The Welfare Cost of Lawlessness: Evidence from Somali Piracy*

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Abstract

This paper estimates the effect of Somali piracy attacks on shipping costs using data on shipping contracts in the dry bulk market. We look at shipping routes whose shortest path exposes them to piracy and find that the increase in attacks in 2008 lead to around a 8 to 12 percent increase in costs. From this we calculate the welfare loss imposed by piracy. We estimate that generating around 120 USD million of revenue for Somali pirates led to a welfare loss of anywhere between 0.9 and 3.3 USD billion. Therefore, piracy is an expensive way of making transfers.

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1 Introduction

For centuries, piracy has posed a threat to ocean-going trade. In essence, it is organized private predation which thrives in locations in which law and order is weak, either because particular states provide safe haven or due to poor international cooperation. And it has repercussions for worldwide trade.[1]

However, despite the long-standing importance of piracy, little is known about its economic costs.[2] The issue has been brought into sharp relief by the upsurge of piracy in the Gulf of Aden which poses a threat to one of the world's busiest shipping routes. Frequently attributed to the collapse of effective authority in Somalia, it has provoked an international response. However, the threat to shipping remains.

This paper does two main things. First, we match data on piracy attacks in the Somalia area to data on around 24,000 shipping contracts. We do this by constructing the closest navigable sea distance between each origin and destination port for which a ship has been chartered. This allows us to exploit the monthly time-series variation in the frequency of piracy attacks in the main areas affected by Somalian piracy to estimate the impact of piracy on shipping costs. Second, we use these estimates to examine the welfare cost of Somali piracy.

Our results show that shipping costs for dry bulk goods rose by around 8% when pirate activity increased in Somalia. This effect varies seasonally; it is around 14% cheaper to charter ships through the Gulf of Aden during the months where weather conditions inhibit pirate activity (December-February and June-September). Moreover, this seasonal pattern in shipping prices is absent prior to the upsurge in pirate activity in the region during 2008.

The extra shipping costs that we uncover are mostly due to higher insurance costs and the increased security measures that are needed to repel pirate attacks. These constitute a welfare cost to the extent that labor and resources are allocated from productive tasks towards protection. We develop a model to compare the extraction of resources through pirate attacks to a tax on shipping which finances an equivalent transfer. This allows us to calculate the welfare loss caused by piracy. Our central estimate suggests that the resource costs incurred in transferring around 120 million USD annually to Somali pirates is well in excess of 630 million USD. This confirms the general point that predation is a lot more costly as a form of extraction than taxation. The former is a form of anarchy while the latter

[1] For example, North (1968) argues that a decline in piracy from 1600 to 1850 accounts for a significant proportion of the observed productivity increases in transatlantic shipping in this period.

[2] Bensassi and Martínez-Zarzoso (2011) study the impact of piracy in the Strait of Malacca on trade costs. Most cited numbers are from One Earth Future Foundation (2010, 2011) reports. Our direct approach is distinct from the One Earth Future Foundation (2010, 2011) reports. Their main shortfall is that they do not have any form of counterfactual for their estimation.

requires a state that exercises a monopoly of force within a territory.

The paper belongs to a wider literature on the value of establishing the rule of law and its role in securing trade and investment.[3] A traditional problem in weakly-institutionalized environments is that bringing goods to market is subject to predation and theft. The consequences of the failure to establish and enforce property rights is a core theme in the development literature, for example, Acemoglu, Johnson and Robinson (2001).

Piracy has always posed a particular issue because of the difficulty of securing international agreement over whose responsibility it is to deal with the problem and how the costs are shared. Private solutions to increase security such as carrying guards aboard ships are inherently less efficient compared to dealing with the public good of security for all.[4] Our calculation of the welfare cost gives a sense of the magnitude of this benefit and we discuss why this is so high compared to tax-based redistribution.

Insecurity due to piracy causes a rise in shipping costs which are an important part of total trade costs. In this respect, our paper relates to studies of the consequences of trade costs for trade patterns.[5] Feyrer (2009) relates in his study of the Suez Canal closure 1967-1975. Our welfare calculations build on his findings.

The remainder of the paper is organized as follows. In the next section, we discuss the background to both our piracy and shipping cost data. Section three presents our estimation procedure and discusses the results while section four provides a framework for thinking about the welfare loss and uses this, along with our estimates, to develop estimates of the welfare loss from piracy. Concluding comments are in section five.

2 Background and Data

In this section we discuss our data on piracy and shipping costs. We present potential channels for piracy to affect these costs. We also discuss how susceptibility to piracy is matched to shipping routes.

2.1 Piracy Data

Our data on piracy attacks comes from the ICC International Maritime Bureau (IMB) annual reports which provide the exact position of the attack, details on the ship and its status

[3] See Dixit (2004) and Rose-Ackerman (2010) for excellent overviews.

[4] See Bandiera (2003) for a similar argument.

[5] For a review see Behar and Venables (2011). See Donaldson (2010) for a recent study of the impact of a change in trade costs due to the advent of railroads in India.

(anchored or steaming) and the type of attack (attempted, boarded, fired upon, hijacked).[6]

We geo-code attacks and focus on the Somali area which we define as the rectangle spanned by the coordinates S11, E38.4 and N18.3, E74.7. We focus on this area because we believe that there are common factors driving piracy attacks within this zone, i.e. if pirates attack in some point along the Somali coast, it is informative about the likelihood of an attack elsewhere within the area. The red dots in Figure 1 represent the locations of the piracy attacks. Figure 1 also depicts a more geographically narrower area – the Gulf of Aden, which we use as a robustness check on our main results below. Piracy in the Somalia area is a sophisticated crime with a large number of ships being hijacked. Pirates rely on both international finance and safe havens on the Somali coast to operate effectively.[7]

Figure 2 illustrates the time-series variation in piracy attacks, showing the upsurge in attacks during 2008. We exploit this to study the effect of Somali piracy on shipping costs. Our identification strategy relies on any changes in shipping during 2008 not being a cause for any change in pirate activity. We show in section 3.5 that, if anything, shipping through Somalia decreased during 2008 making it highly unlikely that changes in traffic patterns were responsible for the increase in pirate activity. There is a consensus among experts on Somali piracy that origins of the upswing in pirate activity lie on land rather than at sea. Hansen (2009), for example, argues that a key trigger for increase in piracy attacks was due to the crisis in public finances in the Puntland government in Somalia which left them unable to pay the police. This, he argues, along with the generally weak state of law and order in Somalia, made it increasingly feasible for pirates to operate without sanction. Pirates had long masqueraded as coast guards protecting Somali territorial waters from illegal fishing. This cloaked a build up of organized violence which emerged strongly after May 2008.

The developments were closely observed by the maritime insurance industry. Table 1 summarizes the piracy data around the date that the Somalia area was declared a *war risk area* by the maritime insurance industry (May 2008). The average number of attacks increased from 2.8 attacks per month before that date to 17.1 attacks per month from May 2008 onwards.

Aside from the structural break, seasonality induced by wind conditions plays a crucial role, which we will exploit in our analysis. Most of the attacks are carried out using small vessels, known as "skiffs". These are typically between 7 – 10 meters long and at most two meters wide with a low freeboard. This renders them particularly vulnerable to wind and waves. The summary in Table 1 illustrates the resulting seasonal pattern. The post May

[6] We discuss our data in the appendix A. Table A1 provides summary statistics.

[7] In a previous draft of this paper we also studied the broader Indonesia area, which has been a hot-spot of piracy as well. The type of piracy there is, however, very distinct from the Somalian piracy. It consists of armed robbery, mainly at ports, and is therefore less severe than Somalian piracy.

2008 column features a strikingly low piracy risk in the Monsoon months of July and August, for example. In these months piracy attacks are indistinguishable from the pre May 2008 levels. The calm spring period is the most dangerous time with over 30 attacks in March and April. The close link between this seasonal pattern in attacks and wind speeds is discussed in detail in appendix A.3.

2.2 Shipping Cost Data

Our shipping cost data comes from the web-site of N. Cotzias Shipping Consultants which provides monthly reports on the time charter market for the period November 2002 until December 2010.[8] The data is comprised of 33,529 individual charters in the dry bulk cargo segment of the market. These are ships that transport primary commodities such as iron ore or agricultural products such as grain. These types of vessels constitute approximately one third of the tonnage of the global shipping fleet. Short term chartering agreements are typical for bulk carrier ships, due to the volatile nature of commodity markets. Since the starting point for these charter agreements are previous agreements ('last done'), shipowners and charterers take an active interest in reports of recent transactions.[9] The individual time charter agreements are also used to construct general shipping indices such as the Baltic Exchange Dry Index (BDI). Thus our data-set provides a window onto the wider shipping market.

In a time charter agreement the shipowner places his ship, with crew and equipment, at the disposal of the charterer and bears the costs of keeping the ship operational. The charterer pays a daily charter rate and decides the type and quantity of cargo to be carried and the ports of loading and discharging. The charterer is also responsible for paying bunkers (fuel) and costs like port charges including the payments due, for example, for using the Suez Canal. The fact that time charter rates are provided on a daily basis makes them comparable across contracts of differing lengths.

The summaries made available on the web-site provide, among other information, the name of the ship, its deadweight tonnage (DWT) - a measure of ship size, the year it was built, the port or country of origin and the port or country of destination. From this information we construct our measure of shipping cost - the rate per day per DWT. We also use the origin and destination to assign the ship's voyage to countries (see appendix A.4). Our data set contains information on around 1600 distinct shipping routes. Most of the charters are from Asia with China making up the bulk of origin and destination locations.

[8]In early 2011, Cotzias merged with Intermodial (www.intermodal.gr). As of 25th July 2012, the Cotzias data was available on `http://www.goo.gl/g5d0c`.

[9]See Stopford (2009) for a detailed discussion of the time charter market.

2.3 Piracy Risks and Shipping Costs

There have been a number of private responses to the piracy threat. A variety of insurance arrangements have emerged to cover piracy risks with higher premia being paid to travel in areas deemed to be at risk. Ships increasingly carry armed guards and other preventive measures (mostly modifications to ship hulls) have become "best practice" which makes them relevant for insurance purposes.[10]

The costs to the shipping industry can be decomposed into five main categories: (i) damage to vessels (ii) loss of hire and delay to cargo delivery while a ship is held to ransom (iii) costs of defensive measures (iv) cost of ransoms and negotiators fees paid when a crew is kidnapped or a vessel is held (v) re-routing of vessels to avoid areas at risk. We discuss these cost factors in detail in Appendix C. Ship owners typically buy insurance to cover themselves against a number of these costs with insurance costs being sensitive to developments in the number of piracy attacks. Throughout the paper we assume a competitive insurance industry along with competitive shipping markets.

Our window on measuring costs is through shipping contracts whose prices adjust to reflect the above costs to the extent that they are borne by the ship owner and shifted to the charterer. This is not unrealistic. The association of independent tanker owners, for example, provides model clauses for chartering agreements with regard to piracy risks, stating that:[11]

> "Charterers shall indemnify Owners against all liabilities costs and expenses arising out of actual or threatened acts of piracy or any preventive or other measures taken by Owners [...], including but not limited to additional insurance premiums, additional crew costs and costs of security personnel or equipment."

Hence, there are good reasons for believing that the lion's share of these costs ultimately falls on charterers who compensate ship owners in the form of higher charter prices. Below, we will discuss the sensitivity of our welfare estimates regarding the division of these costs.

2.4 Identifying Exposure to Piracy Risks

We assign a risk of exposure to piracy attacks to each shipping route. We do this by using the information on the origin and destination of the shipping contract. For example, a vessel with a destination in Germany and an origin in China is quite likely to travel through

[10] Best Practice manuals are published and updated regularly by the shipping industry. See `http://www.goo.gl/zLlUt`, accessed on 10.04.2012.

[11] Refer to `http://www.goo.gl/yShgs`, accessed on 10.04.2012.

the Somalia area. However, there are some cases where it is not entirely clear whether the vessel would travel on a Pacific route or through the Indian Ocean and Atlantic using the Suez canal.

In assigning piracy risk, we therefore employ a path algorithm to obtain an automatic coding of a route.[12] We are then able to see whether the shortest sea route passes though the piracy areas that we study. If it does, we suppose that the shipping contract is subject to a piracy risk based on the forecast number of attacks in the relevant region.

Figure 3 provides a bird's-eye view of the constructed trade-routes for the areas around Somalia. The less opaque a point on a route, the more ships are going through this particular route. We assign a shipping contract to the treatment group if it crosses the white rectangle visible in the graph.

This approach means that we are only able to assign an intention to treat (ITT) rather than the treatment itself. It is, for example, possible that some ships were re-routing around the Cape of Good Hope to avoid exposure to piracy risks. We check for this in the results section and find no evidence for changes in either the extent of traffic through the Suez Canal due to piracy or its composition. Assigning intention to treat based on different routes makes our results even stronger. This supports the view of other commentators, such as One Earth Future (2011), that re-routing around the Cape is not important.

We do not distinguish between attacks on different kind of vessels (container, tanker, dry bulk, etc.) because all kinds of ships and all sizes have been attacked and hijacked in this area. The first successful hijack of a dry bulk ship took place as early as May 2008.[13] Attacks seem sufficiently random not to attempt to distinguish between different bulk ships. We will, however, check for differences in the effect on different ship sizes.

2.5 A Model of Piracy Attacks

To motivate the time-variation in piracy attacks, consider the following simple theoretical model. Suppose that there are M active pirate ships and that in each period each pirate receives an opportunity to hijack a ship where V_{it} is the benefit and c_{it} is the cost.[14] Pirate

[12] Details are discussed in the appendix A.4.

[13] According to a Lloyds List report on July 2008 the ship was freed 41 days later for a ransom of 0.75 million USD.

[14] To endogenize M, suppose that there is a fixed cost becoming an active pirate. Then we would have that a priate will enter if

$$E\left\{V_{it} - c_{it} : \xi_t\right\} > F_i$$

in which case we would also predict that M would be a function of ξ_t, i.e.

$$M_t = H\left(\xi_t\right).$$

i at date t will launch an attack if the expected benefit exceeds the cost:

$$\xi_t V_{it} \geq c_{it}$$

where ξ_t is the success probability, V_{it} is the value of a successful attack and c_{it} is the cost.

A key parameter is the cost-benefit ratio $\rho_{it} = c_{it}/V_{it}$. We suppose that ρ_{it} is drawn for each pirate ship i at date t from a uniform distribution with mean θ_t. Given M independent draws the expected number of pirate attacks at date t is given by:

$$E\left[a_t\right] = \xi_t M. \tag{1}$$

The variation in expected piracy attacks in equation (1) is then captured by ξ_t which we assume captures two elements. First, there can be short-term factors which shape piracy costs and benefits, including weather variation. Second, there can be persistent changes in law and order as we saw after after the break down in law order in Puntland in 2008 which lead to a permanent shift in the feasibility to conduct piracy. To capture these two factors we allow the success probability, ξ_t, to depend on climatic conditions and the insurance evaluation of the industry which requires ships to insure against war risks since May 2008.

3 The Effect of Piracy on Shipping Costs

In this section, we present estimates of the effect of piracy on shipping costs. We will begin with a straightforward comparison of means between regions affected by Somali piracy before and after the recent upsurge. We then present regression-based estimates.

3.1 Difference in Difference Estimates

We now present a simple difference in difference estimate of the effect of Somali piracy on mean shipping costs by looking at the routes affected by piracy before and after May 2008 compared to all other routes. The result of this exercise is reported in Table 2 which gives the average rate per DWT on routes that pass through the Somalia area compared to other shipping routes before and after May 2008.

Column (1) shows that the average shipping costs were not significantly different between routes before May 2008. However, they diverge after that date with the mean cost per DWT

So we would have

$$E\left[a_{rt}\right] = \xi_t H\left(\xi_t\right)$$

and the expected number of pirate attacks will still depend on ξ_t reflecting underlying law and order.

being significantly above the rate for other routes by 0.074 USD per day per DWT. This represents an increase of around 15%.[15] Note that shipping costs fall strongly in late fall 2008, presumably due to the effect of the global recession making it important to control for global macro effects and time effects in all specifications. We now look at how this finding holds up in regression evidence based on individual shipping contracts.

3.2 Piracy Attacks and Shipping Costs

Our core regression specification assumes that the dry bulk shipping market is contestable so that pricing is based on the average cost per day for each voyage.[16] We would then expect prices in that market to reflect expected piracy attacks and any other factors that influence costs.

We denote the cost per dead weight ton (DWT) per day for a ship of size s on route d in month t as:

$$C(s, d, t, A_{dt})$$

where A_{dt} is the forecast number of attacks affecting route d at date t.[17] An effect of piracy on costs is not unrealistic as the shipping conditions at so-called "choke points" (the straits of Hormuz and Malacca, the Suez and Panama canals, the Bosporus) are known to affect freight rates. Since there are scale economies in shipping, we expect this cost function to be decreasing in s.

For simplicity, we adopt the specification:

$$\log C(s, d, t, A_{dt}) = c(s, d, t) + \gamma A_{dt} + \beta x_{dst} + \eta_{dst} \tag{2}$$

where γ is the core parameter of interest, x_{dst} are other time varying controls and η_{dst} captures other idiosyncratic factors which are uncorrelated with A_{dt}.

The cost from piracy depends on the route that the ship takes. As we have already discussed, we construct a treatment indicator for each route depending on whether it passes through the area of Somalia. Denote this as a dummy variable where $\delta_d = 1$ if route d passes through piracy. Then:

$$A_{dt} = \delta_d \times a_t.$$

[15] The effect is not apparent visually when we plot the two series since they are fairly noisy.

[16] See Behar and Venables (2011) for a discussion of the extent of contestability in shipping markets. This is important for our interpretation since otherwise there would be a markup of prices over costs reflecting the extent to which ship owners have market power. In that case, part of the cost of piracy could be absorbed in lower profits.

[17] Due to the absence of good monthly data on ship traffic for our period 2002-2010 we have to use A_{dt} as a measure of piracy risk. This disregards the fact that dense traffic makes journeys less risky for each ship.

is our measure of the cost shock expected on route d where, in the core specification, a_t is the recorded level of pirate attacks in month t. In the basic specification, we do not allow treatment to vary with ship size, s, or route, d. However, we will also allow for a heterogeneous effect in some specifications that we report below.

This baseline specification, in effect, supposes that the best estimate of piracy en route is the level of piracy attacks in the current month, i.e. $E[a_{t+1}] = a_t$. This is somewhat implausible to the extent that there are known seasonal patterns and other understandable features of the time series. Hence, below, we will consider some alternative models for the expected level of piracy attacks.

To reflect this discussion, our core empirical specification is:

$$z_{isdt} = \alpha_s + \alpha_d + \alpha_t + \gamma A_{dt} + \beta x_{dt} + \varepsilon_{isdt} \tag{3}$$

where z_{isdt} is the (log of) daily charter rate per DWT for contract i on a ship of size s, for route d in month t. The parameters $(\alpha_s, \alpha_d, \alpha_t)$ are fixed effects for ship size, route and month. The standard error ε_{isdt} is adjusted for clustering at the route level. Other controls in x_{dt} include the age of the ship and the ballast bonus per DWT (a bonus paid for empty return journeys).

Our key identifying assumption is that factors that drive piracy, the factors in ξ_t in equation (1) are orthogonal to other drivers of shipping costs, conditional on the controls that we use.

The main parameter of interest is γ which we interpret as the additional shipping cost from anticipated piracy attacks. We are expecting that $\gamma > 0$. The empirical approach can be thought of as a difference-in-difference specification where ships that pass through a region where pirates are expected to attack are compared to ships using different routes over the same time period. This exploits monthly time-series variation in piracy attacks.

3.3 Core Results

Our core results are reported in Table 3 which uses the specification in (3). In column (1), the only controls are fixed effects for route, time and ship size. For the latter, the omitted ship size category is "small" Capesize ships between 80,000 and 150,000 DWTs. There is a strongly significant positive coefficient on the expected number of attacks. The point estimate says that one extra anticipated attack in a month increases the daily charter rate by a little under 0.6% in the Somalia region. From Table 1 we know that the mean difference in pirate attacks between the pre May 2008 and the post May 2008 period is around 14.3, this suggests that shipping costs were around 8.2% higher after the upsurge in piracy.[18]

The ship size dummy variables show evidence of significant scale economies in shipping with the smallest ships being around 62% more expensive per DWT than the excluded category. The point estimates decline across the ship size categories. This is a feature of all the estimates that we show.

In column (2), we add the additional ship controls: ballast bonus payments and the vessel's age. We find a large variation in rates paid for younger compared to older vessels with chartering rates for older vessels being significantly lower. However, the point estimates on piracy attacks do not change much after adding these controls.

In column (3), we use only data after Somali piracy increased in May 2008. The variation in piracy attacks is now identified purely from the seasonal (i.e. monthly) differences due to weather. It is encouraging to observe that the sign and significance of the piracy effect remains even though the size of the effect is much smaller. However, this is not surprising given that we are, in effect, throwing away the variation in costs due to the main breakdown in law and order in Somalia. This has an impact on the estimate as many of the costs caused by the heightened level of piracy have a fixed component due to the mean shift after May 2008. War risk insurance, for example, needs to be paid after that date regardless of the month, even though there is month or month variation with July, for example, being as risky as it was prior to the upsurge in activity (see Table 1).

Column (4) explores whether there is a heterogeneous effect across the different ship sizes travelling through the Somalia area. Due to the precision of the estimates, we cannot discern statistically distinct patterns across ship types, except for Capesize vessels which have a different coefficient compared to the other ship categories at 10%. This observation can be thought of as a robustness check on our core results since the largest Capesize vessels cannot use the Suez Canal.[19]

Overall, these results suggest that piracy in the Somalia area has a positive effect on the cost of shipping through this region. The effect is consistent with around an 8% increase in shipping costs on average in the period after piracy attacks increase off the coast of Somalia. We next explore the robustness of these results.

3.4 Robustness

In this section we look at the robustness of our results to alternative ways of forecasting piracy attacks and discuss additional controls for the economic environment. We also explore

[18] This is somewhat lower than the difference-in-difference results in Table 2.

[19] We refrain from coding this category as not treated as some capesize vessels do travel through the Suez Canal (broad vessels and ships in ballast).

alternative definitions of exposure to piracy risk.

An AR(2) Model for Piracy Attacks As an alternative to putting in the number of piracy attacks in month t, we also fitted an AR(2) process to the pattern of attacks in each region. In this case, we use

$$E\left[a_{t+1}\right]=\hat{b}_0+\hat{b}_1 a_t+\hat{b}_2 a_{t-1} \tag{4}$$

as our measure of susceptibility to piracy attacks where $\left(\hat{b}_0, \hat{b}_1, \hat{b}_2\right)$ is the estimated parameter vector.

The results when equation (4) is used instead of a_t to estimate equation (3) is in column (1) of Table 4. The coefficient on Somali piracy remains positive and significant. The change in the AR(2) prediction from the pre May 2008 period to the post May 2008 period is 9.8 which suggests an increase in shipping cost of 7.7% which is indistinguishable from our core estimate. That said, the AR(2) model is unlikely to do a good job at picking up a structural break.

A Markov Chain Model for Piracy Attacks As a more structural approach, we model the level of piracy attacks using a Markov switching model based on an underlying law and order state. This will have an advantage of picking up the persistence of the shift that occurs in the piracy data and captures some of the features of the structural break analysis we perform below.

To motivate the switching model, we can return to the theoretical approach above and allow the probability of a successful pirate attack to depend on a latent state, $\ell \in \{S, W\}$ with $\xi(S)<\xi(W)$ where S stands for "strong" and W for "weak". We assume that the probability of successfully hijacking a ship and demanding a ransom is higher when law and order is weak. Using this in the model of piracy above, the mean number of pirate attacks in state ℓ is

$$\mu_\ell \equiv \xi(\ell) M, \;\; \ell \in \{S, W\}.$$

where $\mu_S<\mu_W$.

Dynamics across law and order states are modeled as a Markov chain governing the process of state transitions. This gives us a filter for emerging data on pirate attacks which can be used to construct a forecast for pirate attacks which can capture the sharp non-linear pattern in the data. We show in appendix B.2 that this model gives the following formula corresponding to equation (1) for the expected number of attacks at $t+1$:

$$E\left[a_{t+1}\right]=\Omega+\left(\mu_W-\mu_S\right)\lambda P_t\left(\ell=W\right) \tag{5}$$

where Ω is a region-specific constant, λ is a measure of persistence of the process and $P_t\left(\ell=W\right)$ is the probability that the region is in the weak state at time t. The latter is the only time-varying factor in equation (5) and evolves according to the history of piracy attacks. By estimating the parameters of the underlying process, we can construct an empirical counterpart to equation (1).[20]

This type of model, first proposed in Hamilton (1989), has been popular among time series economists modeling the non-linear properties of business cycle fluctuations. The model's core parameters are estimated using the data on attacks using the Expectation Maximization (EM) Algorithm described in Hamilton (1990) which generates an estimate of the parameters by iteration and is easy to implement.

The abrupt swings in the forecast number of attacks are driven by changes in $P_t\left(\ell=W\right)$ between values that are close to zero and one while the impact of the estimated probability on expectations is driven by our estimate of $\left(\hat{\mu}_W-\hat{\mu}_S\right)\hat{\lambda}$. It is interesting to observe that the predictions made by our model are that the state shifted in April 2008 which is very much in line with the assessment of the Joint War Committee.

The results when (5) is used instead of a_t to estimate (3) is in column (2) of Table 4. The coefficient on Somali piracy remains. Moreover, this model which allows for the persistence in piracy attacks (an important feature of the data), predicts an estimate of 11.8% which is somewhat higher than the estimate from column (1) of Table 3.

Omitted Economic Trends It is important to observe that, by including time dummy variables (for each month), we are controlling for general developments in the global shipping market. These are important over this period given that the economic crisis erupts around 2008 while the capacity of bulk shipping grows considerably. For this to still create a problem for our analysis, it would have to be the case that the routes that we have classified as being treated are differentially affected by changes in market conditions in a way that increases bulk shipping costs. The main trend in this period is, however, a switch of bulk trade in

[20] We discuss details of the estimation in appendix B.2. Note that $P\left(\ell_t=W\right)$, is a function of the particular history of attacks in month t and the set of Markov chain parameters: two state-specific means, two persistence parameters which together determine λ and two state-specific variances. To forecast piracy attacks, we use the observed number of attacks in month t to calculate the probability $P\left(\ell_t=W\right)$ that the region is in a weak state given a set of known parameters. Equation (5) shows that if $P\left(\ell_t=W\right)$ increases then the expected value of attacks next month increases by $\left(\hat{\mu}_W-\hat{\mu}_S\right)\hat{\lambda}$. The estimate for $\left(\hat{\mu}_W-\hat{\mu}_S\right)\hat{\lambda}$ is 11.45 attacks.

Asia away from Europe and towards other Asian countries, Australia and the Americas.[21] This would work against our core findings as it would put downward pressure on prices for bulk charter agreements between Europe and Asia which pass through the piracy affected area. In any case, we attempt to control for changes in economic factors by route in two main ways which we now report.

Column (3) of Table 4 adds GDP growth controls for the origin and destination of each route. Due to the coarseness of (especially) the destination data, discussed further in Appendix A, we were forced to aggregate to regional GDP for this exercise. Controlling for either annual regional GDP levels (regressions not shown), interpolated monthly regional GDP levels (regressions not show) or regional GDP growth, as shown in column (3) does not change the pattern of coefficients.

In column (4), we further address this concern by incorporating a separate set of time fixed effects for each of the twenty-four start regions (Eastern Africa, Southwest Asia, etc.). All effects of piracy are now identified solely from contracts that start in regions that have observations both inside and outside the area affected by piracy in that month. Even with this rather demanding specification, the core finding regarding the effect of piracy attacks is robust, albeit with a somewhat smaller coefficient compared to column (1) of Table 3. Our results also hold if we control for a set of time fixed effects for each destination region or region-specific time trends.

Alternative Treatment Definitions In order to match the piracy data with the shipping data, it was necessary to impose some structure by defining a region that is susceptible to piracy. We assigned routes to the treatment group if the computed shortest path of the route crossed this region. But evidently, there is some leeway in how this could be done and, in the following specifications, we show that our results are robust to various ways of assigning the treatment and definitions of areas that are subject to piracy threats. The results are shown in columns (5) to (8) of Table 4.

In column (5) we use more narrowly defined piracy regions focusing on the key choke point: the Gulf of Aden.[22] The results show that piracy in the Gulf of Aden still has a significantly positive impact on shipping prices through that area. The point estimate is somewhat larger. However, note that we used only a smaller set of attacks so that the difference between pre May 2008 and post May 2008 now only is 7.4 attacks. The overall magnitude of the effect of piracy is very similar to that reported in the core specification.

Column (6) shows the results when we attempt to disentangle the effect of Somali piracy

[21] See the detailed discussion in UNCTAD 2011 and UNCTAD 2010.

[22] For the Gulf of Aden, the bounding box is given by latitude $\in [10.5, 17]$ and longitude $\in [40, 52.2]$.

on trade through the Gulf of Aden from the effect on trade in the broader region. We now use the number of attacks from our main specification and apply it to two subgroups of maritime routes: a) ships that travel through the Gulf of Aden and b) ships that travel through Somalia, but not through the Gulf of Aden. The key insight from the specification reported on column (6) of Table 4 is that we also find a cost of piracy for routes that do not travel through the Gulf of Aden but through the broader Somalia area. This is important because it suggests that trade between the Middle East and Asia and Africa is affected by Somali piracy as well. Our welfare estimates will take this into account.

Columns (7) and (8) in Table 4 look at robustness regarding the treatment. We need to be wary that ships could be travelling alternative routes in order to avoid the canal fees or the piracy region. We would expect such re-routing to be more of an issue for maritime routes for which there is a feasible alternative route which does not use the Suez Canal and which is not significantly longer than passing through the piracy region. To examine this, we used our algorithm to compute alternative routes while adding the constraint that vessels cannot travel through the Suez Canal. We then assign treatment based on these alternative routes if they are at most 10% (column (7)) or 20% (column (8)) longer than the Suez Canal route. The point estimate for the Somalia area becomes slightly higher but is indistinguishable from our main result in Table 3 column (1).

3.5 Extended Results

We now extend the results in two ways. First, we explore the possibility that, as well as affecting costs, piracy attacks also changed the desirability of shipping on routes affected by piracy. Second, we use data on piracy risk and wind speed to analyze the "reduced form" impact these variables have on shipping costs.

Effects on Shipping Piracy attacks could be a deterrent to shipping goods through areas that are susceptible to piracy attacks. We need to be able to rule this out, because if piracy was positively correlated with the quantity shipped, the observed higher shipping costs may simply reflect increased demand on this particular route. We consider two dimensions in which piracy could affect shipping other than merely increasing the cost of shipping: First, piracy could directly affect the amount of traffic on piracy routes. Second, piracy could affect the composition of ships going through the piracy areas.

The Suez canal offers a way to analyze the impact of piracy on trade volumes. We obtain monthly data on the quantities of cargo in deadweight tons through the Suez canal for each month of our sample period. The task of identifying a piracy effect in this time series is complicated by the fact that the failure of Lehman Brothers, an event which signalled the onset of the most serious phase of the global financial crisis, occurs in September 2008 - only shortly after the upsurge in piracy. As is well known, this led to a significant reduction in world trade.

To disentangle the effect of the economic crisis from the effect of piracy we look for breaks in the time-series of cargo traffic and try to identify in which month, if any, a break took place. Specifically, we use the method described in Bai (1997) to determine the break points in the series for cargo volumes and for piracy attacks in the Somalia region. For the trade volume exercise, we search for the optimal location and number of break-points according to a BIC criterion using the following model:

$$Cargo_t = \beta_0 + \beta_1 t + \epsilon_t$$

for all possible dates t. We find exactly one break-point for the period following November 2008, roughly two months after Lehman Brothers failed. Bai and Perron (2003) propose a method for obtaining a confidence band around an estimated break-point. Applying their approach, we find that with 99% confidence the break occurs in the period October to December 2008. This makes sense given that goods already in transit and on which shipping contracts had been agreed would not have been affected by the Lehman crash. Applying the same approach to piracy attacks, we find that the break in the series is in July 2008. This is different from the break point in the cargo series. That said, the 99% confidence band for the break in the mean level of piracy is a lot wider and ranges from August 2007 to August 2008, the latter still being before Lehman's failure.

This motivates running regressions in which we include a dummy variable for November 2008 onwards to pick up the effect of Lehman Brother's failure when looking for an effect of piracy attacks on the quantity of cargo being shipped through the Suez canal. Thus we run

$$Cargo_t = \lambda_0 + \lambda_1 a_t + \lambda_2 Lehman_t + \lambda_3 t + \eta_t. \tag{6}$$

where $Lehman_t$ is a dummy variable that switches from zero to one in November 2008.

The results from running (6) with and without the Lehman dummy are in columns (1) and (2) of Table 5. Column (1) shows that if we only include the level of piracy attacks, then we get a large and significant effect of piracy attacks on cargo; the effect amounts to a 30% reduction at the mean level of monthly piracy attacks after May 2008. Once we include the structural break identified by the method outlined above, this becomes much smaller in size and insignificant as column (2) shows.

These results do not suggest that piracy had an effect on the amount of cargo shipped through the Suez canal. That said, the 95% interval of the estimate in column (2) is consistent with a negative effect on trade of up to 3.5% which is in line with the Feyrer (2009) estimates of the effect of distance cost on trade.[23] Using his estimates an increase of trade costs by 8% would yield a decrease in trade between 1.6% and 4%.

Effects on Average Ship-Size One possible reaction to piracy would be to use ships that are less susceptible to piracy attack. We look for evidence of a shift in composition by looking at the average DWT of ships in our data over the period and see if this varies in response to the threat of piracy. Thus, we use our data at the route level to calculate the average weight of a ship on route d at t and run the regression:

$$DWT_{dt} = \alpha_d + \alpha_t + \gamma A_{dt} + \psi_{sdt}$$

where (α_d, α_t) are route and month dummies. The effect of piracy is now identified from variation within a route over time using the same treatment assignment as in our core results above.

The results is reported in column (3) of Table 5. While there is a negative coefficient on Somali piracy attacks, this coefficient is not significant at conventional levels. Thus, there does not seem to be any substitution in ship size in response to piracy.

War Risk Declaration and the Impact of Wind Speed Declaring an area as a special war risk area is a significant event in the insurance industry and is bound to capture risk perceptions at the time. So instead of using the level of piracy attacks, we can simply use these dates. The representative of the marine hull war insurance business in the London market, the Joint War Committee, added the Gulf of Aden in May 2008. We now use a dummy variable to represent this event in equation (3) instead of the level of piracy attacks.[24]

The result is in column (4) of Table 5. The coefficient on the war risk dummy suggests around a 12% increase in shipping costs (a larger effect than was found in the baseline estimate of Table 3).

Given the discussion in section 2 one interesting issue is how far during the "treatment period" identified by the Joint War Committee, wind speed variation affected shipping costs. Given that supplementary insurance to pass through high risk areas is priced based on specific

[23] The average traffic pre May 2008 was 43,000 metric tons. The change in the number of attacks was 14.33. This implies a point estimate for the decrease in traffic of $\frac{32.89*14.33}{43000} = 1.1\%$. The upper bound is calculated from the 95% interval $1.1 + \frac{1.96*36.9*14.33}{43000} = 3.5\%$.

[24] May 2008 was in our confidence interval based on our structural break analysis above but does not coincide with the date that was identified there which was July 2008. The results are fairly similar if we use a dummy that is equal to one at this slightly later date.

weeks in high risk zones, we might expect that it would be. We look at this, by allowing the lagged wind speed to be interacted with the treatment dummy since, as we have already shown, piracy attacks are extremely seasonal. The results are reported in column (5) of Table 5. Here we find a negative coefficient on wind speed, i.e. there is a smaller effect on costs with high wind conditions which are likely to reduce the incidence of piracy.

Figure 4 illustrates the fitted values from column (5) Table 5. It shows the shipping cost increase on Somalia routes predicted by the Somalia war risk, wind speed and their interaction. The graph clearly shows the jump due to pirate activity in May 2008. However, it also illustrates the strong seasonality induced by the seasonality in piracy. After May 2008 shipping costs are roughly twice as high when wind conditions favor piracy attacks.

These additional results increase our confidence in the results and the proposition that shipping costs increase due to the risk of maritime piracy attacks.

4 The Welfare Cost of Piracy

We now discuss what our results imply for the welfare cost of piracy. Our approach is distinct from existing estimates such as One Earth Future Foundation (2010, 2011) since we have estimated the impact of piracy on shipping costs directly rather than using an accounting approach. We also adopt an explicit welfare criterion which recognizes that piracy creates a transfer from consumers of traded goods (who ultimately bear the cost) to pirates. We compare piracy to the cost of making a more efficient transfer via a tax. However, not all costs are necessarily captured by the impact of piracy on shipping costs and we will consider the sensitivity of the estimates to such concerns.

4.1 Framework

Piracy leads to a transfer of resources to pirates via ransoms. Resources are used by pirates in securing these ransoms and by ship owners and governments in resisting them. The costs of the ransoms and damage to ships are also borne directly by those who pay them. These costs are pooled across the industry through insurance. Resources are also used in writing insurance costs and in the lengthy process of negotiations with pirates. As with any transfer program, there is a question of who pays in the end. If the market for shipping is competitive then any increased cost will be passed on to consumers of the final goods in the form of higher prices. And full forward shifting is the benchmark that we consider.

Suppose that there is a composite traded good, X, for trade between locations which is susceptible to piracy attacks. Suppose that shipping demand has a fixed coefficient technology so that demand for shipping is νX. The number νX is best thought of as ton days, i.e. as the number of shipped tons multiplied by the average maritime journey time.[25] We assume that the good X is sold in a competitive market and that the marginal cost per unit is denoted as $\psi + \phi$ where ψ is the production cost and ϕ is the shipping cost per unit. Suppose that there is a representative consumer with utility $U(X)$ and additive quasi-linear utility. This allows us to ignore general equilibrium effects. The representative consumer's optimal consumption is given by:

$$U'\left(\hat{X}(\psi + \phi)\right) = \psi + \phi$$

and the indirect utility from consuming tradeable goods of the relevant kind is

$$V(\psi + \phi) = U\left(\hat{X}(\psi + \phi)\right) - \hat{X}(\psi + \phi)[\psi + \phi].$$

As we have already seen, piracy increases shipping costs, ϕ. Suppose that part of that cost increase leads to a transfer to pirates denoted by T and that that we attach a "welfare" weight of μ to these transfers, i.e. to pirate welfare. It is somewhat debatable what this weight should be. Ransoms transfer income to a poor country (Somalia) but they go directly to a particular group, i.e. organized criminals. It is far from clear how these benefits may trickle down to the wider population.[26] We feel that it is best to be agnostic about this and base our welfare approach on Coate (2000). Using his reasoning, we should care principally that any transfer made to pirates is accomplished in the most efficient way and hence the welfare loss are the resources spent in the process of delivering the transfer.

For fixed μ, welfare is

$$W(\phi) = V(\psi + \phi) + \mu T.$$

Now suppose that, as above, the cost of shipping final goods is

$$\phi(\Delta) = \nu[c + \Delta]$$

where c is the base transport cost per unit of shipping expressed in USD and Δ is the increase in transport costs due to piracy.

The part of the cost (again in USD) that is a transfer to pirates is denoted by $\tau(\Delta)$.

[25] This view is very much in line with the usual measure of mile tons. For an interesting discussion regarding this see Stopford (2009). We disregard variable shipping speeds which makes the two measures equivalent.

[26] Shortland (2011) provides some evidence that piracy revenue trickles into Somali society and has a positive developmental effect.

And the total transfer received by pirates is

$$T(\Delta) = \tau(\Delta)\,\nu\hat{X}(\psi + \nu[c + \Delta]).$$

In order to be agnostic about μ, suppose we consider a thought experiment where we replace piracy with a tax on shipping, the proceeds of which are transferred to the pirates, yielding the exact level of net revenues as they now receive from engaging in piracy. Proposing a tax on shipping seems more reasonable than considering lump-sum taxation in this instance and it would clearly fall on the same group as those who currently bear the cost of piracy.

The amount of the required unit tax, t, is defined by

$$t\nu\hat{X}(\psi + \nu[c + t]) = \tau(\Delta)\,\nu\hat{X}(\psi + \nu[c + \Delta]). \tag{7}$$

This equation illustrates the source of the inefficiency of piracy attacks. The increase in charter rates Δ due to piracy is not fully captured by the pirates so that $t \leq \tau(\Delta) < \Delta$. Were the transfer efficient then $t = \tau(\Delta) = \Delta$.[27] In other words, a tax has only the usual excess burden familiar to public finance economists while piracy leads to additional costs such as the costs from the guard labor associated with combatting piracy, damage to ships, negotiation costs to release hijacked ships and costs of additional insurance.

Since the tax keeps the transfer to pirates constant, the welfare cost of piracy is measured by:

$$L(\Delta) = V(\psi + \nu[c + t]) - V(\psi + \nu[c + \Delta]) \tag{8}$$

which, by construction, does not depend on the welfare weight μ.

4.2 Benchmark Estimate

A benchmark (first-order) estimate of (8) can be found by ignoring any trade response (i.e. demand response by consumers). Thus $\hat{X}(\psi + \nu[c + \Delta])$ is completely inelastic and $t = \tau(\Delta)$. In this case equation (8) becomes:

$$L^1(\Delta) = [\Delta - \tau(\Delta)] \times \nu\hat{X}. \tag{9}$$

Estimates of equation (9) for the year 2010 are in column (1) of Table 6. Details of all calculations are in Appendix D. In Panel A we use the detailed data available from the Suez Canal authority on the total amount of tons shipped through the Gulf of Aden. We

[27] Of course, a tax would be costly to administer and we are not including this in our thought experiment. But evidently that could be part of the calculation too.

translate this number into an amount of DWT×days by using the mean bulk ship speed (from Stopford, 2009) and the average length of the trip in the respective sample.[28] Panel B adds an estimate of the DWT×days that do not travel through the Gulf of Aden but through the broader Somalia area.

To get a feel for the plausible range, we present a low and a high estimate. Our low estimate uses the coefficient from column (1) in Table 3 for the Gulf of Aden and estimates in column (6) Table 4 for the broader Somalia area. Our high estimate uses column (4) of Table 5 for the Gulf of Aden and the respective specification reported in the Appendix D for Somalia.

We illustrate our calculations of $L^1(\Delta)$ with the low estimate in panel A of Table 6. We use the increase in attacks in Table 1 and apply it along with column (1) of Table 3 to the average rate charter rate of 0.4726. This yields the following estimate of total piracy costs:

$$\begin{aligned}\Delta \times \nu\hat{X} &= 0.00572 * 14.33 * 0.4726 \times 30.3 * 646,064,000 \\ &= 758 \text{ million USD}\end{aligned}$$

for 2010.[29] This is around 94,000 USD for a Panamax ship.

Our estimate of $\tau(\Delta) \times \nu\hat{X}$ is the gross ransoms paid less the costs incurred by pirates in generating this. A reasonable figure for the gross ransoms is 200 million USD. And netting out the costs of generating these, suggest profits from piracy in the region of 120 million USD.[30] Together with our estimate of $\Delta \times \nu\hat{X}$ this sums to the number

$$L^1(\Delta) = [758 - 120] \text{ million USD} = 638 \text{ million USD}.$$

Even from this lower-bound estimate it should become clear that the additional costs incurred due to the threat of piracy vastly exceeds what it would cost to offer pirates a tax-financed transfer of comparable magnitude to the revenues that they earn.

Panel B shows, not surprisingly, that the estimated cost is much higher when we calculate the value of shipping for the wider region including trade routes that do not cross the Gulf of Aden. Our estimates of the welfare cost increase by around 40%.

[28] We make the assumption all of this cargo is comparable to ours in terms of its exposure to higher shipping costs, journey length and travels though the Gulf of Aden.

[29] Obviously this number is subject to a large margin of error. For example, container traffic is likely to be less affected. Were we to suppose that there was no effect on container ships then the size of the affected deadweight tonnage would be only 279,063,000 and the cost would be considerably lower. We abstract from this as the value of container goods is likely to be much larger which would increase the cost.

[30] For a careful and transparent calculation see `http://www.goo.gl/5T9nW`. This is in line with estimates in Geopolicity (2011).

4.3 Extended Estimates

There are further reasons to believe that our estimates in column (1) of Table 6 are a lower bound. We now consider two of these: (i) the possibility of a demand response which reduces trade and (ii) the possibility that only some of the cost of piracy is paid by the charterer.[31]

Allowing for the possibility of a demand response, we show in the appendix D.2 that the welfare loss caused by a decrease in trade can be approximated by a simple scaling factor on our estimate above, which depends on the elasticity of trade with respect to transport costs, $\hat{\eta}$, and is given by

$$L^2(\Delta) = L^1(\Delta)\left[1 + \frac{1}{2}\frac{\Delta - \tau(\Delta)}{c + \Delta}\hat{\eta}\right]. \tag{10}$$

In other words, the loss due to trade reduction can be approximated by the trade elasticity with respect to transport costs times the share of piracy costs in total transport costs.[32] Obviously, $L^2(\Delta) > L^1(\Delta)$ as long as $\hat{\eta} > 0$.

There are several possible numbers we could use for $\hat{\eta}$. Recent estimates from Feyrer (2009), who uses the Suez Canal closure from 1967 to 1975 as a shock to distance, suggest that a value of $\hat{\eta}$ between 0.2 and 0.5 is reasonable. This is a little lower than the estimate found in a meta study in Disdier and Head (2008) which is 0.9. However, given the context of the Feyrer (2009) study, we use an estimate of 0.5 in column (2) of Table 6. This implies that $L^2(\Delta)$ is larger than $L^1(\Delta)$ by a factor of between 1.017 and 1.03, i.e. the additional welfare loss due to changes in quantity are relatively marginal (consistent with this being a second-order effect in our context). This is confirmed when comparing the new estimates in column (2) of Table 6 with column (1).

Column (3) of Table 6 allows for the possibility that the increase in chartering rates fails to capture *all* of the additional costs imposed by piracy. In particular, we check what would happen if costs were split between ship owner and charterer according to the "general average rule" as it is known in the shipping industry. This rule shares the costs of protecting the ship in proportion to the value of the vessel and the cargo. Assume then that a share ζ of the piracy costs are borne by the ship-owner. The charter rate increase Δ is the transfer that compensates the owner for piracy costs over and above what the charterer bears. Then if charter rates increase by Δ due to shipping costs the overall cost to the industry is given

[31] Similarly, if we believe that the market for ship capacity is not competitive, we could see that piracy related expenses may be forwarded with a markup. This is a possibility we do not explicitly consider further.

[32] Note that we calculate an upper bound this way as charter costs are just a part of total (maritime) transport costs.

by $\frac{\Delta}{2\zeta-1}$.[33] This yields our third measure of welfare cost of:

$$L^3(\Delta) = \left[\frac{\Delta}{2\zeta - 1} - \tau(\Delta)\right] \times \nu\hat{X} \tag{11}$$

which is reported in column (3) of Table 6. This leads to estimates that are somewhat larger than in column (1) of Table 6. For example, the low estimate allowing for general averaging is 130% higher. The details on the calibration of ζ can be found in Appendix D.3.

Adding all this together, our Somalia estimates are between 0.9 billion USD and 3.3 billion USD. While the range of estimates is quite large, the comparison between these numbers of the transfer received by pirates of only 120 million USD is telling. The welfare costs suggested are indeed substantial.

4.4 Predation versus Taxation

We can use equation (7) in the previous section to calculate t - the tax rate on shipping through Aden that would yield the same revenue now going to pirates. Of course there is no reason to expect that such a tax and transfer system provides a realistic solution to the piracy problem. Identifying those who should receive the transfer would be impossible to identify. However, it does provide another way of thinking about the costs involved.

Disregarding the effect on trade we get this tax rate from the following calculation:

$$\begin{aligned} t &= \frac{\tau(\Delta)\nu\hat{X}(\psi + \nu[c + \Delta])}{\nu\hat{X}(\psi + \nu[c + \Delta])} \\ &= \frac{\text{120 million USD}}{0.4726 * 30.3 * 646,064,000 + 0.4648 * 20.67 * 578,000,000} \\ &= 0.008. \end{aligned}$$

This implies that a tax rate of just 0.8% on chartering would be needed to generate a transfer of comparable magnitude to that generated by piracy. This contrasts with our estimates of the increase in shipping costs of between 8% and 13%. This calculation suggests that predatory activity of the kind undertaken by pirates is between 10 and 16 times more costly as a means of giving a similar level of resources to pirates than taxation would be.

It is worth dwelling on the reason why these costs are so high and how far they provide insight into debates about the costs of failure to establish law and order. There are two key

[33] To get an intuition for the formula assume that the shipping cost is 100. The owner has additional costs due to piracy of 20 and the charterer pays 10. The charter rate will go up by 10 due to piracy but overall costs due to piracy is 30. And, indeed, $\frac{1}{2\zeta-1} = \frac{1}{2\frac{2}{3}-1} = 3$ in this case.

factors: (i) the fact that piracy causes direct damage and loss (ii) the fact that efforts to establish law and order are fragmented.

Direct damage comes partly from the damage to property. However, it also comes in part from the fact that pirates have to hold ships for long enough to establish their credibility. This is like an inefficient war of attrition which increases the cost of doing business and creates delay over and above the cost of the ransom.[34]

Somalia is now the focus of international attention although with limited progress. In the context of potential donor interest, it is instructive to consider how many Somali's could be hired for one year using the additional resources that we estimate are expended by the shipping industry in response to the threat of piracy. Using the numbers in panel B of Table 6, a conservative estimate of the costs of piracy to the shipping industry is about 1.05 billion USD. We use wage data from the Somali Food Security and Nutrition Analysis Unit (FSNAU) presented in Shortland (2011) to calculate a yearly wage of about 870 USD.[35] This means that the extra spending due to piracy could finance one year of employment for more than 1.2 million laborers at the going market rate in 2010. This does not mean that such a transfer scheme would be realistic or that it would prevent piracy. But it illustrates the scale of losses to the industry relative to the reality of the Somali economy.

4.5 Investing in Security

The insurance industry appears to be offering some discounts if a vessel is carrying armed guards through the high risk areas. However, our discussions with industry participants suggest that these discounts tend to be small. With this caveat in mind, we can explore an alternative way to understand the inefficiency by calculating the costs of putting private security crews on every ship.[36]

From conversations with security firms, we know that they charge about 3000 USD for a security crew of four per day.[37] The guards typically board the vessel on key points before entering the Indian Ocean. The boarding points are Sri Lanka, the Strait of Hormuz, Madagascar and an anchored vessel in the Red Sea off Djibouti. We compute the average time it takes for a vessel to travel between the boarding points in Sri Lanka, the Strait of

[34] For an analysis of a strikingly related ransom bargaining process see Ambrus et al. (2011) who analyze ransom negotiations during a period of piracy in the Meditteranean sea from 1575-1739.

[35] In 2010 the highest daily wage paid in Somalia was about 100,000 Somali Shillings (SSh). Assuming 261 work days and an exchange rate of about 30,000 SSh/USD this implies a yearly wage of about 870 USD.

[36] We thank Daron Acemoglu for suggesting that we look at this and Marit Rehavi for suggestions on data.

[37] This cost is well in the interval of cost estimates for US security contracts in Iraq. The 2010 United States Government Accountability Office report "Warfighter Support: A Cost Comparison of Using State Department Employees versus Contractors for Security Services in Iraq", for example, gives a range of these costs between 430 USD and 7600 USD for four persons per day.

Hormuz, Madagascar and the Red Sea. Based on this we compute the total cost of hiring security crews for traffic going through the Suez Canal. We arrive at an estimate of 302 million USD and 486 million USD for 2010. Given that no ship with security teams onboard has been hijacked up to now this provides an interesting benchmark for the costs in this area from Table 6 which suggests a cost which lies between 640 million USD and 2.4 billion USD for this area. Taken at face value, it suggests that there is underinvestment in security guards.

When it comes to fragmented law and order, combatting piracy currently has an array of actors all investing in the hope of dealing with the problem. This includes the somewhat uncoordinated efforts of governments. The most efficient outcome would be to establish a monopoly of violence over the seas as we see in established states.[38] Otherwise, each actor will invest until the marginal benefit equals the marginal cost.[39] By protecting particular groups this will tend to shift piracy to other vessels rather than reducing attacks. Thus a pirate repelled by one ship is free to go and attack another ship. Thus it is inefficient to leave piracy protection in private hands.

But international cooperation suffers from free-rider problems as well. While the international community has now attempted to introduce naval patrols to combat Somali piracy, this is extremely expensive and requires international diplomacy between a range of states. Currently member countries of the EU and Nato, the US, China, Russia, India, Saudia Arabia, Iran and Japan deploy maritime forces in the area. They patrol an area of sea approximately equal to the size of western Europe.

But difficulties of coordination is not new as revealed, for example, in the correspondent report on Chinese piracy in *The London and China Telegraph* from 4th February 1867 noted that

> "Besides we are not the only Power with large interests at stake. French, Americans, and Germans carry on an extensive trade [...] Why should we then incur singly the expense of suppressing piracy if each provided a couple of gunboats the force would suffice for the safety foreign shipping which is all that devolves upon [..] why should the English tax payer alone bear the expense?"

It seems striking how little progress on these issues has been made more than 100 years later.

While somewhat sketchy, our estimates in Table 6 can be augmented to include the costs of naval operations which try to limit pirate activities. The costs of Atalanta for the European

[38] See Besley and Ghatak (2010) for development of this argument in relation to property rights enforcement.

[39] In addition, there is anecdotal evidence of an arms race in which pirates are better and better equipped and ship owners move from minor ship modifications to hiring security crews. For a general discussion of these issues see de Meza and Gould (1992).

Union in 2009 was 11 million USD.[40] To this we need to add the costs of the EU member countries. The only available estimates indicate that additional operational costs for the German military involvement (1 vessel, 300 personal) in 2010 was around 60 million USD.[41] Since the overall size of the Atalanta mission is between 4 and 7 vessels this indicates total costs of about 340 million USD for the Atalanta mission. In addition to Atalanta there are two more operations which are, at least partially, occupied with preventing piracy attacks: NATO's Ocean Shield and the Combined Force 151. Causality from piracy to the presence of some of the military forces in the Arabian sea is harder to establish. For example, the Combined Force 151 includes two US aircraft carriers stationed there.

The current reliance of the international community on Naval patrols to combat piracy could succeed in reducing pirate activity further. In the end, the most promising long-term solution would seem to be to restore a functional Somali state which can deny pirates safe haven, thereby dealing with the problem at source.

5 Concluding Comments

Piracy is an important source of predation which creates economic disruption. In this paper, we have used estimates of its effect on shipping prices to estimate the welfare cost of Somali piracy.

While what we have studied here is only one specific kind of lawlessness, estimates of the costs of predatory activity in any specific context are rare. We have shown that the cost of piracy is large relative to the size of the transfer to pirates. This is particularly true compared to a tax levied on shipping to pay a transfer to pirates.

The analysis further underlines the difference between organized extraction by the state in the form of taxation and disorganized predation. We estimate that the latter is at least ten times more costly. In the language of Olson (2000), pirates are roving bandits while the state is a stationary bandit and hence is in a better place to organize extraction at lower costs. Without a return to strong law and order in Somalia, it seems unlikely that these welfare costs will disappear any time soon.

[40] See `http://www.goo.gl/hrqPA`, accessed on 10.04.2012.

[41] Deutscher Bundestag Drucksache 17/179. *Fortsetzung der Beteiligung bewaffneter deutscher Streitkräfte an der EU-geführten Operation Atalanta zur Bekämpfung der Piraterie vor der Küste Somalias.*

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Table 1: Seasonality in Attacks in Somalia Region

month	before May 2008	after May 2008
January	1.5	12.5
Februar	2.7	7.5
March	2.9	31.5
April	5.2	34.1
May	3.7	21.0
June	1.8	10.5
July	3.5	4.6
August	2.1	9.4
September	1.3	14.6
October	3.8	18.7
November	2.2	28.0
December	2.4	12.6
average	2.8	17.1
difference (after-before)		14.3

Table 2: Piracy Attacks and Shipping Costs - Simple Difference in Difference

	before May 2008 (1)	after May 2008 (2)	difference (3)
mean USD per DWT for routes that do not pass through the piracy area	0.486	0.386	0.100
	(0.00306)	(0.00329)	(0.00450)
mean USD per DWT for routes that pass through the piracy area	0.480	0.454	0.026
	(0.00415)	(0.00653)	(0.00781)
difference	0.006	-0.068	0.074
	(0.00516)	(0.00731)	(0.00894)

Table 3: Main Results

VARIABLES	(1) daily charter rate per DWT	(2) daily charter rate per DWT	(3) daily charter rate per DWT	(4) daily charter rate per DWT
number of attacks (Somalia)	0.00572***	0.00589***	0.00259***	
	(0.00128)	(0.00130)	(0.000898)	
attacks * handysize (Somalia)				0.00336
				(0.00283)
attacks * handymax (Somalia)				0.00665***
				(0.00199)
attacks * panamax (Somalia)				0.00597***
				(0.00137)
attacks * small capesize (Somalia)				0.00637***
				(0.00189)
attacks * capesize (Somalia)				0.00206
				(0.00222)
ballast bonus per DWT		-8.04e-06		
		(5.13e-06)		
ship age		-0.00614***		
		(0.000791)		
handysize	0.623***	0.637***	0.607***	0.621***
	(0.0224)	(0.0203)	(0.0369)	(0.0255)
handymax	0.401***	0.403***	0.354***	0.394***
	(0.0218)	(0.0203)	(0.0311)	(0.0258)
panamax	0.149***	0.150***	0.151***	0.153***
	(0.0142)	(0.00912)	(0.0221)	(0.0154)
capesize	-0.0385	-0.0513*	-0.0899	-0.0245
	(0.0398)	(0.0305)	(0.0885)	(0.0486)
route fixed effect	yes	yes	yes	yes
month fixed effect	yes	yes	yes	yes
Observations	24,363	24,332	10,058	24,363
R-squared	0.873	0.877	0.861	0.874

Notes: Standard errors in parentheses. Standard errors are clustered at the route level. *** p<0.01, ** p<0.05, * p<0.1. "DWT" is deadweight tonnage. "Daily charter rate per DWT" is the log of the time charter rate per day per deadweight tonnage. All attack variables are interactions between a dummy that indicates whether a ship will cross the pirate territory and the number of attacks. "Handysize" is a dummy that indicates ships with DWT<35000. "Handymax" are ships with 35000<DWT<55000. "Panamax" are ships with 55000<DWT<80000. "Small capesize" are ships with 80000<DWT<150000 (omitted). "Capesize" are ships with DWT>150000. "Ballast bonus" is a payment that compensates the ship owner for travelling without cargo on return. Column (3) only uses data after the surge in piracy in the Somalia region May 2008. Column (4) controls for interactions between ship categories and a Somalia dummy.

Table 4: Robustness

VARIABLES	(1) daily charter rate per DWT	(2) daily charter rate per DWT	(3) daily charter rate per DWT	(4) daily charter rate per DWT	(5) daily charter rate per DWT	(6) daily charter rate per DWT	(7) daily charter rate per DWT	(8) daily charter rate per DWT
forecast number of attacks (Somalia)	0.00785***	0.0102***						
	(0.00175)	(0.00274)						
number of attacks (Somalia)			0.00590***	0.00289***			0.00673***	0.00580***
			(0.00129)	(0.000896)			(0.00160)	(0.00151)
annual GDP growth start region			0.02368*					
			(0.01159)					
annual GDP growth end region			-0.0047					
			(0.01375)					
number of attacks (Gulf of Aden)					0.0100***			
					(0.00244)			
Somalia number of attacks (route through Gulf of Aden)						0.00660***		
						(0.00146)		
Somalia number of attacks (route not through Gulf of Aden)						0.00226**		
						(0.000894)		
ship size controls	yes	yes	yes	yes	yes	yes	yes	yes
route fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
month fixed effect	yes	yes	yes	no	yes	yes	yes	yes
region-specific month fixed effects	no	no	no	yes	no	no	no	no
Observations	24,363	24,363	24,332	24,363	24,363	24,363	24,363	24,363
R-squared	0.873	0.873	0.877	0.900	0.873	0.874	0.873	0.873

Notes: Standard errors in parentheses. Standard errors are clustered at the route level. *** p<0.01, ** p<0.05, * p<0.1. "DWT" is deadweight tonnage. "Daily charter rate per DWT" is the ln of the time charter rate per day per deadweight tonnage. All piracy variables are interactions between a dummy that indicates whether a ship will cross the pirate territory and the number of attacks. "Forecast number of attacks" is the forecasted number of attacks next month calculated using an AR(2) model in column (1) and a Markov chain model for column (2). Column (4) controls for a seperate set of time fixed effects for each of 24 start regions. Column (5) takes a smaller treatment area and uses piracy estimates from attacks in this area. Column (6) uses the piracy estimates from our main specification and applies them to shipments though different areas. Columns (7) and (8) use the following treatment assignment: alternative routes not using the Suez canal were used if the alternative route was at most 10% and 20% longer than the Suez route, respectively.

Table 5: Extended Results

VARIABLES	(1) Suez Canal cargo traffic	(2) Suez Canal cargo traffic	(3) average ship size	(4) daily charter rate per DWT	(5) daily charter rate per DWT
number of attacks (Somalia)	-359.3***	-32.89	-20.48		
	(87.17)	(36.90)	(56.68)		
cargo traffic break		-20801***			
		(867.8)			
war risk area (Somalia)				0.121***	0.360***
				(0.0319)	(0.0975)
war risk area * windspeed (Somalia)					-0.0373***
					(0.0125)
windspeed (Somalia)					0.00470
					(0.00423)
ship size controls	-	-	-	yes	yes
route fixed effect	-	-	yes	yes	yes
month fixed effect	*	*	yes	yes	yes
Observations	108	108	12,753	24,363	24,363
R-squared	0.611	0.94	0.482	0.873	0.874

Notes: Standard errors in parentheses. Standard errors are clustered at the route level in columns (4) and (5). *** p<0.01, ** p<0.05, * p<0.1. Columns (1) and (2) use monlty time-series data from the Suez canal. Column (3) uses all data but aggregates by dyad. "Suez canal cargo traffic" is measured in DWT. "Average ship size" is the dyad average for that month in deadweight tons. "DWT" is deadweight tonnage. "Daily charter rate per DWT" is the ln of the time charter rate per day per deadweight tonnage. "Cargo traffic break" is a dummy variable that takes a value of 1 after the volume in trade through the Suez canal collapses in November 2008. All piracy variables are interactions between a dummy that indicates whether a ship will cross the pirate territory and the number of (expected) attacks. "War risk area" is a dummy that indicates whether the area was defined as a war risk area by the Joint War Comittee. "Windspeed" is the (predicted) monthly windspeed in the piracy area in the same month. (*) Columns (1) and (2) control for a linear time trend.

Table 6: The Welfare Cost of Piracy in 2010

Panel A: Gulf of Aden	(1)	(2)	(3)
	L1 (in million USD)	L2 (in million USD)	L3 (in million USD)
low estimate	638	649	1495
high estimate	999	1026	2264

Panel B: Somalia	(1)	(2)	(3)
	L1 (in million USD)	L2 (in million USD)	L3 (in million USD)
low estimate	935	952	2127
high estimate	1462	1503	3250

Calulcalations are discussed in section 4 and the appendix D. Column (2) adjusts the welfare loss by taking into account the change in trade. Column (3) adjusts the cost to take into account the share of costs borne by charterers. Panel B uses data on trade to and from the Middle East to calculate the costs for the area including the Indian Ocean.

Figure 1: Attacks and Treatment Areas

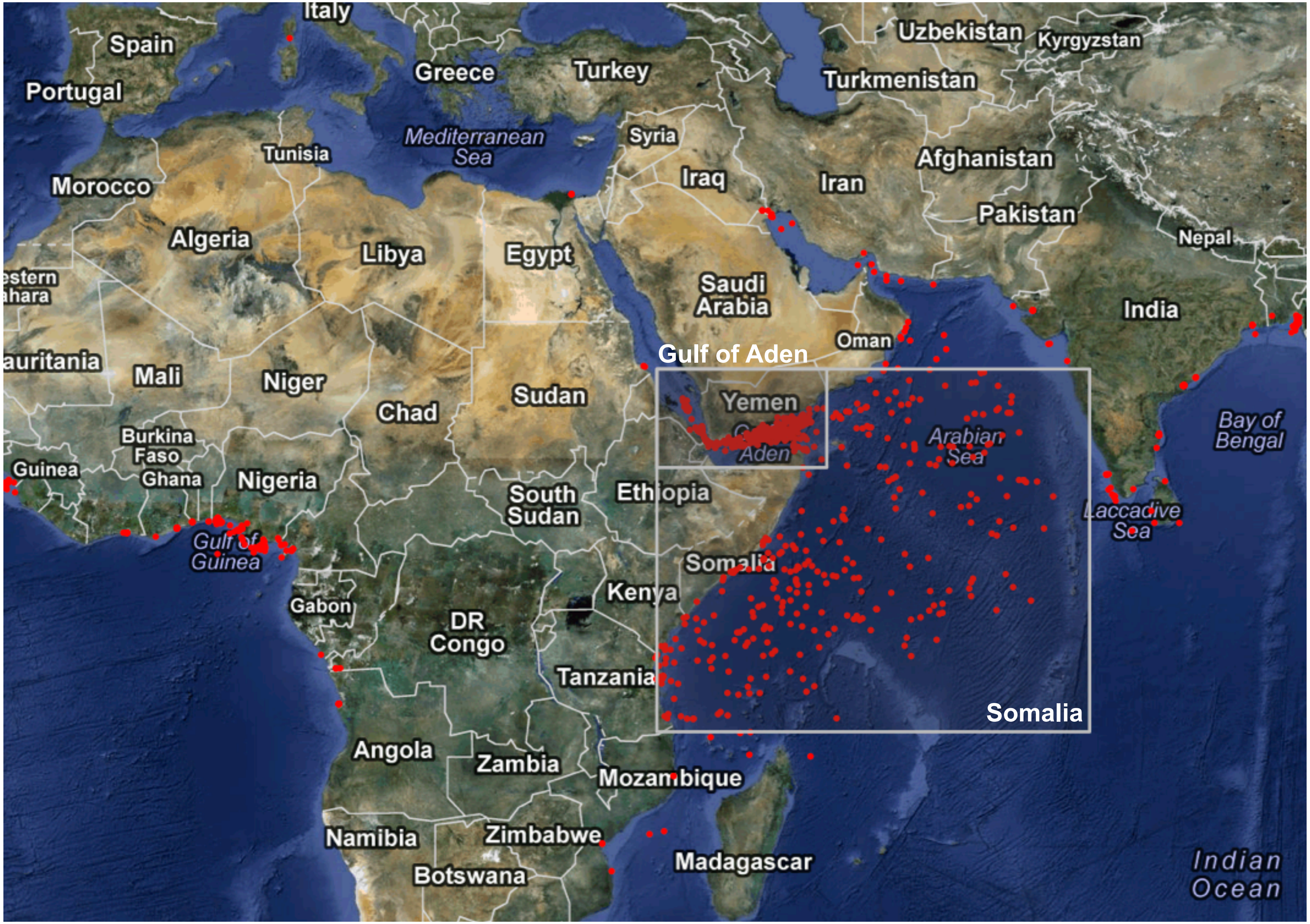

Figure 2: Time Series of Attacks in Somalia

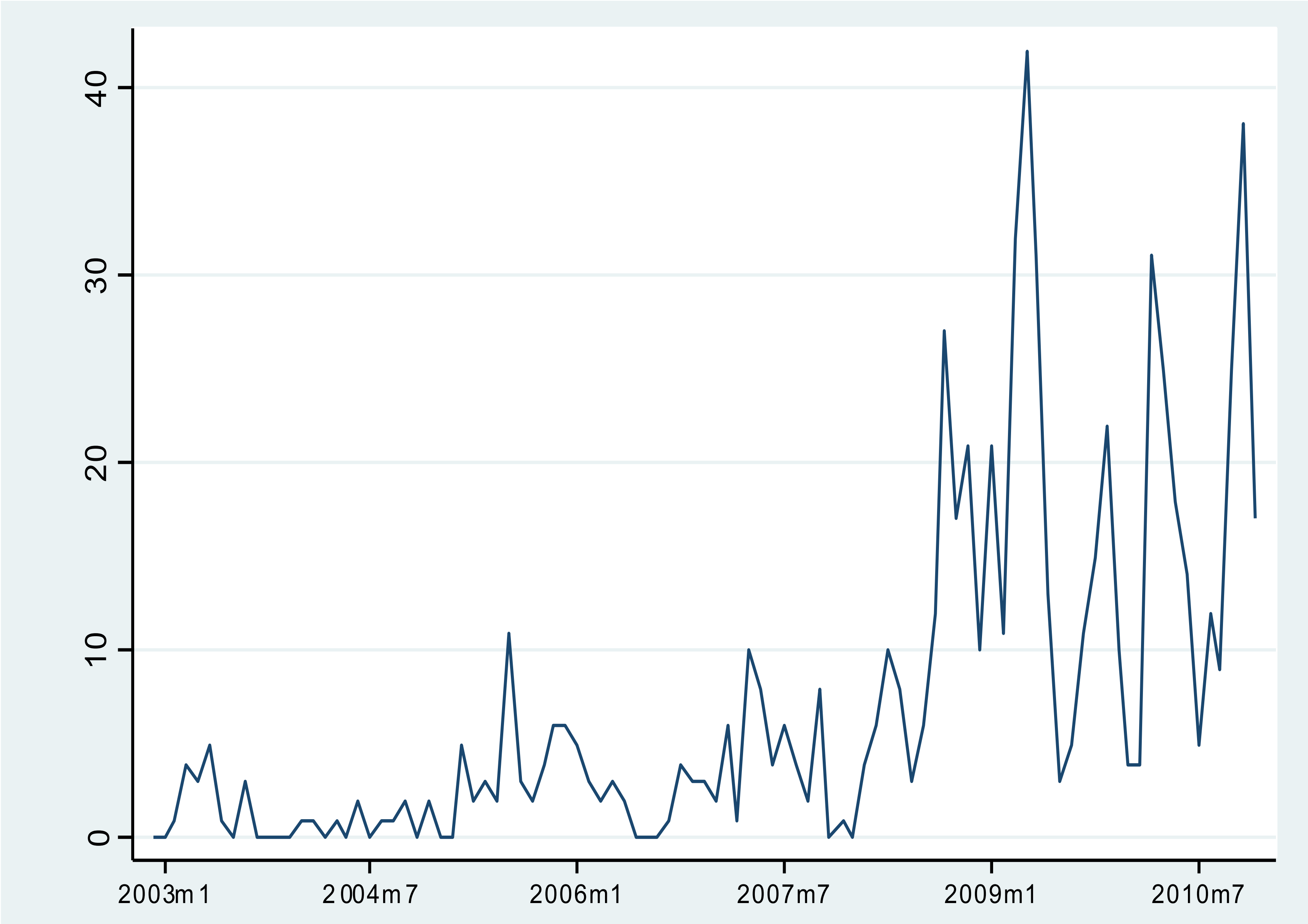

Figure 3: Calculated Shipping Lanes

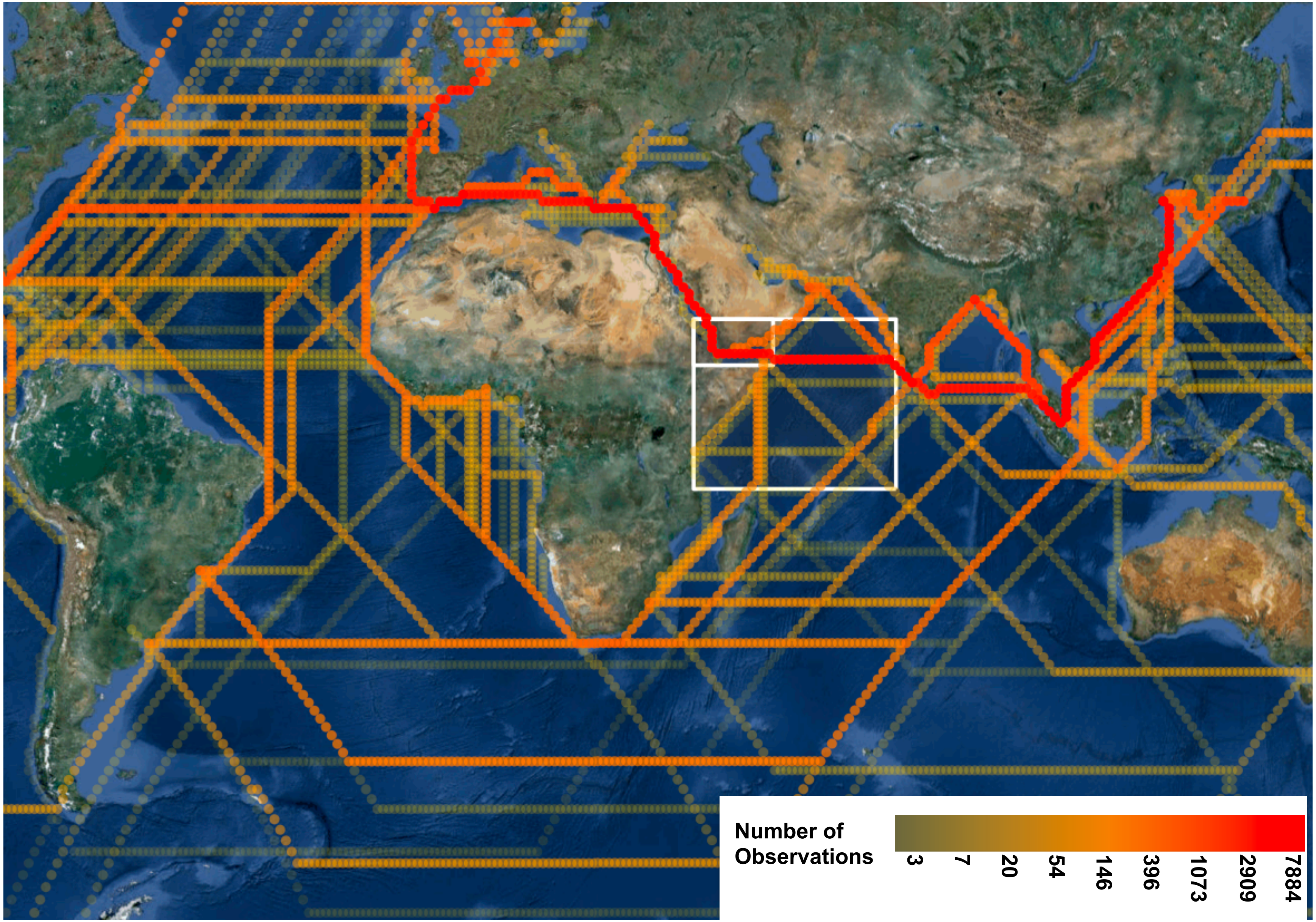

Figure 4: Shipping Cost Prediction of Pirate Activity and Wind Speed