The Trade Consequences of Maritime Insecurity: Evidence from Somali Piracy*

Alfredo Burlando, Anca Cristea, and Logan M. Lee†

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Abstract

In the past decade, pirates from Somalia have carried out thousands of attacks on cargo ships sailing through the Gulf of Aden and the Indian Ocean, causing what others have identified as significant damage to maritime trade. In this paper, we use variations in the spread and intensity of Somali piracy to estimate its effect on the volume of international trade. By comparing trade volume changes along shipping routes located in pirate waters to those that are not, we estimate that Somali piracy reduced bilateral trade passing through the Gulf of Aden by 1.9 percent per year from 2000 to 2010. In addition, we find larger reductions for trade in bulk commodities, which are generally shipped by sea and more likely to fall pray to piracy attacks. While our estimates suggest that the trade costs of piracy are much lower than what has been suggested in the existing literature, we find that they remain significant and unevenly distributed, with five countries and the European Union shouldering 70% of the total costs.

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†Burlando: Department of Economics, University of Oregon, Eugene, OR, 97403-1285, USA, burlando@uoregon.edu. Cristea: Department of Economics, University of Oregon, Eugene, OR, 97403-1285, USA, cristea@uoregon.edu. Lee: Department of Economics, University of Oregon, Eugene, OR, 97403-1285, USA, loganl@uoregon.edu.

1 Introduction

Maritime piracy around Somalia has emerged over the past two decades as a legitimate threat to international trade. The combination of weak governmental institutions, a natural geographic choke point in the Gulf of Aden, and a significant flow of ships through the Gulf has allowed pirates to establish safe harbors from which to attack a plethora of available targets. Successful attacks have significant consequences: hijacked ships, kidnapped crews, expensive ransom negotiations, and loss of life. As merchant ships are attacked and trade flows disrupted, the cost of transporting goods through pirate waters increases, possibly discouraging trade through these regions. This problem has global dimensions. Annually, 12 percent of world trade is estimated to pass through the Suez Canal. For the countries in the Indian Ocean region, whose ports are in relatively close proximity to pirate waters, as much as 60 percent of their imports travel trough pirate infested waters. These countries are potentially exposed to significant disruptions to their trade, and could be the victims of pirate-induced price distortions in their traded goods, with consequent welfare implications.

In this paper, we lay out a simple model of bilateral trade where piracy increases trade costs, and derive an augmented gravity equation to estimate the effect of pirate activity on trade volumes. Using a global panel data set combining information on bilateral volumes of trade and on reported pirate attacks, we first study how annual trade between pairs of countries that transfer goods through pirate infested waters is affected by the intensity of piracy. We then compare this effect to trade between country pairs that arguably use other shipping lanes that are free of Somali pirates.

We estimate the cost of piracy in two ways. We first follow the existing literature in measuring pirate activity as the total number of pirate attacks in a given year that took place around Somalia. This includes successful hijackings and boardings as well as attempted boardings and cases where a ship was fired upon. A drawback of this estimation strategy is that the number of attacks could be endogenous to trade for a number of reasons including reverse causality and omitted factors. For instance, if more ships transit through an area, the probability of an

encounter mechanically increases. Alternatively, if ships hire (unobserved) protective military vessels in response to high piracy risks, we could observe fewer attempted attacks, even though shipping costs would have increased. For this reason, we use the geographic reach of pirates as a second measure of pirate activity, which has the advantage of being generally unrelated to the volume and frequency of international trade. From the early 2000s until 2009, Somali pirates significantly improved and refined their equipment and organizational structures, often by adopting more sophisticated weapon and transportation systems. Technological improvements have allowed pirates to attack further away from their coastal bases in Somalia, increasing considerably the geographic spread of pirate-infested waters and the amount of time ships spend transiting through those waters, thus raising trade costs.

We find that piracy originating from Somalia and occurring in or around the Gulf of Aden significantly reduces trade between county-pairs that ship goods though the Gulf. The reduction in the volume of bilateral trade due to the increase in attacks and in pirate reach between 2000 and 2010 averages 1.9 percent per year. This estimate takes into account all tradeable goods, even those less susceptible to maritime transport. Trade in bulk commodities, which are almost exclusively shipped by sea and are the most likely to respond to trade frictions because of their larger elasticity of demand, is estimated to fall an average of 4.1 percent per year.

We also carry out a heterogeneity analysis to study the variation of trade costs along several relevant dimensions. We find that piracy in the Gulf of Aden reduces trade between countries that are separated by relatively short distances, but not between countries that are far apart. This evidence is consistent with shorter routes witnessing a larger relative increase in trade costs given that a larger fraction of the total distance is traveled through pirate waters. This is also consistent with more distant country pairs having other routing possibilities that avoid the Gulf of Aden. Lastly, when considering which nations are affected the most by the piracy problem, we find that the effect of piracy does not vary systematically with the income level of a trading partner.

Applying our estimates to the value of trade moving through the Gulf of Aden suggests that no country–including those with a significant share of trade moving through Aden–loses more

than 2 percent of trade value because of piracy. However, in our view it would be incorrect to conclude that the costs from piracy are negligible. When considering the *absolute value* of trade losses, we estimate an average annual loss of $25 billion, with most of that accruing to a handful of countries. In particular, our estimates suggest that the European Union lost an annual $11 billion in trade, accounting for 44 percent of total piracy costs.

Our paper provides important and robust evidence that the threat of violence and, more generally, the possibility of disruptions in the transportation network have a negative effect on trade. In this regard, the paper shares an important commonality with Anderson and Marcouiller (2002); Nitsch and Schumacher (2004); Blomberg and Hess (2006); Mirza and Verdier (2008); De Sousa, Mirza, and Verdier (2008), which find an effect of violence and terrorism on international trade. Our paper joins an economic literature assessing modern piracy and its impact on international trade.[1] Besley, Fetzer, and Mueller (2012) estimate that the increase in pirate attacks in 2008 caused an increase in shipping costs between 8 and 13 percent for bulk goods traveling through the Gulf of Aden. Bensassi and Martínez-Zarzoso (2012) study the effect of piracy on the volume of international trade between Europe and Asia, and find that exports fell by 11 percent for every 10 ships that are hijacked by pirates from Somalia, Southern or South-Eastern Asia.[2] A recent report by the World Bank (2013) focuses strictly on Somali piracy and, using a methodology similar to ours, exploits a difference-in-difference strategy on a sample of 150 countries. The study finds that trade flows of affected countries fell by 7.4 percent due to Somali piracy, which corresponds to an increase in trade costs of 0.74 –1.49 percent. The range of estimates from these cited papers are quite similar, pointing to

[1] A broader literature has looked at a number of other interesting aspects of Somali piracy that inform our model and assumptions. For example, de Groot, Rablen, and Shortland (2012) analyze ransom negotiations in the Somali context and find that observables such as length of imprisonment, size of boat, and nationality of the crew are all significant determinants of ransom value. Similarly, Ambrus and Chaney (2013) consider ransom negotiations between Spain and the Barbary pirates in the sixteenth and seventeenth centuries and find that people in captivity for longer periods were ransomed more cheaply.

[2] Since Bensassi and Martínez-Zarzoso restrict the data and analysis to bilateral trade flows between Europe and Asia, their analysis relies mostly on the time variation in pirate attacks as a source of model identification. By considering bilateral trade data from regions trading outside of pirate infested waters, we effectively construct a reference group against which to compare the fluctuations in trade observed along routes impacted by piracy, and reduce omitted variable bias. In addition, it is also worth highlighting that while Bensassi and Martínez-Zarzoso focused on all sources of maritime piracy, their positive results are driven by pirate hijackings, which are mostly carried out by Somali pirates.

substantial costs imposed by piracy on global trade. It is thus perhaps surprising that even though we use a similar methodology and data as the World Bank (2013) study, our results are much more conservative. The main reason for this is that our estimations use a very rich structure of regression fixed effects that account for country-specific changes in the patterns of trade over time (i.e., multilateral resistance terms). Since our results mimic the estimates from the previous literature when we do not control for the multilateral resistance terms, we conclude that part of the trade distortion effects of piracy identified by prior estimates is spurious, as it captures changes in the patterns of trade that are exogenous to the incidence of piracy.

The remainder of this paper proceeds as follows. Section 2 describes piracy in the Gulf of Aden and discusses the mechanisms through which piracy may affect trade volumes and trade costs. Section 3 lays out the empirical model for bilateral trade. Section 4 describes the data sources and variable construction, while section 5 presents our results on the impact of piracy on international trade. Section 6 concludes.

2 Background

2.1 Spread of Somali piracy

Piracy affects a large number of countries in the world, especially around the tropics. The concentration of piracy in these regions can be seen in Figure 1, which maps all recorded instances of pirate attacks collected by the International Maritime Bureau from 2000 to 2011. The Horn of Africa around the Gulf of Aden is the site for a significant number of those attacks. Other areas with a high frequency of attacks include the Malacca Strait, the Gold Coast around West Africa, and the Gulf of Bengal. The emergence of widespread piracy events around Somalia is relatively recent. Figure 2 plots the time series of attacks around the Gulf of Aden and the Malacca Strait over the period 1991-2011.[3] While Indonesian piracy has been

[3]While the number of attacks is high by simple count, the larger volume of vessels passing through the Malacca Strait implies that the ships traveling through that region are less likely to be attacked. While precise numbers are difficult to find, Evers and Gerke (2006) estimate that more than 50,000 ships travel through the Malacca Strait each year, with more recent estimates as high as 70,000 ships per year. On the other hand, the

active for at least two decades, Somali piracy did not occur in large numbers until 2005.[4]

A key characteristic of Somali piracy is that, in a short amount of time, it has experienced a significant technological evolution. Initially, pirates operated *dhows* or fishing boats to assault vessels that came too close to the Somali coast. Over time, pirates enrolled faster and more powerful boats and better arms, which allowed them to seek targets further afield. As operations became more organized and better funded, pirates invested in a "mothership" strategy involving a large pirate ship serving as a base for a number of speed boats located deep in the open ocean. Upon finding a suitable target, pirates would board the speedboats and quickly approach and attempt to hijack the target ship. If captured, the vessel would then be towed back to a pirate safe haven in Somalia, where it remained while ransom negotiations took place (Shortland and Vothknecht, 2011). The result of this technological and organizational evolution is that piracy increased dramatically in intensity, violence, and geographic spread. As Figure 3 shows, all reported pirate attacks occurred within 500 kilometers of the Somali coast until 2003. Starting in 2004, attacks were taking place between 500 and 1,000 kilometers from the coast and, after 2005, some attacks were taking place 1,200 kilometers from the Somali coast. As the reach of piracy extended further and further into the Indian Ocean, ships were spending more and more of their travel time in "pirate waters".

While both the number of attacks and the geographic spread of piracy were increasing in the second half of the decade, the timing between the two dimensions of expansion differed somewhat. Figure 4 graphs the monthly counts of attacks, the distance of the furthest attack from a Somali port by month and year, and (with a dashed line) the maximum distance in kilometers away from Somalia that pirates had attacked up to that point–a distance which we refer to as *Reach*. The frequency of attacks was at its most intense rate in the 2007-2009 period. On the other hand, the ability of pirates to reach targets increased the fastest in the 2005-2007 period.

Suez Canal Authority reports indicate that travel through the Canal peaked in 2008 with 21,415 ships.

[4]Recent reports indicate that piracy may be on the decline in Somalia Saul (2013). Many observers believe the ongoing slow down in attacks is due the presence of navy patrols and enhanced onboard security World Bank (2013). These methods of pirate repression are quite costly; thus, pirate risk is thought to continue to affect trade even in the absence of a significant number of attacks.

2.2 Cost of piracy

Piracy imposes two types of costs on maritime carriers. A direct cost is accrued in the eventuality of pirate capture. Once a ship is captured, it is often driven to the Somali coast where cargo, crew and ship are taken hostage, often for long periods of time, while a ransom is negotiated.[5] Most hijacking cases are resolved with the ship, crew, and cargo being returned to the owner once the ransom has been paid. Sometimes the cargo is sold off in local markets, captured vessels are retained and turned into pirate mother-ships, or crew members are killed or die in captivity.[6]

The probability that a hijacking occurs is generally quite small, although not negligible. For example, in 2009, it is estimated that only 0.2 percent of the ships passing through the Gulf of Aden were boarded by pirates (Gilpin, 2009). Nonetheless, the substantially high costs of capture impose increased *operating* costs on all transiting ships. Ships transiting through pirate waters must pay higher risk premia on insurance, as well as on wages and benefits to crews as a result of the risk of being attacked, taken hostage, or even killed.[7] They must also engage in other defensive measures such as hiring security forces, increasing travel speed in pirate waters with consequent increase in fuel use, and modifying ships to make them less likely to be hijacked (de Groot, Rablen, and Shortland, 2012). Besley, Fetzer, and Mueller (2012) estimate that shipping costs through the Gulf of Aden have increased by 8-13 percent following the increase of pirate activity.

It is important to highlight that Somali pirates are responsible for the great majority of hijackings, because they have access to safe havens in Somalia where hostage ships and crew can be held for a prolonged period of time. In contrast, pirates elsewhere lack such safe havens and must generally limit their activities to theft (Raymond, 2009; Eco, 2013). It is thus no surprise that the costs imposed by pirates outside of Somalia has been found to be relatively

[5]The average duration from hijacking to ransom payment was 6 months in 2011 Bellish (2013).

[6]Somali pirates are estimated to earn $200 million each year in ransom payments Besley, Fetzer, and Mueller (2012). In 2010 alone, 1181 people were taken hostage (International Maritime Bureau, 2011) with detention periods lasting up to 1,178 days World Bank (2013).

[7]Insurance rates reportedly increased 4000 percent from 2008 to 2009 Frump (2009); between 82 and 97 seafarers have died during pirate attacks, in Somali detention, or during rescue operations World Bank (2013)

small. For instance, World Bank (2013) find no change in shipping costs following an increase in attacks in the Malacca Strait, and Martínez-Zarzoso and Bensassi (2013) find that the only form of pirate activity that affects trade is hijacking. Because of this, we do not expect to find significant effects of piracy on trade along routes outside the Gulf of Aden and Indian Ocean.

3 Conceptual framework

In the context of international trade flows, instances of piracy acts can be thought of as shocks that increase shipping costs. In what follows, we model such shocks as a component of the ad-valorem (iceberg) trade cost function and embed this in the standard gravity equation of bilateral trade. The goal is to formalize the direct link between maritime piracy and international trade, which helps us derive the econometric model and the identification strategy.

3.1 The Gravity Equation

Following the trade literature, we consider an N-country world with the representative consumer of each country deriving utility from all available products according to a constant elasticity of substitution (CES) utility function. For simplicity of exposition, we disregard the time dimension available in our panel dataset, and focus for now on characterizing trade at a given point in time. Standard utility maximization subject to the budget constraint leads to the following aggregate import demand function, d_{ij}, in country i for a product traded by country j:

$$d_{ij} = \left(\frac{p_{ij}}{P_i}\right)^{-\sigma} \frac{Y_i}{P_i}, \qquad \text{with} \qquad P_i = \Big[\sum_{j=1}^{N} (p_{ij})^{1-\sigma}\Big]^{1/(1-\sigma)} \tag{1}$$

where σ denotes the elasticity of substitution across products, Y_i is the aggregate expenditure in country i (i.e., GDP), P_i is the CES price index and represents the aggregate price of the entire consumption bundle, and p_{ij} is the import price paid in country i for a good produced in country j. The import price includes the factory gate price, p_j, and the ad-valorem (iceberg)

trade cost τ_{ij}, such that:

$$p_{ij} = \tau_{ij} p_j \tag{2}$$

Summing the expenditure per product in country i across all the n_j symmetric products traded by the exporting country j results in the following equation for the volume of trade between countries i and j:

$$X_{ij} \equiv n_j p_{ij} d_{ij} = n_j Y_i \Big(\frac{\tau_{ij} p_j}{P_i} \Big)^{1-\sigma} \tag{3}$$

Following Anderson and van Wincoop (2003), we can use the goods market clearing condition in the exporting country j (i.e., $Y_j = \sum_{i=1}^{N} X_{ij} = n_j \sum_{i=1}^{N} p_{ij} d_{ij}$), to substitute for the endogenous factory price p_j and for the number of products n_j in equation (3), and get the familiar expression of the gravity equation:

$$X_{ij} = \frac{Y_i Y_j}{Y_W} \Big(\frac{\tau_{ij}}{P_i \Pi_j} \Big)^{1-\sigma} \tag{4}$$

where $Y_W = \sum_{i=1}^{N} Y_i$ represents the world income. Π_j is a function of all countries' CES price indexes that, under the assumption of symmetric bilateral trade costs, becomes equivalent to the own CES price index P_j.[8]

The log of the gravity equation (4) defines the econometric model that is typically taken to the data in order to estimate the impact of the trade costs τ_{ij} on the volume of bilateral trade:

$$lnX_{ij} = -lnY_W + lnY_i + lnY_j + (1-\sigma)\tau_{ij} - (1-\sigma)(lnP_i + ln\Pi_j) \tag{5}$$

As pointed out by Anderson and van Wincoop (2003), one empirical challenge in correctly identifying a gravity equation of bilateral trade comes from the fact that the importer and exporter price indexes, known as "multilateral resistance" terms, are unobservable. And because they are a direct function of the bilateral trade costs and of countries' income levels, their omission from the regression model biases the main coefficients of interest. In our specific

[8] To be precise: $\Pi_j = \left[\sum_{i=1}^{N} \frac{Y_i}{Y_W} \big(\frac{\tau_{ij}}{P_i} \big)^{1-\sigma} \right]^{1/(1-\sigma)}$. When $\tau_{ij} = \tau_{ji}$, then $\Pi_j = P_j$.

case, the effect of maritime piracy on bilateral trade is going to be biased if omitting from the estimation model the multilateral resistance terms. Our solution to this problem is to use importer and exporter specific fixed effects to account for the multilateral resistance terms. Adding also the time subscripts specific to the panel dimension of our dataset, the preferred gravity equation specification can be written as:

$$lnX_{ijt} = \alpha_{it} + \alpha_{jt} + (1-\sigma)ln\tau_{ijt} + \epsilon_{ijt} \tag{6}$$

where ϵ_{ijt} represents an error term and accounts for measurement error in reported trade flows, as well as for any unobserved determinants of bilateral trade.

3.2 Piracy and the Trade Cost Function

We model the bilateral trade costs τ_{ijt} as a function of the transportation cost between countries i and j, as well as other implicit trade frictions known to affect their international trade. The bilateral transportation cost is assumed to be determined by the geographic distance between the two trading partners, $Dist_{ij}$, and by the extent of maritime piracy on that trade route at a given point in time, i.e., $PirateRisk_{ijt}$.[9] We denote the other trade frictions by a vector Z_{ij} of bilateral variables, and consider factors such as common language and colonial linkage indicators, as well as participation in bilateral or multilateral trade agreements.[10] In summary, we assume the following bilateral trade cost function:

$$\tau_{ijt} = f\big(Dist_{ij}, PirateRisk_{ijt}, Z_{ijt}\big) \tag{7}$$

We measure the risk of piracy in two ways. First, we follow the current literature in using the log of the number of reported pirate attacks in a given year carried out in the proximity of

[9]For simplicity of exposition, we ignore the fact that successful hijackings destroy traded goods, and focus only on the indirect trade costs; that is, piracy enters in equations (5) and (6) through τ_{ijt} only.

[10]Common border is another variable typically included in gravity equations, but given our focus on trade shipments transported by sea, in our sample we exclude bilateral trade flows between countries that share a border as we expect a significant fraction of trade to be shipped by ground.

Somalia, $Somali\ Attacks_t$.[11] Unfortunately, this measure is not without problems, as it could severely underestimate the impact of piracy on trade. One reason is reverse causality: the increase in attacks may be partially due to an increase in available targets, something that is quite possible given the significant increase in trade through the gulf of Aden (see figure 5). Another reason is that shipper's unobserved investments in protection (which increase trade costs) could help reduce the number of recorded attacks.

For these reasons, we also use the variable $Reach_t$, defined as the maximum extent of pirate reach into the sea up until time t. This alternative measure of piracy risk has the advantage of being largely free from these problems. We found no strong reason to suspect that pirates' geographic span of control has to increase at the same rate as the growth of regional trade. In the same way, there is no strong reason to believe that in the absence of changes in aggregate trade – beyond what is predicted by countries' geography and rate of economic growth – the reach of maritime piracy cannot vary over time. Our view is that the geographic expansion of pirate activity is more likely an outcome of the safe haven provided by the position and lawless state of Somalia, the increased availability of technology to pirates, and a slow reaction and coordination of anti-pirate activities at international level. These conditions provided the suitable environment for the existence and growth of pirate organizations, whose accumulated capital and experience over time allowed them to expand.

In identifying the effect of piracy on transportation costs, we rely on two assumptions. First, we assume that piracy increases shipping costs only if the predicted trade route between i and j goes through pirate waters. Second, transport costs along pirate waters are monotonically related with the intensity of pirate activity. Given the geography of pirate attacks around Somalia, we assume that trade moves through pirate waters if the most likely trade route (measured by minimum maritime distance between a pair of countries) passes through the Gulf of Aden, or through the Indian Ocean. Letting $Aden_{ij}$ be the indicator variable for trade routes through the Gulf of Aden, and letting IO_{ij} be the equivalent for trade routes through the Indian

[11] In this paper, a pirate attack refers to any reported incident of piracy and armed robbery against ships, with no distinction between actual and attempted attacks. Such data is collected, tabulated and disseminated by the ICC International Maritime Bureau (IMB).

Ocean (see Appendix Table A2 for a tabulation of these two variables by country pair), the trade cost function τ_{ijt} for a given time period t can be written in log form as:

$$ln\tau_{ijt} = \gamma_0 lnDist_{ij} + \gamma_1 Aden_{ij} + \gamma_2 Aden_{ij} \times PirateRisk_t + \\ + \gamma_3 IO_{ij} + \gamma_4 IO_{ij} \times PirateRisk_t + \delta Z_{ijt} + \alpha_t \quad (8)$$

where the time fixed effect α_t captures changes in global trade costs that are common to all country pairs, including changes in the risk of piracy.

The ad-valorem tax imposed by piracy on trade moving through the Gulf of Aden is given by γ_2, while the tax on trade passing through the Indian Ocean is given by γ_4. Note that due to the Gulf of Aden being a narrow passage for ships, all trade transiting through it is subject to piracy. On the other hand, as piracy on the Indian Ocean is concentrated in the North West part of the ocean, not all the trade through the Indian Ocean is occurring in pirate waters. Thus, the average tax on trade through this area, captured by γ_4, should be smaller than γ_2.

Substituting the trade cost function into the gravity equation given by equation (6), we get:

$$lnX_{ijt} = \alpha_{it} + \alpha_{jt} + \beta_0 lnDist_{ij} + \beta_1 Aden_{ij} + \beta_2 Aden_{ij} \times PirateRisk_t + \\ + \beta_3 IO_{ij} + \beta_4 IO_{ij} \times PirateRisk_t + \delta Z_{ijt} + \epsilon_{ijt}, \quad (9)$$

where the coefficients $\beta_\kappa \equiv (1-\sigma)\gamma_\kappa$, with $\kappa \in \overline{0,4}$, are reduced form coefficients. Thus, the estimated reduced form effect of piracy on the volume of bilateral trade, given by β_2, combines the effect of piracy on the cost of transport (γ_2), as well as the price elasticity of demand (σ), which also represents the elasticity of substitution among the products in the consumption basket. An implication of this underlying parameter structure is that for a given piracy shock to the cost of shipping goods between two countries, the responsiveness in the volume of imports is larger if the consumers in country i can easily find a substitute for goods produced by country j (i.e., σ is large).

The trade effect of Somali piracy formalized in equation (9) is identified from the differen-

tial changes in the volume of bilateral trade across affected versus unaffected trade routes (i.e., difference-in-differences). The regression estimates correctly identify the reduction in trade due to piracy provided that piracy does not affect country pairs trading outside of pirate waters. A potential concern could arise if exporters increase trade with "safe" partners in response to diminishing trade with "risky" partners, case in which β_2 and γ_2 would capture an upper bound of the trade destruction effect of piracy. However, based on the theory framework, such substitution patterns across trade partners are entirely driven by variation in the multilateral resistance term (i.e., P_i in equation (1)). More specifically, when the bilateral cost of trading with a particular country increases due to piracy, the importer price index increases as well, lowering the relative price of imports from other countries. As a result, a larger expenditure share gets allocated to products from lower trade cost, i.e., "safe" partners. Essential to our estimation, this reallocation of expenditures and increase in spending towards low trade cost partners is proportional to the change in the importer price index. So, by controlling for the multilateral resistance terms, we already account for substitution effects across trade partners. The potential for substitution effects makes it essential to control for importer-year and exporter-year fixed effects.

In estimating equation (9), it is necessary to account for the fact that trade across different regions grows at different rates for other exogenous reasons, and these growth rates could be spuriously related to trade via the Gulf of Aden. We will address this omitted variable bias problem by showing that our estimate of β_2 is robust to the inclusion of a broad set of importer and exporter controls, including importer-year and exporter-year fixed effects. Finally, we use the Cameron-Gelbach-Miller procedure to cluster standard errors by importer-year pairs to capture any consumer-specific cyclical component in the error term (Cameron, Gelbach, and Miller, 2011). Alternative error structures do not change the significance of our results.

Tariff Equivalent of Maritime Piracy. If reliable data on bilateral trade costs τ_{ijt} were available for a large set of countries, we would estimate an extended version of the equation (8) to directly find the ad-valorem tariff equivalent of maritime piracy, i.e., $\hat{\gamma}_2$. Unfortunately, this

approach is not feasible for us since the c.i.f./f.o.b. price ratios that could be calculated from the COMTRADE data and used as proxies for iceberg trade costs are notoriously noisy (Hummels and Lugovskyy, 2006). Instead, we exploit the structure of the gravity model together with the estimated coefficients from equation (9) to make inferences about the magnitude of the ad-valorem tariff equivalent of maritime piracy. That is, we calculate $\hat{\gamma}_2 = \hat{\beta}_2/(1-\hat{\sigma})$ by using estimates from the trade literature for the elasticity of substitution σ.

4 Data

Pirate risk. The International Maritime Bureau (IMB) via the ICC Commercial Crime Services department collects information on all reported instances of actual and attempted piracy and robbery. This represents the most comprehensive piracy data available for the period 1991-2011. For each reported event, the IMB lists the date, the geographic coordinates, the pirates' suspected country of origin, and the outcome from the episode (i.e., attempted boarding, boarding, highjacking, etc.).[12] From these data we construct our two explanatory variables: *Somali Attacks* and *Reach*.

The first measure of piracy, *Somali Attacks*, is calculated by summing up all the attacks initiated by suspected Somali pirates during each year of the sample, regardless of the assailants' nationality on record. Pirates' nationalities are recorded with significant error, with many attacks in the Gulf of Aden being attributed to a number of nationalities. In our main specifications, we considered as "Somali" all pirate activities that took place in the Gulf of Aden or in the North-Western part of the Indian Ocean (refer to the Appendix Table A1 for the detailed listing of pirate nationalities included in our definition of Somali piracy). However, in one of our robustness exercises we experiment with a more narrowly defined measures of Somali piracy, and show that it has no qualitatively different impact on our estimates.[13]

[12]The data also includes the flag being flown by the attacked vessel. Unfortunately, because of the widespread use of "flags of convenience" and the ability of ships to avoid costly regulations by flying a foreign flag, flag flown is a relatively poor proxy for either the countries involved in the trade or the location of the shipping firm Hoffmann, Sánchez, and Talley (2004).

[13]We also generated a number of piracy variables associated with other regions of the world: West Africa, the Indian Subcontinent, East Asia, Strait of Malacca, and Rest of World. The Appendix Table A1 indicates how

To construct the second measure of piracy, *Reach*, we use a GIS program to calculate the geographic distance d_{i_t} between the location of each attack i that took place at time t and the closest point along the Somali coast. We define the geographic reach of pirates as the distance of the furthest attack into the sea up to that time period, i.e., $Reach_t = \max_{s \leq t}\{d_{i_s}\}$. Since this measure is sensitive to outliers (i.e., isolated events of local piracy across the East African or Arabian peninsula coast), we consider only those attacks attributed to Somalian, Yemeni, or Eritrean pirates. As the GPS coordinates of each attack were not reported by the IMB prior to year 2000, the measure *Reach* is available only from that year onwards. For consistency, we limit our main data analysis to the sample period 2000-2010 (although we exploit the information on piracy attacks prior to 2000 in one robustness exercise).

Our two measures of piracy risk are likely to suffer from nonstandard measurement error. For instance, it is possible that not all the incidents that actually happened over time were reported by the victimized ships to the IMB. It is also possible that the degree of underreporting may have changed with sailors' awareness of the Somali piracy problem. To the extent that underreporting is more of an issue in the early years of the sample, we would overestimate the true increase in piracy over time. This will reduce both the magnitude and precision of the regression coefficients, making our estimates a lower bound. A second potential problem is that, lacking the GPS coordinates of pirate attacks prior to the year 2000, we could underestimate the true geographic reach of pirates in the early part of the sample (if, for example, pirate reach was extensive prior to 2000). However, we believe that this is unlikely to be the case, as anecdotal evidence suggests Somali piracy was limited to the coastal regions throughout the nineties and early 2000s.

Bilateral trade volumes. Our bilateral trade data comes from the COMTRADE database provided by the United Nations. It specifies, for all 150 countries in the sample, the total value of imports by product category and source country of these imports in a given year. The data are available from 1991, but we restrict attention to the period 2000-2010 to match the

attacks from different nationalities are assigned to regions.

time window of the piracy (reach) variables. Starting from the HS 6-digit level of product differentiation, we construct two measures of bilateral trade: one that captures the total value of trade, aggregated across all traded goods, and one that measures only trade in "bulk goods"– unprocessed and semi-processed agricultural and mineral goods. Appendix Table A3 lists the HS 2-digit sectors included in our bulk commodities classification. Due to their low value to weight ratio, these goods are more likely to travel by ship rather than air, and are particularly valuable to pirates because, as undifferentiated goods, they are presumably more easily sold off in local markets. In addition, bulk goods are transported by ships that are much easier for pirates to attack and board compared to containerized ships.

Trade routes and piracy exposure. We define trade between countries i and j to be exposed to Somali piracy if the trading route connecting the two locations passes through the Indian Ocean or the Gulf of Aden. Since the COMTRADE database does not include information on maritime routes, these routes were imputed by mapping the shortest sea path linking a trade country pair. We then determined whether the shortest path transits through the Indian Ocean or the Gulf of Aden. The Appendix Figure A1 indicates how countries were assigned to regions while Appendix Table A2 indicates how region-pairs were assigned to trade routes.[14] All countries for which data are available are included in these regions except for those with multiple route profiles, which comes from having ports on multiple seas (e.g., Russia, Saudi Arabia), and landlocked countries without a clear sea trade route (e.g., Kazakhstan). These countries are designated as "other" in Figure A1 and were dropped from the sample. In addition, we removed Somalia from the sample as Somali trade is likely to be endogenous with Somali pirate activity.

Control variables. The trade regressions estimated in this paper follow the gravity model common in the trade literature and, as such, we rely on a standard set of regression control variables. The CEPII Gravity Dataset provides all gravity variables that are constant over

[14]While not central to our analysis, we also computed measures of trade exposure to other pirate regions, such as those in the Malacca Strait, Far East, Indian Subcontinent and Western Africa. All assignments are reported in the appendix table A2.

time.[15] For time varying variables, this publicly available dataset only goes to 2006. We use updated values for population and GDP from the IMF World Economic Outlook Database[16], and an updated list of trading partners in a Regional Trade Agreement (RTA) or in GATT / WTO using information provided by the World Trade Organization (WTO).[17]

Summary statistics. Panel A of Table 1 indicates mean values in thousands of US dollars of the imputed trade through the Gulf of Aden as compared to the rest of world trade, by country pair. The annual value of trade between country pairs that use the Gulf of Aden is, on average, less than half of the value of trade between country-pairs that do not. Trade in bulk goods makes up a small fraction of the total value of trade, both through the Gulf of Aden and through other routes. That does not mean that bulk trade is unimportant: since bulk trade has low value to weight ratio, it represents a much larger fraction of ship tonnage. For instance, 23% of ships and 16% of tonnage transiting through the Suez Canal in 2009 transported bulk products (Suez Canal Authority, 2013).[18]

[Table 1 Here]

Panel B provides summary statistics for some explanatory variables, including the number of attacks and the furthest distance from the Somali coast to an attack. 31 percent of the country-pairs used in the analysis have an imputed trade linkage through the Gulf of Aden. The canal provides passage to 16.8 percent of the total trade and 9.8 percent of bulk trade in our dataset. We use these values to calculate the total trade cost of piracy.

5 Estimation Results

Total trade volumes. We begin with the analysis of the effects of piracy on the volume of bilateral trade. We estimate equation (9) and report in Table 2 five different fixed effects spec-

[15] Details about the data construction can be found in (Head, Mayer, and Ries, 2010). The data source is available at: http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp.

[16] http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/index.aspx

[17] List of Regional Trade Agreements: http://rtais.wto.org/UI/PublicAllRTAList.aspx
List of membership into the WTO: http://www.wto.org/english/thewto_e/thewto_e.htm

[18] http://www.suezcanal.gov.eg/TRstat.aspx?reportId=3

ifications. Each specification gradually restricts the amount of data variation used for model identification in order to contain the sources of omitted variable bias. In column 1, we estimate a gravity model that includes importer, exporter, and year fixed effects. This specification controls for time-invariant country specific characteristics such as geography, industrial specialization, or the average openness to international trade. The time fixed effects account for aggregate shocks to world-wide trade that affect equally all trading partners. To better control for idiosyncratic shocks and differential growth rates across countries, column 2 includes importer-specific year dummies, and column 3 exporter-specific linear time trends. To account for the fact that the 2008 recession caused a large decline in global trade, with potentially differential consequences across countries, in column 4 we interact a "financial crisis" dummy (set equal to one starting with year 2008) with the exporter-specific linear trend. This specification presumes that the crisis affected not only the level of exports, but also the trend. Our most flexible specification is presented in Column 5, which incorporates both importer-year and exporter-year fixed effects. This specification accounts for year-by-year changes in import and export patterns that are specific to each trading country but common across their bilateral trade partners. While demanding in terms of data variation, this is the preferred specification as it accounts for the unobserved multilateral resistance terms defined in the theory section.

Across all specifications, we are interested in the interaction between the annual Somali pirate attacks and trade through the gulf of Aden. We find a negative estimated coefficient on this interaction term: bilateral trade through the Gulf of Aden falls relative to trade through other routes in the years of high Somali pirate activity. The magnitude of the estimate decreases as we implement a more exhaustive structure of fixed effects, going from -0.07 (in the estimation that does not account for any country-specific trends) to -0.04 in the preferred specification reported in column 5. This coefficient change suggests that the importer and exporter-specific time trends are essential in accounting for unobservable trade determinants, whose omission would otherwise bias the piracy effect upwards. The larger estimates that we find when using less stringent fixed effect models, such as, for example, the Column 1 specification, are consistent with the results found in previous studies (e.g., World Bank (2013) and Bensassi and Martínez-

Zarzoso (2012)).

To quantify the impact of maritime piracy, we use the fact that pirate attacks grew by an average of 48.1 percent per year from 2000-2010. Based on our preferred specification, this implies a $0.481 * (-0.04) = 0.019$ or 1.9 percent annual reduction in trade passing through the Gulf of Aden due to piracy over that period, relative to trade through other routes. Applying our estimates to the period 2006 - 2007, when we observe a 134 percent increase in attacks, we estimate an economically significant 5.4 percent decrease in international trade. These results represent a significant displacement of trade. Using our imputed trade routes, we estimate that between 2000 and 2010 an average of 1.3 trillion US$ passed through the Gulf of Aden each year. A 1.9 percent reduction in trade through the Gulf of Aden thus represents a trade loss of approximately $25 billion annually, with a peak of $70 billion in 2006-2007.

Table 2 also reports coefficients on the interaction between piracy and trade through the Indian Ocean. The estimated coefficients are negative, suggesting that piracy has a negative impact on trade between countries in the Indian Ocean. However, the results are not statistically significant in our most rigorous specifications.[19] Finally, the gravity control variables are generally significant and have the expected sign. This is true throughout our analysis and, as such, we report only the variables of interest in the remaining tables.

[Table 2 Here]

Table 3 estimates equation (9) with the alternative measure of piracy – pirate reach. Exploiting this alternative source of data variation in maritime piracy, we again find strong significance in our key variables of interest. As before, the coefficient magnitude decreases as we include more stringent controls and fixed effects. These controls are therefore important in preventing one from overstating the impact of piracy. The estimated coefficient on the interaction between Indian Ocean trade and piracy remains negative, statistically insignificant, and consistently smaller than the interaction between the Gulf of Aden indicator and piracy. In terms of magni-

[19]We also ran each specification while including a dummy variable for trade traveling through the Strait of Malacca and an interaction term with attacks in Malacca. Generally, the coefficients on these variables are not significant and their inclusion do not affect our other estimated coefficients.

tude, the estimate in column 5 suggests that a 100 percent increase in pirate reach is associated with an 8.2 percent decrease in trade through the Gulf of Aden, relative to other routes. Pirate reach increased an average of 21.3 percent per year from 2000 to 2010 including a 51 percent increase in 2007 alone. This corresponds to an average 1.7 percent trade reduction per year, with a 4.2 percent reduction in 2007. This suggests the loss of trade through the Gulf of Aden is $22 billion annually. As an upper bound, the increased pirate activity in 2007 may have prevented $111 billion in trade from traveling through the Gulf of Aden.

[Table 3 Here]

Bulk goods trade. We next assess how piracy has affected trade in bulk goods, the category we expect to be most susceptible to piracy. We estimate Equation (9) and report the results in Table 4. For conciseness, we only report the three more comprehensive fixed effects specifications corresponding to columns 3 - 5 in Tables 2 and 3. In displaying the bulk trade results, the first three columns use the number of pirate attacks as the measure of pirate activity, while the final three columns use the pirate reach variable.

Focusing on the magnitude of the coefficients, we find larger estimated effects of piracy on bulk trade relative to overall trade. This is expected given the larger demand elasticity of homogenous goods, such as the bulk commodities, but also the higher responsiveness of the trade cost to piracy risks, which is explained by the fact that ships carrying bulk goods are more likely to be attacked. The estimate from the preferred specification in column 3 of Table 4 implies a 4.1 percent reduction in trade per year from 2005-2010 as a result of the 48.1 percent increase in pirate attacks annually in the Gulf of Aden, while column 6 suggests a 3.3 percent reduction due to the 21.3 percent annual increase in reach.

[Table 4 Here]

Trade Costs. As discussed in section 3.2, we can infer the tariff equivalent of maritime piracy from the gravity equation estimates. Focusing on the results for bulk trade reported in column 3 of Table 4, and assuming an elasticity of substitution for bulk commodities of 10, we calculate a

tariff equivalent of maritime piracy equal to 0.009.[20] Given an average increase in piracy attacks by 48.1 percent per year, the implied increase in transport cost is 0.45 percent on average.

Making the same comparison based on the piracy reach coefficients, the tariff equivalent of maritime piracy derived from the estimates in Table 4 column 6 is 0.017 percent. At an average annual increase in piracy reach by 21.3 percent, the estimate implies an increase in transport cost from piracy risk of 0.36 percent.

The inferred ad-valorem tariff equivalent of piracy turns out to be much smaller in magnitude than the existing estimates in the literature, e.g., Besley, Fetzer, and Mueller (2012). However, we think that the range of values that our calculated tariff equivalents fall into are more likely to be representative for a larger group of traded goods.

5.1 Robustness Tests

We next explore the robustness of our coefficients of interest to a number of alternative specifications. The results are reported in Table 6. Each reported specification follows the preferred structure of fixed effects as used in column 5 of Table 2.

So far, we have assumed that the trade effect of pirate attacks and the attacks themselves are observationally instantaneous. It may be the case, however, that it takes a significant amount of time for trade to adjust to pirate events. In addition, pirate attacks and trade happen throughout the year, and it is reasonable to assume that attacks in December of 2007 have more of an impact on trade in 2008 than in 2007. An alternative specification would thus assume that attacks in a given year affect trade only in the following year, in which case piracy would enter Equation (9) with a one year lag.

Panel A displays the results for our key variables of interest when we lag the piracy measure by one year. The results are similar to our estimates using a contemporaneous measure of attacks (reach), but they are smaller in magnitude and less significant. Further lags (2 years,

[20] To calculate the tariff equivalent of maritime piracy, we divide the gravity equation estimate of -0.085 from Column 3 in Table 4 by $1 - \sigma = 1 - 10 = -9$. Note that the values for the elasticity of substitution σ typically assumed in the trade literature range between 5 and 10 for all goods trade (see Anderson and van Wincoop (2003) among others). Given our focus on more homogenous product categories such as bulk commodities, we have decided to experiment with the upper bound value of σ.

etc.) as were used in Bensassi and Martínez-Zarzoso (2012) yielded insignificant results. The significance of both contemporaneous and one year lagged attacks indicates that there is some delay in trade responsiveness but the delay is much less than a full year.

In panel B we account for pirate activity in the Strait of Malacca in order to ensure that our estimates for Somali piracy are not spuriously capturing other effects. Thus, we include a dummy for trade passing through the Strait of Malacca, as well as an interaction term between the Malacca dummy and the number of recorded attacks in Malacca. We take this exercise a step further in panel C and include all piracy regions around the world and the associated attack measures. Comparing these panels to the results in Table 2 indicates that our estimates are robust to conditioning on piracy activity in other regions.

[Table 6 Here]

In panel D, we report estimates based on a more narrow definition of Somali attacks, which includes only those countries used to create our reach variable. While this measure is in some sense more precise, we believe it is inaccurate when measuring attacks because pirates' country of origin is based on the judgement of the attacked ship. In the early years of Somali piracy, captains almost always simply chose the closest country as the likely initiator of the attack. In later years, as Somali piracy became more well known, captains began to assume attacks came from Somali bases regardless of what country shores the ship was closest to when the attack occurred.

In panel E, we return to our baseline specification and definition of attacks, but limit our sample to the period 2005-2010, years in which Somali pirates were the most active. With the sample size reduction, we lose some precision; however, the results are broadly consistent with the findings from the baseline sample. While insignificant, it is interesting that the 2005-2010 subsample in panel E delivers the largest estimates of the effect of pirate reach. Finally, in our last robustness exercise reported in panel F we expand our sample to include all available observations going back to 1991. Our piracy attacks measure becomes larger and more significant when early years are included.

5.2 Heterogeneity Analysis

We now explore the underlying heterogeneity of the estimated trade cost of piracy, starting with differences in country pair distance. There are a number of reasons to think that partners trading through the Gulf of Aden and located in close proximity to one another should suffer larger trade losses compared to more distant country pairs. For instance, the distance travelled through pirate waters represents a larger fraction of the total route distance. Further, there may be fewer or less appealing ocean routes that could be taken as feasible substitutes to transiting via the Gulf of Aden. To study this issue, we estimate equation (9) on the subsample of country pairs whose bilateral distance is below (above) the median distance. Panels A and B of table 6 report the results. It is immediately clear that the estimated trade costs are associated with short routes rather than long routes. The coefficient estimate on $Aden \times PirateRisk$ is twice as large on short routes relative to the baseline specification from tables 2 and 3, respectively, and they are strongly significant. Looking at bulk trade, the coefficient of interest goes from -0.085 (using the number of attacks) in the full sample, to -0.300, and from -0.154 (using pirate reach) to -0.436. On the other hand, the coefficients estimated on the subsample of long routes are much smaller and statistically insignificant. Clearly, proximity to pirate waters matters.

We next consider the possibility that the "piracy tax" is unevenly distributed across poorer and richer countries. This could occur if, for instance, pirates target cargo ships transporting goods originating from or destined to developing countries. A more realistic scenario is that pirates do not target, and shipping companies commingle cargo from different countries; in this case, we should not observe heterogeneity in our estimates along income. In panel C and D, we run regressions on country pairs where at least one partner is below (panel C) or above (panel D) the median level of income (as measured in our database). Our estimates of all trade effects of piracy remain negative but lose precision, while the estimates for bulk trade remain consistently negative and significant. More importantly, the estimated coefficients remain very similar across the two panels, suggesting a lack of an income gradient.[21]

[21] Alternative ways of cutting the data, for instance by considering the income of sender only or importer only, lead to similar results.

5.3 Distribution of the Burden of Piracy

A final consideration must be made about the distribution of the burden of trade costs across countries. Using annual data averaged over the sample period 2000-2010, we have constructed estimates of the annual value of lost trade for all the countries in our database. Table 7 reports the estimates for the most affected countries. Columns 1 and 2 provide country level statistics on the average income and value of trade traveling through the Gulf of Aden, while column 3 shows the share of total trade going through the Gulf of Aden. Column 4 reports the monetary value of the trade lost per year due to piracy,[22] and column 5 reports it as a fraction of total trade. The last column computes what fraction of the global cost of piracy is accounted for by a particular country, where the global cost is estimated to average about $24.8 billion loss in trade per year.

Panel A of table 7 lists the countries with the highest value of trade lost through piracy as a share of their total trade. Not surprisingly, all but one of the countries in this list are located in the Indian Ocean and trade heavily with Europe or the Mediterranean region. At the upper end of the distribution, fully 2/3 of trade to Mayotte, and half of total trade of Qatar, Eritrea and Kuwait are estimated to go through Aden. Yet, as a fraction of total trade, the impact of piracy remains fairly limited (column 3). No country loses more than 2% of annual trade due to piracy, and only the three most exposed countries lose more than 1%. In addition, since the countries in the list are generally "small" countries, the value of their losses represents only a small fraction of the total cost (column 5).[23] In monetary terms, losses for the countries in the list range from 1 million dollars per year to 230 million per year; only India and the United Arab Emirates have estimated losses of more than one billion dollars per year.

An alternative way to illustrate the way in which trade losses are distributed across countries is to rank countries by the *absolute* value of trade lost due of piracy. This is reported in panel B of table 7. The countries dominating this list have significantly lower shares of trade moving

[22] This is calculated as $\frac{b}{1-b} \times TradeSuez$, where b is the estimated per year loss of trade (1.92%) and TradeSuez is the value of trade through Suez, i.e., column 2 of the table.

[23] The list excludes a possibly important large country, Saudi Arabia, for which we could not precisely estimate partnerships affected by piracy.

through the Gulf of Aden. However, being large countries, their value of trade makes up a large share of total trade transiting through the Gulf of Aden. Looking at the piracy problem in this way, it is clear that the burden of piracy falls very heavily on one trading block in particular–the European Union. We estimate annual losses approximating $11 billion dollars, which represents a fully 44 percent of the global burden of piracy.[24] China, Japan, the UAE, and India make up the remaining countries with costs over $1 billion. Thus, 70 percent of the global cost of piracy accrue to only five countries and the EU.

Table 7 highlights an important fact about piracy: while the estimated costs are not particularly large on a global scale and represent a very small share of trade for any country in the world, the monetary value of the losses are large and concentrated on few countries–most prominently, the European Union. It is thus unsurprising that the anti-piracy response has been led by countries on this list–the EU and US (through NATO), India, and China.

6 Conclusion

In this paper, we study the extent to which maritime insecurity affects international trade flows by exploiting the dramatic increase in piracy risk around Somalia. Between 2000 and 2010, pirate attacks increased seven-fold around the gulf of Aden and the Somali coast, with increasingly daring highjackings taking place further and further away from Somalia. The paper provides evidence that the escalating maritime insecurity did cause a reduction in trade volumes, suggesting that Somali piracy remains a global problem affecting countries trading through the Suez Canal.

Using a panel data set combining information on bilateral volumes of trade and on reported pirate attacks, we identify the effect of piracy on trade through a difference in difference strategy. Our empirical model compares the trade response to changes in the risk of piracy between countries trading through pirate waters relative to those pairs of countries trading through

[24]Within the EU, the burden for Germany is $2.5 billion, for the UK is $1.7 billion, for France is $1.3 billion, for the Netherlands is $1.2 billion. Italy, Spain and Belgium have burdens ranging between $700 million and $1 billion, with the remaining countries contributing $300 million or less per year.

waters free from Somali pirates. Using two alternative measures of piracy risk–the number of attacks carried out by Somali pirates, and the geographic reach of pirates off the Somali coast–we find that piracy in the Gulf of Aden reduces the volume of trade between the affected country pairs by an average of 1.9 percent per year from 2000-2010, with larger and more significant effects for trade in bulk commodities.

We estimate that this reduction in trade represents a loss of $25 billion per year. This is a large number in relation to the benefits gained by pirates which were estimated by the World Bank (2013) to be about $50 million per year from 2005-201, but it is much smaller than existing estimates of the trade effects of piracy. Our more conservative estimates are the result of addressing important limitations in the existing literature, namely the presence of omitted variable biases and the endogeneity of pirate attack incidents. While smaller than previously thought, we find that these costs are not evenly distributed, with a handful of countries shouldering a great majority of the costs.

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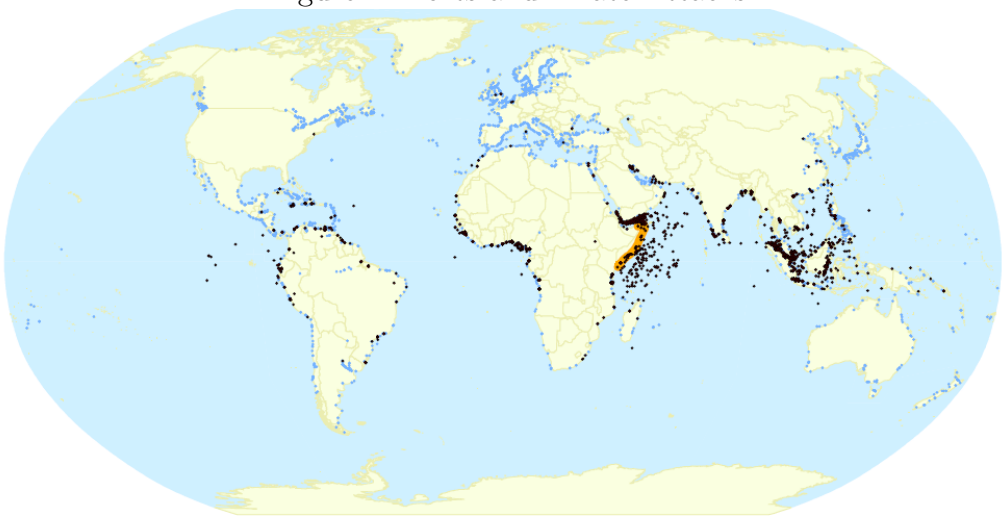
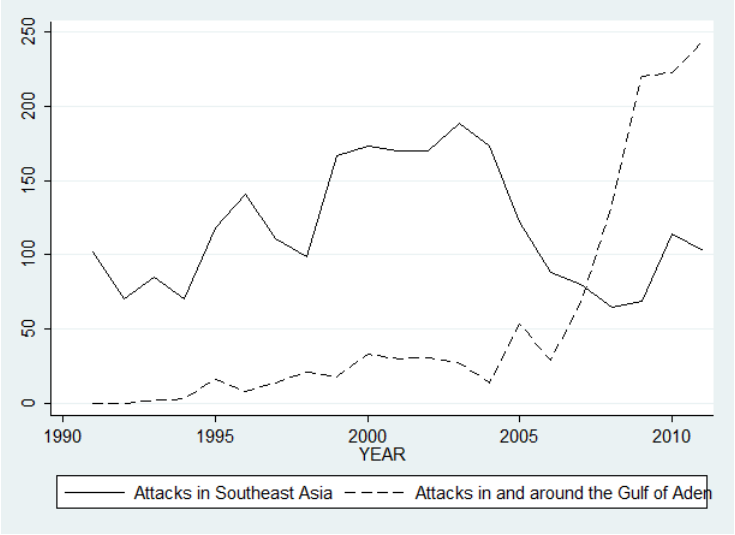
7 Tables and Figures

Figure 1: Ports and Pirate Attacks



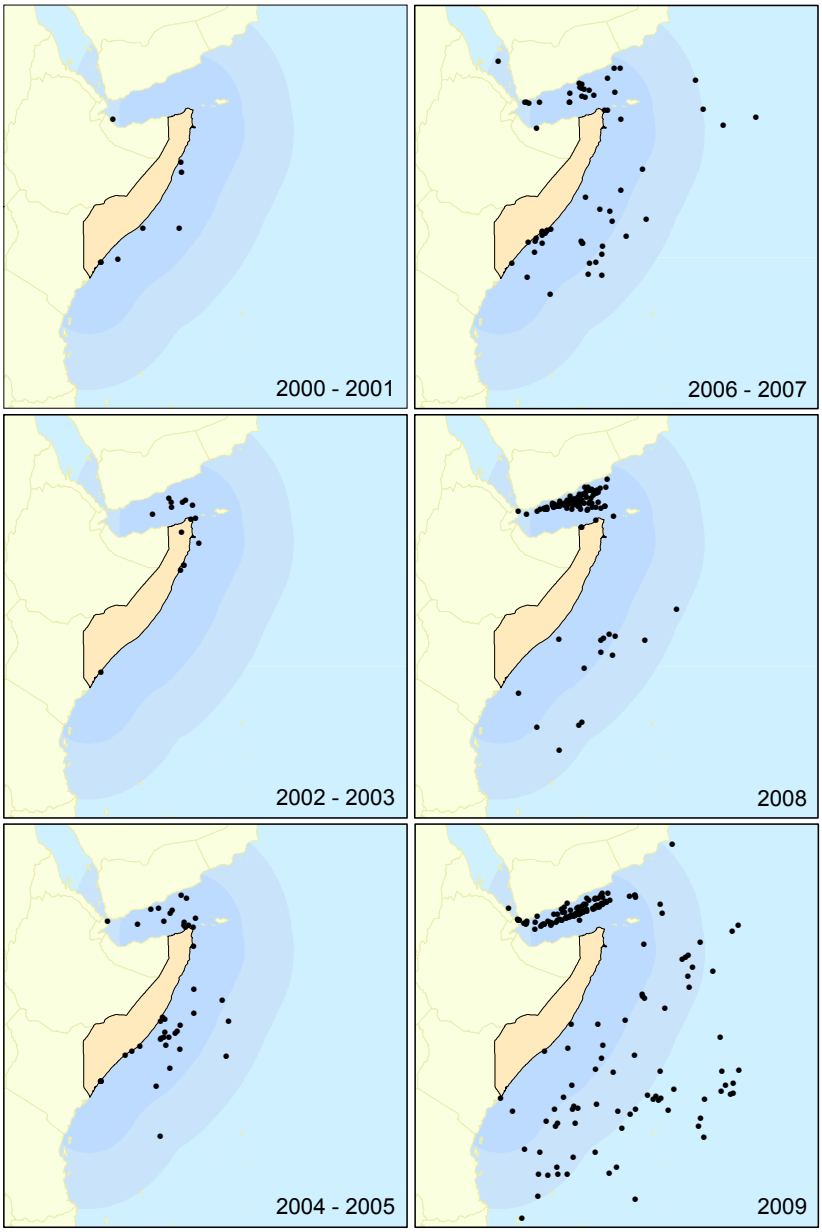
Note: Locations of pirate attacks and ports represented by dark and light dots respectively.

Figure 2: Total Number of Pirate Attacks by Year and Region



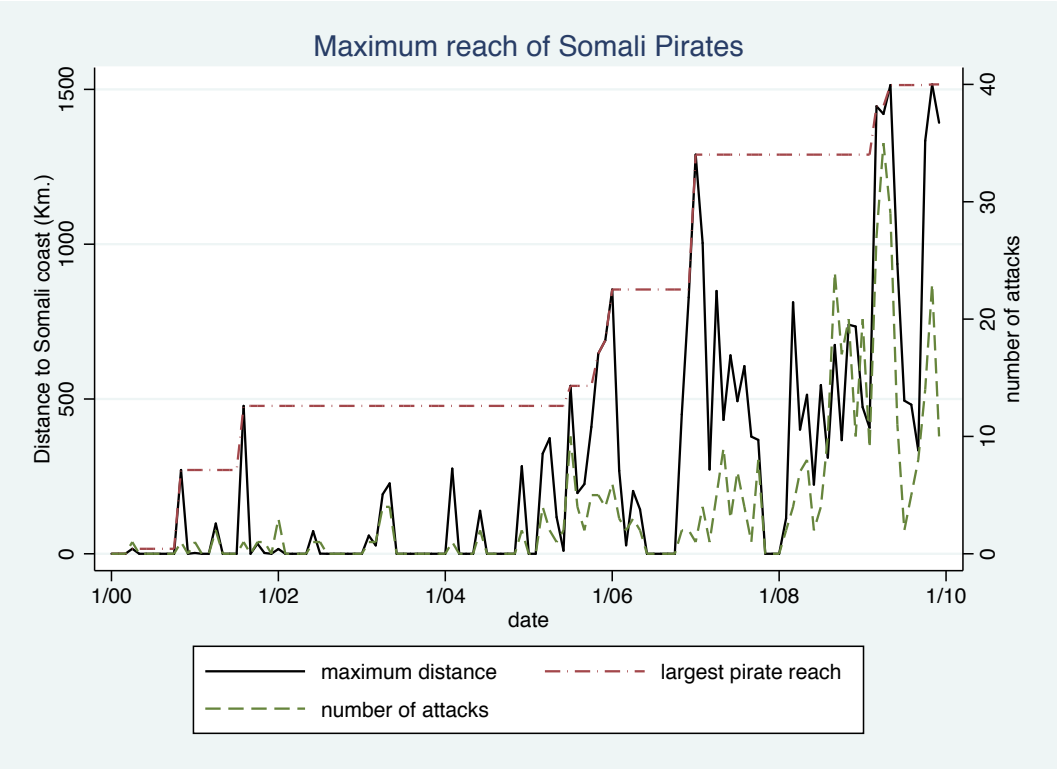
Note: Attacks attributed to Somali or Malacca strait as described by table A1.

Figure 3: Somali attacks over time



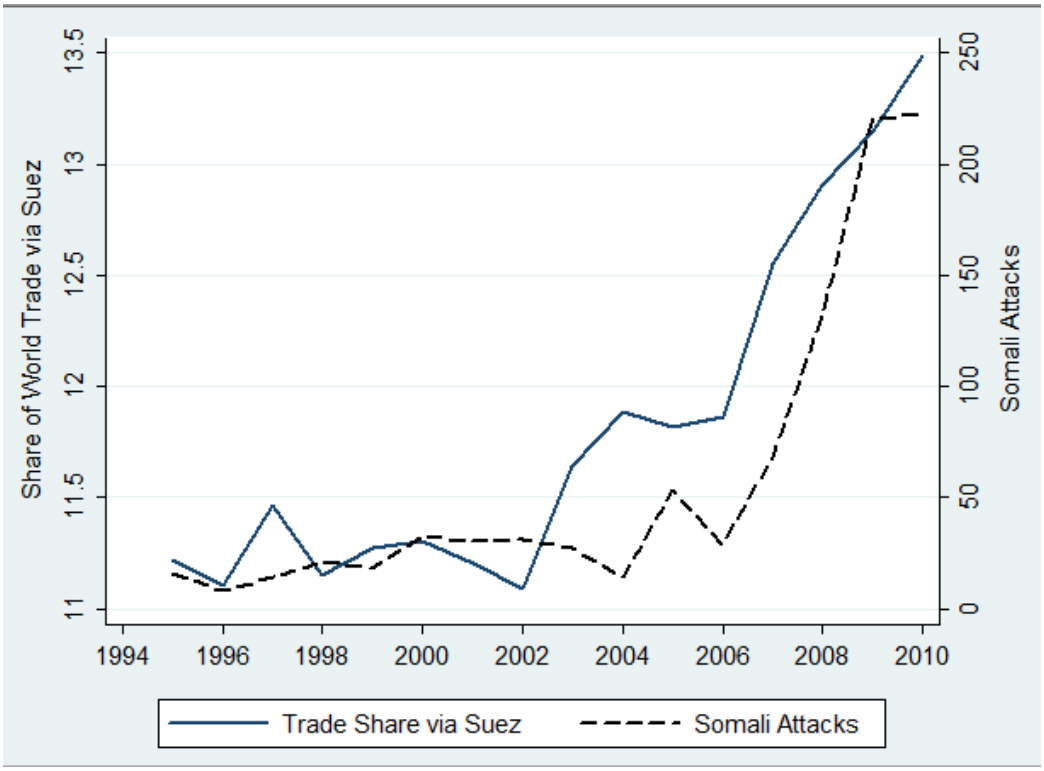
Pictured: Horn of Africa near Somalia; dots are locations of individual pirate attacks

Figure 4: Maximum Reach of Somali Pirates



Note: Monthly attacks attributed to Somali pirates as described by table A1. The maximum reach is calculated based on individual attacks.

Figure 5: Attacks around Somalia and the Fraction of Global Trade in the Gulf of Aden



Note: Attacks attributed to Somali or Malacca strait as described by table A1. Trade Share calculated by dividing the annual sum of trade between all county-pairs using the Gulf of Aden for maritime trade by the annual sum of all trade.

Table 1: Summary Statistics

Panel A: Bilateral Measures

	Gulf of Aden Trade		**Other trade**	
	Mean	St. Dev.	Mean	St. Dev.
Log of All Trade volume (thousands of $)	7.30	4.02	7.88	4.13
Log of Bulk Trade volume (thousands of $)	5.44	3.33	5.99	3.55
Percent of All Trade that is Bulk Trade (%)	0.03		0.06	
Average Distance All Trade	8,434	3,388	6,737	4,354
Average Distance Bulk Trade	8,346	3,085	6,231	4,447

Panel B: Explanatory variables

	Mean	**St. Dev.**
Somali Attacks (per year)	82.31	75.42
Log of Somali Attacks (per year)	4.01	0.88
Reach (km)	883.21	449.14
Log of Reach (km)	6.64	0.56
Log of Importer GDP (billions of $)	3.92	2.24
Log of Importer Population (millions)	2.33	1.88
Log of Importer GDP per capita (thousands of $)	1.60	1.57
Aden dummy	0.32	0.47
Percent of all-trade through Gulf of Aden	16.95	1.42
Percent of bulk-trade through Gulf of Aden	9.83	0.54

Note: Volume statistics measured in US dollars, distance measured in km.

Table 2: All Trade

	(1)	(2)	(3)	(4)	(5)
Aden Dummy	0.319***	0.340***	0.206**	0.202**	0.198**
	[0.102]	[0.090]	[0.093]	[0.094]	[0.096]
Aden × Somali Attacks	-0.070***	-0.075***	-0.042*	-0.041*	-0.040*
	[0.020]	[0.022]	[0.023]	[0.023]	[0.024]
Ind. Ocean Dummy	-0.407***	-0.369***	0.133	0.225*	0.294**
	[0.151]	[0.098]	[0.116]	[0.128]	[0.146]
Ind. Ocean × Somali Attacks	0.126***	0.117***	-0.010	-0.033	-0.050
	[0.031]	[0.023]	[0.028]	[0.031]	[0.035]
Log GDP Exporter	0.459***	0.454***	0.107	0.070	
	[0.042]	[0.051]	[0.080]	[0.100]	
Log Population Exporter	-1.021***	-1.054***	-0.167	-0.138	
	[0.202]	[0.227]	[0.630]	[0.771]	
Log Distance	-1.564***	-1.560***	-1.561***	-1.560***	-1.561***
	[0.058]	[0.021]	[0.021]	[0.021]	[0.021]
Common Language	0.686***	0.686***	0.686***	0.686***	0.683***
	[0.075]	[0.028]	[0.028]	[0.028]	[0.028]
Colonial Ties	1.081***	1.084***	1.083***	1.084***	1.085***
	[0.128]	[0.042]	[0.041]	[0.041]	[0.042]
Common Colonizer (post 1945)	0.697***	0.696***	0.695***	0.695***	0.694***
	[0.089]	[0.034]	[0.034]	[0.034]	[0.034]
RTA	0.345***	0.372***	0.360***	0.362***	0.365***
	[0.080]	[0.033]	[0.033]	[0.033]	[0.034]
Both WTO	0.226***	0.230***	0.128**	0.157***	0.196***
	[0.057]	[0.044]	[0.055]	[0.058]	[0.068]
ACP - EU	0.022	0.027	0.006	0.008	0.006
	[0.113]	[0.044]	[0.044]	[0.044]	[0.045]
Constant	16.519***	20.009***	17.918***	17.880***	17.686
	[0.947]	[0.775]	[2.036]	[2.490]	[0.000]
Fixed Effects	Importer Exporter Year	Imp-Year Exporter	Imp-Year Exp×Trend	Imp-Year Exp×Trend Exp×Crisis	Imp-Year Exp-Year
Observations	154,781	154,781	154,781	154,781	154,781
R-squared	0.698	0.699	0.703	0.703	

*** p≤0.01, ** p≤0.05, * p≤0.1. Errors clustered by importer-year.

Note: Estimated using Equation (9). Dependent variable is the log of total annual trade between countries. Aden Dummy and Ind. Ocean Dummy equal 1 if a given country-pair's shortest maritime trade route contains the Gulf of Aden or Indian Ocean respectively. See Table A1 for list of reported countries included in Somali attacks.

Table 3: All Trade - Reach

	(1)	(2)	(3)	(4)	(5)
Aden Dummy	0.947***	1.030***	0.640***	0.639***	0.582**
	[0.247]	[0.222]	[0.238]	[0.239]	[0.241]
Aden × Somali Reach	-0.137***	-0.150***	-0.091**	-0.091**	-0.082**
	[0.035]	[0.033]	[0.036]	[0.036]	[0.036]
Ind. Ocean Dummy	-1.553***	-1.482***	0.265	0.253	0.444
	[0.390]	[0.238]	[0.353]	[0.353]	[0.375]
Ind. Ocean × Somali Reach	0.249***	0.239***	-0.026	-0.024	-0.053
	[0.058]	[0.035]	[0.053]	[0.053]	[0.056]
Fixed Effects	Importer	Imp-Year	Imp-Year	Imp-Year	Imp-Year
	Exporter	Exporter	Exp×Trend	Exp×Trend	Exp-Year
	Year			Exp×Crisis	
Observations	154,781	154,781	154,781	154,781	154,781
R-squared	0.698	0.699	0.703	0.703	

*** p≤0.01, ** p≤0.05, * p≤0.1. Errors clustered by importer-year.

Note: Estimated using Equation (9). Dependent variable is the log of total annual trade between countries. Controls for exporter population, exporter GDP, distance, common language, colonial ties, common colonizer, RTA, both WTO, ACP-EU, and constant not reported. Somali reach calculated as the furthest distance from the location of a Somali pirate attack to the closest port on the Somali coast from 2000-2010.

Table 4: Bulk Trade

	(1)	(2)	(3)	(4)	(5)	(6)
Piracy measure	Attacks	Attacks	Attacks	Reach	Reach	Reach
Aden Dummy	0.341***	0.306**	0.284**	1.052***	1.066***	0.965***
	[0.128]	[0.131]	[0.134]	[0.328]	[0.327]	[0.331]
Aden × Piracy Measure	-0.100***	-0.092***	-0.085***	-0.168***	-0.170***	-0.154***
	[0.031]	[0.032]	[0.033]	[0.050]	[0.049]	[0.050]
Ind. Ocean Dummy	-0.425**	-0.289	-0.200	-0.204	-0.202	-0.075
	[0.189]	[0.202]	[0.220]	[0.519]	[0.519]	[0.538]
Ind. Ocean × Piracy Measure	0.031	-0.003	-0.026	-0.015	-0.015	-0.035
	[0.049]	[0.052]	[0.057]	[0.080]	[0.080]	[0.083]
Fixed Effects	Imp-Year	Imp-Year	Imp-Year	Imp-Year	Imp-Year	Imp-Year
	Exp×Trend	Exp×Trend	Exp-Year	Exp×Trend	Exp×Trend	Exp-Year
		Exp×Crisis			Exp×Crisis	
Observations	82,362	82,362	82,362	82,362	82,362	82,362
R-squared	0.435	0.437		0.435	0.437	

*** p≤0.01, ** p≤0.05, * p≤0.1. Errors clustered by importer-year.

Note: Estimated using Equation (9). Dependent variable is the log of bulk annual trade between countries. Controls for exporter population, exporter GDP, distance, common language, colonial ties, common colonizer, RTA, both WTO, ACP-EU, and constant not reported.

Table 5: Robustness

	All Trade		Bulk Trade	
	Aden Dummy	Aden × Piracy	Aden Dummy	Aden ×Piracy
Panel A: One year lags				
Lag Somali Attacks	0.195*	-0.042	0.206	-0.071*
	[0.102]	[0.027]	[0.144]	[0.038]
Lag Reach	0.542**	-0.078**	0.897***	-0.147***
	[0.228]	[0.035]	[0.329]	[0.051]
Panel B: Malacca Attacks Included				
Somali Attacks	0.201**	-0.044*	0.284**	-0.087**
	[0.098]	[0.023]	[0.138]	[0.034]
Reach	0.628**	-0.091**	0.961***	-0.154***
	[0.247]	[0.037]	[0.341]	[0.052]
Panel C: All Regions Included				
Somali Attacks	0.202**	-0.044**	0.279**	-0.086**
	[0.098]	[0.024]	[0.142]	[0.035]
Reach	0.625**	-0.090**	0.971***	-0.156***
	[0.247]	[0.037]	[0.349]	[0.053]
Panel D: Somalia, Yemen, Eritrea				
Somali Attacks	0.102*	-0.023	0.114	-0.061**
	[0.053]	[0.017]	[0.073]	[0.024]
Panel E: 2005-2010 sample				
Somali Attacks	0.176	-0.032	0.261	-0.075
	[0.176]	[0.038]	[0.256]	[0.055]
Reach	0.719	-0.097	1.064	-0.162
	[0.703]	[0.099]	[1.007]	[0.142]
Panel F: 1991-2010 sample				
Somali Attacks	0.341***	-0.077***	0.474***	-0.132***
	[0.056]	[0.015]	[0.078]	[0.021]

*** p≤0.01, ** p≤0.05, * p≤0.1. Errors clustered by importer-year.

Note: Each row and pair of columns represents a separate estimation of Equation (9) including importer-year and exporter-year fixed effects. Dependent variable is the log of total (first 2 columns) or bulk (second 2 columns) annual trade between countries. Controls for Ind. Ocean dummy, Ind. Ocean × piracy measure, exporter population, exporter GDP, distance, common language, colonial ties, common colonizer, RTA, both WTO, ACP-EU, and constant not reported. Panel B includes but does not report Malacca dummy and Malacca × pirate attacks in Malacca. Panel C includes but does not report Malacca dummy, Malacca × pirate attacks in Malacca, Far East dummy, Far East × Far East pirate attacks, West Africa dummy, and West Africa × West Africa attacks. Reach measures for non-Somali piracy could not be calculated, as such, in panels B and C the reach the piracy measure for non-Somali piracy is the number of pirate attacks in the relevant region. Panel D redefines Somali attacks to only include attacks attributed to Somalia, Yemen, or Eritrea.

Table 6: Heterogeneity Analysis

	All Trade		Bulk Trade	
	Aden Dummy	Aden × Piracy	Aden Dummy	Aden ×Piracy
Panel A: Shortest 50% of Routes				
Somali Attacks	0.123	-0.070*	0.905***	-0.292***
	[0.155]	[0.039]	[0.276]	[0.070]
Reach	0.718*	-0.132**	2.635***	-0.436***
	[0.384]	[0.058]	[0.698]	[0.107]
Panel B: Longest 50% of Routes				
Somali Attacks	-0.086	-0.045	-0.228	0.021
	[0.143]	[0.034]	[0.225]	[0.058]
Reach	0.216	-0.073	-0.333	0.028
	[0.378]	[0.057]	[0.562]	[0.086]
Panel C: Either Exporter, Importer, or Both in Poorest 50%				
Somali Attacks	0.163	-0.028	0.493***	-0.100**
	[0.105]	[0.026]	[0.169]	[0.042]
Reach	0.477*	-0.064	1.266***	-0.176***
	[0.261]	[0.039]	[0.423]	[0.064]
Panel D: Either Exporter, Importer or Both in Wealthiest 50%				
Somali Attacks	0.180	-0.035	0.244	-0.103**
	[0.130]	[0.033]	[0.198]	[0.050]
Reach	0.462	-0.064	1.028**	-0.180**
	[0.333]	[0.050]	[0.503]	[0.077]

*** p≤0.01, ** p≤0.05, * p≤0.1. Errors clustered by importer-year.

Note: Each row and pair of columns represents a separate estimation of Equation (9) including importer-year and exporter-year fixed effects. Dependent variable is the log of total (first 2 columns) or bulk (second 2 columns) annual trade between countries. Controls for Ind. Ocean dummy, Ind. Ocean × piracy measure, exporter population, exporter GDP, distance, common language, colonial ties, common colonizer, RTA, both WTO, ACP-EU, and constant not reported. Subsamples in panel A and B calculated using the sample median distance of 7,117 Km, corresponding approximately of the distance between India and Ireland. Rich/Poor classification for Panels C and D drawn from World Bank GNP per capita values for 2001.

Table 7: Distribution of Piracy Burden across Countries

	Country	GDP (billions) (1)	Trade via Suez (millions) (2)	Trade Share via Suez (percentage) (3)	Annual Loss in Trade (millions) (4)	Annual Loss as Share of Trade (percentage) (5)	Fraction of Global Loss (percentage) (6)
Panel A: Most affected countries as fraction of total trade lost							
1	Mayotte	-	318	0.65	6	1.25	0.03
2	Qatar	54	6,440	0.53	126	1.03	0.51
3	Eritrea	1	229	0.53	4	1.02	0.02
4	Kuwait	87	7,660	0.49	150	0.95	0.60
5	Iran	190	11,600	0.48	227	0.93	0.92
6	Seychelles	1	223	0.48	4	0.92	0.02
7	Djibouti	1	301	0.47	6	0.91	0.02
8	UAE	287	59,000	0.46	1,157	0.89	4.66
9	Bahrain	15	2,270	0.40	45	0.78	0.18
10	India	884	58,400	0.40	1,145	0.76	4.61
11	Burundi	1	98	0.38	2	0.74	0.01
12	Niger	4	329	0.36	6	0.70	0.03
13	Sudan	30	2,170	0.35	43	0.68	0.17
14	Rwanda	3	196	0.35	4	0.67	0.02
15	Ethiopia	17	1,650	0.34	32	0.66	0.13
Panel B: Most affected countries, in absolute value of lost trade							
1	EU	12,972	557,763	0.04	10,937	0.08	44.01
2	China	2,860	102,000	0.17	2,000	0.33	8.05
3	Japan	4,590	66,600	0.13	1,306	0.26	5.26
4	UAE	287	59,000	0.46	1,157	0.89	4.66
5	India	884	58,400	0.40	1,145	0.76	4.61
6	United States	12,420	44,600	0.03	875	0.06	3.52
7	Korea, Rep.	782	33,500	0.13	657	0.24	2.64
8	Hong Kong	186	30,200	0.10	592	0.20	2.38
9	Singapore	139	29,100	0.15	571	0.29	2.30
10	Australia	740	28,200	0.24	553	0.47	2.23
11	Turkey	466	23,000	0.22	451	0.42	1.81
12	Taiwan	323	18,400	0.14	361	0.26	1.45
13	Malaysia	151	14,900	0.14	292	0.27	1.18
14	Thailand	207	14,400	0.12	282	0.24	1.14
15	Czech Republic	135	12,200	0.16	239	0.30	0.96

Note: Trade share constructed from sample data and excludes intra-regional trade and certain trade routes (see appendix table A3). All values in dollar terms. Column 4: Estimated trade lost is the value of total trade through Suez (column 2) multiplied by the estimated loss of trade and corresponding to 0.019 percent per year. Column 5: Loss in trade measured as the amount of trade lost per year (column 5) divided by the amount of total trade in the sample. Column 6: Share is the amount of trade lost (column 5) divided by the sum of all trade losses (computed to be equal to $24.85 billion per year).

8 Data Appendix

Table A1: Pirate Assignments

The alleged nationality of pirates as reported in the IMB database are aggregated into six separate regional groups and used to create the piracy explanatory variables.

Somalia and Indian Ocean (1186 total attacks, 56 per year): Somalia, Mozambique, Djibuti, Egypt, Eritrea, Kenya, Madagascar, Oman, Tanzania, Yemen.

Malacca Strait and South East Asia (2038 total attacks, 97 per year): Cambodia, Indonesia, Malacca Strait, Malaysia, Myanmar (Burma), Philippines, Singapore Strait, Thailand.

West and Central Africa (680 total attacks, 33 per year): Algeria, Angola, Benin, Cameroon, Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mauritania, Morocco, Nigeria, Senegal, Sierra Leone, South Africa, Togo, Zaire (DRC).

Far East (441 total attacks, 21 per year): China/Hong Kong/Macau, East China Sea, Hong Kong/Luzon/Hainan (HLH), Papua New Guinea, Solomon Islands, South China Sea, Taiwan, Vietnam.

Indian Subcontinent (689 total attacks, 33 per year): Bangladesh, India, Sri Lanka.

Rest of World (unassigned) (723 total attacks, 34 per year): Albania, Arabian Gulf, Arabian Sea, Australia, Brazil, Bulgaria, Caribbean, Colombia, Costa Rica, Cuba, Denmark, Dominican Republic, Ecuador, France, Georgia, Greece, Guatemala, Guyana, Haiti, Honduras, Iran, Iraq, Italy, Jamaica, Location not available, Malta, Martinique, Mexico, Netherlands, Nicaragua, Pacific Ocean, Panama, Peru, Portugal, Russia, Salvador, Trinidad and Tobago, Turkey, UAE, United Kingdom, Uruguay, USA, Venezuela.

Table A2: Trade Region Pairs by Route

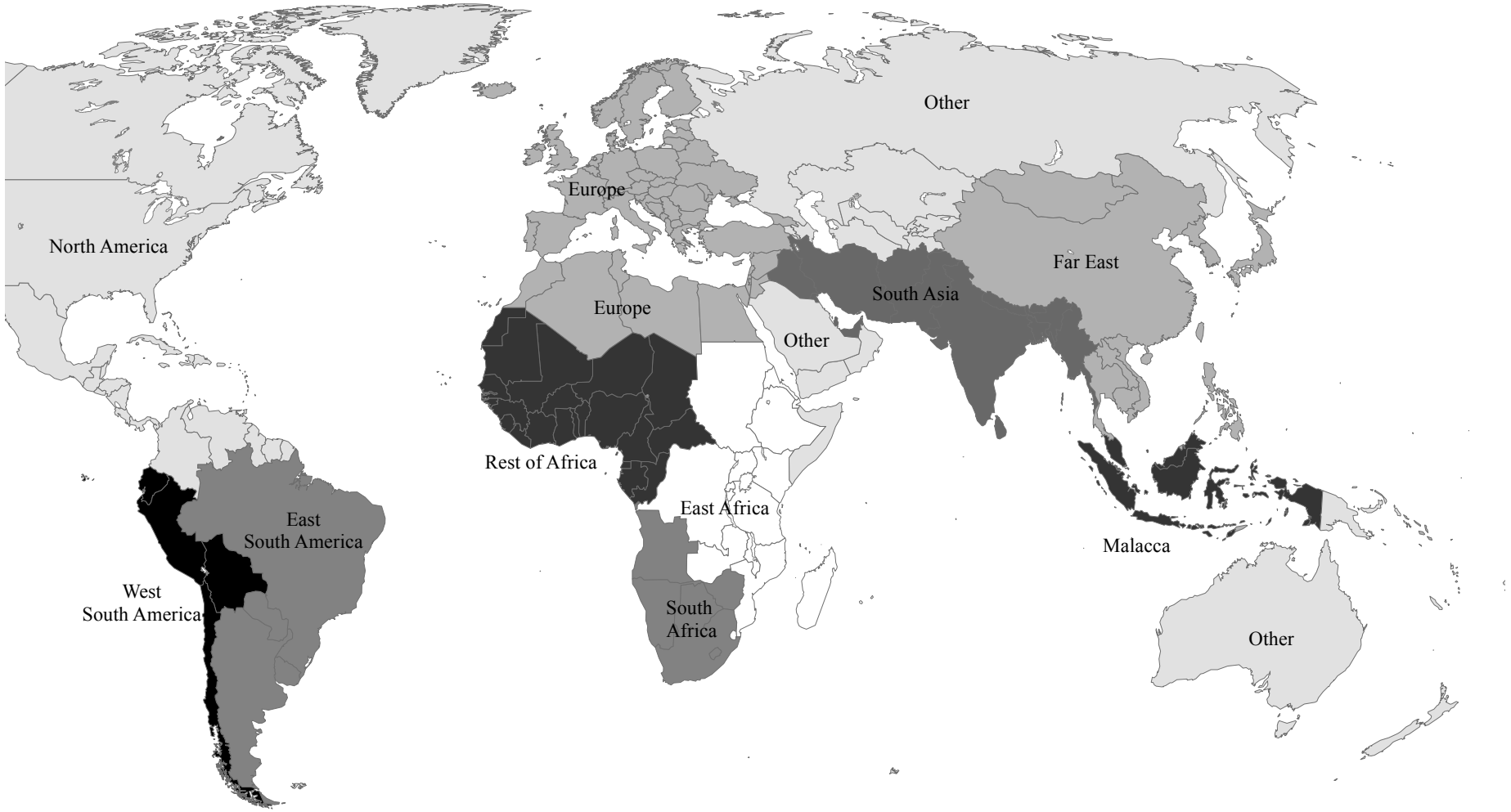
Route		Gulf of Aden	Malacca	Indian Ocean	Far East	Rest of Africa
Pirate threat		Somalian	Malacca	Somalian Indian subcontinent	Far East	West and Central African
From	To					
East Africa	Europe	1	0	0	0	0
	North America	1	0	0	0	0
	Rest of Africa	1	0	0	0	1
	Indian subcontinent	0	0	1	0	0
	Malacca	0	1	1	0	0
	Far East	0	1	1	1	0
Southern Africa	Europe	0	0	0	0	1
	Rest of Africa	0	0	0	0	1
	Indian subcontinent	0	0	1	0	0
	Malacca	0	1	1	0	0
	Far East	0	1	1	1	0
Rest of Africa	North America	0	0	0	0	1
	Western South America	0	0	0	0	1
	Eastern South America	0	0	0	0	1
	Europe	0	0	0	0	1
	Indian subcontinent	1	0	1	0	1
	Malacca	1	1	1	0	1
	Far East	1	1	1	1	1
Indian Subcontinent	North America	1	0	1	0	0
	Western South America	0	0	1	1	0
	Eastern South America	1	0	1	0	0
	Europe	1	0	1	0	0
	Malacca	0	1	1	0	0
	Far East	0	1	1	1	0
South East Asia	North America	0	1	0	1	0
	Western South America	0	1	0	1	0
	Eastern South America	0	1	0	1	0
	Europe	1	1	1	0	0
	Far East	0	1	0	1	0
Far East	North America	0	0	0	1	0
	Western South America	0	0	0	1	0
	Eastern South America	0	0	0	1	0
	Europe	1	1	1	1	0

Note: The indicator 1 denotes the routes along which ships are at risk of piracy occurring in the region described by the appropriate column.

Table A3: Bulk Goods Classification

HS 2-digit Code	**Description**	**# HS 6-digit codes**
6	Live Trees, Plants, Bulbs, Cut Flowers etc.	9
9	Coffee, Tea, Spices	26
10	Cereals	14
12	Oil Seeds, Grains, Seeds, Medical Plants	39
14	Vegetable Plaiting Materials & Products	1
18	Cocoa And Cocoa Preparations	1
23	Food Industry Residues & Waste	2
24	Tobacco And Manufactured Tobacco Substitutes	3
25	Salt, Sulfur, Earth & Stone Lime, Cement Plaster	63
26	Ores, Slag & Ash	24
27	Mineral Fuel, Oil, Bituminous Substances, Wax	8
31	Fertilizers	1
52	Cotton, including Yarn and Woven Fabric	1
53	Vegetable Textile Fibers; Yarn and Woven Fabric	7
71	Pearls, Stones, Precious Metals, Coins	4

Figure A1: Trade Region Assignments



Note: Trade regions were designed to encompass all countries that would use similar sea routes to trade with another given trade region Countries labeled as other have been dropped from the sample