Table 1), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Robust standard errors are clustered at the location-month level are reported in parenthesis. Spatially adjusted standard errors are reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Appendix Table 2: Direct and External Estimates of the Effect of Private Security on Vessel Safety in Open Waters, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
Private Security	-0.088***	-0.060***	0.263***	-0.030*	0.001	-0.058***
	[0.027]	[0.006]	[0.007]	[0.018]	[0.004]	[0.018]
	-0.007*	-0.002	0.009*	-0.003	-0.001	0.000
Σ(Private Security)	[0.004]	[0.004]	[0.005]	[0.004]	[0.001]	[0.003]
Region Fixed Effects	X	X	X	X	X	X
Month x Year FEs	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X
Controls	X	X	X	X	X	X
Adjusted R^2	0.407	0.414	0.305	0.076	0.052	0.388
Observations	1,447	1,447	1,447	1,447	1,447	1,447

This table reports incident-level estimates of the effect of private security utilization on security of unsecured vessels. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted robust standard errors are clustered at the month-location level and reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Appendix Table 3: Incident- and Monthly-Level Estimates of the Effect of Private Security on the Number of Deaths and Injuries, 2007-2014

	Incident-Level Deaths	Monthly-Level Deaths	Incident-Level Injuries	Monthly-Level Injuries
	0.002	-0.054***	-0.085***	0.137
Private Security	[0.007]	(0.011)	(0.012)	(0.216)
Region Fixed Effects	X	X	X	X
Month x Year FEs	X	X	X	X
Location-specific linear trend	X	X	X	X
Controls	X	X	X	X
R^2	0.052	0.479	0.043	0.208
Observations	1,789	388	1,789	388

This table reports incident and monthly-level estimates of the effect of the private security utilization on the number of deaths and injuries. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted standard errors that are clustered at the location level are reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Appendix Table 4: Incident-Level Estimates of the Direct and External Effect of Private Security on the Number of Deaths and Injuries, 2007-2014

	I	II	III	IV

	Incident-Level Deaths	Incident-Level Deaths	Incident-Level Injuries	Incident-Level Injuries
Private Security	0.003 [0.008]	0.004 [0.010]	-0.060*** [0.014]	-0.037** [0.020]
Σ(Private Security)	-0.001*** [0.000]	-0.000 [0.002]	-0.018*** [0.005]	-0.016*** [0.005]
Region Fixed Effects	X	X	X	X
Month x Year FEs	X	X	X	X
Location-specific linear trend	X	X	X	X
Controls	X	X	X	X
R^2	0.052	0.057	0.043	0.030
Observations	1,789	1,447	1,789	1,447

This table reports incident and monthly-level estimates of the effect of the private security utilization on the number of deaths and injuries. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Columns I and III include the full sample while columns II and IV examine only incidents in open water. Spatially adjusted standard errors that are clustered at the location level are reported in brackets.

*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Appendix Table 5: Incident-level Estimates of the Effect of Private Security interacted with other Security Measures, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
Private Security	-0.205*** [0.021]	-0.188*** [0.006]	0.228*** [0.025]	-0.039 [0.026]	-0.020*** [0.007]	-0.166*** [0.019]
Private Security x Speed	-0.070** [0.027]	-0.065*** [0.021]	-0.155 [0.222]	0.124* [0.065]	-0.017 [0.012]	-0.059** [0.031]
Private Security x Anti-Piracy Measures	0.141*** [0.057]	0.141*** [0.047]	-0.024 [0.110]	-0.022* [0.013]	-0.021* [0.011]	-0.108*** [0.033]
Private Security x Attention	0.079*** [0.020]	0.104*** [0.007]	0.062** [0.027]	0.017 [0.029]	0.024* [0.013]	-0.070** [0.022]
Private Security x Evasive Maneuvers	0.246*** [0.029]	0.235*** [0.015]	0.173 [0.209]	-0.093** [0.043]	0.018 [0.012]	-0.204*** [0.031]
Private Security x Hoses	0.085*** [0.031]	0.071*** [0.018]	-0.239 [0.152]	0.055 [0.090]	-0.019 [0.019]	-0.056* [0.031]
Region Fixed Effects	X	X	X	X	X	X
Month x Year FE's	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X
Controls	X	X	X	X	X	X
R^2	0.428	0.436	0.317	0.084	0.137	0.330
Observations	1,447	1,447	1,447	1,447	1,447	1,447

This table reports incident-level estimates of the effect of private security utilization on security of unsecured vessels. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates

(chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted robust standard errors are clustered at the month-location level and reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Appendix Table 6: Incident-level Estimates of the Effect of Private Security with Spatial Dependence, 2007-2014

	Boarded	Hijack	Shots Fired	Injury	Death	Hostage
	-0.084***	-0.050***	0.248**	-0.033*	-0.005**	-0.043***
Private Security	[0.028]	[0.008]	[0.026]	[0.017]	[0.009]	[0.016]
Region Fixed Effects	X	X	X	X	X	X
Year Fixed Effects	X	X	X	X	X	X
Month x Year FE's	X	X	X	X	X	X
Location-specific linear trend	X	X	X	X	X	X
Cubic Lat/Long	X	X	X	X	X	X
Controls	X	X	X	X	X	X
R^2	0.366	0.391	0.312	0.074	0.013	0.359
Observations	1,517	1,517	1,517	1,517	1,517	1,517

This table reports incident-level estimates of the effect of private security utilization on security of unsecured vessels. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted robust standard errors are clustered at the month-location level and reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Appendix Table 7: Permutation Tests of Direct and External Private Security Estimates

	Direct Effect			External Effect		
	Estimate	2.5 percentile	97.5 percentile	Estimate	2.5 percentile	97. 5 percentile
Boarded	-0.099*	-0.003	0.004	-0.003*	-0.0004	0.004
Hijack	-0.061*	-0.003	0.003	-0.000	-0.001	0.000
Shots Fired	0.252*	-0.003	0.003	0.007*	-0.0003	0.003
Injury	-0.034*	-0.001	0.007	-0.005*	-0.0006	0.0001
Death	0.005*	-0.0001	0.0006	-0.002*	-0.0002	0.0001
Hostage	-0.059*	-0.003	0.004	0.001*	-0.0005	0.0002

Coefficient estimates are taken from Table 6. The 95 percent confidence intervals are generated using the same specification utilized to generate the results for Table 5, while randomly assigning private security.
* denotes that the coefficient estimates fall outside of the 95 percent confidence intervals.

Appendix Table 8: Monthly-Level Estimates of the Effect of Six Month Aggregate Private Security on Future Attacks, 2012-2015

	1 Month	3 Months	6 months
	-0.005	-0.032**	-0.025**
Σ(Private Security)	[0.004]	[0.012]	[0.010]

Region Fixed Effects	X	X	X
Year Fixed Effects	X	X	X
Month x Year FE's	X	X	X
Location-specific linear trend	X	X	X
Controls	X	X	X
R^2	0.400	0.545	0.710
Observations	387	385	382

This table reports monthly-level estimates of the effect of one, three, and six month aggregate private security utilization on future vessel attacks. Additional controls include the type of vessel (see list in Table 2), zone of water (territorial, international, port), actions taken by the vessel (increasing speed, evasive maneuvers, use of water hoses, sounding a horn or whistle, etc.), actions taken by pirates (chase vessel, aggressively pursue, attempt to board, etc.), total number of pirates and pirated attempts per month by location, and whether or not the ship reported the event. Spatially adjusted robust standard errors are clustered at the month-location level and reported in brackets.
*, **, *** indicate significance at the 10, 5 and 1 percent levels, respectively.

References

Altonji, Joseph G., Todd E. Elder, and Christopher R. Taber (2005). Selection of Observed and Unobserved Variables: Assessing the Effectiveness of Catholic Schools. *Journal of Political Economy*, 113(1): 151-84.

Anderson, A. G. (1979). *The Business of Organized Crime*. The Board of Trustees of the Leland Stanford Junior University.

Andreoni, J. (1988). Privately Provided Goods in a Large Economy: The Limits of Altruism. *Journal of Public Economics, (35) 1*, 57-73.

Andreoni, J. (1989). Giving with Impure Altruism: Applications to Charity and Ricardian Equivalence. *Journal of Political Economy, (97) 6*, 1447-1458.

Ayres, I., & Levitt, S. D. (1998). Measuring Positive Externalities From Unobservable Victim Precaution: An Empirical Analysis of Lojack. *The Quarterly Journal of Economics 113*, 43 - 77.

Barker, S. (2013). International Maritime Piracy: An Old Profession that is Capable of New Tricks, But Change is Possible. *Case Western Reserve Journal of International Law, 46*, 387-396.

Becker, G. S. (1968). Crime and Punishment: An Economic Approach. *Journal of Political Economy, 76(2)*, 169-217.

Bellais, R. (2013). Fighting Piracy and International Public Goods: The Atalanta Experiment in the Horn of Africa. *Peace Economics, Peace Science, and Public Policy 19*, 73-101

Bellows, John and Edward Miguel (2009). War and Local Collective Action in Sierra Leone. *Journal of Public Economics, 93(11-12): 1144-57.*

Benson, B. L. (1989). Enforcement of Private Property Rights in Primitive Societies: Law without Government. *The Journal of Libertarian Studies, (9)1*, 1-26.

Benson, B. L. (1990). *Enterprise of Law: Justice Without the State*. San Francisco: Pacific Research Institute for Public Policy.

Bergstrom, T., Blume, L., & Varian, H. (1986). On the private provision of public goods. *Journal of Public Economics; 29(1)*, 25-49.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan (2004). How much Should we Trust Differences-in-Differences Estimates? *Quarterly Journal of Economics*, 119(1): 249-275.

Bohnet, I., Frey, B. S., & Huck, S. (2001). More Order with Less Law: On Contract Enforcment, Trust, and Crowding. *American Political Science Association, (95)1; Cambridge University Press.*

Bueger, C. (2013). Practice, Pirates and Coast Guards: the grand narrative of Somali piracy. *Third World Quarterly*, 1811-1827.

Chalk, P. (2010). Piracy Off the Horn of Africa: Scope, Dimensions, Causes and Responses. *Brown Journal of World Affairs*.

Chalk, P. (2012). *Private Maritime Security Companies (PMSCs) and Counter-Piracy.* Dubai: Institute for Near East and Gulf Military Analysis (INEGMA) on behalf of the second United Arab Emirates Counter Piracy Conference, 'A Regional Response to Maritime Piracy: Enhancing Public-Private Partnerships and Strengthening Global Engagement', organi.

Chang, J.-J., Lu, H.-C., & Chen, M. (2005). Organized Crime or Individual Crime? Endogenous Size of a Criminal Organization and the Optimal Law Enforcement. *Economic Inquiry, 43(3)*, 661-675.

Clarkson Research Services Limited. (2013). *Shipping Market Overview.* London: Security Associated for the Maritime Industry.

Cloninger, D. I. (1975). The Deterrence Effect of Law Enforcement: An Evaluation of Recent Findings and Some New Evidence. *American Jounral of Economics and Sociology, (34)3*, 323-335.

Clotfelter, C. T. (1978). Private Security and the Public Safety. *Journal of Urban Economics, (5)3*, 388-402.

CNN. (2008). Somali Piracy Threatens Trade, Boosts Terrorists, Analysts Say. *CNN.*

Cook, P. J., & MacDonald, J. (2011). Public Safety Through Private Action: an Economic Assessment of BIDS. *The Economic Journal, (121)552*, 445-462.

Cornes, R., & Sandler, T. (1996). *The Theory of Externalities, Public Goods, and Club Goods.* Cambridge University Press.

DeAngelo, G., & Hansen, B. (2014). Life and Death in the Fast Lane: Police Enforcement and Traffic Fatalities. *American Economic Journal: Economic Policy. 6(2)*, 231-257.

Dell, Melissa (2010). The Persistent Effects of Peru's Mining Mita. *Econometrica*, 78(6): 1863-1903.

Dick, A. R. (1995). When Does Organized Crime Pay? A Transaction Cost Analysis. *International Review of Law and Economics, 15(1)*, 25-45.

Dixit, A. (2007). *Lawlessness and Economics: Alternative Modes of Governance*. Princeton, NJ: Princeton University Press.

Ehrlich, I. (1975). The Deterrent Effect of Capital Punishment: A Question of Life and Death. *American Economic Review, 65(3).*

Ellickson, R. C. (1994). The Aim of Order Without Law. *Journal of Institutional and Theoretical Economics, (150)1*, 97-100.

Evans, W. N., & Owens, E. G. (2007). COPS and Crime. *Journal of Public Economics, 91(1-2)*, 181-201.

Fiorentini, G., & Peltzman, S. (1997). *The Economics of Organised Crime*. Cambridge University Press.

Friedman, D. (1984). Efficient Institutions for the Private Enforcement of Law. *The Journal of Legal Studies, (13)2*, 379-397.

Garoupa, N. (2000). Corporate Criminal Law and Organization Incentives: A Managerial Perspective. *Managerial and Decision Economics, 21(6)*, 243-252.

Helland, E., & Tabarrok, A. (2004). The Fugitive: Evidence on Public Versus Private Law Enforcement from Bail Jumping. *Journal of Law and Economics, (47)1*, 93-122.

Hylton, K. N. (1996). Optimal Law Enforcement and Victim Precaution. *The RAND Journal of Economics, (27)1*, 197-206.

Imrohoroglu, A., Merlo, A., & Rupert, P. (2004). What Accounts for the Decline in Crime. *International Economic Review, 45(3)*, 707-729.

International Monetary Fund. (2015). World Economic Outlook. Retrieved from http://www.imf.org/external/data.htm

Isaac, R. M., Walker, J. M., & Williams, A. W. (1994). Group Size and the Voluntary Provision of Public Goods: Experimental Evidence Utilizing Large Groups. *Journal of Public Economics, (54)1*, 1-36.

Jankowski, M. S. (1991). *Islands in the Street: Gangs and American Urban Society*. University of California Press.

Jones, T., & Newburn, T. (1998). *Private Security and Public Policing*. New York, NY: Oxford University Press.

Kahan, D. M. (1999). The Secret Ambition of Deterrence. *Harvard Law Review, (113)2*, 413-500.

Kaul, I., Conceicao, P., Le Goulven, K., & Mendoza, R. U. (2003). *Providing Global Public Goods: Managing Globalization*. Oxford University Press.

Kaul, I., Grunberg, I., & Stern, M. A. (1999). *Global Public Goods: International Cooportation in the 21st Century*. New York: Oxford University Press.

Konrad, K. I., & Skaperdas, S. (1998). Extortion. *Economica, 65(260)*, 461-477.

Landes, W. M., & Posner, R. A. (1975). The Private Enforcement of Law. *Journal of Legal Studies*.

Laury, S. K., & Holt, C. A. (1998). Voluntary Provision of Public Goods: Experimental Results with Interior Nash Equilibria. *Handbook of Experimental Economic Results*.

Lee, D. S., & McCrary, J. (2009). The Deterrence Effect of Prison: Dynamic Theory and Evidence. *Princeton University, Industrial Relations Section Working Papers, 550*.

Leeson, P. T. (2007). Better Off Stateless: Somalia Before and After Government Collapse. *Journal of Comparative Economics, 35*, 689-710.

Leeson, P. T. (2007a). Better Off Stateless: Somalia Before and After Government Collapse. *Journal of Comparative Economics, 35*, 689-710.

Leeson, P. T. (2007b). An-arrgh-chy: The Law and Economics of Pirate Organization. *Journal of Political Economy, (115)6*, 1049-1094.

Levitt, S. D. (1997). Using Electoral Cycles in Police Hiring to Estimate the Effects of Police on Crime. *The American Economic Review, 87(3)*, 270-290.

Lott, J. R., & Manning, R. (2000). Have Changing Liability Reules Compensated Workers Twice for Occupational Hazards? Earnings Premiums and Cancer Risks. *Journal of Legal Studies, (99).*

McCormick, R. E., & Tollison, R. D. (1984). Crime on the Court. *Journal of Political Economy, 92(2)*, 223-235.

Mikolov, Tomas, Quoc Le & Ilya Sutskever (2013). Exploiting Similarities among Languages for Machine Translation, available at http://arxiv.org/pdf/1309.4168.pdf.

Naysnerski, W., & Tietenberg, T. (1992). Private Enforcement of Federal Environmental Law. *Land Economics, (68)1*, 28-48.

Nunn, Nathan & Leonard Wantchekon (2011). The Slave Trade and the Origins of Mistrust in Africa. *American Economic Review*, 101: 3221-3252.

Oceans Beyond Piracy. (2010). *The Economic Costs of Somali Piracy.* Oceans Beyond Piracy, The One Earth Future Foundation.

Oceans Beyond Piracy. (2011). *The Economic Cost of Somali Piracy.* Oceans Beyond Piracy, The One Earth Future Foundation.

Oceans Beyond Piracy. (2012). *The Economic Cost of Somali Piracy.* Oceans Beyond piracy, One Earth Future Foundation.

Oceans Beyond Piracy. (2014). *The State of Maritime Piracy* . Oceans Beyond Piracy, The One Earth Future Foundation.

Osnin, N. A. (2006). Private Maritime Security Company (PMSC) in the Strait of Malacca- Options for Malaysia. *WMU Journal of Maritime Affairs, (5)2*, 195-206.

Pitney Jr., J. J., & Crocker, R. P. (2013). *Private Anti-Piracy Navies: How Warships for Hire are Changing Maritime Security.* Lexington Books.

Ploch, L., Blanchard, C. M., O'Rourke, R., Mason, R. C., & King, R. O. (2011). *Piracy off the Horn of Africa.* Washingston, D.C. : Congression Research Service, CRS Report for Congress.

Polinsky, A. M., & Shavell, S. (1979). The Optimal Tradeoff between the Probability and Magnitude of Fines. *The American Economic Review, 69(5)*, 880-891.

Powell, B., Ford, R., & Nowrasteh, A. (2008). Somalia After State Collapse: Chaos or Improvement? *Journal of Economic Behavior & Organization, (67)3-4*, 657-670.

Reuter, P. (1983). *Disorganized Crime: The Economics of the Visible Hand.* MIT Press.

Samatar, A. I. (2007). *Post-Conflict Peace-Building in the Horn of Africa; Ethiopian Occupation and American Terror in Somalia.* Lund University, Department of Social Anthropology, Department of Political Science. Lund: Research Report in Social Anthropology.

Samuelson, P. A. (1954). The Pure Theory of Public Expenditure. *The Review of Economics and Statistics 36*, 387-389.

Savridis, J. G., & LeBron, R. E. (2011). Taming the Outlaw Sea. *EPS Quarterly*, 1-14.

Shavell, S. (1991). Individual Precautuons to Prevent Theft: Private Versus Socially Optimal Behavior. *International Review of LAw and Economics, (11)2*, 123-132.

Sherman, L. W., Gottfredson, D., MacKenzie, D., Eck, J., Reuter, P., & Bushway, S. (1997). *Preventing Crime: What Works, What Doesn't, What's Promising: A Report to the United States Congress.* US Department of Justice, Office of Justice Programs.

Skaperdas, S. (2001). The Political Economy of Organized Crime: Providing Protection when the State does Not. *Economics of Governance, 2*, 173 - 202.

Stringham, E. P. (2015). *Private Governance: Creating Order in Economic and Social Life.* New York, NY: Oxford University.

Sykes, A. O. (2005). Public versus Private Enforcement of International Economic Law: Standing and Remedy. *The Journal of Legal Studies, (34)2*, 631-666.

The World Bank. (2013). *The Pirates of Somalia.* Washington DC: International Bank for Reconstruction and Development / The World Bank.

The World Bank. (2013). *The Pirates of Somalia: Ending the Threat, Rebuilding a Nation.* Washington, D.C.: International Bank for Reconstruction and Development/The World Bank - Vice-Presidency for Africa.

The World Bank. (2013). *The Pirates of SOmalia: Ending the Threat, Rebuilding a Nation.* Washington D.C.

Viscusi, W. K., & Aldy, J. E. (2003). The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World. *Journal of Risk and Uncertainty, (27)1*, 5-76.

William P. Jennings, J. (1984). A Note on the Economics of Organized Crime. *Eastern Economic Journal, 10(3)*, 315-321.