Migration at Sea: Unintended Consequences of Search and Rescue Operations*

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Abstract

The Central Mediterranean Sea is the most dangerous crossing for irregular migrants in the world. At any point in time, over half a million potential migrants wait in Libya to travel to Italy with the aid of human smugglers. In response to high profile shipwrecks and mounting deaths, European nations intensified search and rescue operations beginning in 2013. We develop a model of irregular migration in order to identify the effects of these operations on activity along this smuggling route. Leveraging plausibly exogenous variation from rapidly varying weather and sea conditions, we find that smugglers responded to these operations by shifting from seaworthy wooden boats to flimsy inflatable rafts. In doing so, these operations induced more crossings and had the ultimate effect of entirely offsetting the intended safety benefits of search and rescue operations, which were captured at least in part by smugglers.

Keywords: Central Mediterranean sea crossings, international, undocumented, irregular migration, search and rescue operations, rubber boats, deaths
JEL codes: F22 (International Migration); H12 (Crisis Management).

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1 Introduction

Many Western countries are facing increased migratory pressure, be it over land or sea.[1] In less than a quarter of a century, annual migratory flows from Africa to Italy alone have jumped from a few hundred to almost 200,000 and these flows are expected to continue to increase because of high population growth in Africa coupled with increasing desertification.[2] This global development has prompted a variety of reactions in destination countries: the United States has raised sanctions on migrants apprehended attempting to enter the U.S. illegally and has built barriers along the Mexican border;[3] Australia detains sea-bound immigrants in offshore facilities located on Nauru and Manus Islands; Hungary has erected a barrier on its border with Serbia and Croatia; Europe's Border and Coast Guard agency (Frontex), often in cooperation with the EU member states, patrols Europe's borders to detect (and ostensibly deter) undocumented migrants, most of whom try to cross the Mediterranean sea to reach Italy, Malta, Greece or Spain.[4]

Recently, European populist or nationalist parties in a number of countries (Hungary, Austria, Italy, Estonia, Poland, and Switzerland) have won seats in government by running primarily on anti-immigration platforms, and the United Kingdom's referendum on BREXIT was fueled in part by anti-immigration appeals. This has sent shock waves through European politics and has made immigration one of the most salient political issues of the day. In most other European countries, the vote shares of similarly-oriented parties have frequently reached double digits. According to recent polls, the Italian party "Lega", a populist anti-immigration party led by Italy's former Minister of Interior Salvini, jumped from about 10 percent to 35 percent of the vote share. The enormous gain is believed to be due to his attempts to ban refugee boats, including NGO rescue vessels, from entering Italian ports.

[1] While most international migration occurs legally, there are over 30 million irregular migrants living in the world today according to the most recent World Migration Report of the United Nations (slightly more than 10 percent of the total number of international migrants). Irregular migrants are defined by the UN as migrants who either entered, remained in, or worked in a country illegally (McAuliffe and Ruhs, 2017).

[2] Over the next 50 years population growth in sub-Saharan Africa is expected to be five times as large as the growth in Latin American population over the past 50 years (Hanson and McIntosh, 2016). The population of sub-Saharan Africa is expected to double in 30 years. Kniveton et al. (2012) model how migration will be affected by the interaction between population growth and a changing African climate.

[3] Bazzi et al. (2018) find that the increased sanctions have lowered recidivism in illegal entry, while Feigenberg (forthcoming) and Allen et al. (2018) find that the border wall reduced entry, though at a very high cost.

[4] Indeed, the Mediterranean sea has been dubbed the "New Rio Grande" (Hanson and McIntosh, 2016). Recently, Fasani and Frattini (2019) describe the recent migration flows through external European Union borders assessing how border enforcement policies deter or not migrants across different routes.

The renewed focus on immigration in Italian politics follows directly from the fact that a major European migratory route is the "Central Route" along which irregular migrants board vessels on the North African coast en route to Italy.[5] In March 2015, the executive director of Frontex told the Italian Associated Press National Agency (ANSA), "Anywhere between 500,000 to a million people are ready to leave from Libya," and from 2009 to 2017 over 750,000 irregular migrants and refugees reached Italy along this route.[6] Despite it's short distance, this is now agreed to be the deadliest water crossing in the world (McAuliffe and Ruhs, 2017). Between 2009 and 2017, roughly 11,500 people are believed to have perished in the Central Mediterranean, with countless others dying along the journey through the Sahara desert (UNODC, 2018). In comparison, annual deaths along the US-Mexico border range in the low hundreds.[7]

The reaction to this slowly unfolding tragedy has been inconsistent at best. In the wake of large, high profile shipwrecks, Italy and the EU established extensive search and rescue (SAR) operations at sea in the form of operations *Hermes*, *Mare Nostrum* and *Triton*. Despite intensifying efforts, some of the deadliest years on record followed. While these well-intentioned operations ostensibly reduced the risk of death *ceteris paribus*, they may have also induced greater numbers of migrants to attempt crossing, leading to an ambiguous effect on total migrant deaths.[8] Moreover, to the extent that these additional crossings were made on flimsier boats in a cost-saving measure, the operations may have unintentionally increased the risk of death itself. While the EU has reduced the geographic scope of its operations, several NGOs have recently stepped in by sending rescue vessels to newly unpatrolled areas.

It is hard to determine whether SAR operations have been successful for several reasons. First and foremost, it is unclear what the correct metric of success is since the objective of the EU is ill-defined and varies across member states. A successful operation likely reduces deaths, but it is not obvious whether it ought to reduce the total number of attempted crossings or even the riskiness of the journey. Second, it is difficult to estimate the risk of passage because the details of crossings are largely unobserved. Third, it is challenging to ascertain the counterfactual numbers of migrant crossings and deaths that would have occurred in the absence of SAR

[5] Malta is a secondary destination of migrants along the Central Route.

[6] See "Up to one million poised to leave Libya for Italy," *ANSAmed*, March 6, 2015.

[7] Between 1994 and 2000, about 1,700 deaths were reported to Mexican Consulates along the US-Mexico border (Cornelius, 2001).

[8] According to Porsia (2015), smugglers quickly learned to monitor Mare Nostrum vessels' positions through the Marine Traffic website (`http://www.marinetraffic.com/`).

because these are endogenously determined in a strategic equilibrium with smugglers. Moreover, SAR operations change infrequently and ostensibly cover the entire Central Mediterranean so a contemporaneous counterfactual is unavailable.

In light of these obstacles, we develop an alternative approach in this paper to better understand how SAR operations have shaped migration along the Central Route. We circumvent the first obstacle by focusing on more modest – yet crucial – questions, as an unambiguous determination of the objectives of the EU is beyond the scope of this paper. In particular, we seek to determine the effects of SAR on attempted migrant crossings, migrant deaths, and crossing risk (i.e., the probability that a crossing attempt results in death).

We address the second obstacle with the use of novel, restricted data on daily crossing attempts that we obtained from the *Polizia di Stato*, the Italian State Police in charge of migration. To the best of our knowledge, these data have not been used in any other analysis of migration along the Central Route, and they offer an unparalleled perspective on how migration changes at high frequency. We complement this with a robust dataset on migrant deaths that we cross-reference from four high quality sources, daily data on physical crossing conditions and forecasts from meteorological authorities, and a carefully researched catalog of search and rescue operations from 2009-2017.

In order to address the third obstacle, we develop an identification strategy that combines empirical tests of strategic behavior of smugglers and migrants with a theoretical model of migration that illuminates the implications of such behavior. Briefly, we empirically show that smugglers and migrants systematically respond to SAR operations and favorable crossing conditions by shifting from seaworthy wooden boats to flimsy inflatable boats. This strategic shift implies that SAR operations increased crossings, had little effect on equilibrium crossing risk (and plausibly increased it), and likely increased deaths during our sample period.

Despite the importance of this issue, there has been little empirical analysis and formal theoretical modeling of irregular migration along this important route, as pointed out by Friebel and Guriev (2013).[9] Friebel et al. (2017) and Aksoy and Poutvaara (2019) explore who chooses to migrate to Europe and their motivations for doing so.[10] The authors also consider some

[9] Orrenius and Zavodny (2015) reviews the scant literature on the determinants of illegal migration and human trafficking. McAuliffe and Laczko (2016) reviews the larger literature in the migration literature, which tends to be less quantitative.

[10] In addition, Arcand and Mbaye (2013) develop a model that attempts to estimate individuals' willingness to pay to migrate using data from a survey conducted in Senegal.

unintended effects of stricter border regulations on (negative) circular migration and (positive) demand for smugglers. Two other papers have modelled the smuggling of migrants: Woodland and Yoshida (2006) study the effects of tougher government policy for the detection, arrest, and deportation of illegal immigrants; and Tamura (2010) develop a model in which smugglers differ in their capacity to exploit their clients' labor opportunity at the destination.

Our paper also builds on a long standing literature stemming from Peltzman (1975) that argues that the potential safety benefits of new technologies or policies may be offset by the behavioral responses of different agents, be they drivers (Winston et al., 2006), drug users (Doleac and Mukherjee, 2018; Evans et al., 2019), or in this case, smugglers. Indeed, Cornelius (2001) find that the more aggressive enforcement along the US-Mexico border in the 1990s increased prices for *coyotes* and the number of deaths along the border, and Gathmann (2008) finds that in addition to a moderate price effect, aggressive border enforcement induces migrants to shift to more remote crossing points where the chances of a successful crossing are presumably higher. Because search is costly, it can lead to greater risk of death. This literature underscores the inescapable fact that the strategic responses of smugglers to search and rescue operations and the residual responses of potential migrants generate moral hazard that must be considered when developing enlightened policy toward such humanitarian tragedy.

The paper is organized as follows: in Section 2, we provide some background on the Central Route and SAR operations that have been implemented by individual countries, the EU, and various NGOs. In Section 3, we present a simple model of human smuggling that highlights the incentives that shape the decisions of smugglers and potential migrants. In Section 4, we describe the various sources of data that we use in our analysis. In Section 5, we present an empirical approach to test the extent to which SAR operations have impacted the numbers of crossings and deaths on the Central Route and the riskiness of this passage. We present a variety of robustness checks in Section 6 before concluding in Section 7.

2 Background

The Mediterranean Sea has been the home of trade and migration routes for millennia. Italy, with its strategic central position and proximity to African shores, has always been an important trading hub as a well as a major port of entry into Europe. One major migratory route runs from Libya to the Italian island of Lampedusa, which is closer to Africa (103 miles from Ras Kaboudja, Tunisia and 184 miles from Tripoli, Libya) than to Italy itself (174 miles to Sicily and 246 miles to continental Italy).

Between 1997 and 2008, the number of irregular crossings from North Africa to Italian shores was stable at around 20,000 per year. On August 30, 2008, the Italian Prime Minister Berlusconi flew to Benghazi to sign a treaty with Libya to reduce migratory pressure. As a result, Libyan arrivals to Italian shores dropped to about 9,500 in 2009 and 4,500 in 2010.

Pro-democracy uprisings during the "Arab Spring" of 2011 sharply increased migratory pressure.[11] The instability that spread across the Arab world, especially in North Africa, led to a marked increase in refugee crossings across the Central Mediterranean that reached particularly high levels between February and June 2011. Unsavoury actors with ties to Al Qaeda quickly controlled parts of the market for human smuggling into Europe, which was largely organized out of Libya. By the end of 2011, more than 50,000 immigrants from North Africa had reached European shores, and Italy became the main port of disembarkation on the Central Route.[12] After two relatively calm years, attempted crossings to Italy further skyrocketed and reached close to 200,000 in 2016. This escalation was accompanied by a sharp increase in the number of people dying along the sea route from North Africa with death rates of about 2 percent. We summarize these aggregate trends in Figure 1.

As irregular migration surged and became more deadly, Italy and the EU launched a number of search and rescue (SAR) operations with specific objectives. We summarize their operating dates, jurisdiction and budgets in Table 1.[13]

[11] In January 2011, following a month of protests against his rule, the President of Tunisia, Ben Ali, was forced to flee to Saudi Arabia. Tripoli fell in August 2011 and Muammar Gaddafi was captured and killed on October 20, 2011 as for other North African leaders. Additional unrest took place in Egypt, where President Hosni Mubarak was ousted, arrested, and charged (he later died in prison).

[12] The Libyan Army and the police often worked together to force migrants that had been living and working in Libya to leave for Italy (Frontex, 2012).

[13] Moreover, in response to the many casualties several Non-governmental organizations started providing aid and emergency medical relief to refugees and migrants. The first vessels of the NGO Migrant Offshore Aid Station (MOAS) started looking for migrant boats in distress close to Libyan shores towards the end of August 2014. Other NGOs followed in later years (a full list is shown in Table 2). Since MOAS was the first NGO to operate close to Libya and discloses all its operational plans, including the exact period of SAR operations, later in the paper we use these dates to proxy for NGO presence.

Hermes

In the years preceding the Arab Spring, EU planes, helicopters and naval assets patrolled Italian shores from North Africa as part of *Operation Hermes*, which had a monthly budget of less than €1 million Euro (Frontex, 2009, 2010). In response to the surge following the Arab Spring, the Joint Operation European Patrol Network (EPN) *Hermes* was launched in February 2011 and lasted until August along with a near tripling of the operational budget.

The main objectives of *Hermes* as laid out by Frontex were (i) border surveillance, (ii) early detection of crossings to inform third countries and seek cooperation (iii) information gathering on crossings, (iv) identification and return of third country nationals, and (v) prevention and fight of smuggling of migrants and trafficking of human beings. Its geographical operational area extended up to 24 nautical miles from Sicily, which corresponds to Italian territorial waters plus contiguous zones. Frontex extended the operations twice.

Mare Nostrum

Large scale sea accidents led to important changes at the end of 2013. On October 3, a boat carrying migrants from Libya sank off of the Italian island of Lampedusa. The death toll after an initial search was 359 (it was later revised upward). Later in the week, a second shipwreck near Lampedusa led to an additional 34 deaths. In response to these twin tragedies, the Italian government initiated *Mare Nostrum* on October 18, 2013, the first military operation with an explicit humanitarian aim in the Central Mediterranean Sea.

Unlike Hermes, *Mare Nostrum* had the explicit goal of safeguarding human life at sea. The force included personnel as well as sea and air assets of the Navy, the Air Force, the Carabinieri, the State and the Financial Police, and the Coastal Guard (Ministry of Defense, 2013). Once rescued, "irregular" migrants were generally channelled to the existing reception system for asylum seekers (Bratti et al., 2017).[14]

[14] The system of reception in Italy up until September 2018 is structured into three main steps (Legislative Decree 142/2015): (i) Aid, first assistance and identification centers that are in places most subject to disembarkations (as for Pozzallo; Porto Empedocle; Trapani; Lampedusa). In these places are carried out the rescue operations, first health assistance and pre-identification of irregular migrants. (ii) Migrants are moved afterwards to the centres of first reception (First Aid and Reception Centres, CPSA; Centre for the Reception of Asylum Seekers, CARA and Accommodation Centres for Migrants, CDA) for the time of identification, formalization of the asylum request and verifying potential situations of vulnerability. However, apart from rare cases, these structures have not been fully operational. (iii) Finally, migrants are sorted into second reception centers, namely the protection system for asylum seekers and refugees (SPRAR) centers, that deal with the integration and the protection of the migrants with orientation to employment; training and languages courses and other support

Operationally, *Mare Nostrum* consisted of permanent patrols in the search and rescue zones of Libya and Malta as well as Italy. This extended 138 miles south of Sicily and included naval and aircraft deployments that were carried out by military personnel. The monthly cost of the operation was around €9.5 million, dwarfing that of Hermes. Despite seemingly broad public support, the operation was criticized as an unfair burden for Italy to bear alone. *Mare Nostrum* was also criticised by UK's former foreign office minister, Lady Anelay, who described it as, "an unintended 'pull factor', encouraging more migrants to attempt the dangerous sea crossing and thereby leading to more tragic and unnecessary deaths."

Triton

In spite of opposition from the UK, patrolling activities were taken over by the Frontex-led Operation *Triton* on November 14th 2014, which officially superseded *Mare Nostrum* (Frontex, 2014). The European Commission specified that the *Triton* mission would differ from *Mare Nostrum* since its primary objective was not the search and rescue of migrant boats in distress but rather surveillance of the external borders of the European Union. However, the European Parliament and the Council of the European Union clarified that the operation would not escape the obligations of international and European law, which required intervention where necessary to rescue migrants in difficulty (Regulation EU 656/2014).

Triton's initial operational SAR area shrunk to only 30 miles from the Italian and Maltese coasts. However, after two more high profile shipwrecks in a single week in April 2015 resulted in over one thousand migrant deaths, the funding and operational power of *Triton* expanded dramatically. The second phase of *Triton* expanded the SAR area up to 138 miles south of Sicily and tripled its operational budget. In addition, Frontex began to destroy migrant smuggler vessels to prevent them being reused.[15]

in looking for a job and house (law 189/2002). According to law 142/2015, if the availability of places within the first or second reception facilities is exhausted, extraordinary measures are taken by the Prefect that can move the migrants to large collective structures (extraordinary reception centers, CAS). The length of stay in the CAS should be limited to the time strictly necessary for the transfer of an applicant to the first or second reception centers. Migrants that do not comply with asylum seeker requirements are moved to the identification and expulsion centers (CIE) where they are kept waiting to be repatriated.

[15] On May 2015, the EU launched a military operation known as European Union Naval Force Mediterranean (EUNAVFOR Med) Operation Sophia. The main mandate was to take systematic measures to identify and stop boats used or suspected of being used by human traffickers in the Central Mediterranean. On 20 June 2016, the Council added two additional tasks to the mission's mandate: (i) training the Coast Guard and the Libyan Navy and (ii) contributing to the implementation of the UN arms embargo on the high seas off the coast of Libya. On December 21, 2018, the European Council extended the mandate of the operation until March 31, 2019. The Operational budget until 27 July 2016 was 11.82 million (12 months) while for the period 28 July 2016 to 27 July

Operation Triton ended in February 2018. The following Joint Operation Themis is not part of our data. Themis vessels are not patrolling further than 24 miles from the European coast, and most rescues are now done by NGO private vessels.

Figure 2 summarizes the timeline of all SAR operations along the Central route. Non Governmental Organizations have also participated in SAR operations, which we discuss in more detail in Section 6.3.

3 Model

We present a model of irregular migration that highlights the important incentives faced by smugglers and potential migrants and provides a useful guide for empirical analysis of irregular migration. Because many features of this market are either unobserved or incompletely observed (e.g., prices, vessel types), the implications of our model allow us to draw inferences on the incidence of search and rescue operations on the various agents involved.

On the demand side of the market for passage across the Mediterranean we assume a unit mass of potential migrants. Each migrant may cross on a safe boat ($b = S$, e.g., a sturdy, wooden boat) or an unsafe boat ($b = U$, e.g., a crowded inflatable raft with an under-powered outboard motor, see Figure A.1 in the Appendix) at a price of p_b respectively. Migrant i has utility

$$u_i = \alpha_i \sigma_b^R(w) - p_b$$

where α_i is an individual specific parameter that reflects the intensity of i's desire to cross and is distributed according to the continuous density f. For a given set of prices, if neither boat option provides migrant i with positive utility, they will decline to cross.

σ_b^R represents the probability of a successful passage on a boat of type b. This is a decreasing function of crossing conditions, w, and varies if search and rescue operations are in place ($R = 1$) or not ($R = 0$). We make the following three assumptions on crossing technologies:

2017, the reference amount for the common costs of EUNAVFOR MED operation SOPHIA was 6.7 million.

$$\sigma_U^R(w) < \sigma_S^R(w) \tag{A1}$$

$$\frac{\partial \sigma_U^R(w)}{\partial w} \leq \frac{\partial \sigma_S^R(w)}{\partial w} < 0 \tag{A2}$$

$$\sigma_U^1(w) - \sigma_U^0(w) > \sigma_S^1(w) - \sigma_S^0(w) > 0 \tag{A3}$$

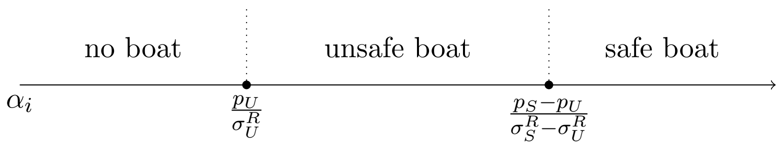
The trivial assumption (A1) simply states that irrespective of weather conditions "safe" boats are more likely to complete the journey than "unsafe" boats. According to Assumption (A2) unsafe boats are more susceptible to crossing conditions. Assumption (A3) captures the fact that search and rescue operations increase the safety of unsafe boats more than they increase the safety of safe boats. These common-sense assumptions are empirically validated in our analysis.

On the supply side, smugglers offer passage to migrants at prices p_b and at costs c_b respectively. Seats on safe boats are more costly to provide than seats on unsafe boats (i.e., $c_S > c_U$).[16] We begin by noting that less motivated migrants (lower α_i) will never choose a safer boat than a more motivated migrant, which we formalize in Lemma 1.

Lemma 1. *Under Assumption* (A1), *if* $\alpha_i < \frac{p_U}{\sigma_U^R}$, *then* i *will not cross. If* $\frac{p_U}{\sigma_U^R} \leq \alpha_i < \frac{p_S - p_U}{\sigma_S^R - \sigma_U^R}$ *then* i *will cross on an unsafe boat. Otherwise,* i *will cross on a safe boat.*

Proofs may be found in the Appendix. Lemma 1 imposes an ordering on migrants' α_i that allow us to pin down the number of attempted crossings as illustrated in Figure 1.

Figure 1: Migrant's Crossing Decisions



Finally, if fractions M_S^R and M_U^R of migrants attempt to cross on safe and unsafe boats respectively, then we can define the crossing risk, or the probability that a migrant is observed to die as

[16] According to Libyan smugglers that have been interviewed by investigative reporters crossing the Mediterranean sea during this period costs at least \$500 with higher prices charged for passage on wooden boats (Mannocchi, 2018).

$$\rho^R = 1 - \frac{\sigma_S^R M_S^R + \sigma_U^R M_U^R}{M_S^R + M_U^R} \tag{1}$$

For simplicity, we first consider the case in which the market for smuggling is perfectly competitive, i.e., prices are set to marginal cost.[17]

Proposition 1. *Under Assumptions* (A1)-(A3) *and perfect competition, the introduction of search and rescue operations will result in:*

1. *Increases in total attempted crossings and attempted crossings on unsafe boats; decreases in attempted crossings on safe boats.*

2. *An ambiguous effect on crossing risk.*

3. *Total attempted crossings becoming more elastic to crossing conditions if σ_U^0 is small.*

The first two parts of Proposition 1 follow immediately from Lemma 1. Because prices remain at $p_U = c_U$ and $p_S = c_S$ irrespective of whether search and rescue operations are in place, the resulting decrease in σ_U and increase in $\sigma_S - \sigma_U$ shift the two thresholds in Figure 1 to the left and right respectively (part 1). These shifts may or may not outweigh the increased safety from the operations (part 2). The third part of Proposition 1 follows from the fact that if unsafe journeys are unlikely to be successful without search and rescue, then the introduction of these operations provides an additional margin along which smugglers and migrants may adjust their decisions.

We now consider the polar case in which smugglers are monopolists and hence can set prices freely depending on the extent of search and rescue operations.[18] The smuggler's problem can thus be written as

[17] The extent to which different militias and criminal networks compete with each other in this market has not been definitely established. On one hand, Pastore et al. (2006) argue using judicial data that different smugglers compete in prices, but they also use marketing strategies to highlight specific characteristics of the service provided. Interviews with Frontex officers seem to confirm the view that entry costs are fairly low (Campana, 2017). On the other hand, there is also evidence that smugglers cooperate amongst themselves when storing boats, and by steering in formation to offer mutual assistance. For local, tribal, and community interests, smuggling is sometimes perceived as a way to finance their security in times of civil unrest (Micallef, 2017). This is likely to generate some local monopoly power.

[18] For expositional simplicity, we assume that are unable to adjust their prices to short run fluctuations in crossing conditions (w). This could be relaxed with the introduction of additional technical assumptions on the ordering of the marginal effects of crossing conditions on successful passage with and without SAR. These can be intuitively understood as second order assumptions on σ_b^R.

$$\max_{p_S^R, p_U^R} M_S^R \cdot (p_S^R - c_S) + M_U^R \cdot (p_U^R - c_U)$$

with the understanding that the M_b^R are endogenously determined. To better characterize this market under monopoly, we make a standard monotone likelihood ratio assumption on f that can be easily expressed in terms of the hazard function $\lambda(\cdot)$:

$$\lambda(\cdot) = \frac{f(\cdot)}{1 - F(\cdot)} \text{ is non-increasing.} \tag{A4}$$

Proposition 2. *Under Assumptions* (A1)-(A4)*, for a monopolist smuggler, the introduction of search and rescue operations leads to:*

1. *The same results as under perfect competition as listed in Proposition 1.*
2. *Increases in p_U, p_S and $p_S - p_U$ if σ_U^0.*
3. *An increase in smuggler's profits.*

We can express the markups that monopolists charge as follows:

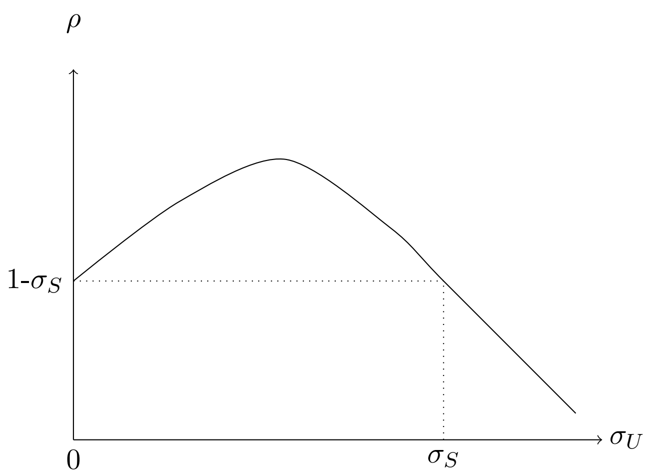
$$p_U^R = c_U + \frac{\sigma_U^R}{\lambda\left(\frac{p_U^R}{\sigma_U^R}\right)} \tag{2}$$

$$p_S^R = c_S + \left[(p_U^R - c_U) + \frac{\sigma_S^R - \sigma_U^R}{\lambda\left(\frac{p_S^R - p_U^R}{\sigma_S^R - \sigma_U^R}\right)} \right] \tag{3}$$

These expressions have intuitive interpretations. The markup on p_U^R is greater when unsafe boats are safer and when there are fewer price sensitive migrants on the margin. The markup on p_S^R has a similar interpretation, plus it is increasing in the markup on p_U^R. This reflects a degree of price discrimination which yields two important implications: First, monopolist smugglers respond to search and rescue operations by raising prices (part 2), though not by so much that they deter inframarginal migrants from attempting to cross (part 1). Second, search and rescue operations make smugglers unambiguously better off (part 3), as they are able to capture, at least partially, the safety benefits of the operations. However, it is ambiguous as to whether migrants will on net be better off since search and rescue operations may make the journey *more* treacherous by driving a large enough share of migrants to now cross on unsafe boats instead of safe boats.

Perhaps surprisingly, when σ_U is small, it is more likely that search and rescue operations will increase the crossing risk, and only when σ_U is large will the crossing risk decrease. The intuition for this is conveyed in Figure 2. When $\sigma_U = 0$, all travel occurs on safe boats, hence $R = 1 - \sigma_S$. As σ_U grows larger, an increasing amount of travel occurs on unsafe boats, so R increases. When $\sigma_U \geq \sigma_S$, all travel occurs on unsafe boats, so $R = 1 - \sigma_U$. The continuity of the objective function implies that in some range of large but not too large σ_U, R will be decreasing. Whether we are on the increasing or decreasing portion of the curve in Figure 2 (and hence whether search and rescue operations increase or decrease crossing risk) is thus an empirical question.

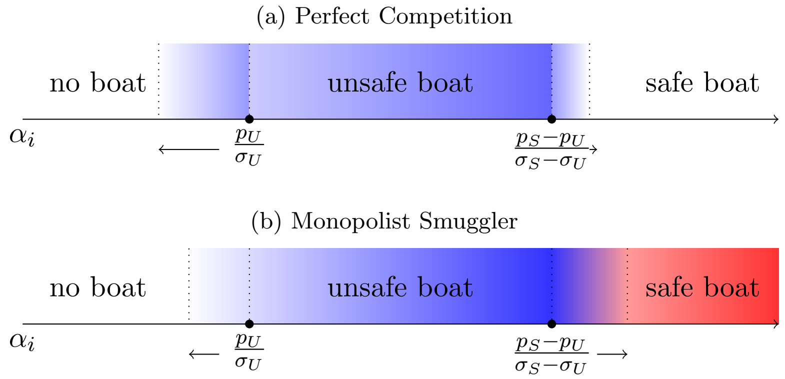
Figure 2: Net Crossing Risk



We can illustrate the effects of search and rescue operations and their incidence on migrants in Figure 3. The analysis is qualitatively the same whether smugglers face competition or not. In the presence of search and rescue operations, the migrant who is indifferent between passage on an unsafe boat and no passage at all now has a lower α_i. Intuitively, the increased safety of the journey offsets any increase in price. All migrants close to this threshold are made better off by search and rescue operations (indicated in blue). In this region, migrants with greater α_i enjoy greater benefits from the search and rescue operations since they value safety more.

The migrant who is indifferent between passage on a unsafe boat and a safe boat now has a higher α_i since there is less of a safety premium to taking the safe boat (and it may have gotten

Figure 3: Incidence of Search and Rescue Operations on Migrants



Note: The blue region contains migrants who are made better off by search and rescue operations, and the red region contains migrants who are made worse off by search and rescue operations. A greater intensity of color reflects a greater (positive or negative) incidence.

more expensive as well). If smugglers have any market power, then all migrants who still take the safe boat will be made worse off by search and rescue operations since they pay a higher price but get no added benefit. Moreover, those migrants who are just to the left of this new threshold will also be worse off since they highly value safety but are now priced out of safe boats.

Search and rescue operations have two key effects in this model: they increase the likelihood of crossing attempts on unsafe boats, and they increase the sensitivity of migrants and smugglers to local variation in crossing conditions. Both of these predictions are testable empirically. Support for these predictions constitutes evidence regarding the broader impacts of search and rescue operations on the overall market for smuggling along the central route along with migrant and smuggler welfare.

4 Data

We combine data from different sources that focus on the migration along the Central Route from 2009 to 2017. Extralegal behavior is by its very nature often difficult to observe. As such, we always rely on multiple sources for those variables that are least well documented in official statistics. Our final dataset contains daily information on irregular crossings, deaths, tidal conditions and search and rescue operations.

4.1 Data on Crossings

We obtained a novel database on the number of daily irregular migrants to Italy from the *Polizia di Stato* (State Police) who operate under the control of the Department of Public Security (Ministry of Interior). The Department oversees all activities related to public order, which includes operational support for search and rescue missions. In addition to collecting information on irregular migration, they are tasked with controlling the flow of migrants into Italy and enforcing regulations regarding the entry of and stay of migrants. We use their data to construct our measure of daily arrivals to the Italian shores, which constitutes the bulk (over 75%) of all arrivals along the Central Route.[19] We then compute total daily crossings as the sum of arrivals and deaths in transit.

Attempted crossings have increased over the sample period, peaking in 2016 (see Figure 1) There are on average 170 attempted crossings per day along the Central Route, and they follow a strong seasonal pattern as shown in Figure 3. Nevertheless, there is significant variation in seasonality across the different years of our sample.

Unfortunately, we cannot observe daily attempted crossings that are intercepted by the Libyan Coast Guard (LCG), but during our period 2009-2017 such operations were in place only after 2016. Based on our data on crossings merged with UNHCR (2017) data, the fraction of migrants rescued by the LCG is around 10 percent and starts growing only towards the end of 2017. Our results are robust to dropping these two years.

We also gathered information on the type of vessel used from 2013-2017 from Frontex, though many crossing vessels in that sample period are unknown. We summarize these data in Figure 4. It is immediate that over time, especially at the start of *Triton II* operations in mid-2015, inflatable boats become the main vessel used by smugglers.

4.2 Data on Deaths

Although official statistics on deaths in transit are difficult to come by, a number of large transnational organizations (some government supported) make great efforts to document these deaths. We cross-reference these data sets to create a comprehensive single measure of daily deaths. The average number of daily deaths is 3.6, which corresponds to a crossing risk that

[19] Most of the migrants arrive on the Lampedusa shores (22%), Augusta (20%) and Pozzallo (14%) in Sicily.

ranges between 2.7 to 5.5 percent depending on how it is calculated (see below).

Our primary source is UNITED for Intercultural Action, the European network in support of migrants, refugees and minorities. The organization has monitored the deaths at sea since 1993 with the support of more than 560 organisations and institutions from 46 European countries (including the European Commission, the Council of Europe, OSCE-ODIHR and Heinrich-Böll-Stiftung). UNITED monitors the number of deaths during border crossing attempts around the world and counts refugees, asylum seekers and undocumented migrants who have died through their attempts to enter Europe. To produce the *List of Deaths* dataset, UNITED collects information from field organizations, institutional sources, and the migrants' protection systems of various European countries. This dataset contains information on where, when, and under which circumstances a migrant died, including whether it happened during an attempted border-crossing.

Although the *List of Deaths* database is considered to be the largest and most comprehensive source on deaths at sea, we augment it with information provided by the Missing Migrants Project that covers the portion of our sample period in 2017.[20] For robustness, we also cross-reference our data with data from Frontex that spans 2014-2016 and the *Migrants File* dataset that spans 2009-2016.[21]

In Figure 5, we present a map of sea accidents during our sample period. Larger circles correspond to more deadly shipwrecks. Not only does the number of deaths increase over time, deaths also appear to occur closer to the Libyan shore. This is consistent with the increasing use of unsafe boats for attempted crossings.

Calculating Daily Crossing Risk

The crossing risk in equation (1) is an aggregate function of all crossings and deaths. Our goal is to construct a daily measure of crossing risk for departures based on observed daily arrivals and daily deaths. If all attempted crossings concluded in a single day, then daily crossing risk could simply be calculated as

[20] UNITED has not geolocalized more recent data; as such our last extraction was on May, 30 2017. The Missing Migrants Project, which fills this gap, is supported by UK Aid from the Government of the United Kingdom and International Organization for Migration (IOM).

[21] The *Migrants File* database collects information from Puls, a project run by the University of Helsinki, Finland and commissioned by the Joint Research Center of the European Commission. (See `http://www.themigrantsfiles.com/`.) Relative to other official sources, this seems to under-count deaths.

$$\rho_t = \frac{\text{Total Deaths}_t}{\text{Total Attempted Crossings}_t} \tag{4}$$

In practice, the journey may take up to three days, so daily departures do not necessarily correspond to daily arrivals. As a result, we calculate crossing risk in a variety of different but complementary ways. Specifically, we generalize equation (4) and define

$$\rho_t^{c,d} = \frac{(\text{Total Deaths}_t + ... + \text{Total Deaths}_{t+d})/(d+1)}{(\text{Total Attempted Crossings}_t + ... + \text{Total Attempted Crossings}_{t+c})/(c+1)} \tag{5}$$

where $\rho_t^{c,d}$ represents the crossing risk as calculated using an average of deaths during a d day period and arrivals (total attempted crossings) over a c day period. Note that $\rho_t^{0,0}$ corresponds to the naive calculation of crossing risk defined in equation (4).

4.3 Data on Crossing Conditions

We proxy for crossing conditions with the significant height of combined wind, waves, and swell, which is commonly known as the significant wave height ($H^{1/3}$). The combined height of the sea and swell is the average height of the highest tercile of the waves experienced by mariners in open waters (measured from the wave crest to trough of the preceding wave). Wind-sea waves are directly affected by local winds, and swell, the waves that were generated by the wind at a different location or time. The significant wave height takes account of both.[22] We obtained detailed tidal data from the European Centre for Medium-Range Weather Forecasts (ECMWF), an independent intergovernmental organization that is supported by 34 mostly European states.

These data are based on high frequency readings from satellite measurements, but also on surface-based data sources (buoys, radar wind, drop-sonde and ships) as well as on aircraft reports (Dee et al., 2011). We also collected data on wave forecasts, which use the above data up until time t to forecast wave conditions at $t + 1$, $t + 2$, etc.. According to the ECMWF, these forecasts are not calibrated for the Libyan region and may thus overestimate actual wave

[22] Appendix Table A.1 describes wave and swell in terms of height and length. Waves can vary from zero (calm) with no waves breaking, to very high (towering seas) or phenomenal which is a rare case as for hurricanes or cyclones. Figure A.2 shows the density of the significant wave height by season. As expected, waves are calmer in summer months. During Spring and colder seasons, tidal conditions are most often characterized by sea deeply furrowed and disturbed with rollers.

conditions. We adjust the significant wave height forecasts error to have mean zero.[23] We measure tidal conditions at a variety of potential departure points along the North African coast: Tripoli, Libya; Benghazi, Libya; Al Huwariyah, Tunisia; and Annaba, Algeria. Average significant wave height varies between 1.08 and 1.47 meters depending on where it is measured. We summarize all of our main variables in Table 3.

5 Empirical Approach and Results

Our goal is to identify the effects of search and rescue (SAR) operations on attempted crossings, deaths in transit, and the risk of crossing. A natural starting point is a series of naive regressions of the form

$$Y_t = \sum_k \beta^k \mathrm{SAR}_t^k + f(t) + \epsilon_t. \tag{6}$$

where Y_t corresponds to one of the three outcomes, the subscript k indexes each search and rescue operation that was implemented during our sample period, f(t) is a function of time and includes a cubic polynomial in t to control for the long term trends and week of the year fixed effects to control for seasonality. We compute Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days (Newey and West, 1994). We estimate these regressions and present the results in Table 4. Consistent with our model, all SAR operations are associated with greater numbers of crossings. Despite the increase in crossings, we find no statistically significant associations between SAR operations and deaths or crossing risk.

Of course, this naive analysis is limited by the facts that SAR operations are initiated infrequently and may respond to changes in the crossing environment, so we take an alternative empirical approach. We do not attempt to estimate causal responses of attempted crossings, deaths and crossing risk to SAR precisely for the reasons given above. Instead, our strategy is to estimate a series of responses to plausibly exogenous changes in the environment – in particular, daily crossing conditions. Because daily crossing conditions vary at high frequency, are well measured, and are generated exogenously, we can more confidently interpret these responses as causal, especially when comparing these responses depending on whether SAR operations

[23] Appendix Figure 6 plots unadjusted and adjusted forecasts of $H^{1/3}$ against their realizations.

are in place.[24] We argue that each of our estimates either (1) validates one of Assumptions (A1)-(A3), (2) constitutes a test of the Propositions, or (3) reflects optimizing behavior on the part of smugglers and migrants; this evidence is summarized at the end of this section in Table 5. As such, our empirical analysis, viewed through the lens of our model, allows us to conclude that SAR has affected migration along the Central Route in several systematic ways.

Our primary source of exogenous variation in crossing conditions is the daily weather and tides near the Libyan shore. Rough winds and seas can dramatically affect the probability of safe passage on an inflatable boat, but sturdier boats are largely impervious to all but the worst conditions. We proxy for these conditions with a measure of significant wave height $H^{1/3}$, which is a widely used measure in navigation that corresponds to the average height of the largest third of the waves in the open sea. Significant wave height is commonly modelled using the Rayleigh distribution (Battjes and Groenendijk, 2000), which allows the calculation of average wave heights above given percentiles. This is particularly relevant to our analysis, as shipwrecks are most likely to be caused by only the very largest waves. For example, 1 in 10 waves have an average height of $H^{1/10} = 1.27H^{1/3}$. Given J waves, the maximum wave height can be approximated as $\sqrt{0.5\log(J)}H^{1/3}$, which, for large J, is about twice the significant wave height $2H^{1/3}$. This means that with a significant wave height of 1.5 meters, a vessel crossing the Mediterranean sea would most likely encounter waves of up to 3 meters of height. The linearity of H (in its exponent) implies that modelling crossing, deaths and risk of death as a linear function of significant wave height $H^{1/3}$ is empirically equivalent to choosing any other wave height (with coefficients appropriately).

Figure 7 presents scatter plot of the total number of daily (t =day) crossings against wave height. We model the crossings, deaths, and death rates as a function of contemporaneous significant wave height after controlling for interacted week/year fixed effects (λ_w, which also capture all our SAR periods):[25]

$$Y_t = \omega_0 H_t^{1/3} + \sum_k \omega_k \mathrm{SAR}_t^k H_t^{1/3} + \lambda_w + \epsilon_t. \tag{7}$$

[24] Given our time-series approach using wave height has the additional advantage that the series is stationary.

[25] Starting from the fraction of potential migrants crossing the sea, a uniform distribution of α_i and an inverse relationship between wave height and p_U/σ_U would lead to a linear specification. Later we test whether the results are robust to choosing a different functional form. We also test whether lagged wave heights are a better proxy for crossing conditions.

We present our results in Table 6. In the odd columns, we leverage only high frequency variation in safety. Not surprisingly, crossings are over 75% less likely to be attempted when waves are high (column 1). As a result, there are fewer opportunities for deaths along the journey (column 3). This strategic response to waves mitigates an increase in crossing risk (column 5). Taken together, these results confirm that significant wave height is a meaningful proxy for crossing conditions.

In the even columns of Table 6 we explore the extent to which SAR operations mediate the effects of crossing conditions. During all operational periods (with the exception of the unfunded *Hermes* extensions) crossings are more sensitive to significant wave height than in non-operational periods (column 2). This difference is particularly large starting with *Mare Nostrum*, and then grows further during *Triton II*.[26] This findings coincide exactly with the predictions of our model. Fewer attempts under adverse conditions translates into fewer deaths (column 4). Once again, crossing risk is largely unaffected by SAR operations (column 6).[27]

Altogether, these results suggest that during periods of SAR operations, smugglers shift from safe boats to unsafe boats, as safe boats should be less responsive to short-run fluctuations in crossing conditions. Moreover, this substitution pattern is weaker during periods of lower intensity SAR (e.g., *Hermes* and *Hermes* Extension), which is consistent with such operations generating a smaller increase in σ_U than their better funded counterparts.[28] We test for substitution across vessel type more directly by re-estimating equation 7 specifying the attempted crossings by different types of vessels as dependent variables. Results are presented in Table 7. With the caveat that these dependent variables are noisy (Frontex classifies 6.8% of vessels as "other" and 20% of vessels as unknown),[29] and our vessel data begins only in May 2013 and ends in October 2017, our results are consistent with strategic smuggler responses as predicted by the model. Because these regressions include fixed effects at the month-year level (there is

[26] This is in line with smugglers admitting in Porsia (2015) that they soon understood the humanitarian aim of *Mare Nostrum* and "... quickly took the advantages from that, adapting the amount of fuel and supply's to cover the shorter distance up to coordinates where Italian forces were."

[27] All of our results should be understood to be conservative in the face of potential measurement error in deaths. If deaths (and hence, by extension, calculated crossing attempts) were more likely to be observed during periods of greater SAR intensity, then our estimates of ω_k would be biased downwards in columns 2 and 4 of Table 6.

[28] These findings are also consistent with the evolution in the share of inflatable boats as shown in Figure 4. Inflatable dinghies purchased online (see Appendix Figure A.1) were used in greater numbers starting in the summer of 2014 towards the end of the *Mare Nostrum* operation.

[29] The number of unknown vessels is strongly correlated with the number of inflatable dinghies, which is why we put the two categories together. Nothing changes if we analyze them separately.

insufficient variation to include week-year fixed effects), they reveal that smugglers shift between different types of vessels at a very high frequency.

The evidence presented above broadly supports the notion that various SAR operations had the unintended consequences of (1) increasing crossings and (2) diverting crossings from safer boats to less safe boats. We further analyze the behavioral responses of smugglers and migrants by estimating month-specific responses to crossing conditions with the following regression equation:

$$Y_t = \omega_m H_t^{1/3} + \lambda_w + \epsilon_t \tag{8}$$

The key modification in equation (8) is that the coefficient on $H_t^{1/3}$ is allowed to vary by year/month of the sample. Hence we can directly estimate changing responses over time and assess the extent to which they correspond to periods of SAR operations.

In Figure 8 we specify Y_t as daily crossings and present estimates of ω_m over time along with 95% confidence intervals. When there are no operations, $\hat{\beta}_m$ is effectively zero. Only during periods of SAR do the number of crossings vary with weather conditions, which reflects the use of unsafe boats. These responses are greatest during the periods of highest intensity SAR operations corresponding to Hermes 2011, Hermes 2013, Mare Nostrum and Triton II (see Table 1).

As seen in Figure 9, deaths are also more responsive to weather conditions during periods of SAR. As argued before, this is likely due to changes in the numbers of crossings rather than reductions in crossing risk, as Figure 10 reveals no systematic relationship between crossing risk and SAR operations.

We conduct a similar data-driven exercise to gauge the extent to which smugglers respond to crossing conditions by repeatedly estimating the following equation

$$Y_t = [\omega_0 + \omega_{t^\star}\mathbb{I}(t > t^\star)]H_t^{1/3} + \lambda_w + \epsilon_t. \tag{9}$$

where Y_t is daily attempted crossings, and each value of $t^\star$ corresponds to each of the 3287 days in our sample. We then plot the R^2 from each regression against $t^\star$, which we present in Figure 11. Intuitively, peaks of this plot correspond to more likely dates that represented a "structural break" in how smugglers operated (assuming there is only one). The highest peak (March 21,

2014) corresponds to the first spring season in which *Mare Nostrum* was in place. Other notable peaks correspond to the beginnings of *Hermes* 2011, *Triton I* and *Triton II.* This suggests that, based only on observed crossing attempts and contemporaneous weather conditions, we can infer that behavior was likeliest to have changed near times of operational change.

We present further suggestive evidence that smuggler and migrant behavior is shaped by changing incentives by estimating how our outcome variables respond to contemporaneous forecasts of future weather conditions. A systematic response to expected crossing conditions (conditional on currently observed crossing conditions) would constitute evidence of sophisticated behavior in this market. We estimate regression equations of the form:

$$Y_t = \sum_k \omega_k \text{SAR}_t^k \mathbb{I}(H_t^{1/3} < E_t[H_t^{1/3}]) + \lambda_w + \epsilon_t \tag{10}$$

where $\mathbb{I}(H_t^{1/3} < E_t[H_t^{1/3}])$ is an indicator variable that is equal to 1 if contemporaneous wave height is lower than an unbiased forecast of future wave height, i.e,. if crossing conditions are better today than tomorrow.

Given that during intense SAR operations refugee boats are typically rescued soon after leaving the Libyan shore, we expect ω_k to be positive. We present our estimation results in Table 8. When crossing conditions are more favorable today than tomorrow, smugglers send more migrants (column 1), and this strategic decision is more pronounced during the most intense periods of search and rescue operations (column 2). Deaths are lower when crossing conditions are more favorable today than tomorrow (columns 3 and 4), and the risk of crossing is also lower at those times (columns 5 and 6). This is consistent with the fact that crossing conditions matter, smugglers are aware of this, and they use this information in a strategic manner.

Given the anecdotal evidence of Chinese rubber boats reaching Libya through neighbouring countries, as a final piece of indirect evidence of the substitution across boat types, we track the total number of rubber boats (and similar vessels) that were imported (on net, and mainly from China) by Malta, Egypt and Turkey. As a control group we use the total number of ferries, and we normalize the numbers to be 100 in 2010. Figure 12 shows that in the period prior to operations, these crossings displayed little trend. However, they begin to diverge after the introduction of *Mare Nostrum* in 2014, and this divergence is exacerbated after *Triton* in 2015.

By the time of *Triton II* the imports had increased by more than 15 times.[30]

This pattern is further supported by trends in imports of life-jackets to Egypt, Libya and Malta, which we present in Figure 13. Indeed, a sharp increase in imports of these inexpensive safety devices, whose benefits would largely accrue to passengers on unsafe, inflatable vessels, is indirect evidence that traffickers offset the safety benefits of search and rescue operations.[31]

To summarize, we find that in periods when SAR operations are in place, irregular migration along the Central Route increases, though the probability of perishing on this crossing does not. These increases are largest when SAR operations are most intense. Moreover, traffickers respond strategically to adverse weather and tidal conditions. The fact that these responses are largest when SAR is in place is evidence that the operations have induced traffickers to shift from safer wooden boats to less seaworthy inflatable craft. This is supported by direct, albeit incomplete, data on the types of vessels used by migrants and indirect data on alternative safety measures such as life jackets. The implications of these findings as interpreted through the lens of our model are that SAR operations have increased irregular migration along the Central Route and that the potential safety benefits of these operations have been offset by the greater use of unsafe boats, which has allowed smugglers to capture the benefits of these operations.

6 Robustness

6.1 Alternative Specifications of Crossing Conditions

Because Tripoli and Lampedusa are 184 miles apart, the journey takes 61 hours at a speed of 2.5 knots, a typical speed for fishing boats and fully cramped rubber boats.[32] Hence, to smugglers expecting a 2 or 3-day trip what may matter is the maximum wave condition over the following few days ($\mathbf{H}_t^{1/3} = \max(H_t^{1/3}, H_{t-1}^{1/3}, ...)$). We test this by estimating the following regression equation:

$$Y_t = \omega_0 \mathbf{H}_t^{1/3} + \sum_k \omega_k \text{SAR}_t^k \mathbf{H}_t^{1/3} + \lambda_w + \epsilon_t. \tag{11}$$

[30] In July 2017 the EU introduced an export ban on inflatable boats and outboard motors to Libya.

[31] The conjectured use of life-jackets on unsafe boats is also evidence that traffickers are constrained by the safety concerns of migrants through competition.

[32] In our sample period, 22% of disembarkments occurred in Lampedusa. Faster boats may attempt to reach mainland Sicily in three days. Pozzallo, where 14% of the disembarkments took place is 282 miles away from Tripoli.

and present results in Table 9. Each of the columns in Table 9 are analogs to the columns of Table 6. The results are broadly similar: crossings decrease under adverse conditions, and they are more sensitive when SAR operations are in place (column 1 and 2). Deaths follow a similar pattern as crossings (column 3 and 4), but this appears to be driven primarily by fewer opportunities for fatalities, as crossing risk is largely unchanged (column 5 and 6).

In our main results, we proxy for crossing conditions with tidal conditions measured outside of Tripoli, Libya, which is the main embarkation point for irregular migrants. However, not all crossings originate from the same location in North Africa. In Table 10 we conduct a horse race between significant wave height in four different locations (Tripoli and Benghazi, Libya; Al Huwariyah, Tunisia; and Annaba, Algeria). The results are broadly consistent with our previous results, though direct comparisons are inadvisable since sea conditions at each of these locations are are highly correlated to one other. Nevertheless, crossings consistently respond most strongly to conditions outside of Tripoli.

6.2 Alternative Specifications of Crossing Risk and Functional Form

As discussed in Section 4, it is difficult to precisely measure crossing risk in our data since crossings are measured at the time of arrival while deaths occur during a multi-day journey. In Table 11 we re-estimate equation (7) with several alternative measures of crossing risk.[33] There are two operational periods in which larger waves increase crossing risk: when no operations are in place and during Triton II. Because these are the two periods with the least potential substitution across types of vessels, this is consistent with our model.

6.3 NGO Operations

In addition to official operations by the EU government, several humanitarian operations were conducted by NGOs during our sample period; however these were much smaller in scope and intensity than official operations. The most active NGO, Malta-based Migrant Offshore Aid Station (MOAS), deployed fishing vessels and two drones (MOAS, 2014, 2015, 2016, 2017). MOAS offered an example that was later been imitated by other NGOs. In 2015, the Brussels and Barcelona branches of Médecins Sans Frontiéres (MSF) developed their own SAR capa-

[33] Additional results that use Crossing Risk defined as $R_t^{1,2}$, $R_t^{2,2}$, $R_t^{1,1}$ and $R_t^{2,1}$ are shown in Figures 14, 15, 16 and 17.

bilities using their own vessels; German NGO Sea-Watch also purchased a vessel to search for migrant boats in distress in 2015. In February 2016, SOS Mediterranee chartered a 77 meter ship to conduct operations in partnership with the Amsterdam branch of MSF.

All of these organizations usually initiate rescues between 10 and 30 nautical miles off the coast of Libya upon authorization of the Italian Maritime Rescue Coordination Centre (MRCC). NGOs follow one of two different operating models. MOAS, MSF, and SOS-Mediterranee conduct extensive SAR operations that involve the rescuing of migrants with larger vessels that can transport them to Italian ports. Smaller NGOs such as Sea-Watch and Pro-Activa focus on rescue and the distribution of life preservers and emergency medical care while waiting for larger ships to transport migrants to Italian port.

In Figure 18, we see that NGO activity only constituted a substantial portion of all SAR activity starting in June 2016 during *Triton II*. Hence our estimates of responsiveness to crossing conditions during early SAR operational periods are likely to be unaffected by NGO activity. Nevertheless, in Table 12 we re-estimate our main regressions controlling explicitly for MOAS operations. The coefficient on MOAS activity is negative is fairly large in column 1, which may indicate that NGO vessels induce substitution towards unsafe boats. And again we find that deaths and crossing risk do not respond to crossing conditions (columns 2 and 3).

In response to the NGOs SAR activity, former interior ministry Marco Minniti established a code of conduct for NGO vessels that the organizations were asked to sign. NGO vessels were required to: i) stay out of Libyan waters, except in situations of serious and imminent danger; ii) not interfere with the activity of the Libyan Coast Guard; iii) not send any communications to facilitate the departure of boats carrying migrants; and iv) allow Italian police officers to be onboard of their vessels. Seven out nine NGOs refused to sign the code of conduct, putting their vessels at risk of confiscation.[34] The interaction between SWH and a post code of good conduct dummy has a positive but not significant effect on crossings, deaths and crossing risks (columns 4-6), while the rest of the coefficients are almost unchanged. Our results are also robust to alternative functional form specifications. In columns 7-10 we use the inverse hyperbolic sine

[34] The code of conduct comprises thirteen rules and is available at `http://www.interno.gov.it/sites/default/files/codice_condotta_ong.pdf`. As a matter of fact, we observe that the percentage of irregular migrants intercepted by Tripoli's Government of National Accord (GNA) Coast Guard increases by ten percentage points throughout the end of 2017 (from 10% to 20%) meaning that migrants were brought back to Libya (Figure 19). Over the same period, it occurred that some inflatable boats were sent a few miles off the Libyan coast to be rescued and then Libyan smugglers stole the outboard engine of their dinghy to be reused or to sell it on land.

transformation of daily crossings $\log(Y_t + (Y_t^2 + 1)1/2)$ to make sure that the results are not simply driven by differences in the number of crossings between SAR and non-SAR periods.

7 Conclusion

Irregular migration is a large and growing issue that concerns the governments of rich and poor countries alike. In the Central Mediterranean, the large humanitarian toll of irregular migration is borne directly by migrants from the Middle East and Sub-Saharan Africa, but also indirectly by European countries who conduct costly search and rescue operations and whose internal politics have been shaken to the core by this issue.

Looking back at nearly a decade of data on crossings, we find that while these search and rescue operations have no doubt saved lives directly, they may have had adverse unintended consequences that must be considered. First, by reducing the risk of crossing, these operations likely induced more migrants to attempt to cross, which exposes more people to the risk of death along the passage. Second, by reducing the costs to traffickers of using unsafe boats, these operations induced a large substitution away from seaworthy wooden vessels and towards flimsy, inflatable boats. Thus, the benefits of search and rescue operations have been, to some extent, captured by human smugglers.

Well-intentioned policymakers who are motivated to take action face a genuine dilemma. By failing to act, it is likely crossings would continue and deaths would continue to mount. But by intervening along the route, it is likely that more migrants would attempt an extremely dangerous undertaking. Saving a migrant at sea seems to be an obvious decision; weighing that action against the many potential migrants who might be encouraged to undertake such a treacherous passage in the future complicates this immensely. Although our work, unfortunately, does not guide this decision definitively, it does provide clear evidence that migration and smuggling are strategic choices that are made by thoughtful agents in a fraught environment.

Perhaps there is a third choice. Ultimately, addressing this issue will require interventions that reduce demand for irregular migration. There are two clear margins on which policymakers could act. First, the EU could reduce demand for immigration out of migrants home countries. This would require not only encouraging economic activity in these countries, but also improving their security and political environments. Second the EU could facilitate safe, legal migration from home countries to the EU so such a vital activity would be taken away from the hands of smugglers and into a rules-based order. Indeed, in all regions where irregular migration has emerged as a burning issue, such as Southeastern Europe, Turkey and the Middle East, and the US-Mexico border, politicians and policymakers would be well advised to heed these lessons. In light of these crises, it is concerning that avoiding the policies necessary for its mitigation is so politically expedient.

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A Proofs

Lemma 1. *Under Assumption* (A1)*, if* $\alpha_i < \frac{p_U}{\sigma_U}$*, then* i *will not cross. If* $\frac{p_U}{\sigma_U} \leq \alpha_i < \frac{p_U - p_S}{\sigma_U - \sigma_S}$ *then* i *will cross on an unsafe boat. Otherwise,* i *will cross on a safe boat.*

Proof. Consider two migrants i and j, and assume $i < j$. We first establish an ordering on crossing decisions. Specifically, we seek to prove:

1. If j does not cross then i does not cross.

2. If j takes an unsafe boat then i will not take a safe boat.

For (1), suppose j does not cross. Then $\alpha_j \sigma_b - p_b < 0$ for all b. This implies $\alpha_i \sigma_b - p_b < 0$ for all b, hence i does not cross.

For (2), suppose j takes an unsafe boat. Then a rearrangement of equation (3) implies that $\alpha_j < \frac{p_S - p_U}{(\sigma_S - \sigma_U)}$. Now suppose i took a safe boat. Then $\alpha_i > \frac{p_S - p_U}{(\sigma_S - \sigma_U)}$. But $\alpha_j > \alpha_i$, so this contradicts Assumption (A1).

The remainder of the lemma follows from a rearrangement of equation (3). □

Proposition 1. *Under Assumptions* (A1)-(A3) *and perfect competition, the introduction of search and rescue operations will result in:*

1. *Increases in total attempted crossings and attempted crossings on unsafe boats; decreases in attempted crossings on safe boats.*

2. *An ambiguous effect on* ρ*.*

3. *Total attempted crossings becoming more elastic to crossing conditions if* σ_U^0 *is small.*

Proof.

1. By (A3), $\frac{p_U}{\sigma_U^1} < \frac{p_U}{\sigma_U^0}$, so Lemma 1 implies that total attempted crossings will increase under SAR. Also by (A3) $\frac{p_S - p_U}{\sigma_S^1 - \sigma_U^1} > \frac{p_S - p_U}{\sigma_U^0}$, so Lemma 1 implies that attempted crossings on safe boats will decrease under SAR. It follows that attempted crossings on unsafe boats will increase under SAR.

2. From the first part of the proposition, SAR will lead to a greater fraction of crossings to be attempted on unsafe boats. If this is offset by the safety benefits of SAR ($\sigma_U^1 - \sigma_U^0$ and $\sigma_S^1 - \sigma_S^0$ scaled according to M_S and M_U which are determined by F) then ρ will decrease. If not, then ρ will increase. Hence the ambiguity.

3. From Lemma 1, total attempted crossings is given by $M_S + M_U = 1 - F\left(\frac{p_U}{\sigma_U^R}\right)$ for any R. We wish to prove that the derivative of total crossings with respect to w is lower under SAR. This is equivalent to showing

$$f\left(\frac{p_U}{\sigma_U^1}\right)\frac{p_U}{(\sigma_U^1)^2}\frac{\partial\sigma_U^1}{\partial w} < f\left(\frac{p_U}{\sigma_U^0}\right)\frac{p_U}{(\sigma_U^0)^2}\frac{\partial\sigma_U^0}{\partial w} \tag{12}$$

By (A2), it suffices to show that $f\left(\frac{p_U}{\sigma_U^1}\right)\frac{p_U}{(\sigma_U^1)^2} > f\left(\frac{p_U}{\sigma_U^0}\right)\frac{p_U}{(\sigma_U^0)^2}$. Note that

$$\lim_{\sigma_U^0\to 0} f\left(\frac{p_U}{\sigma_U^0}\right)\frac{p_U}{(\sigma_U^0)^2}\frac{\partial\sigma_U^0}{\partial w} = 0 \tag{13}$$

This follows from enough successive applications of l'Hopital's rule, since for any pdf f, it must be the case that $\lim_{x\to\infty} f^{(n)}(x) \leq 0$ for some even n or $\lim_{x\to\infty} f^{(n)}(x) \geq 0$ for some odd n.

Hence, for small σ_U^0, total attempted crossings are more elastic to w under SAR, which completes the proof.

□

Proposition 2. *Under Assumptions* (A1)-(A4)*, for a monopolist smuggler, the introduction of search and rescue operations leads to:*

1. *The same results as under perfect competition as listed in Proposition 1.*
2. *Increases in p_U, p_S and $p_S - p_U$ if σ_U^0.*
3. *An increase in smuggler's profits.*

Proof. 1. For a given R, the first order conditions from the smuggler's objective (equation (3)) are given by:

$$\frac{\partial M_S^R}{\partial p_S^R}(p_S^R - c_S) + M_S^R + \frac{\partial M_U^R}{\partial p_S^R}(p_U^R - c_U) = 0 \tag{14}$$

$$\frac{\partial M_S^R}{\partial p_U^R}(p_S^R - c_S) + \frac{\partial M_U^R}{\partial p_U^R}(p_U^R - c_U) + M_U^R = 0 \tag{15}$$

Note that prices and crossings are now allowed to vary by R. Adding equations (14) and (15) together, we obtain

$$\left(\frac{\partial M_S^R}{\partial p_S^R} + \frac{\partial M_S^R}{\partial p_U^R}\right)(p_S^R - c_S) + \left(\frac{\partial M_U^R}{\partial p_S^R} + \frac{\partial M_U^R}{\partial p_U^R}\right)(p_U^R - c_U) + M_S^R + M_U^R = 0 \tag{16}$$

Lemma 1 implies that $\frac{\partial M_S^R}{\partial p_S^R} + \frac{\partial M_S^R}{\partial p_U^R} = 0$ (see the threshold between unsafe and safe passage in Figure 1) and $\frac{\partial M_U^R}{\partial p_S^R} + \frac{\partial M_U^R}{\partial p_U^R} = -\frac{1}{\sigma_U^R} f\left(\frac{p_U^R}{\sigma_U^R}\right)$ (see the threshold between unsafe and no passage in Figure 1). Given that $M_S^R + M_U^R = 1 - F\left(\frac{p_U^R}{\sigma_U^R}\right)$ by Lemma 1, and defining the hazard rate $\lambda(\cdot) = f(\cdot)/(1 - F(\cdot))$, it follows that

$$\begin{aligned} p_U^R &= c_U + \frac{M_S^R + M_U^R}{\frac{1}{\sigma_U^R} f\left(\frac{p_U^R}{\sigma_U^R}\right)} \\ &= c_U + \frac{\sigma_U^R}{\lambda\left(\frac{p_U^R}{\sigma_U^R}\right)} \end{aligned} \tag{17}$$

The second term in equation (17) is simply the monopolist's markup for unsafe boat passengers. Following Lemma 1, in order to show that crossings increase under SAR, it suffices to show that $\frac{p_U^1}{\sigma_U^1} < \frac{p_U^0}{\sigma_U^0}$. Following equation (17), we can write

$$\frac{p_U^1}{\sigma_U^1} - \frac{p_U^0}{\sigma_U^0} = \left[\frac{1}{\lambda\left(\frac{p_U^1}{\sigma_U^1}\right)} - \frac{1}{\lambda\left(\frac{p_U^0}{\sigma_U^0}\right)}\right] + \left[c_U\left(\frac{1}{\sigma_U^1} - \frac{1}{\sigma_U^0}\right)\right] \tag{18}$$

(A4) implies that the first term of equation (18) is negative, and (A3) implies that the second term of equation (18) is negative, hence the total number of crossings increases.

Now, substituting from equation (14), we obtain

$$M_S^1 - M_S^0 = \frac{\partial M_S^1}{\partial p_S^1}(p_S^1 - c_C) + \frac{\partial M_U^1}{\partial p_S^1}(p_U^1 - c_U) - \left[\frac{\partial M_S^0}{\partial p_S^0}(p_S^0 - c_C) + \frac{\partial M_U^0}{\partial p_S^0}(p_U^1 - c_U)\right] \tag{19}$$

Assuming $p_S^1 > p_S^0$ and $p_U^1 > p_U^0$ (which we will establish independently later on in this proof), (A4) implies that the right hand side of equation (19) is less than zero, hence the total number of crossings on safe boats decreases with SAR.

If SAR causes the total number of crossings to increase and the total number of crossings on safe boats to decrease, then it must be the case that SAR causes the total number of crossings on unsafe boats to increase.

The ambiguity of the effect of SAR on ρ follows the exact same logic as in the case of perfect competition.

The effect of SAR on the elasticity of total crossings to crossing conditions also follows the same logic as in the case of perfect competition. This is because prices are not allowed to respond to short-run changes in w.

2. Substituting from equation (17), we have

$$p_U^1 - p_U^0 = \frac{M_S^1 + M_U^1}{\frac{1}{\sigma_U^1} f\left(\frac{p_U^1}{\sigma_U^1}\right)} - \frac{M_S^0 + M_U^0}{\frac{1}{\sigma_U^0} f\left(\frac{p_U^0}{\sigma_U^0}\right)} = \frac{\sigma_U^1}{\lambda\left(\frac{p_U^1}{\sigma_U^1}\right)} - \frac{\sigma_U^0}{\lambda\left(\frac{p_U^0}{\sigma_U^0}\right)} \tag{20}$$

This combined with (A4) implies that the right hand side of equation (20) is greater than zero, so p_U increases under SAR.

Rearranging equation (14) yields

$$M_S^R = -\left[\frac{\partial M_U^R}{\partial p_S^R}(p_U^R - c_U) + \frac{\partial M_S^R}{\partial p_S^R}(p_S^R - c_S)\right] \tag{21}$$

Substituting for $\frac{\partial M_U^R}{\partial p_S^R}$ and $\frac{\partial M_U^R}{\partial p_U^R}$ as calculated from Lemma 1, we can use equation (21) to express p_S^R as

$$p_S^R = c_S + \left[(p_U^R - c_U) + \frac{\sigma_S^R - \sigma_U^R}{\lambda\left(\frac{p_S^R - p_U^R}{\sigma_S^R - \sigma_U^R}\right)}\right] \tag{22}$$

from which the markup on p_S^R is given in the second term. Using equation (22), we can write

$$p_S^1 - p_S^0 = (p_U^1 - p_U^0) + \left[\frac{\sigma_S^1 - \sigma_U^1}{\lambda\left(\frac{p_S^1 - p_U^1}{\sigma_S^1 - \sigma_U^1}\right)} - \frac{\sigma_S^0 - \sigma_U^0}{\lambda\left(\frac{p_S^0 - p_U^0}{\sigma_S^0 - \sigma_U^0}\right)}\right] \tag{23}$$

p_U was shown to increase under SAR, so the first term of equation (23) is greater than zero. Similarly, total safe crossings were shown to decrease under SAR, so (A3) and (A4) together imply that the second term of (23) is greater than zero, hence p_S increases under SAR. Finally, if we move the first term on the right hand side of equation (23) to the left hand side, the same logic implies that $p_S - p_U$ increases under SAR.

3. This result follows immediately from the results of part 1 of this Proposition and the envelope theorem.

□

Main Tables

Table 1: EU Operations

EU Operations	Dates	Maritime SAR Distance from Italian shores	Budget per month	Budget total
Hermes (Main operation)	16 Apr – 16 Oct 09	24	0.9	5.2
	14 Jun – 29 Oct 10	24	0.8	3.3
	20 Feb – 31 Aug 11	24	2.5	15.0
	02 Jul – 30 Oct 12	24	1.0	4.1
	06 May – 07 Oct 13	24	1.5	9.0
Hermes (Extension)	01 Sep 11 – 31 Mar 12	12*		
	01 Nov 12 – 31 Jan 13	12*		
Mare Nostrum	18 Oct 13 – 31 Oct 14	138	9.5	113
Triton I	01 Nov 14 – 30 Apr 15	30	2.9	27.5
Triton II	01 May 15 – 31 Dec 17	138	10	320

NGO Operations	Dates	Maritime SAR Distance from Italian shores	Fundraising per month	Fundraising total
MOAS	25 Aug – 15 Oct 14	Libya	2.1	4
MOAS	01 May – 01 Oct 15	Libya	1.1	5.7
MOAS	06 Jun – 31 Dec 16	Libya	0.86	6
MOAS	01 Apr – 01 Sep 17	Libya	0.55	3.3

Note: Budget numbers are in million Euro. Information on the extent of the SAR zone is sometimes hidden in the official Operational Plans. In these instances our best guess based is that surveillance occurred within the territorial sea, as defined by the 1982 United Nations Convention on the Law of the Sea (12 nautical miles from the coastal state).

Table 2: NGO Vessels and Operational Period

NGO	Country	Flag	Vessel	Operational Period
Jugend Rettet	Germany	The Netherlands	Iuventa	Jul 2016 - Nov 2016
LifeBoat	Germany	Germany	Minden	Jun 2016 - Nov 2016
Médecins Sans Frontières (MSF)	France	Italy	Vos Prudence	Mar 2017 - Oct 2017
Médecins Sans Frontières (MSF)	France	Panama	Dignity I	May 2015 - Dec 2016
Médecins Sans Frontières (MSF)	France	Luxembourg	Bourbon-Argos	May 2015 - Nov 2016
ProActiva Open Arms	Spagna	Panama	Golfo Azzurro	Dec 2016 - Sep 2017
ProActiva Open Arms	Spagna	The United Kingdom	Astral	Jun 2016 - Nov 2016
Save the Children	International Organization	Italy	Vos Hestia	Sep 2016 - Nov 2016
Sea-Watch	Germany	Germany	Sea-Watch	Jun 2015 - Nov 2016
Sea-Watch	Germany	The Netherlands	Sea-Watch 2	Mar 2016 - Nov 2016
Sea-Eye	Germany	The Netherlands	Sea-Eye	Feb 2016 - Nov 2016
SOS Méditerranée	France-Italy-Germany	Gibraltar	Aquarius	Feb 2016 - Dec 2016

Source: Italian Navy report (2017).

Table 3: Summary Statistics

Variables	Observations	Mean	SD	Min	Max
Crossings	3287	170.44	397.23	0.00	4001
Inv. Hyp. Crossings	3287	2.49	3.00	0.00	8.99
Deaths	3287	3.62	29.95	0.00	846
Crossing Risk	1521	0.05	0.19	0.00	1.00
Crossing Risk Type 1A	2017	0.04	0.17	0.00	1.00
Crossing Risk Type 2A	2036	0.05	0.20	0.00	1.00
Crossing Risk Type 3A	2065	0.07	0.23	0.00	1.00
Crossing Risk Type 4A	2099	0.09	0.26	0.00	1.00
Crossing Risk Type 1B	2305	0.03	0.13	0.00	1.00
Crossing Risk Type 2B	2315	0.04	0.15	0.00	1.00
Crossing Risk Type 3B	2325	0.04	0.17	0.00	1.00
Crossing Risk Type 4B	2347	0.06	0.19	0.00	1.00
Wave Tripoli	3287	0.82	0.51	0.11	4.41
Max Wave Tripoli	3287	1.08	0.61	0.20	4.41
Wave Bengazi	3287	1.21	0.73	0.22	4.85
Wave Al Huwariyah	3287	1.48	0.91	0.13	5.27
Wave Annaba	3287	1.40	0.92	0.21	5.58
Unbiased Wave Forecast	3287	0.82	0.60	0.02	4.44
Unknown Vessel	791	145.07	191.19	0	1120
Other Vessel	791	50.132	141.77	0	1385
Inflatable Boat	791	29.126	103.78	0	1554
Fishing Boat	791	26.545	106.24	0	1365
Motor Boat	791	83.359	226.20	0	2458

Table 4: Irregular Migration During Search and Rescue Operations

	(1) Crossings	(2) Deaths	(3) Crossing Risk
Hermes	11.67	0.61	-0.01
	(50.84)	(2.54)	(0.02)
Hermes Ext	30.61	0.88	0.05
	(25.41)	(1.51)	(0.04)
Mare Nostrum	289.32***	3.24	-0.03
	(53.64)	(2.63)	(0.03)
Triton I	243.95***	7.40	-0.04
	(46.92)	(5.00)	(0.03)
Triton II	382.77***	1.27	-0.09**
	(73.78)	(3.65)	(0.04)
Observations	3,287	3,287	1,521
R-squared	0.10	0.01	0.02

Note: SAR coefficients are estimated relative to a baseline in which no SAR operations were in place. Crossing Risk is defined as $\rho_t^{0,0}$. All regressions control for a cubic polynomial in day t and for week of the year fixed effects. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days are in parentheses (Newey and West, 1994).
* p<.10 ** p<.05 *** p<.01.

Table 5: Summary of Theoretical and Empirical Findings

	Results	Interpretation
Ass. 1	Use of more expensive sturdy boats	$\sigma_u^R < \sigma_s^R$
Ass. 2	Tab. 4 (1) and Tab. 5 (odd)	Crossings shift from U to S with waves
Ass. 3	Tab. 5 (even)	Crossings shift from U to S with waves more under SAR
Ass. 4	Tab. 4 (6), Fig. 11	Risk sensitivity to waves does not change much (or is slightly negative) under SAR
Prop. 1.1/2.1	Tab. 3 (1)	Crossings increase during SAR
Prop. 1.2/2.1	Tab. 4 (2)	SAR has an ambiguous effect on risk
Prop. 1.3/2.1	Tab. 4 (5), Fig. 9	Crossings are more sensitive to waves under SAR
	Tab. 6	Smugglers and/or migrants optimize behavior based on current information

Note: Parentheses contain the corresponding columns for each table.

Table 6: Wave Height, Crossings, Deaths and Crossing Risk

	(1)	(2)	(3)	(4)	(5)	(6)
	Crossings		Deaths		Crossings Risk	
Wave	-130.88***	-41.61***	-3.17***	0.52	0.02	0.09
	(20.07)	(15.66)	(1.18)	(0.71)	(0.03)	(0.12)
Wave * Hermes		-116.26**		-3.63*		-0.05
		(51.60)		(1.86)		(0.14)
Wave * Hermes Ext		24.49		-0.27		-0.13
		(17.15)		(0.81)		(0.12)
Wave * Mare Nostrum		-127.95*		-3.18*		-0.16
		(67.69)		(1.71)		(0.12)
Wave * Triton I		-128.68*		-14.06*		-0.27*
		(67.72)		(7.46)		(0.16)
Wave * Triton II		-174.68***		-5.25*		-0.03
		(50.43)		(2.74)		(0.12)
Observations	3,287	3,287	3,287	3,287	1,521	1,521
R-squared	0.02	0.04	0.00	0.00	0.00	0.01
Mean Outcome	170.44	170.44	3.62	3.62	0.05	0.05
Mean Wave	0.82	0.82	0.82	0.82	0.82	0.82
Week-Year FE	Y	Y	Y	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the week by year fixed effects. Wave variable is measured in front of Tripoli (Libya). Crossing Risk is defined as $\rho_t^{0,0}$. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days are in parentheses (Newey and West, 1994). This time period was chosen following the rule of thumb presented in Stock and Watson (2015).
* p<.10 ** p<.05 *** p<.01.

Table 7: Vessel Types During Search and Rescue Operations

Boat Type	(1) Inflatable	(2)	(3) Fishing	(4)	(5) Motor	(6)	(7) Other	(8)
Wave	-167.22***	-27.66	4.61	-22.72	-0.63	-60.94*	9.32	-9.63
	(42.97)	(21.45)	(13.45)	(21.84)	(15.32)	(32.62)	(19.43)	(6.79)
Wave * Mare Nostrum		-28.75		55.22*		85.53*		-5.09
		(35.34)		(30.69)		(50.28)		(30.22)
Wave * Triton I		-28.15		5.12		55.98		73.63
		(29.39)		(39.03)		(34.39)		(59.75)
Wave * Triton II		-522.80***		22.12		54.52		10.61
		(89.66)		(28.27)		(36.80)		(8.24)
Observations	791	791	791	791	791	791	791	791
R-squared	0.03	0.07	0.00	0.00	0.00	0.01	0.00	0.03
Mean Wave	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Mean Outcome	228.42	228.42	50.13	50.13	29.13	29.13	26.55	26.55
Month-Year FE	Y	Y	Y	Y	Y	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the month by year fixed effects. Wave variable is measured in front of Tripoli (Libya). Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 29 days are in parentheses (Newey and West, 1994).
* p<.10 ** p<.05 *** p<.01.

Table 8: Trafficker Responses to Weather Forecasts

	(1) Crossings	(2)	(3) Deaths	(4)	(5) Crossing risk	(6)
I($Wave_t < UForecast_{t+1}$)	59.76***	12.33	0.36	-1.45	-0.01	0.00
	(15.66)	(7.96)	(1.10)	(0.92)	(0.01)	(0.03)
I($Wave_t < UForecast_{t+1}$) * Hermes		-18.56		2.54		0.04
		(24.23)		(2.22)		(0.04)
I($Wave_t < UForecast_{t+1}$) * Hermes Ext		-19.23**		0.58		0.09
		(9.07)		(1.13)		(0.09)
I($Wave_t < UForecast_{t+1}$) * Mare Nostrum		79.55*		-5.67*		-0.08*
		(41.75)		(3.28)		(0.04)
I($Wave_t < UForecast_{t+1}$) * Triton I		39.68		16.30*		0.03
		(33.94)		(9.82)		(0.05)
I($Wave_t < UForecast_{t+1}$) * Triton II		142.86***		2.84		-0.04
		(38.74)		(2.25)		(0.03)
Observations	3,287	3,287	3,287	3,287	1,521	1,521
R-squared	0.01	0.02	0.00	0.01	0.00	0.02
Week-Year FE	Y	Y	Y	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the week by year fixed effects. Wave variable is measured in front of Tripoli (Libya). Crossing Risk is defined as $\rho_t^{0,0}$. We use the unbiased tidal forecast at Tripoli. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days are in parentheses (Newey and West, 1994).
* p<.10 ** p<.05 *** p<.01.

Table 9: Max Wave Height, Crossings, Deaths and Crossing Risk

	(1)	(2)	(3)	(4)	(5)	(6)
	Crossings		Deaths		Crossings Risk	
Max Wave	-151.78***	-48.11**	-3.71***	-0.57	0.02	0.04
	(23.60)	(22.90)	(1.40)	(0.40)	(0.02)	(0.05)
Max Wave * Hermes		5.30		-1.50		-0.06
		(31.15)		(1.44)		(0.06)
Max Wave * Hermes Ext		33.13		0.57		-0.08
		(24.56)		(0.45)		(0.07)
Max Wave * Mare Nostrum		-101.31		0.07		-0.04
		(63.24)		(0.70)		(0.05)
Max Wave * Triton I		-180.54**		-6.18*		-0.07
		(72.70)		(3.58)		(0.06)
Max Wave * Triton II		-254.95***		-7.70*		0.02
		(60.50)		(4.13)		(0.06)
Observations	3,287	3,287	3,287	3,287	1,521	1,521
R-squared	0.03	0.06	0.00	0.01	0.00	0.01
Mean Outcome	170.44	170.44	3.62	3.62	0.05	0.05
Mean Max Wave	1.08	1.08	1.08	1.08	1.08	1.08
Week-Year FE	Y	Y	Y	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the week by year fixed effects. Max Wave variable is measured in front of Tripoli (Libya) and it takes the maximum values of wave over t, t-1 and t-2. Crossing Risk is defined as $\rho_t^{0,0}$. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days are in parentheses (Newey and West, 1994). This time period was chosen following the rule of thumb presented in Stock and Watson (2015).
* p<.10 ** p<.05 *** p<.01.

Table 10: Wave Height in Libya, Tunisia and Algeria: Crossings, Deaths and Crossing Risk

	(1) Crossings	(2) Deaths	(3) Crossings Risk
Libia			
Wave Tripoli	-34.25***	2.88	0.03
	(11.65)	(2.79)	(0.10)
Wave Tripoli * Hermes	-127.42**	-3.38	-0.00
	(55.37)	(3.48)	(0.12)
Wave Tripoli * Hermes Ext	31.45**	-2.27	-0.32
	(13.14)	(2.93)	(0.20)
Wave Tripoli * Mare Nostrum	-72.84	-0.68	-0.06
	(57.40)	(3.46)	(0.13)
Wave Tripoli * Triton I	-67.49	-16.98*	-0.24
	(58.14)	(10.06)	(0.17)
Wave Tripoli * Triton II	-205.37***	-6.10	0.01
	(61.11)	(4.86)	(0.11)
Wave Bengazi	-4.07	-1.71	0.04
	(4.81)	(1.49)	(0.06)
Wave Bengazi * Hermes	53.24*	1.20	-0.03
	(28.45)	(3.29)	(0.07)
Wave Bengazi * Hermes Ext	-2.68	1.57	0.09
	(6.96)	(1.53)	(0.11)
Wave Bengazi * Mare Nostrum	-117.57**	0.60	-0.03
	(47.13)	(2.34)	(0.07)
Wave Bengazi * Triton I	-88.85***	2.73	-0.01
	(27.68)	(8.09)	(0.09)
Wave Bengazi * Triton II	-66.70*	-1.18	-0.05
	(37.11)	(2.46)	(0.06)
Tunisia			
Wave Al Huwariyah	6.94	-1.10	0.06
	(8.41)	(1.08)	(0.08)
Wave Al Huwariyah * Hermes	-31.80*	-2.31	-0.05
	(16.91)	(3.60)	(0.09)
Wave Al Huwariyah * Hermes Ext	-11.69	0.35	0.04
	(10.81)	(1.22)	(0.12)
Wave Al Huwariyah * Mare Nostrum	11.81	-7.17	-0.14
	(85.79)	(4.86)	(0.09)
Wave Al Huwariyah * Triton I	-31.71	1.30	-0.03
	(23.48)	(3.77)	(0.11)
Wave Al Huwariyah * Triton II	154.14***	2.54	0.02
	(51.94)	(3.29)	(0.09)
Algeria			
Wave Annaba	-14.11	-0.28	-0.03
	(13.50)	(0.54)	(0.04)
Wave Annaba * Hermes	21.94	1.21	0.03
	(16.36)	(3.22)	(0.06)
Wave Annaba * Hermes Ext	6.51	0.94	0.22**
	(13.82)	(0.80)	(0.10)
Wave Annaba * Mare Nostrum	-9.48	4.12	0.06
	(65.12)	(2.84)	(0.05)
Wave Annaba * Triton I	53.35**	-0.41	-0.01
	(27.04)	(3.21)	(0.07)
Wave Annaba * Triton II	-94.91**	-1.18	-0.07
	(44.27)	(2.63)	(0.06)
Observations	3,287	3,287	1,521
R-squared	0.05	0.01	0.03
Mean Outcome	170.44	3.62	0.05
Wave Tripoli	0.82	0.82	0.82
Wave Bengazi	0.92	0.92	0.92
Wave Al Huwariyah	1.08	1.08	1.08
Wave Annaba	1.03	1.03	1.03
Wee-Year FE	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the week by year fixed effects. Wave variable is measured in front of Tripoli (Libya). Crossing Risk is defined as $R_t^{0,0}$. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days (15 days for the crossings risk) are in parentheses (Newey and West, 1994).
* p<.10 ** p<.05 *** p<.01.

Table 11: Robustness: Different Types of Crossing Risk

	(1) CR Type 3A	(2) CR Type 4A	(3) CR Type 3B	(4) CR Type 4B
Wave	0.12*	0.12	0.05	0.03
	(0.07)	(0.08)	(0.05)	(0.06)
Wave * Hermes	-0.11	-0.04	-0.07	-0.01
	(0.08)	(0.09)	(0.05)	(0.07)
Wave * Hermes Ext	-0.03	0.07	-0.09	0.01
	(0.14)	(0.17)	(0.07)	(0.11)
Wave * Mare Nostrum	-0.08	-0.07	-0.00	0.02
	(0.08)	(0.09)	(0.06)	(0.07)
Wave * Triton I	-0.21**	-0.13	-0.11	-0.06
	(0.09)	(0.13)	(0.07)	(0.08)
Wave * Triton II	-0.02	0.03	0.01	0.08
	(0.08)	(0.09)	(0.06)	(0.07)
Observations	2,065	2,099	2,325	2,347
R-squared	0.02	0.04	0.02	0.03
Week-Year FE	Y	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the week by year fixed effects. Wave variable is measured in front of Tripoli (Libya). Crossing Risk 3A is defined as $R_t^{1,3}$, Crossing Risk 4A is defined as $R_t^{1,4}$, Crossing Risk 3B is defined as $R_t^{2,3}$ and Crossing Risk 4B is defined as $R_t^{2,4}$. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44, 18, 24 and 21 days, respectively, are in parentheses (Newey and West, 1994).
* p<.10 ** p<.05 *** p<.01.

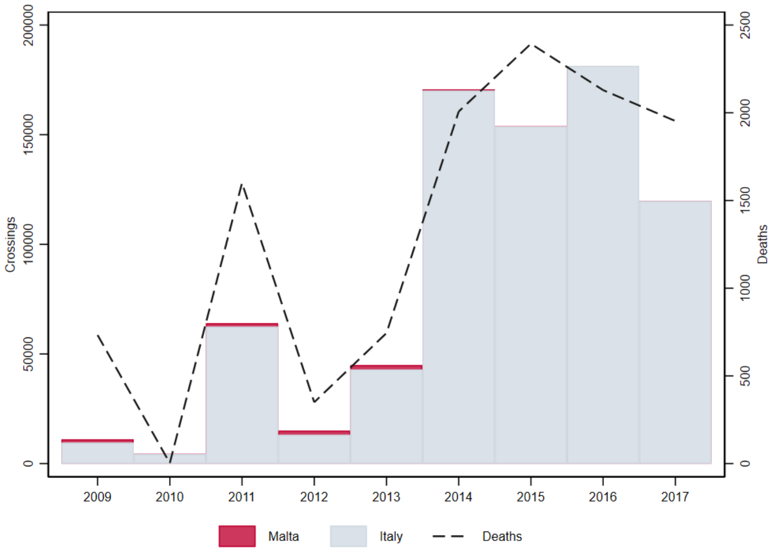
Table 12: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Crossings	Deaths	Crossing Risk	Crossings	Deaths	Crossing Risk	Hyperbolic Crossings			
Wave	-41.61***	0.52	0.09	-41.61***	0.52	0.09	-1.10***	-1.10***	-1.10***	
	(15.66)	(0.71)	(0.12)	(15.66)	(0.71)	(0.12)	(0.23)	(0.23)	(0.23)	
Wave Tripoli * Hermes	-116.26**	-3.63*	-0.05	-116.26**	-3.63*	-0.05	-1.28***	-1.28***	-1.28***	
	(51.60)	(1.86)	(0.13)	(51.60)	(1.86)	(0.14)	(0.40)	(0.40)	(0.40)	
Wave Tripoli * Hermes Ext	24.49	-0.27	-0.13	24.49	-0.27	-0.13	0.28	0.28	0.28	
	(17.15)	(0.81)	(0.12)	(17.15)	(0.81)	(0.12)	(0.34)	(0.34)	(0.34)	
Wave Tripoli * Mare Nostrum	-119.28*	-2.86*	-0.15	-120.07*	-2.89*	-0.15	-0.31	-0.28	-0.28	
	(67.68)	(1.60)	(0.12)	(67.66)	(1.61)	(0.12)	(0.37)	(0.37)	(0.37)	
Wave Tripoli * Triton I	-128.68*	-14.06*	-0.27	-128.68*	-14.06*	-0.27*	-0.60	-0.60	-0.60	
	(67.72)	(7.46)	(0.18)	(67.72)	(7.46)	(0.16)	(0.59)	(0.59)	(0.59)	
Wave Tripoli * Triton II	-107.23***	-3.59	-0.00	-132.28***	-4.47	-0.05	-0.58*	-0.38	-0.41	
	(40.19)	(3.47)	(0.13)	(48.78)	(4.35)	(0.12)	(0.33)	(0.33)	(0.36)	
Wave Tripoli * MOAS	-201.39**	-5.02	-0.05	-181.55*	-4.33	-0.01		-0.60	-0.57	
	(100.34)	(5.00)	(0.06)	(99.53)	(5.50)	(0.04)		(0.48)	(0.49)	
Wave Tripoli * NGO Code of Conduct				114.47*	4.02	0.12			0.14	
				(60.11)	(4.11)	(0.09)			(0.49)	
I($Wave_t < UForecast_{t+1}$)										0.04
										(0.13)
I($Wave_t < UForecast_{t+1}$) * Hermes										-0.38
										(0.24)
I($Wave_t < UForecast_{t+1}$) * Hermes Ext										-0.29
										(0.20)
I($Wave_t < UForecast_{t+1}$) * Mare Nostrum										0.70**
										(0.30)
I($Wave_t < UForecast_{t+1}$) * Triton I										0.41
										(0.54)
I($Wave_t < UForecast_{t+1}$) * Triton II										0.75***
										(0.22)
Observations	3,287	3,287	1,521	3,287	3,287	1,521	3,287	3,287	3,287	3,287
R-squared	0.04	0.01	0.01	0.04	0.01	0.02	0.07	0.07	0.07	0.01
Week-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Note: All regressions control for individual SAR fixed effects, though most of these are absorbed by the week by year fixed effects. Wave variable is measured in front of Tripoli (Libya). Crossing Risk is defined as $\rho_t^{0,0}$. We use the unbiased tidal forecast in front of Tripoli. Newey-West standard errors that allow for heteroskedasticity and serial correlation of up to 44 days (10 and 11 days in columns 3 and 10, respectively) are in parentheses (Newey and West, 1994).
* p<.10 ** p<.05 *** p<.01.

Figures

Figure 1: Crossings and Deaths Along the Central Route, 2009-2017



Note: The left axis measures the total number crossings to Malta and Italy, the right one measures the number of deaths in transit. Italian and Maltese data are available from UNHCR at `http://data.unhcr.org/mediterranean` and `http://www.unhcr.org.mt/charts/category/12`.

Figure 2: Timeline of Major Search and Rescue Operations in the Central Mediterranean Sea

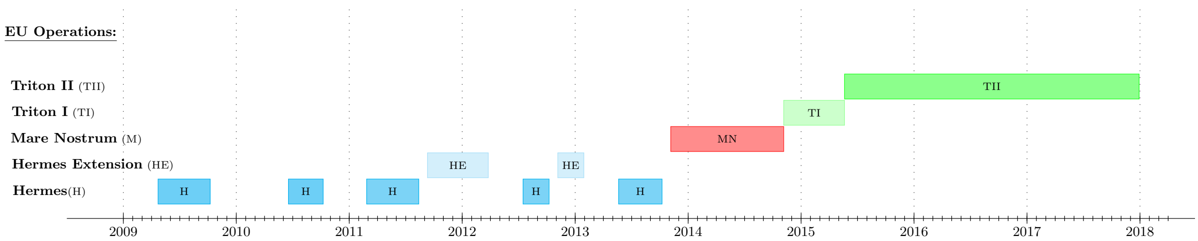
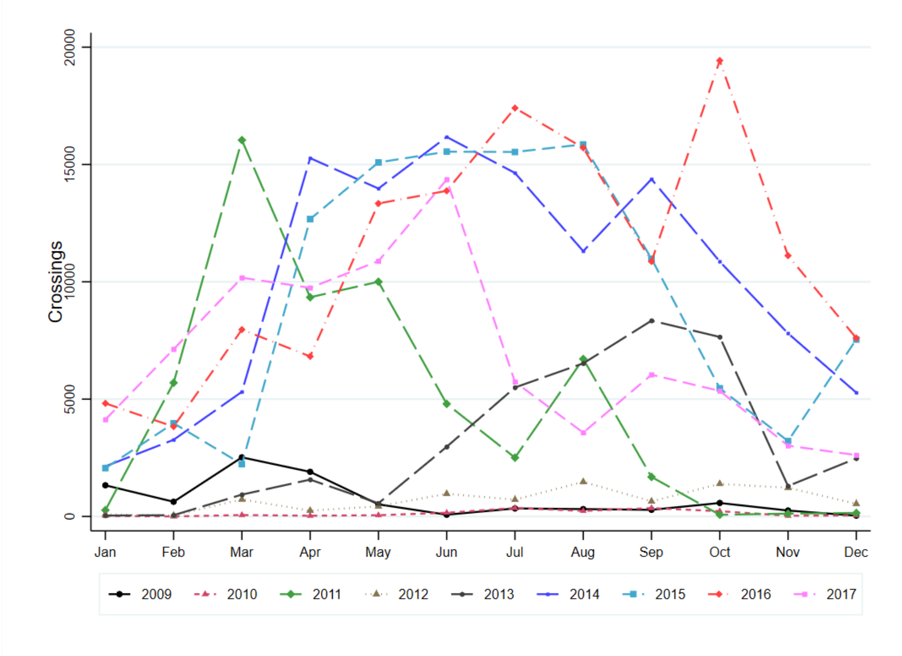
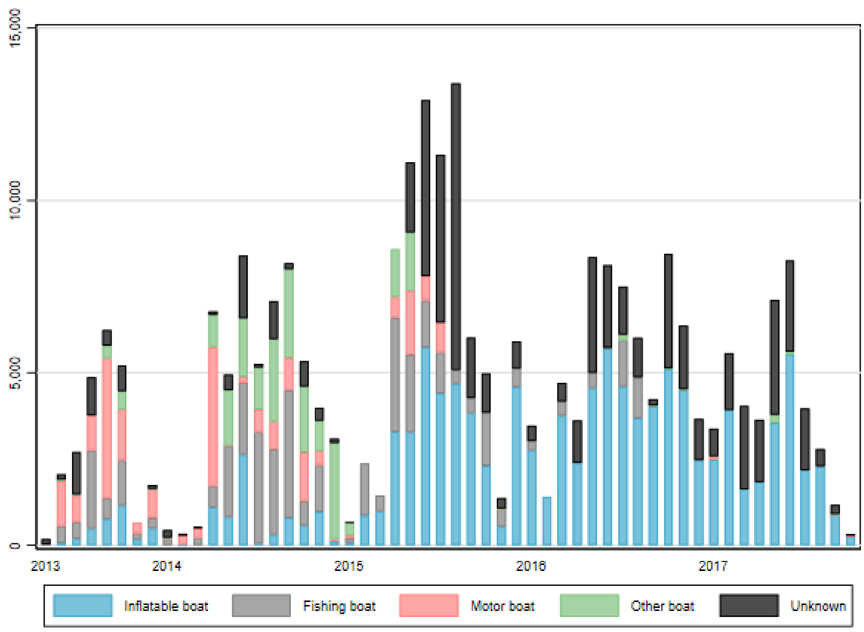


Figure 3: Monthly Crossings



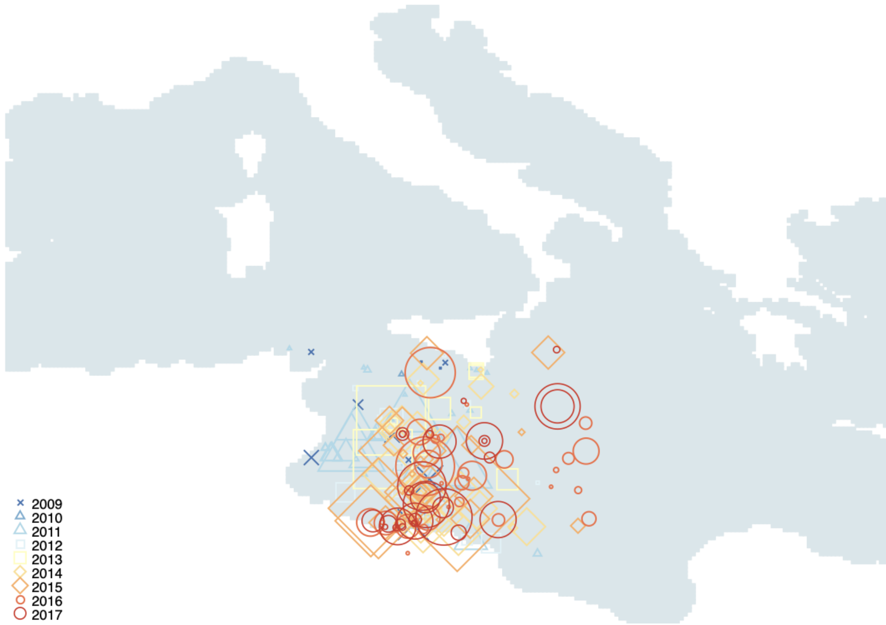
Note: Monthly crossings to Italy for each year between 2009 and 2017. Based on data from the Italian Ministry of Interior.

Figure 4: Types of Vessels Used, 2013-2017



Note: Frontex published data on vessel type only for the years 2013 to 2017.

Figure 5: Deaths by Location and Year



Source: Authors calculations based on UNITED data. See Section 4.2.

Figure 6: Unbiased (left) and Biased (right) Forecasts of Waves

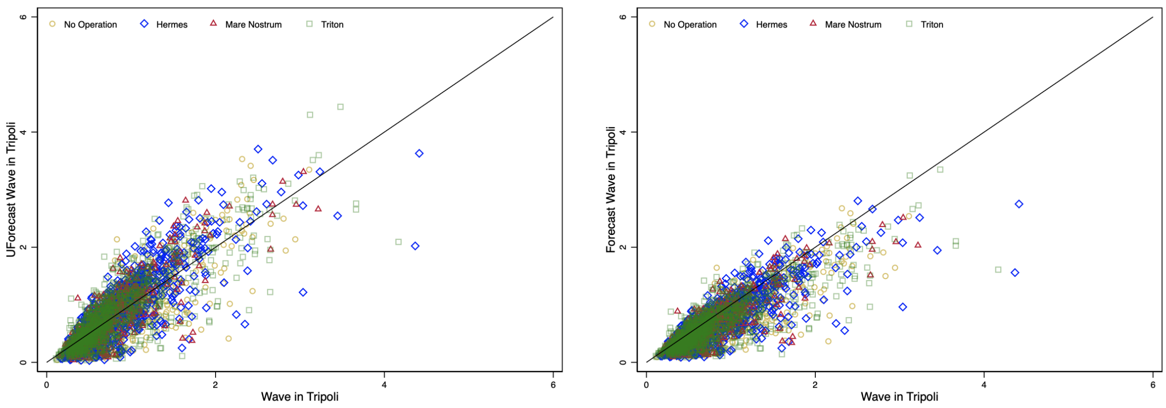


Figure 7: Crossings, Waves and EU Operations

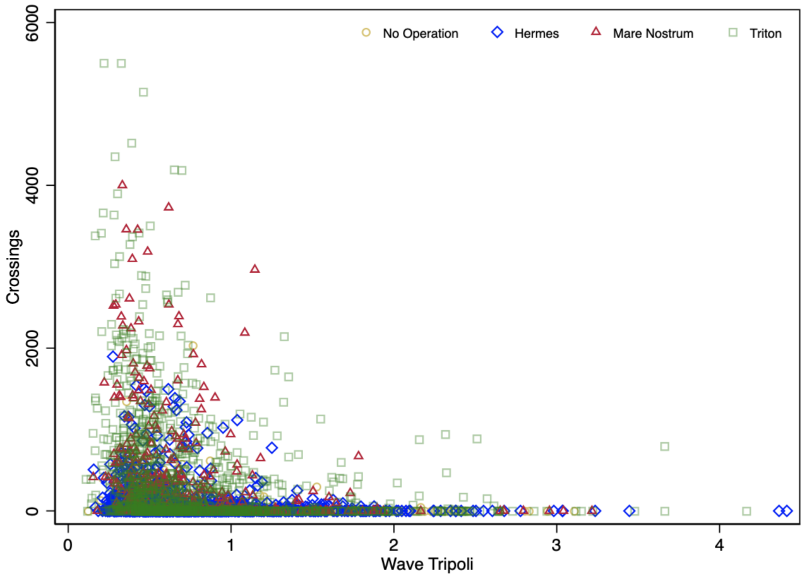
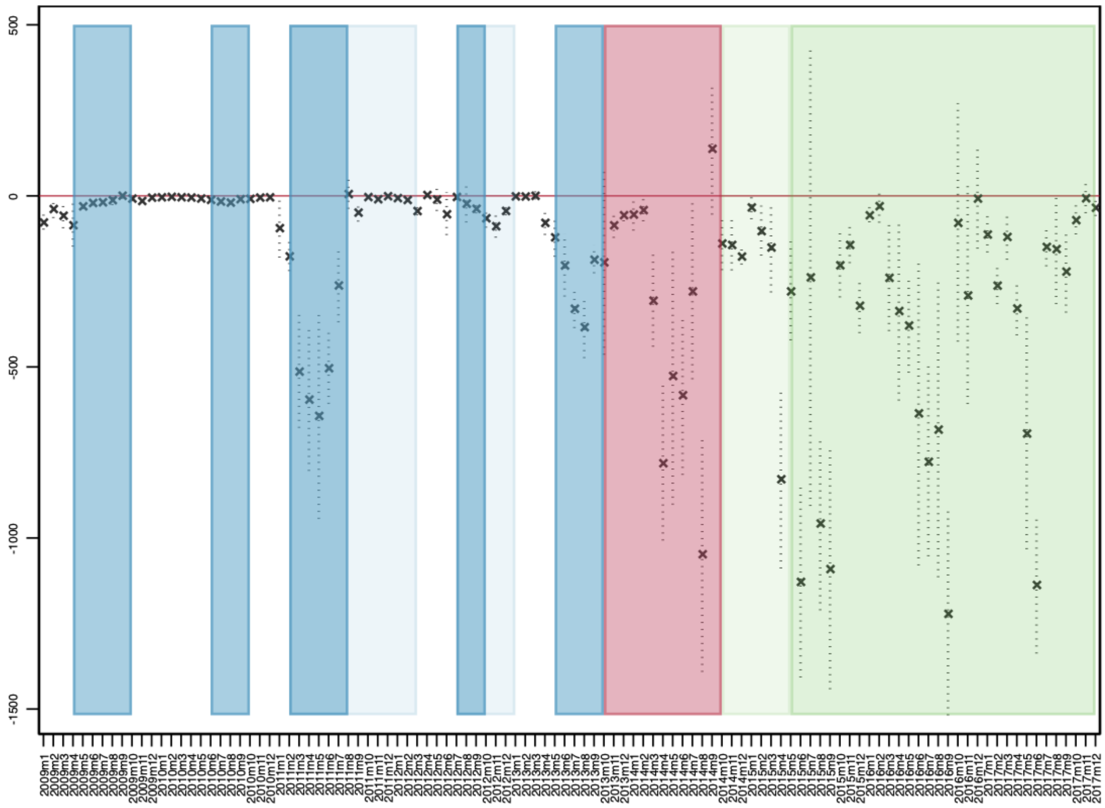
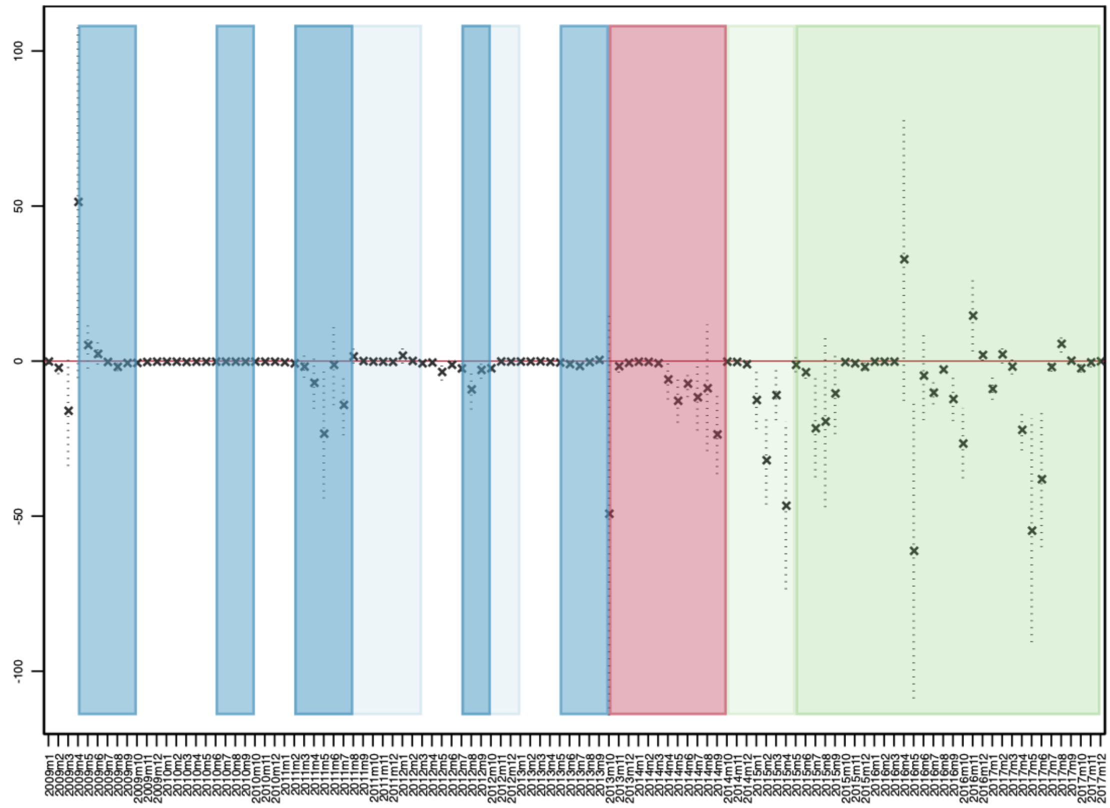


Figure 8: Crossings and Wave Conditions



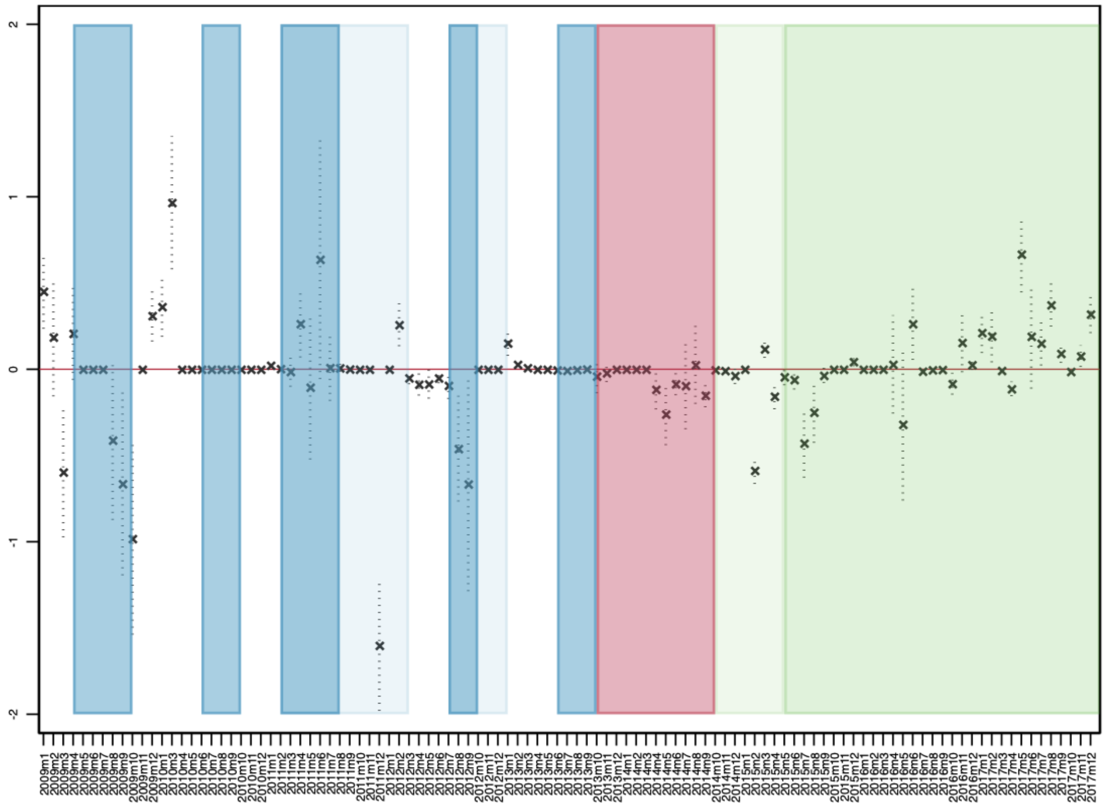
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year×Week fixed effects are included.

Figure 9: Deaths and Wave Conditions



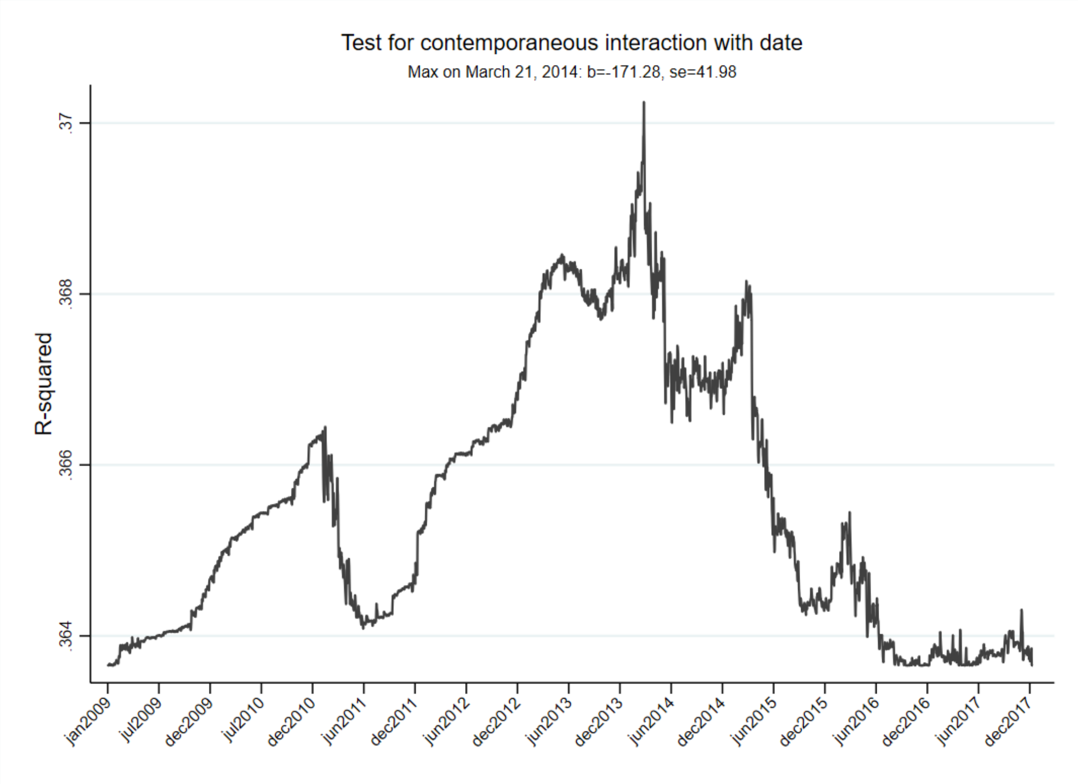
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year$\times$Week fixed effects are included.

Figure 10: Crossing Risk and Wave Conditions



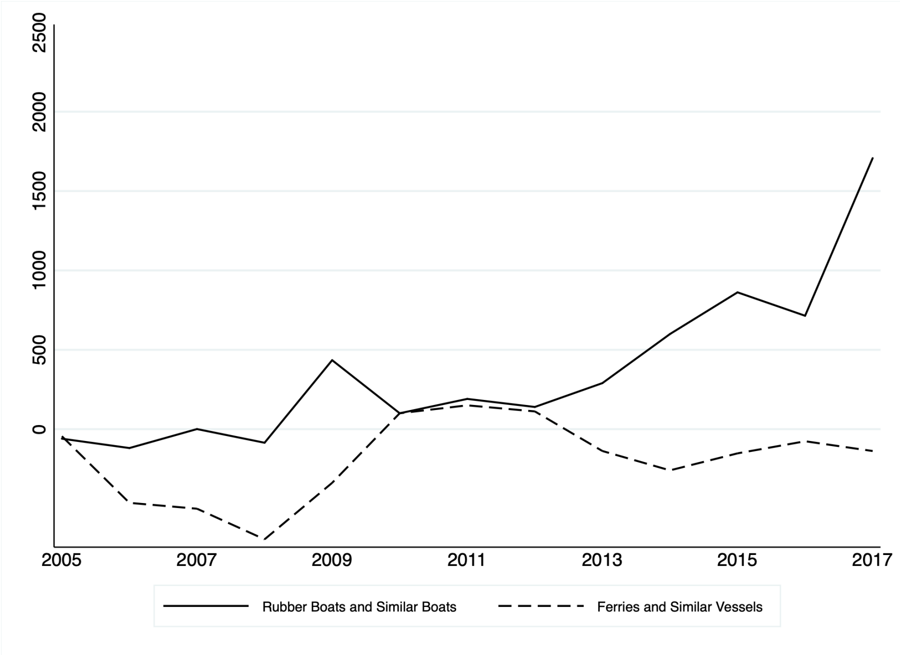
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year×Week fixed effects are included.

Figure 11: Structural Break Test of Wave Conditions on Crossings



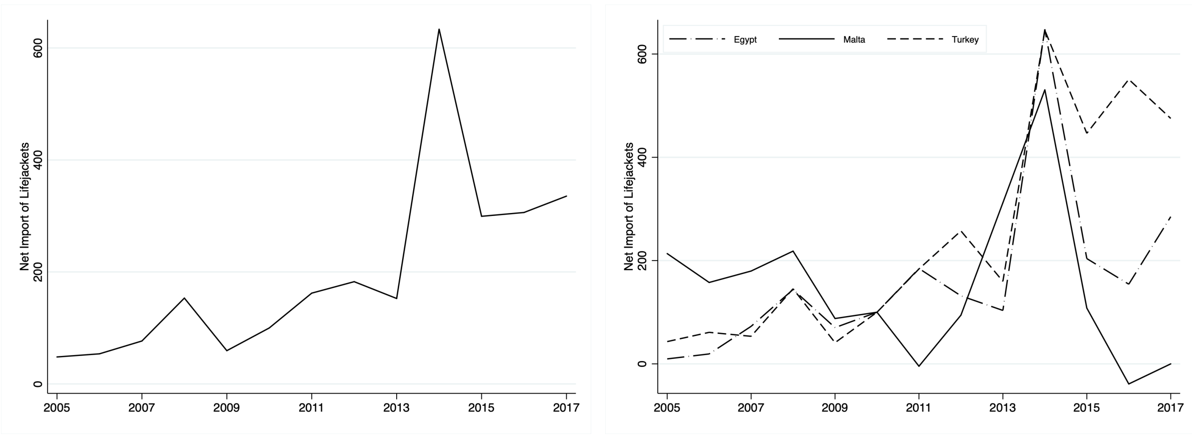
The figure plots the R^2 of equation 9 against the date of the break.

Figure 12: Rubber Boats against Wooden Ferries



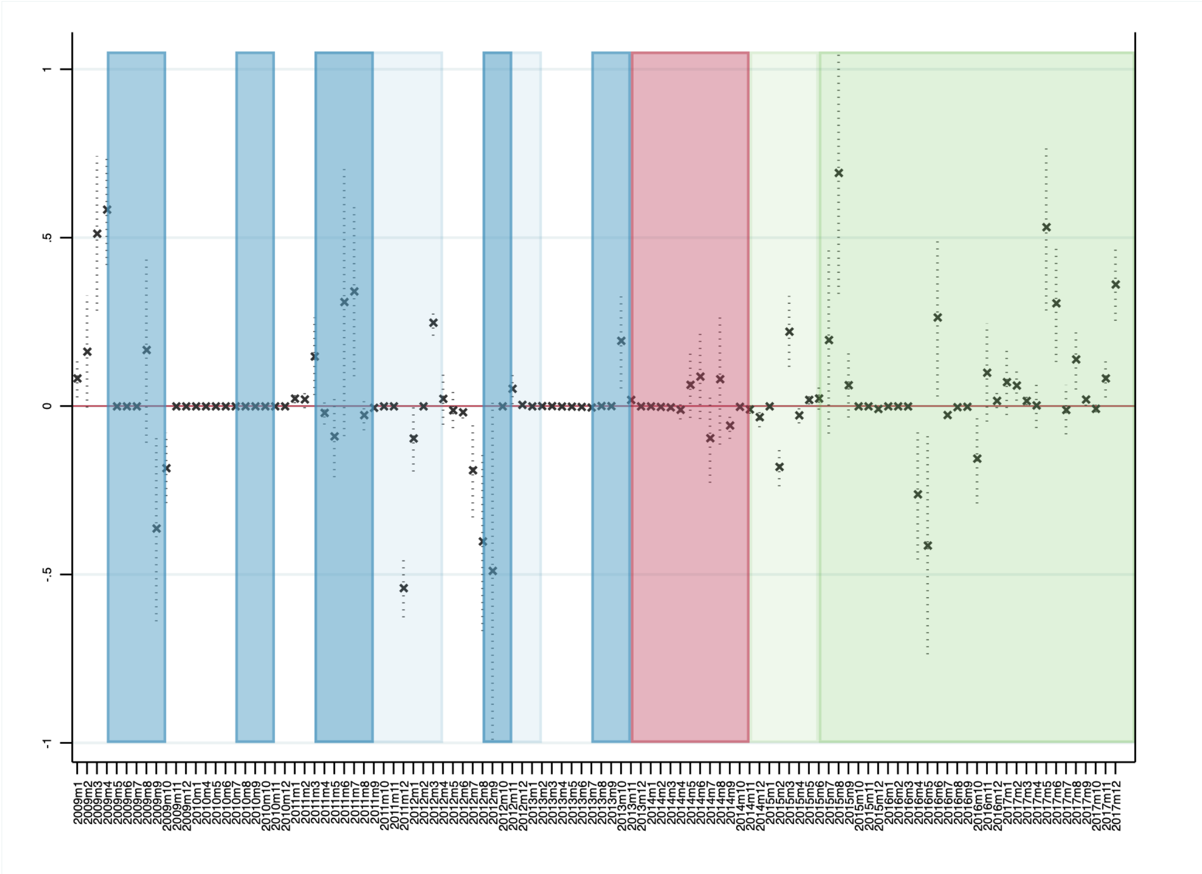
Note: The series show net-imports of rubber boats and ferries to countries near Libya for which data are available (Malta, Turkey, and Egypt). The data source is the United Nations Comtrade. Both series are normalized to 100 in 2010.

Figure 13: Net Import of Life Jackets



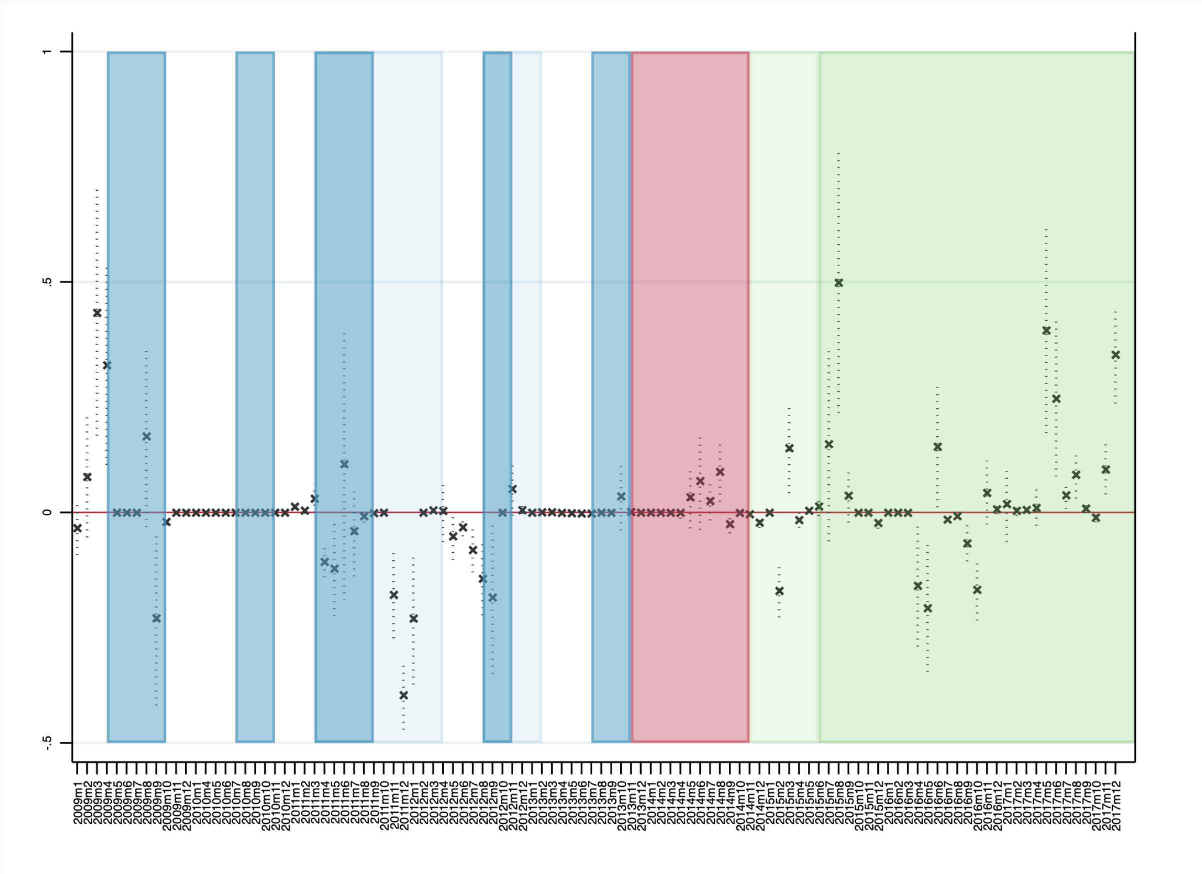
Note: The series show net-imports of life jackets to countries near Libya for which data are available (Malta, Turkey, and Egypt). The data source is the United Nations Comtrade. Both series are normalized to 100 in 2010.

Figure 14: Crossing Risk Type 2A and Wave Conditions



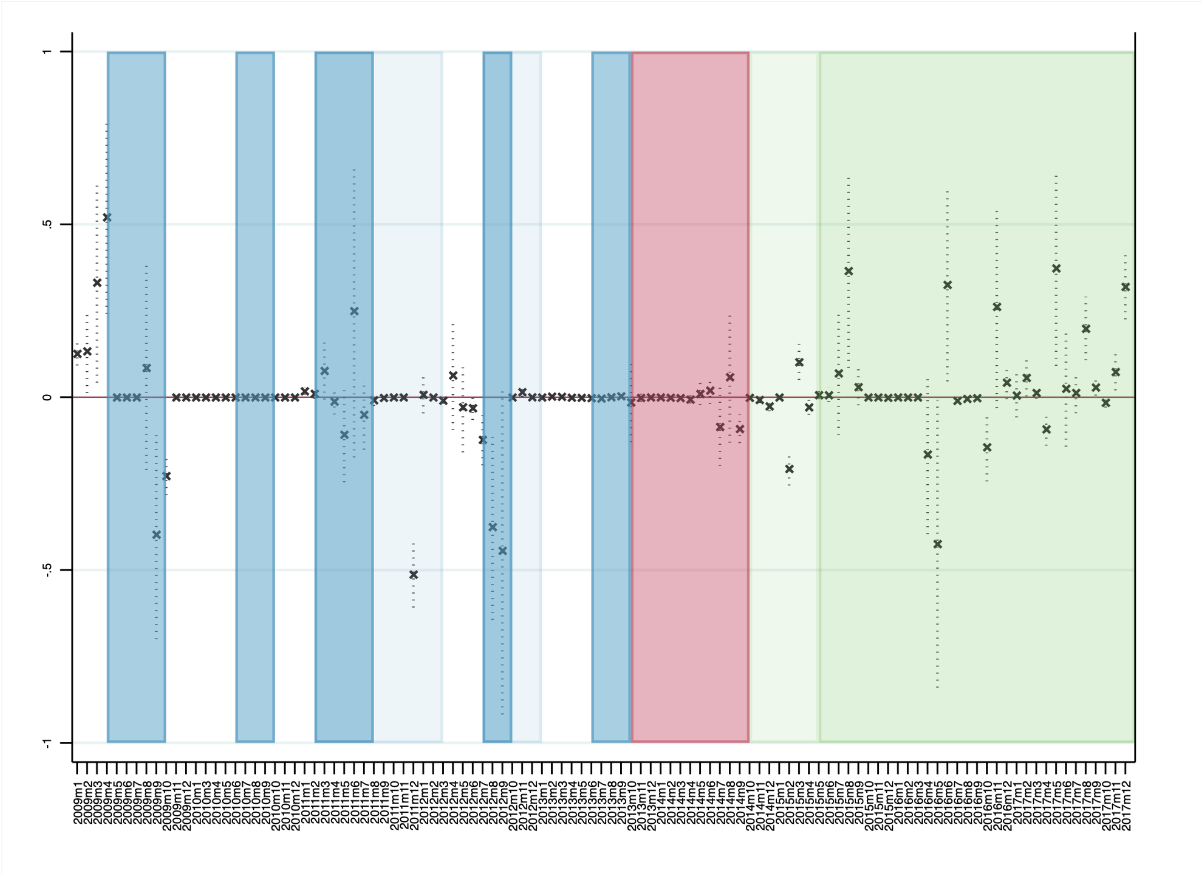
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year$\times$Week fixed effects included.

Figure 15: Crossing Risk Type 2B and Wave Conditions



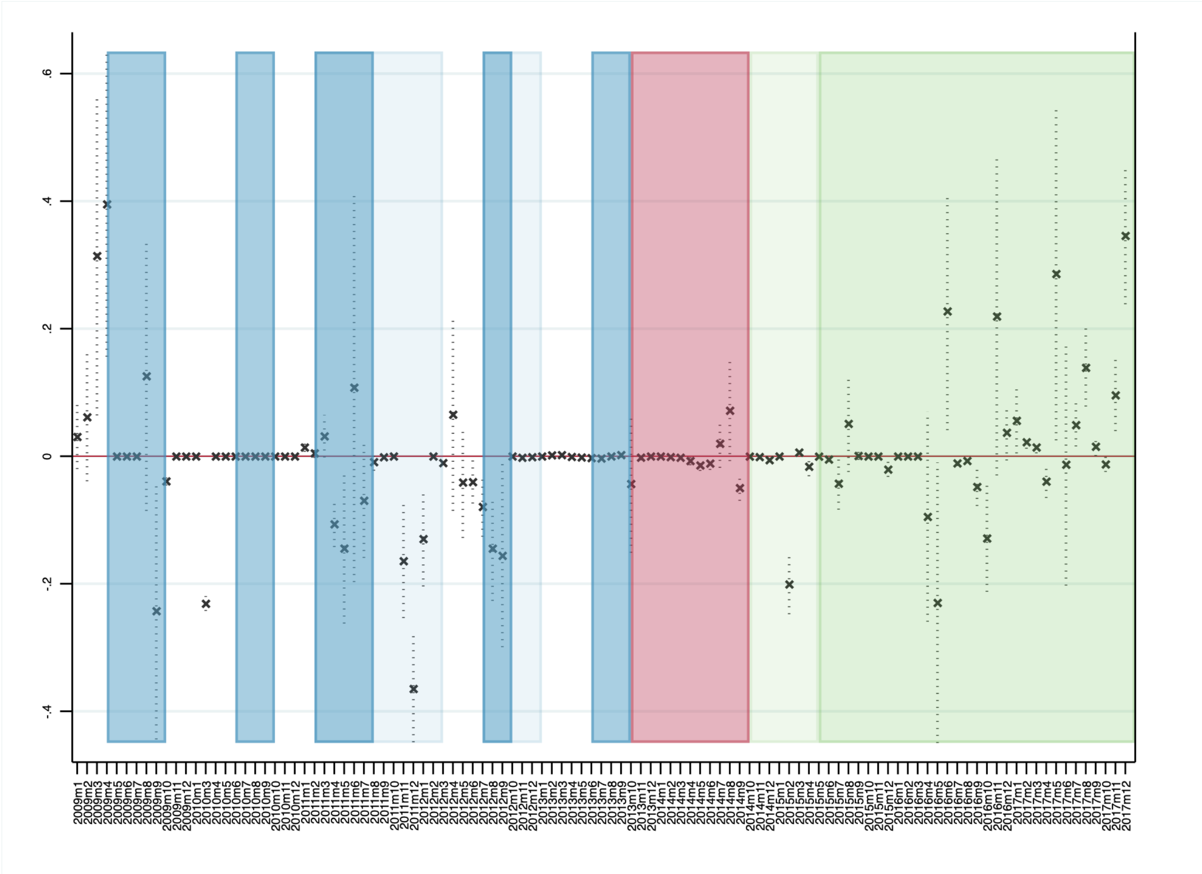
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year$\times$Week fixed effects included.

Figure 16: Crossing Risk Type 1A and Wave Conditions



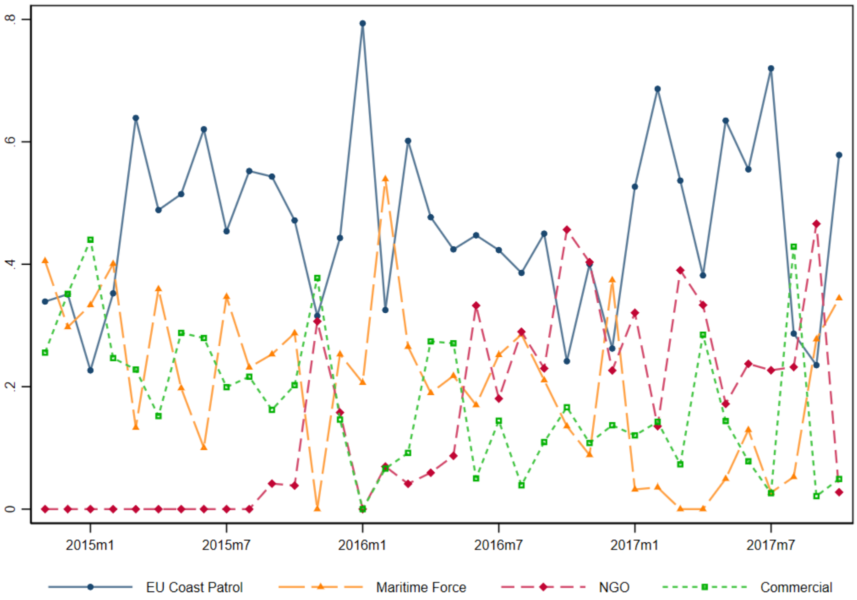
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year×Week fixed effects included.

Figure 17: Crossing Risk Type 1B and Wave Conditions



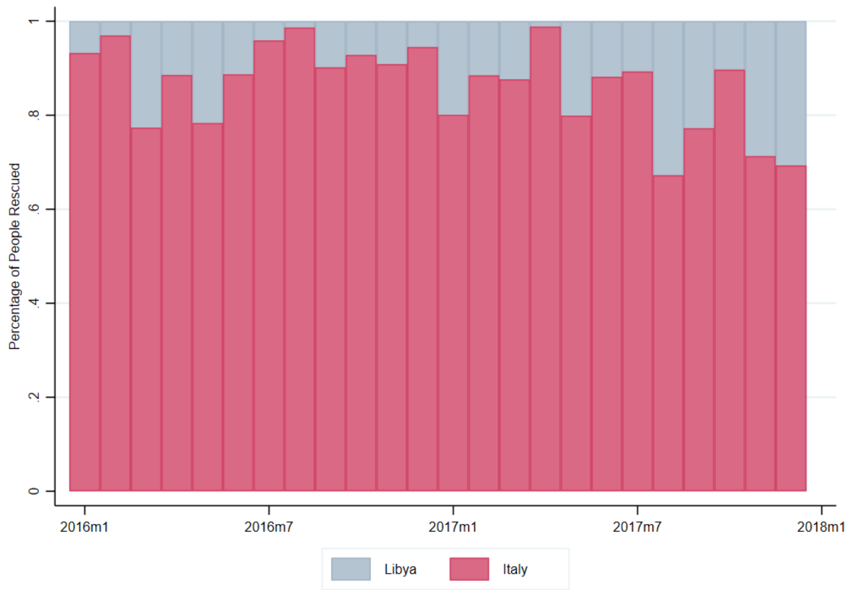
Note: Each "X" corresponds to an estimate of ω_m, along with its dotted 95% confidence interval computed using Newey-West standard errors as in Table 6. The dark and light blues, the red and the green shaded backgrounds indicate when Hermes and its Extension, Mare Nostrum and Triton were operating, respectively. Year×Week fixed effects included.

Figure 18: Rescue Activity by Organization 2014-2017



Note: Each line represents the fraction fraction of monthly crossings that are intercepted by any given organization. Their sum is always one.

Figure 19: Percentage of Migrants Intercepted at Sea by Libyan and Italian Coast Guards



Source: Authors calculations from UNHCR data (2017).

Appendix: Additional Tables and Figures

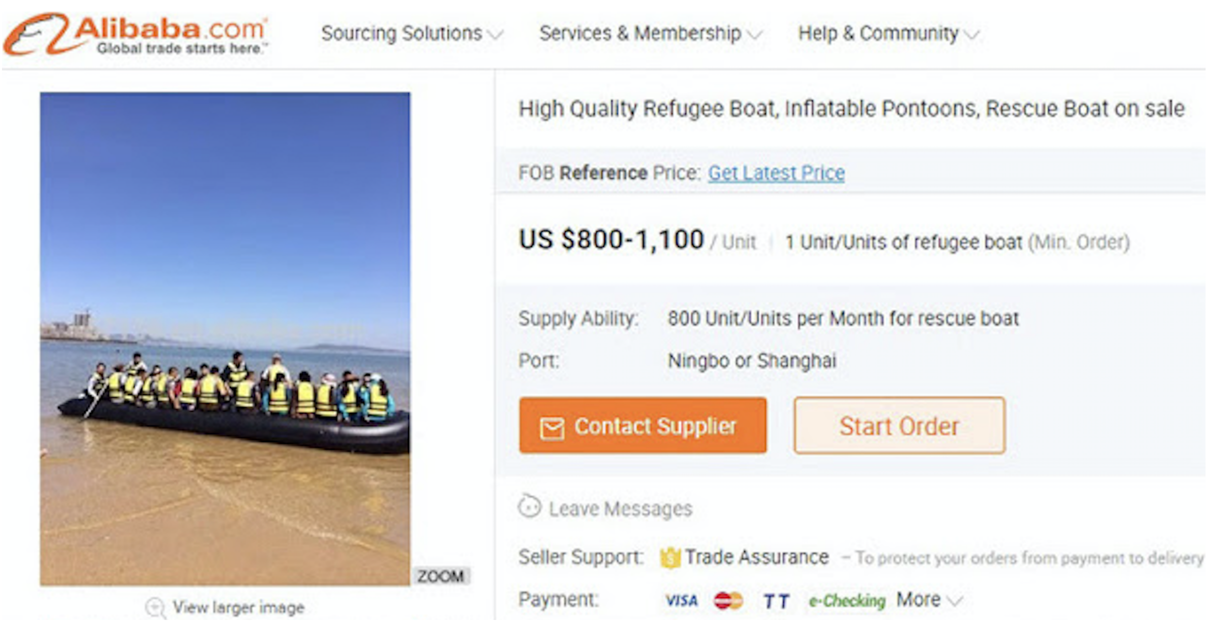
Table A.1: Wave and Swell Explanations

Wave: Description	Height (metres)	Effect
Calm (rippled)	0.00 - 0.10	No waves breaking
Smooth	0.10 - 0.50	Slight waves breaking
Slight	0.50 - 1.25	Waves rock buoys and small craft
Moderate	1.25 - 2.50	Sea becoming furrowed
Rough	2.50 - 4.00	Sea deeply furrowed
Very rough	4.00 - 6.00	Sea much disturbed with rollers
High	6.00 - 9.00	Sea disturbed with damage to foreshore
Very high	9.00 - 14.00	Towering seas
Phenomenal	>14	Precipitous seas (only in cyclones)

Swell: Description	Wave Length (metres)	Wave Height (metres)
Low swell of short or average length	0 - 200	0 - 2
Long, low swell	over 200	0 - 2
Short swell of moderate height	0 - 100	2 - 4
Average swell of moderate height	100 - 200	2 - 4
Long swell of moderate height	over 200	2 - 4
Short heavy swell	0 - 100	over 4
Average length heavy swell	100 - 200	over 4
Long heavy swell	over 200	over 4

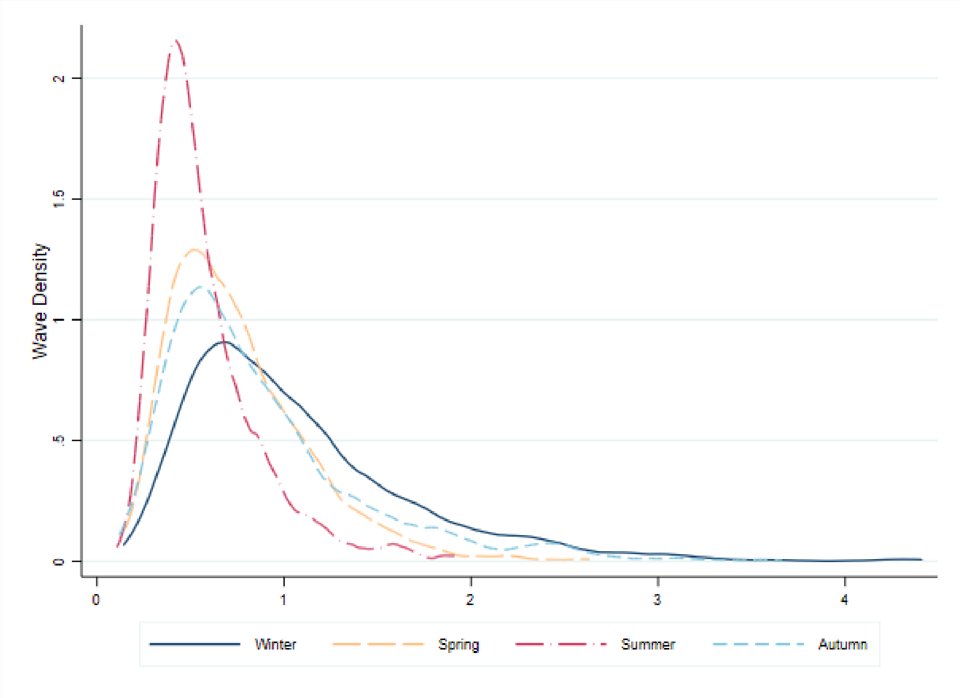
Note: The Bureau of Meteorology. See `http://www.bom.gov.au/marine/knowledge-centre/reference/waves.shtml`

Figure A.1: A Typical Inflatable Boat



Source: `https://www.alibaba.com`.

Figure A.2: Density of Significant Wave Height by Season



Source: European Centre for Medium-Range Weather Forecasts (ECMWF).