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

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Abstract

The Central Mediterranean Sea is the world's most dangerous crossing for irregular migrants. In response to mounting deaths, European nations intensified search and rescue operations in 2013. We develop a model of irregular migration to identify the effects of these operations. Leveraging plausibly exogenous variation from rapidly varying crossing conditions, we find that smugglers responded by sending boats in adverse weather and shifting from seaworthy boats to flimsy rafts. In doing so, these operations induced more crossings, ultimately offsetting their intended safety benefits. A more successful policy should restrict the supply of rafts and expand legal alternatives to irregular migration.

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] For instance, annual migratory flows from Africa to Italy alone have jumped from a few hundred to almost 200,000 over the past quarter century, and these flows are only expected to increase further due to high African population growth 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 while 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.

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 is short distance, this is now

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

[3] Bazzi et al. (forthcoming) find that the increased sanctions have lowered recidivism in illegal entry, while Feigenberg (2020) 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). Fasani and Frattini (2019) test whether Frontex deters migrants from attempting to enter Europe and find evidence that deterrence is high for land routes but not sea routes.

[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.

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*.[8] 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.[9] 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 and private actors have recently stepped in by sending rescue vessels to newly unpatrolled areas.

Our goal in this paper is to identify how SAR operations reshaped the market for smuggling along the Central Route. In particular, did SAR affect the numbers of crossing attempts, and did it affect the risk incurred by migrants attempting to cross? These questions are difficult to answer for three reasons. First, the details of crossings and rescues are largely unobserved to researchers. Extralegal activities are fundamentally difficult to observe for obvious reasons; journeys may vary dramatically in terms of type of craft, expected duration, and expected route; and SAR operations span a vast expanse of sea over many months-long periods, so they are likely to affect crossings heterogeneously. Second, it is challenging to ascertain the counterfactual numbers of migrant crossings and deaths that would have occurred in the absence of SAR because these are endogenously determined in a strategic equilibrium with smugglers. And third, SAR operations change infrequently and ostensibly cover the entire Central Mediterranean, so a contemporaneous counterfactual is unavailable.

In light of these obstacles, standard approaches to estimate the effect of a policy change are unsuitable. Instead, we pursue an indirect identification strategy that combines unique data on crossing attempts, the insights of a novel model of smuggling, and plausibly exogenous, high-frequency variation in the physical conditions of each crossing attempt.[10] We find substantial heterogeneity in the effects of SAR operations along the Central Route. Broadly, more far-reaching SAR operations induced more migrants to attempt crossings in bad weather and eventually led smugglers to shift to unsafe boats. We estimate that almost all additional migrants who attempted the journey did so on unsafe, inflatable boats, which are estimated to

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

[8] Over the European migration crisis of 2015-2016, Hatton (2020) analyses how public opinion and politics shaped European asylum policies. Battiston (2020) shows that rescue operations become more intense when media attention is high.

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

[10] Like in a sufficient-statistic approach, we use quasi-experimental evidence to make welfare considerations based on policy simulations.

be about 20 times more dangerous compared to sturdy, wooden boats. As a result, the safety benefits of SAR were offset and the *ex ante* riskiness of passage likely increased during the most intense periods of operation.

An increase in crossing attempts and increase in the riskiness of passage implies that SAR operations increased the total number of deaths in transit. However, we stress that our findings *do not* imply that SAR operations should be curtailed or eliminated. Indeed, SAR almost certainly led to an increase in total migrant welfare: while some migrants could have been worse off by SAR-induced changes in prices, migrants were made better off in aggregate since more could now afford to attempt the journey in the first place. Rather, our analysis offers some nuance for any evaluation of the costs and benefits of SAR operations, as even a well-intentioned policymaker who is faced with balancing such difficult to enumerate costs and benefits would be wise to consider behavioral responses to their decision.

Because there is no exogenous variation in the timing or intensity of SAR and there are no comparable migratory routes that are "untreated," we cannot directly estimate the effects of SAR. Instead, we develop a theoretical model of smuggling that allows migrants to choose between safe and unsafe boats, or to abstain from crossing, smugglers to adjust their offerings depending on whether SAR is in place or not, and departures to vary by weather and tidal conditions at crossing. The value of the model lies in the fact that it allows us to infer indirectly the effects of SAR on crossing attempts and risk from changes in the elasticity of crossing attempts with respect to crossing conditions when SAR is in place versus when it is not. These elasticities can be estimated under the weaker assumption that daily variation in crossing conditions are exogenous, and they can be used to identify the types of boats on which the additional crossings induced by SAR occurred.

To implement our identification strategy, we rely on daily observation of activity along the Central Route. This is accomplished with the use of unique, restricted daily data on 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, the ideal frequency to exploit changes in sea conditions. 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, data on migrant boat types, and a carefully researched catalog of SAR operations from 2009-2017.

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).[11] Friebel et al. (2017) and Aksoy and Poutvaara (2019) explore who chooses to migrate to Europe and their motivations for doing so.[12] The authors also consider some unintended effects of stricter border regulations on (negative) circular migration and (positive)

[11] 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.

[12] 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.

demand for smugglers. Battiston (2020) uses an instrumental variables approach to show that crossing risk depends on the distance from potential rescuers, and that such distance depends on public and thus political attention.

Two other papers have modeled 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) finds 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.

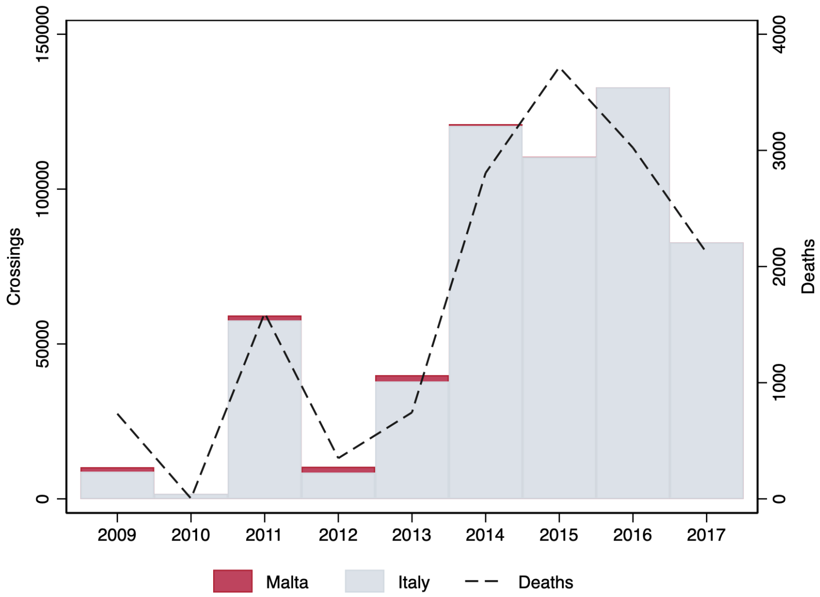
The paper is organized as follows: in Section 2, we provide some background on the Central Route and SAR operations that have been implemented by individual countries, the EU, and various NGOs. We also describe the various sources of data used in our analysis. In Section 3, we present a simple model of human smuggling that highlights the incentives that shape the decisions of smugglers and potential migrants. In Section 4, we estimate the responsiveness of smugglers and migrants to crossing conditions, which we combine with our model to identify the effects of SAR on crossings and riskiness of this passage. In Section 5, we develop a complementary, data-driven approach to identify the effects of SAR on crossings to ensure the robustness of our baseline findings. We conclude in Section 6.

2 Background and Data

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 (167km or about 100 miles from Ras Kaboudja, Tunisia and 296km from Tripoli, Libya) than to Italy itself (205km to Sicily and 395km to continental Italy). Another common port of entry is Pantelleria, which is just 71km away from Kelibia (Tunisia).

In calm waters migrant boats would typically travel at a speed of 11 to 13km/h (Heller et al., 2012), meaning that on the shortest path from Tunisia it would take about 6 hours to reach Pantelleria and about 14 hours to reach Lampedusa. When leaving from Libya the boat

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



Note: The total number crossings to Malta and Italy are on the left axis, and the number of deaths in transit are on the right axis. Italian and Maltese data are available from the Ministry of Interior and UNHCR at `http://data.unhcr.org/mediterranean`, respectively.

trip would usually take more than a day. At a speed of 12km/h, it would take 25 hours to travel from Libya to Lampedusa. The trip may be much shorter if migrants are rescued early and transported to Lampedusa on military or NGO vessels.[13]

Between 1997 and 2008, the number of irregular crossings from North Africa to Italian shores was stable at around 20,000 per year until Italy and Libya signed a treaty on August 30, 2008 and crossings dropped to roughly 9,500 in 2009 and 4,500 in 2010. This established Tunisia as a major point of departure for migrants, particularly after the pro-democracy uprisings during the "Arab Spring" of 2011.

In January, the Tunisian President Ben Ali was forced to flee following a month of protests. According to the 2012 Frontex Evaluation Report (Frontex, 2012) by August 2011 nearly 20,000 illegal migrants departed from Tunisia, representing about a third of all 2011 crossings (see Figure 1). Appendix Figure B.1 shows that in 2011 on the Central-Mediterranean route almost half of all migrants were Tunisians.

As result the Italian government quickly signed a readmission agreement, which allowed a maximum of 100 Tunisian per week to be returned to Tunisia. This slowed down crossings from Tunisia, but Tripoli fell in August of 2011, leading to a surge in refugees from Libya.

[13] Military vessels tend to travel in excess of 30km/h and can cover the Tripoli-Lampedusa distance in less than 10 hours. For example, the Triglav 11 Slovenian patrol boat used during Mare Nostrum has a top speed of 50km/h. The two Minerva-class corvettes used in the same operation have a top speed of 33km/h. The patrol boats "Classe Costellazioni/Comandanti" reach a top speed of 46km/h. NGO vessels tend to be slower but still much faster than typical migrant boats. For example, the "Open Arms" travels at an average speed of 17km/h.

Libyan dictator Muammar Ghaddafi was captured and killed in October 2011, rendering the previously signed treaty with Italy moot, and instability quickly travelled to Egypt and the Middle East, bringing with it further waves of refugees. Unsavory actors with ties to Al Qaeda quickly controlled parts of the market for human smuggling into Europe, which by then was largely organized out of Libya. By the end of 2011, almost 60,000 immigrants from North Africa had reached European shores, and Italy became the main port of disembarkation on the Central Route.[14] After two relatively calm years, attempted crossings to Italy further skyrocketed with the deepening of civil war in Libya, reaching close to 150,000 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 (see Figure 1).

For our analysis, we combine data from several sources that focus on irregular 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. In total, we construct a dataset that includes detailed information on search and rescue operations alongside daily data on irregular crossings, deaths and crossing tidal conditions each of which we describe in further detail.

2.1 Search and Rescue Operations

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.[15]

Search and rescue operations usually begin with distress calls to "Marine Rescue Coordination Centers (MRCC)" which take immediate action to rescue the migrant boat in need. In the Central Mediterranean, migrant and civil rescue boats would traditionally call the Italian MRCC located in Rome even if they were closer to Tunisian or Libyan territorial waters because even though both African countries are signatories to the 1979 International Convention on Maritime Search and Rescue, neither one has officially established their SAR area. This implies that no single country is responsible for the area between the territorial waters of the two African countries and the Maltese and Italian SAR areas. Moreover, the 1979 Convention dictates that rescued migrants must be taken to a "place of safety" where migrants' fundamental rights are preserved, and neither Tunisia nor Libya are classified as safe. As a result, migrants rescued during our period of analysis would be transferred almost exclusively to Italy (see Figure 1).

[14] 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).

[15] 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 C.1). 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.

Table 1: EU Operations

EU Operations	Dates	Maritime SAR Distance from Italian shores (in km)	Budget per month	Budget total
Hermes (Main operation)	16 Apr – 16 Oct 09	44	0.9	5.2
	14 Jun – 29 Oct 10	44	0.8	3.3
	20 Feb – 31 Aug 11	44	2.5	15.0
	02 Jul – 30 Oct 12	44	1.0	4.1
	06 May – 07 Oct 13	44	1.5	9.0
Hermes (Extension)	01 Sep 11 – 31 Mar 12	22*		
	01 Nov 12 – 31 Jan 13	22*		
Mare Nostrum	18 Oct 13 – 31 Oct 14	244	9.3	112
Triton I	01 Nov 14 – 30 Apr 15	56	2.9	27.5
Triton II	01 May 15 – 31 Dec 17	256	10.7	343
NGO Operations	Dates	Maritime SAR Op. Area	Fundraising per month	Fundraising total
MOAS	25 Aug – 15 Oct 14	Libyan shore	2.1	4
MOAS	01 May – 01 Oct 15	Libyan shore	1.1	5.7
MOAS	06 Jun – 31 Dec 16	Libyan shore	0.86	6
MOAS	01 Apr – 01 Sep 17	Libyan shore	0.55	3.3

Note: Budget numbers are in millions of Euro. Information on the extent of the SAR zone is sometimes hidden in official Frontex Operational Plans (2009-2014). Information on *Mare Nostrum* and *Triton I* are gathered from a report by Italian Parliament(2017) and Senate Statistical Office (2015). The 2016 and 2018 Frontex budgets provide details on Joint Operations (Frontex, 2016, 2018). In these instances our best guess (*) 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, or 22 km from the coastal state).

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 (Frontex, 2009, 2010). In response to the surge of migrants 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 (approximately 44km) 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 fishing 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 (Italian Parliament, 2017). Once rescued, "irregular" migrants were generally channelled to the existing reception system for asylum seekers (Bratti et al., 2020).

Operationally, *Mare Nostrum* consisted of permanent patrols in the SAR zones of Libya, Malta and Italy. Patrols were supposed to extend up to 120 nautical miles from the Italian territorial waters (about 244km south of Lampedusa) but often reached Libyan territorial waters and included naval and aircraft deployments carried out by military personnel. The monthly cost of this *extensive* 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 UK opposition, 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 area shrunk to only 30 nautical miles (56km) 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 (256km) south of Lampedusa and tripled its operational budget. In addition, Frontex began to destroy migrant smuggler vessels to prevent them being reused, which might have further prompted smugglers to switch from seaworthy but expensive vessels to inflatable rafts, which are an order of magnitude cheaper.[16] Operation *Triton* ended in February 2018.[17]

2.2 Data on Crossings

We obtained a novel database containing the numbers of daily irregular migrants to Italy from the *Polizia di Stato* (State Police) who operates 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 SAR 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.[18] According to the 2017 Euro Asylum Seeker Survey Bank (2018), which collected information from a random sample of adult migrants in Italian asylum centers, 96 percent of migrants were crossing on boats that were intercepted by Italian or EU naval assets. This implies that the number of daily arrivals is unlikely to be measured with sizeable error.

We then compute total 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 B.2. 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 (see Appendix Fig. C.1), 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 this period.

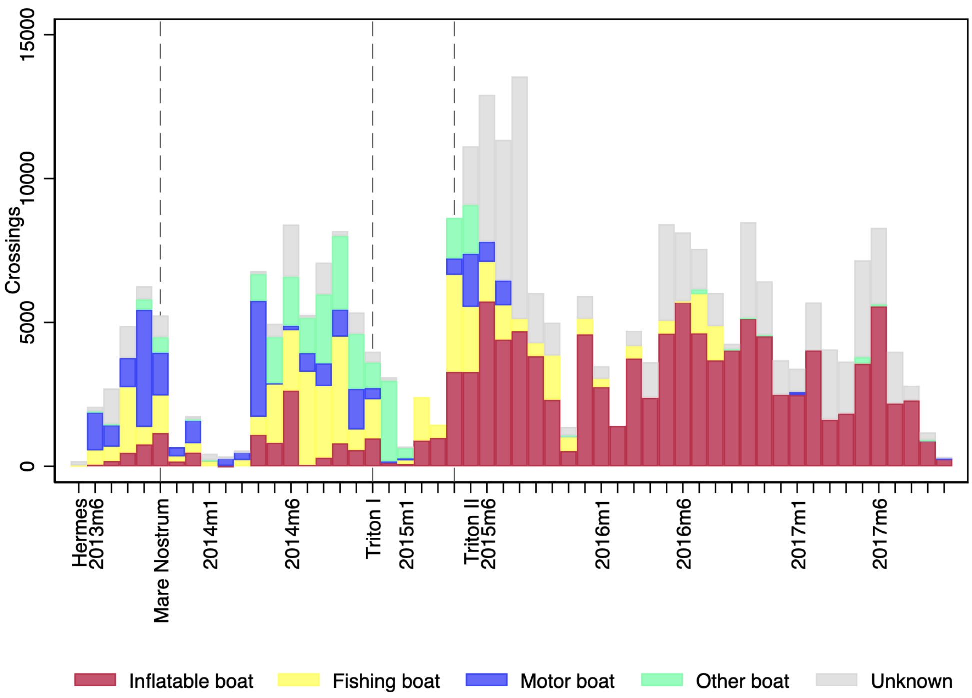
We also gathered information through a Freedom of Information Act (FOIA) request on the type of vessel used from 2013-2017 from Frontex (we were denied access to information for the years 2009 to 2013). We summarize these data in Figure 2. Even though many crossing vessels in that sample period are described as unknown, 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.

[16] 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 annually while for the period 28 July 2016 to 27 July 2017, the reference amount for the common costs of operation *Sofia* was €6.7 million.

[17] Joint Operation *Themis* followed *Triton*, but *Themis* vessels patrol no further than 24 nautical miles (44km) from the European coast, and most sea rescues are now done by private NGO vessels. We discuss the role of NGOs in more detail in Appendix C.

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

Figure 2: Types of Vessels Used, 2013-2017



Source: Frontex. Data is available only from 2013-2017. Vertical dotted lines display the start of SAR Operations: Mare Nostrum, Triton I and II.

This increase coincides with a massive increase in imports of rubber boats from China to Malta, Turkey, and Egypt, from where rubber boats are believed to reach Libya. According to Figure 3 between 2005 and 2012 imports are fairly flat. There is some increase by 2013, but the large one happens in 2014 and 2015 (between the end of Mare Nostrum and the beginning of Triton II). In those two years net-imports increase by a factor of 5. Another large increase happens towards the end of Triton II, in 2017. By comparison, imports of other vessels are flat.[19] This pattern is further supported by trends in imports of life-jackets to Egypt, Libya and Malta, which we present in Appendix Figure B.3. 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 SAR.[20]

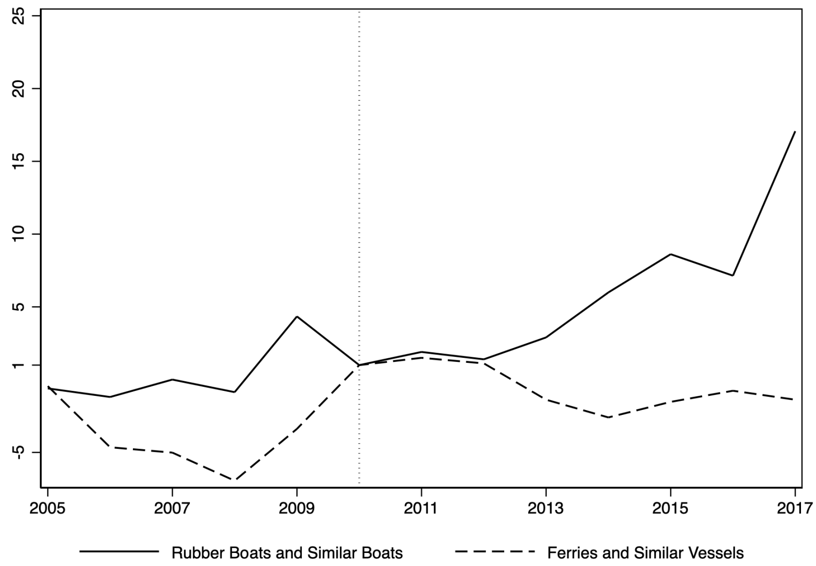
2.3 Data on Deaths

Although official statistics on deaths in transit are difficult to come by, a number of large transnational organizations 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 4.5, which corresponds to a crossing risk (of death) of 9 percent.

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

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

Figure 3: 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 1 in 2010.

Our primary source is UNITED for Intercultural Action, the European network in support of migrants, refugees and minorities.[21] 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.[22] We also consider the data from Frontex that spans 2014-2016 and the *Migrants File* dataset that spans 2009-2016.[23]

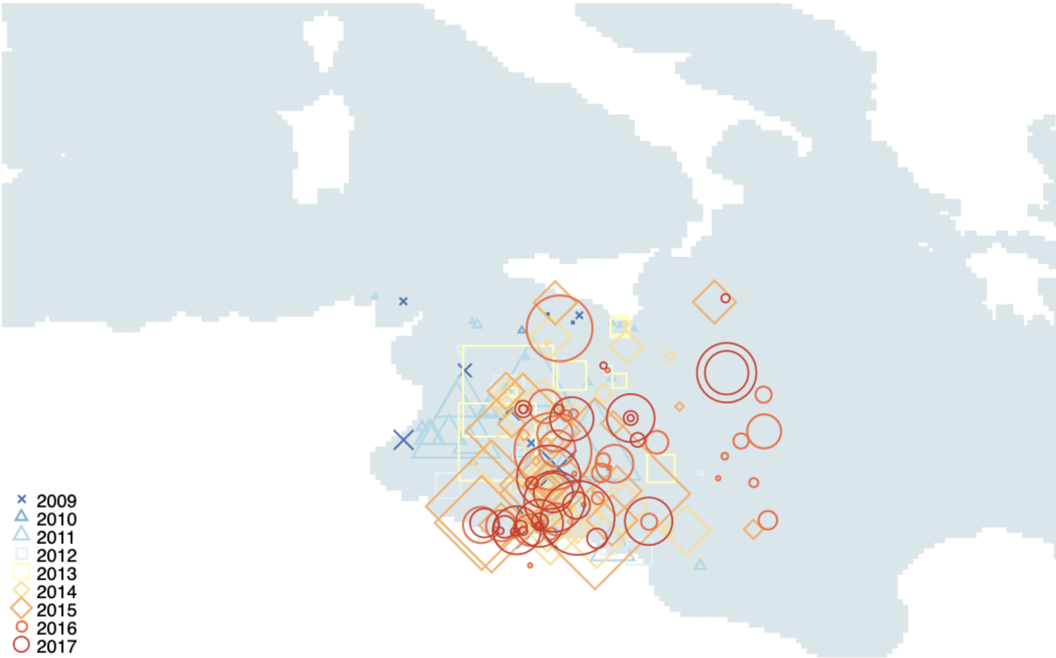
In Figure 4, we present a map of fatal sea accidents during our sample period. Larger

[21] UNITED has monitored 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.

[22] UNITED has not geolocated 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).

[23] 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. Deaths are primarily gathered from the *List of Deaths* spanning from Jan 1st, 2009 to Jun 1st, 2017. In case of missing information on the number of deaths, we consider the data from IOM, Frontex and *Migrants File*.

Figure 4: Migrant Deaths by Location and Year



Note: Authors calculations. See Section 2.3.

indicators 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.[24]

2.4 Data on Crossing Conditions

We proxy for crossing conditions with significant wave height, $H^{1/3}$, a widely used measure in maritime navigation that corresponds to the average height of the largest tercile of waves in the open sea. It combines information on wind, waves and swell, all of which may cause shipwrecks.[25] Significant wave height is commonly modeled with the Rayleigh distribution (Battjes and Groenendijk, 2000), which allows for straightforward calculation of average wave heights above given percentiles. This is particularly useful to us, as shipwrecks tend 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. Linearity of H (in its exponent) implies that modelling outcomes as linear functions of significant wave height $H^{1/3}$ is empirically equivalent to choosing any other specific wave height $H^{1/k}$ (with coefficients appropriately rescaled).

[24] Columns 3 to 7 of Appendix Table B.1 show that during intensive SAR periods casualties happen closer to Libya and farther away from Lampedusa, with changes that cover more than half of the entire distance between the two.

[25] Appendix Table B.2 describes wave and swell in terms of height and length.

We obtained detailed data on significant wave height from the European Centre for Medium-Range Weather Forecasts (ECMWF). These data are constructed using high frequency readings from satellite measurements, surface-based data sources (buoys, radar wind, drop-sonde and ships) and aircraft reports (Dee et al., 2011), and they are measured at a variety of potential departure points along the North African coast: Tripoli, Libya; Benghazi, Libya; and Al Huwariyah, Tunisia. Figure B.4 shows the density of the significant wave height by season. We summarize all of our main variables in Table B.3.

3 Model

We present a model of irregular migration that highlights the important incentives faced by smugglers and potential migrants and guides our empirical analysis. Because many features of this market are incompletely observed at best (e.g., prices, vessel types), the implications of our model allow us to draw inferences on the incidence of search and rescue operations (SAR) on the various agents involved. For simplicity, we abstract away from any strategic interaction between migrants and smugglers and treat them as consumers and producers, respectively, in the market for crossing attempts. This modeling choice follows from the fact that smugglers value the safety of migrants due to reputational concerns, obviating a potential agency problem.[26] We start with a simple baseline in which only a single type of boat is available and we explore how SAR affects migrants' decisions (as noted in Section 2.2, this roughly corresponds to the pre-*Mare Nostrum* period). We then introduce heterogeneity in boats and obtain more nuanced predictions of smuggler and migrant behavior.

On the demand side of the market for passage across the Mediterranean we assume a unit mass of potential migrants. Migrant i has utility

$$u_i = \alpha_i \sigma^R(h) - p$$

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, and p is the price of passage.[27] We make a standard monotone likelihood ratio assumption on f that can be easily expressed in terms of the hazard function $\lambda(\cdot)$:

[26] Given the fact that we observe only aggregate behavior, i.e., we do not observe any information on individual migrants or the sequence of decisions that they make, we present a static model of crossing. While the introduction of dynamic decisionmaking might lead to additional results, we would be unable to test them empirically; in any case, the key incentives that we highlight in a static model should be present in a dynamic model.

[27] Migrants pay smugglers very high prices to traverse on the Central Route. According to Bank (2018), for Sub-Saharan Africans the average cost of the entire journey, which is close to US$2,250 and includes the cost of reaching the African coast, is equivalent to three years of income. According to Libyan smugglers who have been interviewed by investigative reporters crossing the Mediterranean sea during this period, passage on inflatable boats costs at least $500 and higher prices ARE charged for passage on wooden boats (Mannocchi, 2018). According to Italian investigators (see Breines et al., 2015), the normal price for a crossing on unsafe boats for Sub-Saharan Africans is US$700 and large, safer boats cost between US$2000 and US$2500.

$$\lambda(\cdot) = \frac{f(\cdot)}{1 - F(\cdot)} \text{ is non-increasing.}^{28} \tag{A1}$$

σ^R represents the probability of successful passage. This is a decreasing function of crossing conditions (wave height), h, and varies if SAR is in place ($R = 1$) or not ($R = 0$). We make the following assumptions on σ:

$$\sigma^1(h) > \sigma^0(h) \tag{A2}$$

$$\frac{\partial \sigma^0(h)}{\partial h} \leq \frac{\partial \sigma^1(h)}{\partial h} < 0 \tag{A3}$$

Assumption A2 states that SAR increases the likelihood of successful passage. Assumption A3 states that adverse crossing conditions (higher h) reduce the likelihood of successful passage, and SAR mitigates this effect. Without loss of generality, we assume that migrant i will attempt passage if $u_i > 0$ and that smugglers are price takers (we will relax this assumption later on).

Proposition 1. *Under Assumptions A1, A2 and A3, the introduction of search and rescue operations will result in:*

1. *Increases in total attempted crossings.*
2. *Total attempted crossings becoming less elastic to crossing conditions.*

All proofs may be found in the Appendix. The first part of Proposition 1 follows from Assumption A2, as the introduction of SAR reduces the α_i of the marginal migrant who attempts to cross. This result, combined with Assumptions A1 and A3 immediately yield the second part of Proposition 1.

We now generalize this model by positing that each migrant may cross either 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 B.5 in the Appendix) at a price of p_b respectively. Migrant i's utility can now be written as

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

where the probability of successful passage and price of passage now vary by boat type. We make the following common-sense assumptions on crossing technologies:

$$\sigma_u^R(h) < \sigma_s^R(h) \tag{A4}$$

$$\frac{\partial \sigma_u^R(h)}{\partial h} \leq \frac{\partial \sigma_s^R(h)}{\partial h} < 0 \tag{A5}$$

$$\sigma_u^1(h) - \sigma_u^0(h) > \sigma_s^1(h) - \sigma_s^0(h) > 0 \tag{A6}$$

[28] Given that only a minority of potential migrants attempts to cross, we are likely to observe the behavior of individuals who are in the right tail of the distribution of α, which makes this assumption quite plausible.

Figure 5: Migrant's Crossing Decisions

Assumption A4 simply states that irrespective of weather conditions "safe" boats are more likely to complete the journey than "unsafe" boats. According to Assumption A5, unsafe boats are more susceptible to crossing conditions. Assumption A6 expands on Assumption A2 and captures the fact that SAR increases the safety of unsafe boats more than it increases the safety of safe boats.[29]

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 ($c_s > c_u$). Let M_s^R and M_u^R represent the fractions of migrants who attempt to cross on safe and unsafe boats respectively

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. *Define* $\underline{\alpha} = \frac{p_u}{\sigma_u^R}$ *and* $\overline{\alpha} = \frac{p_s - p_u}{\sigma_s^R - \sigma_u^R}$ *Under Assumption A4, if* $\alpha_i < \underline{\alpha}$*, then i will not cross. If* $\underline{\alpha} \leq \alpha_i < \overline{\alpha}$ *then i will cross on an unsafe boat. Otherwise, i will cross on a safe boat.*

All 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 5. The two thresholds, $\underline{\alpha}$ and $\overline{\alpha}$ fully characterize the equilibrium of the market.

The model with a single type of boat is a straightforward extension of the model with two types of boats. In a world where only safe boats are available, as characterized by Proposition 1, there is only a single threshold $\underline{\alpha}'$ describing the marginal migrant who is indifferent between crossing on a safe boat and not attempting to cross. This threshold can be expressed as a convex combination of the two thresholds described in Lemma 1 as follows

Lemma 2. *Define* $\theta = \frac{\sigma_U}{\sigma_S}$*. Then*

$$\underline{\alpha}' = \theta \underline{\alpha} + (1 - \theta) \overline{\alpha}$$

Lemma 2 has an intuitive interpretation: in an environment in which the crossing risks on safe and unsafe boats are similar ($\theta = 1$) such as when trips originate in Tunisia and are very short, most of the crossings that would occur on unsafe boats if they were available have occurred on safe boats anyway. In an environment in which the safe boats are much safer than unsafe boats such as when trips originate in Libya and are much longer, most of the crossings that would occur on unsafe boats if they were available would not have occurred otherwise.

[29] With multiple boat types available, our analysis no longer requires any assumptions on the relative impact of SAR on the elasticity of successful passage with respect to waves like Assumption A3.

For simplicity, we first consider the case in which the market for smuggling is perfectly competitive, i.e., prices are set to marginal cost.[30] We define crossing risk ρ as the *ex ante* probability that a migrant dies along the journey, which is a weighted sum of $1 - \sigma_u$ and $1 - \sigma_s$.

Proposition 2. *Under Assumptions A4-A6 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 2 follow immediately from Lemma 1. Because prices remain at $p_u = c_u$ and $p_s = c_s$ irrespective of whether SAR is in place, the resulting decrease in σ_u and increase in $\sigma_s - \sigma_u$ shift $\underline{\alpha}$ and $\overline{\alpha}$ to the left and right respectively in Figure 5 (part 1). These shifts may or may not outweigh the increased safety from SAR (part 2). The third part of Proposition 2 follows from the fact that if unsafe journeys are unlikely to be successful without SAR, then its introduction 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 SAR.[31] The smuggler's problem can thus be written as

$$\max_{p_s^R, p_u^R} M_s^R \cdot (p_s^R - c_s) + M_u^R \cdot (p_u^R - c_u)$$

with the understanding that the M_b^R are endogenously determined.

Proposition 3. *Under Assumptions A1 and A4-A6, 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 2.*
2. *Increases in p_u, p_s and $p_s - p_u$ if σ_u^0 is small.*
3. *An increase in smuggler's profits.*

We can express the markups that monopolists charge as follows:

[30] 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.

[31] For expositional simplicity, we assume that are unable to adjust their prices to short run fluctuations in crossing conditions (h). 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.

$$p_u^R = c_u + \frac{\sigma_u^R}{\lambda\left(\underline{\alpha}\right)} \tag{1}$$

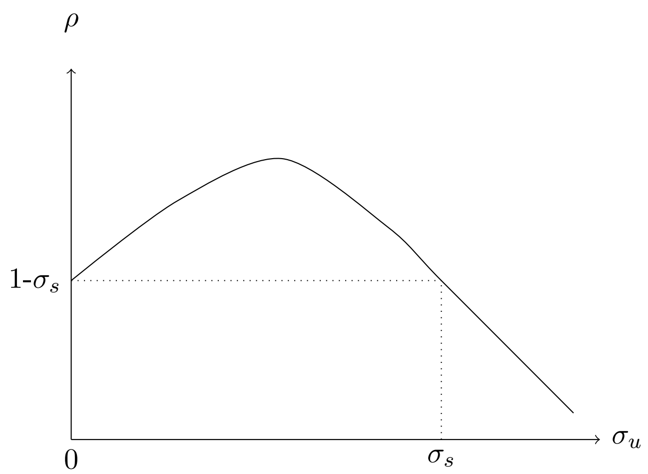
$$p_s^R = c_s + \left[(p_u^R - c_u) + \frac{\sigma_s^R - \sigma_u^R}{\lambda\left(\overline{\alpha}\right)} \right] \tag{2}$$

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 SAR by raising prices (part 2), though not by so much that they deter inframarginal migrants from attempting to cross (part 1). Second, SAR makes 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 SAR 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 SAR 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 6. When $\sigma_u = 0$, all travel occurs on safe boats, hence $\rho = 1 - \sigma_s$. As σ_u grows larger, an increasing amount of travel occurs on unsafe boats, so ρ increases. When $\sigma_u \geq \sigma_s$, all travel occurs on unsafe boats, so $\rho = 1 - \sigma_u$. The continuity of the objective function implies that in some range of large but not too large σ_u, ρ will be decreasing.

We can illustrate the effect of SAR and its incidence on migrants in Figure 7. The analysis is qualitatively the same whether smugglers face competition or not. In the presence of SAR, 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

Figure 6: Net Crossing Risk



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 SAR 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 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 SAR 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.

Finally, by placing some additional structure on f_α, we can approximate θ from Lemma 2 in terms of the semi-elasticities of crossings to weather conditions and relative prices. Given information on prices, it follows that we can use estimates of these semi-elasticities to determine the effects of SAR on crossing risk (note that low values of θ imply that SAR increases crossing risk per Figure 6). Formally, if we replace assumption A1 with the stronger assumption

$$\alpha_i \sim \text{exponential}(\lambda) \tag{A7}$$

we obtain the following result

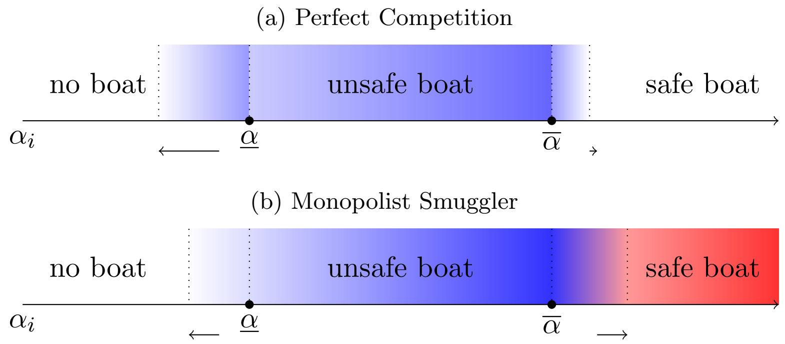
Proposition 4. *Under assumptions A6 and A7,*

$$\theta \approx \frac{\omega_s^R}{\omega_u^R}\left(\frac{p_s - p_u}{p_u} + \frac{\omega_s^R}{\omega_u^R}\right)^{-1}$$

where $\omega_b^R = \frac{\partial \text{total crossings}_b}{\partial h}$

Since only a small fraction of potential migrants attempt a crossing, approximating f_α with a single tailed distribution is appropriate. Moreover, Assumption A7 implies a constant hazard of λ. Hence, under this assumption, our qualitative assumptions are unlikely to vary under

Figure 7: 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.

different market structures, and under perfect monopoly.

4 Results

For our baseline analysis, we use the information that is fully observable to us. In particular, we exploit information on crossing attempts, crossing conditions, boat types, and official SAR operations. Because boat type is only observable from 2013-2017, this analysis can only be performed on a subsample from May, 7 2013 to October, 4 2017. In Section 5, we conduct a complementary analysis where we attempt to use all of the data that is (even partially) available over the full sample period from 2009-2017 and relax a number of modeling assumptions in a series of data driven exercises.

Our main empirical test is a test of whether crossings respond more strongly to crossing conditions (significant wave height measured in meters, $h_t = H_t^{1/3}$) when search and rescue operations are in place *and* migrants are capable of switching from sturdy to inflatable crafts. Following the model, the total number of crossings c_t is a function of $\underline{\alpha}_t = \frac{p_t}{\sigma_t}$, where prices and risk refer to the least safe boat type available. Assuming that the αs are distributed approximately exponentially, $c_t = e^{-\lambda \frac{p_t}{\sigma_t}}$, where λ is the constant hazard. Since h_t is known to follow the Rayleigh distribution, then if risk depends on the likelihood of encountering tall outlier waves, the number of arrivals will also be an exponential function of wave height.[32] This indicates the following Poisson Quasi-ML regression[33]

$$c_t = \exp\left[h_t(\omega_0 + \omega_1 \mathrm{ISAR}_t + \omega_2 \bar{u}_{w(t)} + \omega_3 \bar{u}_{w(t)} \times \mathrm{ISAR}_t) + \mu_{w(t)}\right] + \epsilon_t \tag{3}$$

where crossings, c_t, depend on wave height h_t interacted with the presence of an (intense)[34] search a rescue operation (ISAR_t) per official records, and the fraction of unsafe boats, ($\bar{u}_{w(t)}$), deployed in a specific week t.[35]

Our Newey-West standard errors allow for heteroscedasticity and autocorrelation within 28-day periods.[36] Because our model predicts a shift from safe boats to unsafe boats, we estimate a model with week-by-year fixed effects $\mu_{w(t)}$ that subsume all variation in $\bar{u}_{w(t)}$, thereby controlling for the endogeneity of boat choice. In combination with the exponential model, the fixed effects also play a critical role in mitigating bias in our parameter estimates due to measurement error in crossings. Although attempts and deaths may be more likely to

[32] See the proof of Proposition 4 in Appendix A for a derivation of this result. Later we test the extent to which our results are robust to alternative specifications.

[33] The Poisson specification offers two additional practical advantages. First, it is well suited to analyze discrete data without biasing estimates when a high fraction (48%) of days have no crossings (Santos Silva and Tenreyro, 2006). Second, our estimates are not contaminated with a size effect due to a general change in the overall number of crossings over time with the inclusion of fixed effects. Nevertheless, in Appendix Table B.4 we show that OLS regressions generate similar results.

[34] We refer to SAR operations as intense in equation (3) because we are only able to observe boat type after January 2013. As a result, the baseline operation in regression refers to *Hermes*, which is the least intense SAR operation according to official operational descriptions.

[35] $\bar{u}_{w(t)}$ is the unweighted fraction of inflatable, or inflatable and unknown boat type. When we weight this fraction by the number of migrants on each boat we get very similar results.

[36] Results with different types of standard errors are shown in Appendix Table B.5.

Table 2: Attempted Crossings

	(1)	(2)	(3)
		Total Attempts	
		Wave Height in Tripoli (t)	
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-6.55***	-5.45***	-4.17***
	(1.93)	(1.40)	(1.29)
Wave Height	-0.89**	-1.43**	-1.46**
	(0.37)	(0.60)	(0.61)
Wave Height * Fr. Boat	2.13	1.91	1.63
	(1.81)	(1.34)	(1.13)
Wave Height * Post SAR	0.21	1.17*	1.00
	(0.46)	(0.65)	(0.73)
Observations	1,469	1,469	1,469
Week-Year FE	X	X	X
Pre Mean Oucome	131.57	131.57	131.57

Note: SAR coefficients are estimated relative to a baseline in which Hermes operations were in place. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

be observed when SAR is in place, our reliance on within-week variation in crossing conditions for identification of $\omega_0 - \omega_3$ eliminates this source of bias since SAR does not vary at such high frequency. Moreover, what matters is the relative size of the semi-elasticities. Given that SAR assets withstand any rough sea observed in the Mediterranean sea and are ex-ante unaware of the type of boat used by the migrants, the ωs are unlikely to be differentially influenced by any measurement error.

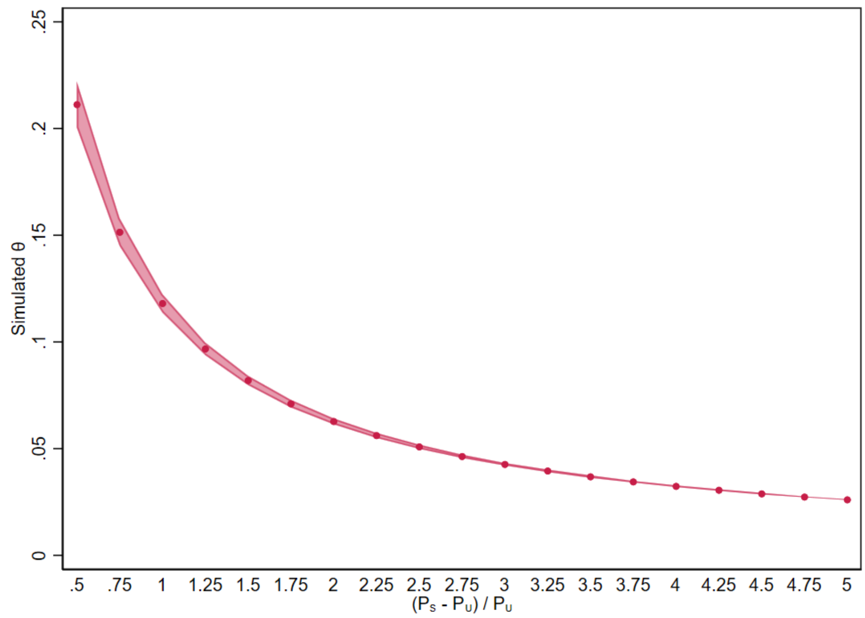
Results are presented in Table 2. We consider three different classifications of unsafe boats. In all specifications, we find that adverse crossing conditions lead to a greater shift from unsafe boats to safe boats under more intense SAR operations. We find a 10 percent increase in wave height at time t reduces the total number of crossings by between 5 and 9 percent, but in the presence of intense SAR, there is an additional reduction of between 25 and 39 percent. As predicted by the model, when unsafe boats are unavailable, the response to intense SAR is positive, though it is not statistically significant (except once). In appendix Table B.6, we replicate our analysis using information on crossing conditions from earlier days because journeys may take more than one day. All results are similar.

For a given $\frac{p_S - p_U}{p_U}$, Proposition 4 provides a way that to simulate θ as a function of our parameter estimates since $\omega_u = \omega_0 + \omega_1 + \omega_2$ and $\omega_s = \omega_0 + \omega_1$ as estimated in equation Eq. 3. We present our simulated $\hat{\theta}$ in Figure 8.

For $p_s \approx 3 \times p_u$, which is in line with media reports (see footnote 27), $\hat{\theta}$ is less than 5%.[37] Indeed, for any plausible price ratio, we conclude that θ is likely to be less than 10%. This does

[37] A series of robustness are provided in the Appendix. Table B.6 shows results using different types of wave height. Results using squared wave height are shown in Appendix Table B.7.

Figure 8: Simulated Likelihood of a Successful Journey on Unsafe vs. Safe Boats ($\hat{\theta}$)



Notes: The $\hat{\theta}$s are simulated using the semi-elasticities estimated in Column (1) of Table 2. 95% confidence intervals shown with standard errors are computed using the δ-method.

also imply that any measurement error bias would have to be very large and differ by migrant boat type to undo this result.

There are two clear implications of this finding. First, following Lemma 2, almost all additional crossings induced by SAR took place on unsafe boats. Second, following Figure 6, SAR operations likely increased crossing risk for migrants, which is consistent with the raw differences in crossing risk estimated in Column 2 of Appendix Table B.1.

5 Sensitivity Analysis

In order to extend our sample period back to 2009, we develop a complementary empirical strategy that does not control for boat switching explicitly but instead attempts to detect it from changes in crossing patterns. Our approach is sensitive to multiple distinct sources of uncertainty: (1) We are unable to observe high frequency or geographic variation in the intensity of SAR, (2) We are unable to observe the (expected) duration of each attempted crossing, and (3) We are unable to observe the precise location of departure for each attempted crossing. In light of this, we first conduct a baseline analysis in which we resolve these sources of uncertainty with plausible assumptions. We then proceed with three data-driven empirical exercises which relax these assumptions in an intuitive way.

We being by modeling crossing attempts as a function of significant wave height at departure and at arrival, and we allow this relationship to vary by official SAR period (but not boat type). We posit that prior to the death of Ghaddafi, journeys commenced from Tunisia, and afterwards, they commenced from Tripoli. These modeling decisions yield the following three assumptions on the crossing environment: (1) SAR is homogeneous within official operational periods; (2) crossings prior to Ghaddafi's death are expected to take a single day, and crossings afterwards are expected to take two days (see the discussion about travel distances in Section 2); and (3) we can proxy for crossing conditions for all journeys with conditions outside of Al Huwariya, Tunisia prior to Ghaddafi's death and with conditions outside of Tripoli, Libya afterwards. Under these assumptions, we use a Poisson Quasi-ML model to estimate the following baseline equation

$$c_t = \exp\left[\omega_0 h_t + \sum_k \omega_k h_t \times \mathrm{SAR}_{k,t} + \mu_{w(t)}\right] + \epsilon_t, \tag{4}$$

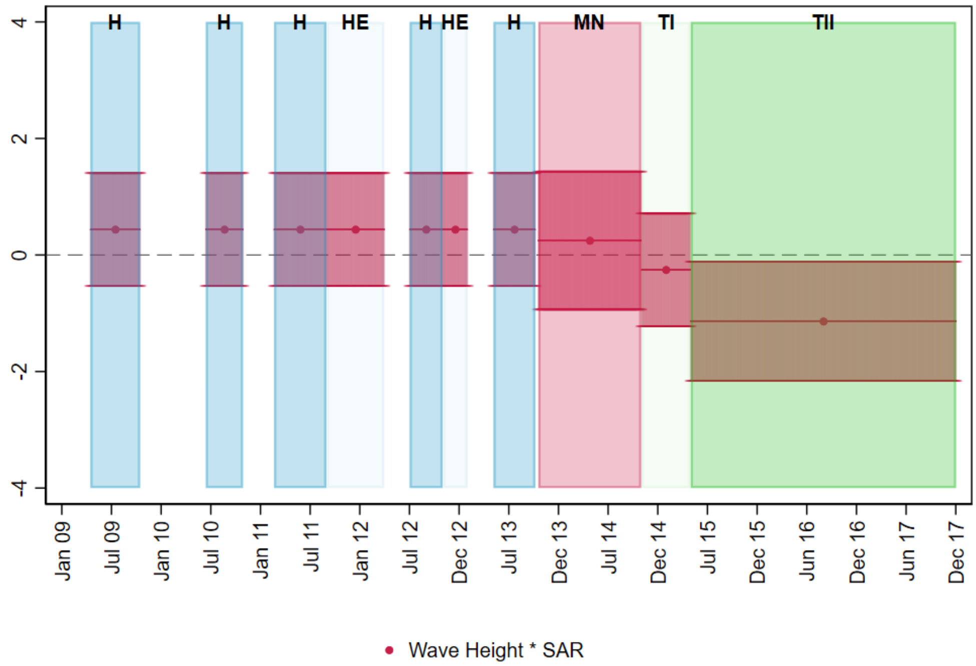
where c_t is the number of attempted crossing attempts that would have arrived on date t; sea conditions h_t is equal to $H_t^{1/3}$ as measured outside Al Huwariya for $t \leq$ October 20, 2011 and $H_{t-1}^{1/3}$ as measured outside Tripoli for $t >$ October 20, 2011; $\mu_w(t)$ is a week-by-year fixed effect, and $SAR_{k,t}$ is a dummy variable equal to 1 if SAR operation k is in place on day t.

We graphically present our results in Figure 9 where differently colored regions represent the official periods of SAR operations. A full listing of estimates can be found in Appendix Table B.8. The large, negative and statistically significant estimates of ω_0 indicate that significant wave height is a meaningful proxy for crossing conditions.

As predicted by the model, SAR induced crossings in adverse conditions when rubber boats were less available (e.g., during *Hermes*), but the effects are not statistically significant. During *Triton I* and *Triton II*, when rubber boats became more widely available, crossings become more responsive to sea conditions, hence SAR induced crossing attempts. The effects are statistically significant and more pronounced during *Triton II* compared to *Triton I*, which could reflect an increase in SAR intensity (both in an official capacity and through increased NGO activity) coupled with the availability of boats.

We explore this further in Table 3 where we replace attempted crossings on the left hand side of equation (4) with the fraction of migrants by each type of boat, and we include only crossing conditions at departure on the right hand side. On average, adverse crossing conditions substantially reduce the share of crossings attempted on inflatable boats, but they leave operations on other boats largely unaffected, which supports both the assumptions and conclusions of our model. We also find that SAR completely attenuates this effect, which we should note is also consistent with the predictions of our model. Whereas *total* crossing attempts should be more elastic to crossing conditions (Proposition 1.3), the *fraction* of attempts on unsafe boats need not be; indeed, if σ_u^0 is sufficiently smaller than σ_u^1 as we might presume in later SAR periods, then we should expect this. A further implication of this result would be that in later periods, SAR increased crossing risk.

Figure 9: Effects of Crossing Conditions on Crossing Attempts



Notes: Estimates correspond to the interaction effects of crossing conditions (ω_k). 95% confidence intervals are constructed with standard errors clustered by month of the year. Colored regions represent official periods of SAR operations.

5.1 Relaxing Empirical Assumption 1 (SAR Operations)

Because many particulars of journeys and SAR are unobservable to us as researchers, our baseline analysis relies on several simplifying assumptions. We deepen our analysis by dispensing with *a priori* assumptions on the timing, duration and intensity of SAR operations throughout the sample period. We iteratively search for short intervals of time within the sample period where the responsiveness of crossing attempts to crossing conditions shifts the most relative to baseline. These sequential structural breaks (see Bai, Jushan and Perron, Pierre, 1998) can be interpreted as periods of more (or less) SAR through the lens of our model.

Specifically, we perform the following procedure:

1. For every day in our sample period (t_0) we consider hypothetical values of (t_1) that are 30 days later. We allow t_1 and t_0 to be at a maximum of one year. We then repeat the procedure moving t_0 by 15 days.

2. For every interval $[t_0, t_1]$ we estimate equation (4) where SAR operation k refers to that interval. We select the interval $[t_0, t_1]$ that provides best model fit (on the basis of the Poisson's pseudo log-likelihood) and interpret that as a structural break.

3. We repeat steps 1 and 2 by re-estimating equation (4) disregarding the period that have

Table 3: Fraction of Migrants by Boat Type and Crossing Conditions

Fraction of Migrants	(1) Inflatable	(2) Fishing	(3) Motor	(4) Other	(5) Unknown
Wave Height	-0.16**	0.07	-0.08	-0.01	0.18*
	(0.06)	(0.11)	(0.15)	(0.03)	(0.11)
Wave Height * Mare Nostrum	0.03	-0.04	0.30	0.02	-0.32**
	(0.10)	(0.22)	(0.20)	(0.10)	(0.13)
Wave Height * Triton I	0.06	-0.10	0.13	0.14	-0.23**
	(0.07)	(0.13)	(0.16)	(0.13)	(0.12)
Wave Height * Triton II	-0.00	-0.06	0.11	0.02	-0.07
	(0.11)	(0.11)	(0.15)	(0.03)	(0.13)
Observations	768	768	768	768	768
Week-Year FE	X	X	X	X	X
Pre Mean Outcome	0.11	0.22	0.35	0.04	0.27
$\omega_0 + \omega_{Mare}$	-0.128	0.034	0.217*	0.011	-0.134*
	(0.081)	(0.189)	(0.127)	(0.097)	(0.073)
$\omega_0 + \omega_{TritonI}$	-0.096**	-0.035	0.050	0.125	-0.044
	(0.03)	(0.065)	(0.045)	(0.128)	(0.046)
$\omega_0 + \omega_{TritonII}$	-0.163*	0.013	0.025	0.013	0.111
	(0.092)	(0.026)	(0.018)	(0.010)	(0.078)

Notes: SAR coefficients are estimated relative to a baseline in which *Hermes* was in place. All regressions are estimated by least squares and include week-by-year fixed effects. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

previously been identified as a SAR operation. We stop when the p-value of the interaction terms is not significant at 0.1% level.

We present the results of this exercise in Figure 10.[38] Estimates of the interaction effects of conditions during structural breaks imply that official SAR periods are presented purely for reference as they play no role in this analysis. Importantly, we identify structural breaks only during periods when SAR was likely to be most intense: *Hermes* 2011, which had the largest budget of all *Hermes* operations, and *Mare Nostrum* and *Triton II* which had large budgets and the most expansive operational areas. When operation are scaled back, e.g. during *Triton I*, smugglers no longer respond differently to adverse crossing conditions. When they resume, strategic responses resume in kind.

Unlike the case where the interactions were predicted to have an effect for the whole official duration of the operation, the data show that most of the effects are concentrated after the summer of 2013 (*Mare Nostrum* started in the fall).

The fact that we find multiple breaks within *Mare Nostrum* and *Triton II*, suggests that we are picking up variation in the intensity of SAR. Indeed, the periods in which crossings respond most negatively to crossing conditions correspond to periods in which certain NGOs increased their operations, thereby supplementing official SAR efforts. This can be seen in Figure B.9, as the spikes in the red line, which correspond to the highest levels of NGO activity and hence the (likely) higher total amount of SAR operations, line up closely with the later structural breaks

[38] Appendix Figure B.6 presents the results showing departure and arrival estimates using the procedure explained in the text for 15 days. Appendix Figures B.7 and B.8 show robustness exercises with a procedure using 30-day steps.

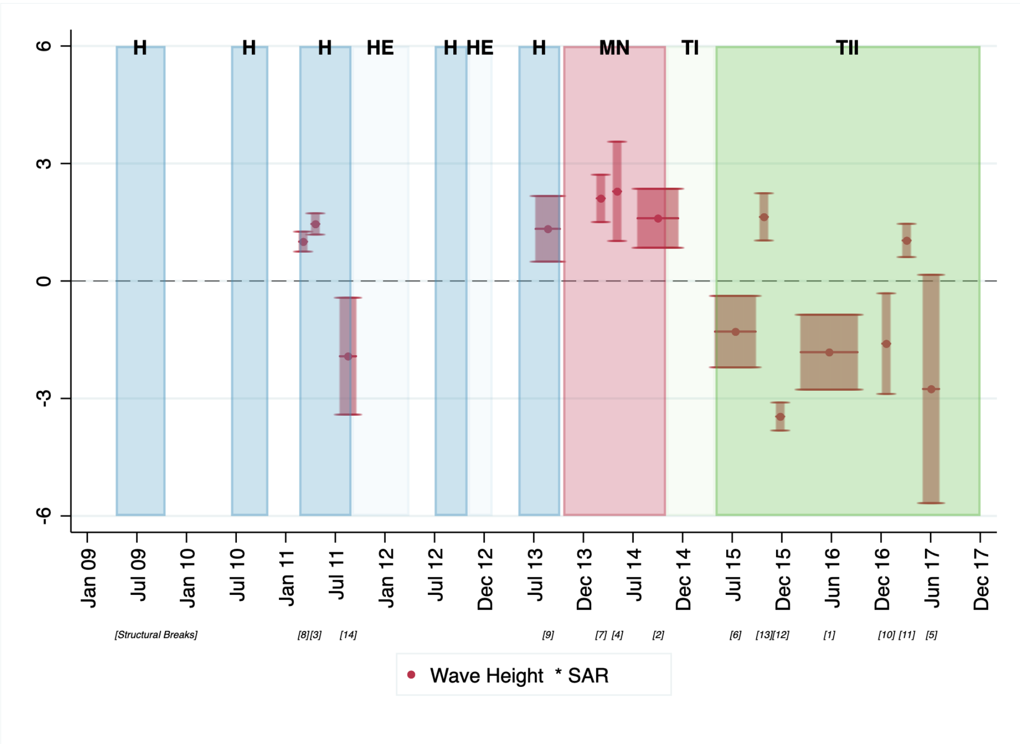
that we identify. Overall, the results of this exercise are consistent with the predictions of the model and capture greater nuance in the market for smuggling on the Central Route that we were unable to incorporate into our baseline model.

5.2 Relaxing Empirical Assumption 2 (Expected Journey Length)

We now relax the assumption that all journeys attempted prior to Ghaddafi's death took a single day and those attempted afterwards took two days. Instead, for each day in our sample period, we predict the likelihood that a crossing attempt leaving that day was expected to last one day or two days. We then repeat the structural break-finding exercise described above, but we modify estimating equation (4) to incorporate our earlier prediction. We remain completely agnostic as to the timing, duration and intensity of SAR operations throughout the sample period. Specifically, we perform the following procedure:

1. For each day t in our sample period, we estimate the following three regressions on the subsample of our data that excludes day t:

Figure 10: Effects of Crossing Conditions on Crossing Attempts: Structural Break Search



Note: Structural breaks are identified using the procedure outlined in the text. Estimates correspond to the interaction effects of crossing conditions (ω_k). 95% confidence intervals are constructed with standard errors clustered by month of the year. Differently colored regions represent different SAR operations.

$$c_t = \omega^A H_t^{1/3} + \mu_{w(t)} + \epsilon_t \quad (5)$$

$$c_t = \omega^D H_{t-1}^{1/3} + \mu_{w(t)} + \epsilon_t \quad (6)$$

$$c_t = \omega^A H_t^{1/3} + \omega^D H_{t-1}^{1/3} + \mu_{w(t)} + \epsilon_t \quad (7)$$

2. For each day t, we compare the three (out-of-sample) predictions of c_t. If equation (6) or (7) performs best, then we infer that journeys that concluded on day t were expected to take two days and hence departed on day $t-1$. If equation (5) performs best, then we infer that journeys that concluded on day t were expected to take one day and hence departed on day t.

3. For every day in our sample period (t_0) we consider hypothetical values of (t_1) that are 30 days later. We allow t_1 and t_0 to be at a maximum of one year. We then repeat the procedure moving t_0 by 15 days.

4. For every interval $[t_0, t_1]$ we estimate equation (4) where SAR operation k refers to that interval. Importantly, we replace $H_{t-1}^{1/3}$ with the significant wave height on the day of departure as inferred in steps 1 and 2 (wave in Tripoli), and we replace $H_t^{1/3}$ with significant wave height on the day of arrival as inferred in steps 1 and 2 (wave in Tunisia). We select the interval $[t_0, t_1]$ that provides best model fit (on the basis of the Poisson's pseudo log-likelihood) and interpret that as a structural break.

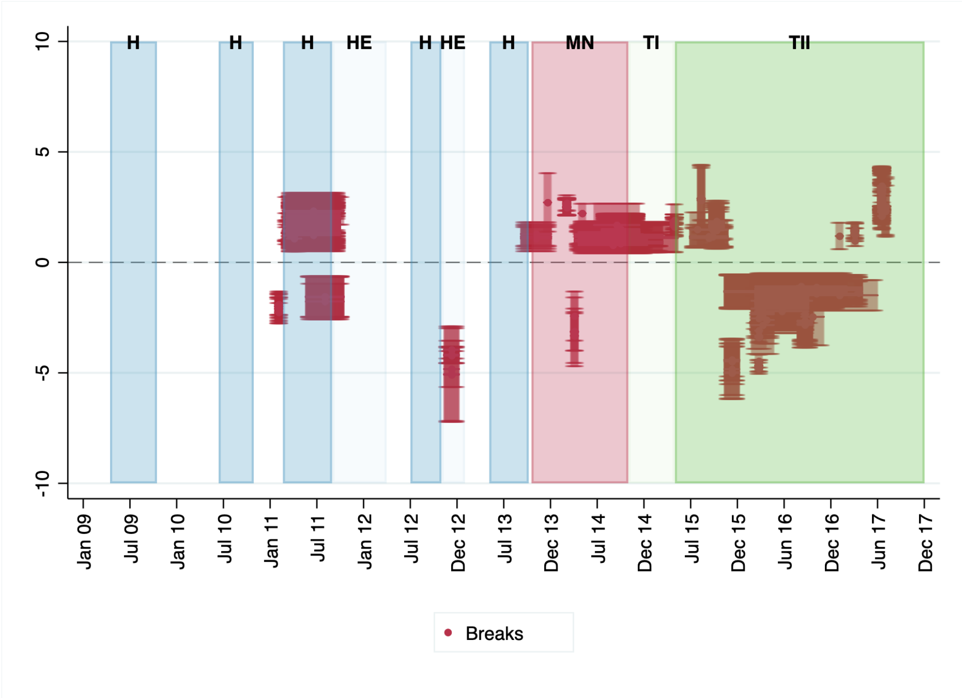
5. We repeat steps 3 and 4 by re-estimating equation (4) disregarding the period that have previously been identified as a SAR operation. We stop when the p-value of the interaction terms is not significant at 0.1% level.

In order to capture the sampling variation arising from step 1, we bootstrap the sample at the weekly level before performing such step, and we present our results in Figure 11. Because the relevant conditions to smugglers and migrants are those upon departure, and we identify those with greater confidence in this exercise, we show only the effects of conditions at departure on crossing attempts.

Each red interval corresponds to a structural break whose duration is equal to the horizontal length of the interval and whose break-specific estimate of ω_k is equal to the height of the interval. It is evident that the breaks that we identify correspond closely to both our baseline results and the first set of structural breaks that we identified in Figure 10.

As before, official SAR periods are presented purely for reference. These findings provide further empirical support for our interpretation of the baseline results. In particular, (1) the effect of crossing conditions at departure during *Hermes* 2011 is now clearly negative, which is consistent with the fact that journeys during this period were likely shorter (1 day) as they disproportionately left from Tunisia (Figure B.1); (2) the effects of crossing conditions at departure during the *Mare Nostrum* structural breaks are now clearly negative, which is consistent with

Figure 11: Effects of Crossing Conditions on Crossing Attempts When Searching



Note: Structural breaks are identified using the procedure outlined in the text. Estimates correspond to the interaction effects of crossing conditions (ω_k). 95% confidence intervals are constructed with standard errors clustered by month of the year. Differently colored regions represent different SAR operations.

the fact that inflatable boats became the dominant form of transport; (3) attempted crossings during the structural breaks during *Triton II* are now even more elastic to crossing conditions, which is consistent with the fact that a greater patrol area (see Table 1) might have reduced the expected journey length.

5.3 Relaxing Empirical Assumption 3 (Point of Departure)

We now no longer make assumptions on the point of departure of journeys. Instead, we repeat the structural break-finding exercise described in Section 5.2, but we now allow for smugglers and migrants to respond to crossing conditions at one of three distinct points along the North African shore: Tripoli and Benghazi, Libya; and Al Huwariyah, Tunisia. We remain agnostic to the timing and intensity of SAR operations and to the expected duration of crossings. Specifically, we perform the following procedure:

1. For each day t in our sample period, we estimate the following three regressions on the subsample of our data that excludes day t. In this case $\mathbf{H}$ is a vector comprising four different locations (Tripoli, Benghazi and Al Huwariyah):

$$c_t = \omega^A \mathbf{H}_t^{1/3} + \mu_{w(t)} + \epsilon_t \tag{8}$$

$$c_t = \omega^D \mathbf{H}_{t-1}^{1/3} + \mu_{w(t)} + \epsilon_t \tag{9}$$

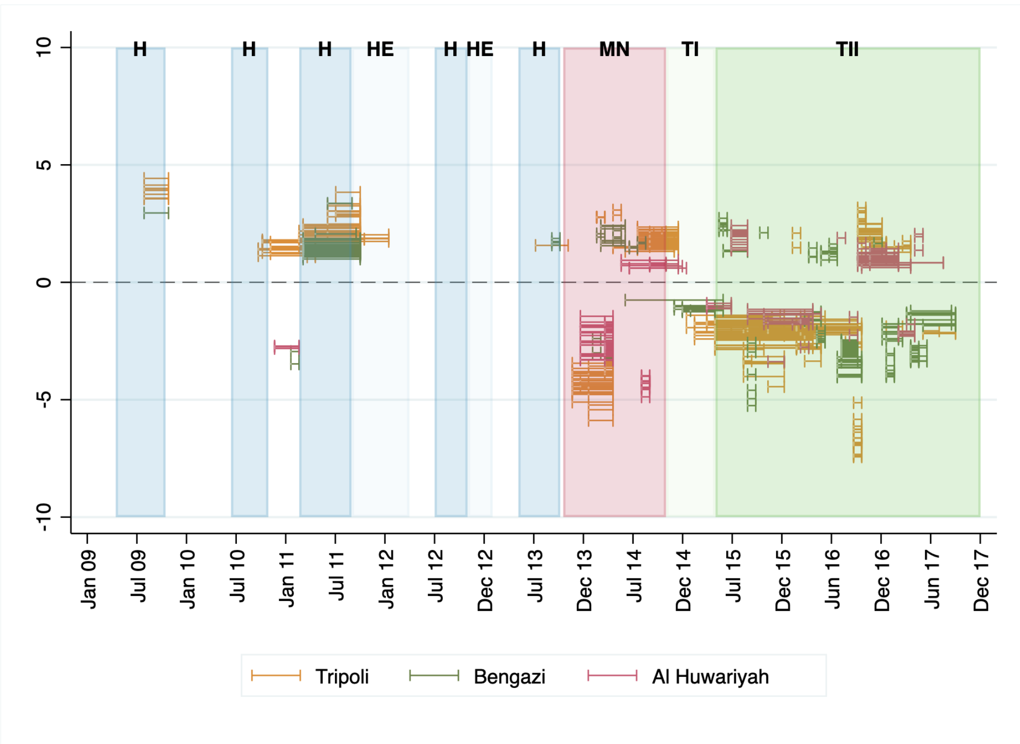
$$c_t = \omega^D \mathbf{H}_{t-1}^{1/3} + \omega^A \mathbf{H}_t^{1/3} + \mu_{w(t)} + \epsilon_t \tag{10}$$

2. For each day t, we compare the three (out-of-sample) predictions of c_t. If equation (9) or (10) performs best, then we infer that journeys that concluded on day t were expected to take two days and hence departed on day $t-1$. If equation (8) performs best, then we infer that journeys that concluded on day t were expected to take one day and hence departed on day t.

3. For every day *and a given location* in our sample period (t_0) we consider hypothetical values of (t_1) that are 15 or more days later. We allow t_1 and t_0 to be at a maximum of one year.

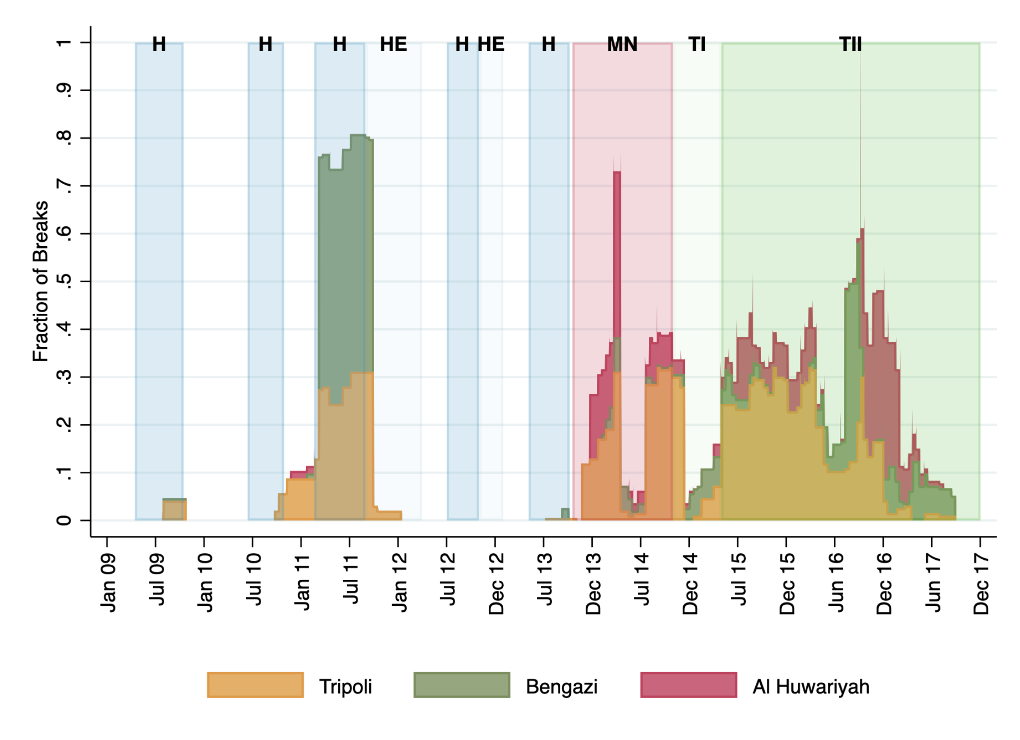
4. For every interval $[t_0, t_1]$ we estimate equation (4) where SAR operation k refers to that interval. Importantly, we replace $H_{t-1}^{1/3}$ with the significant wave height on the day of

Figure 12: Effects of Crossing Conditions on Crossing Attempts When Searching for Structural Breaks in Different Locations



Note: Structural breaks are identified using the procedure outlined in the text. Estimates correspond to the interaction effects of crossing conditions (ω_k). Differently colored regions represent different SAR operations.

Figure 13: Fraction of Daily Crossings Influenced by SAR by Point of Departure



Note: A crossing is influenced by SAR if it lies in a structural break identified by the procedure outlined in the text. Differently colored bars indicate how likely a crossing originated in Tripoli, Bengazi (Libya) or Al Huwariyah (Tunisia) over 100 bootstrapped repetitions. Differently colored background regions represent different SAR operations.

departure as inferred in steps 1 and 2, and we replace $H_t^{1/3}$ with significant wave height on the day of arrival as inferred in steps 1 and 2. We select the interval $[t_0, t_1]$ that provides best model fit (on the basis of the Poisson's pseudo log-likelihood) and interpret that as a structural break.

5. We repeat steps 3 and 4 by re-estimating equation (4) disregarding the period that have previously been identified as a SAR operation. We stop when the p-value of the interaction terms is not significant at 0.1% level.

6. We repeat steps 3, 4 and 5 for each of the four locations.

We present the results of this exercise in Figure 12. Early in our sample period, the bulk of breaks appear to originate from Tripoli, and later during *Triton II* the breaks migrate to Benghazi. This is consistent with unrest in Tunisia driving the initial waves of migration from Tripoli, and a once more distant journey being shortened by an expanded SAR zone and driving the later waves of migration from Libya.

Our empirical findings can be summarized succinctly in Figure 13 below. The heights of the bars in this figure correspond to the likelihood that a crossing on that day was influenced by SAR, which is inferred entirely from crossing and tidal data and uses zero information on official SAR operations. The colors of each bar correspond to the estimated share of crossings that were initiated at each of three points of departure. Our analysis strongly suggests that the most intense SAR operations (*Triton II*, *Mare Nostrum* and *Hermes* 2011) were also the most influential and that most departures were from Libya.

6 Conclusion

Irregular migration is a large and growing concern for 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 (SAR) and whose internal politics have been riven by this issue.

After analyzing nearly a decade of data on crossings, we find that while SAR has no doubt saved lives directly, it may have had adverse unintended consequences that must be considered. First, by reducing the risk of crossing, SAR likely induced more migrants to attempt to cross, and in doing so, exposed more people to the risk of death along the passage. Second, by reducing the costs to traffickers of using unsafe boats, SAR induced a large substitution away from seaworthy wooden vessels and towards flimsy, inflatable boats. Thus, the benefits of SAR have been, to some extent, captured by human smugglers.[39]

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. The obvious parallel to well-known "trolley problems" in philosophy suggests that this is a moral dilemma with no unambiguous solution. 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.[40] In the interest of being constructive, our analysis suggests that a major policy goal of SAR operations should be to limit substitution from seaworthy boats to inflatable ones.[41] One way to do so would by interceding in the trade of such items to Libya. The EU's ban on inflatable craft exports to Libya is a step in the right direction, though most craft are produced in China and Figure 3 suggests that they may still enter Libya through Egypt and Turkey.

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

[39] Our results are consistent with Fasani and Frattini (2019)'s finding that increased EU border enforcement over land deters migrant crossings, while over sea it does not.

[40] European policy makers would also have to consider the conditions that migrants face in Libya while attempting to cross the sea.

[41] This is in line with Spain's decision to ban underpowered (less than 150kwh) inflatable boats that are longer than 8 meters.

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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Appendix A: Proofs

Proof. Proposition 1. Note that migrant i will cross if $\alpha_i > \frac{p}{\sigma^R(h)}$.

1. By Assumption A2, $\frac{p}{\sigma^1(h)} < \frac{p}{\sigma^1(h)}$, so the marginal migrant under SAR has lower α_i than in the absence of SAR. The claim follows.

2. By Assumption A3, the α_i of the marginal migrant decreases less under SAR than in the absence of SAR, and under Assumption A1 the number of marginal migrants decreases more under SAR than in the absence of SAR. The claim follows.

□

Proof. Lemma 1. 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 A4.

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

Proof. Proposition 2.

1. By A6, $\frac{p_u}{\sigma_u^1} < \frac{p_u}{\sigma_u^0}$, so Lemma 1 implies that total attempted crossings will increase under SAR. Also by A6 $\frac{p_s - p_u}{\sigma_s^1 - \sigma_u^1} > \frac{p_s - p_u}{\sigma_s^0 - \sigma_u^0}$, 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 h is lower under SAR. This is equivalent to showing

$$f\left(\frac{p_u}{\sigma_u^1}\right)\frac{p_u}{(\sigma_u^1)^2}\frac{\partial \sigma_u^1}{\partial h} < f\left(\frac{p_u}{\sigma_u^0}\right)\frac{p_u}{(\sigma_u^0)^2}\frac{\partial \sigma_u^0}{\partial h} \tag{11}$$

By A5, 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

$$\lim_{\sigma_u^0 \to 0} f\left(\frac{p_u}{\sigma_u^0}\right)\frac{p_u}{(\sigma_u^0)^2}\frac{\partial \sigma_u^0}{\partial h} = 0 \tag{12}$$

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 h under SAR, which completes the proof.

□

Proof. Proposition 3.

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

$$\frac{\partial M_s^R}{\partial p_s^R}(p_s^R - c_s) + M_s^R + \frac{\partial M_u^R}{\partial p_s^R}(p_u^R - c_u) = 0 \tag{13}$$

$$\frac{\partial M_s^R}{\partial p_u^R}(p_s^R - c_s) + \frac{\partial M_u^R}{\partial p_u^R}(p_u^R - c_u) + M_u^R = 0 \tag{14}$$

Note that prices and crossings are now allowed to vary by R. Adding equations (13) and (14) together, we obtain

$$\left(\frac{\partial M_s^R}{\partial p_s^R} + \frac{\partial M_s^R}{\partial p_u^R}\right)(p_s^R - c_s) + \left(\frac{\partial M_u^R}{\partial p_s^R} + \frac{\partial M_u^R}{\partial p_u^R}\right)(p_u^R - c_u) + M_s^R + M_u^R = 0 \tag{15}$$

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 5) 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 5). 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

$$\begin{aligned} p_u^R &= c_u + \frac{M_s^R + M_u^R}{\frac{1}{\sigma_u^R} f\left(\frac{p_u^R}{\sigma_u^R}\right)} \\ &= c_u + \frac{\sigma_u^R}{\lambda\left(\frac{p_u^R}{\sigma_u^R}\right)} \end{aligned} \tag{16}$$

The second term in equation (16) 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 (16), we can write

$$\frac{p_u^1}{\sigma_u^1} - \frac{p_u^0}{\sigma_u^0} = \left[\frac{1}{\lambda\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{1}{\lambda\left(\frac{p_u^0}{\sigma_u^0}\right)} \right] + \left[c_u \left(\frac{1}{\sigma_u^1} - \frac{1}{\sigma_u^0} \right) \right] \tag{17}$$

A1 implies that the first term of equation (17) is negative, and A6 implies that the second term of equation (17) is negative, hence the total number of crossings increases.

Now, substituting from equation (13), we obtain

$$M_s^1 - M_s^0 = \frac{\partial M_s^1}{\partial p_s^1}(p_s^1 - c_C) + \frac{\partial M_u^1}{\partial p_s^1}(p_u^1 - c_u) - \left[\frac{\partial M_s^0}{\partial p_s^0}(p_s^0 - c_C) + \frac{\partial M_u^0}{\partial p_s^0}(p_u^1 - c_u) \right] \tag{18}$$

Assuming $p_s^1 > p_s^0$ and $p_u^1 > p_u^0$ (which we will establish independently later on in this proof), A1 implies that the right hand side of equation (18) 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 h.

2. Substituting from equation (16), we have

$$p_u^1 - p_u^0 = \frac{M_s^1 + M_u^1}{\frac{1}{\sigma_u^1} f\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{M_s^0 + M_u^0}{\frac{1}{\sigma_u^0} f\left(\frac{p_u^0}{\sigma_u^0}\right)} = \frac{\sigma_u^1}{\lambda\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{\sigma_u^0}{\lambda\left(\frac{p_u^0}{\sigma_u^0}\right)} \tag{19}$$

This combined with A1 implies that the right hand side of equation (19) is greater than zero, so p_u increases under SAR.

Rearranging equation (13) yields

$$M_s^R = -\left[\frac{\partial M_u^R}{\partial p_s^R}(p_u^R - c_u) + \frac{\partial M_s^R}{\partial p_s^R}(p_s^R - c_s) \right] \tag{20}$$

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 (20) to express p_s^R as

$$p_s^R = c_s + \left[(p_u^R - c_u) + \frac{\sigma_s^R - \sigma_u^R}{\lambda\left(\frac{p_s^R - p_u^R}{\sigma_s^R - \sigma_u^R}\right)} \right] \tag{21}$$

from which the markup on p_s^R is given in the second term. Using equation (21), we can write

$$p_s^1 - p_s^0 = (p_u^1 - p_u^0) + \left[\frac{\sigma_s^1 - \sigma_u^1}{\lambda\left(\frac{p_s^1 - p_u^1}{\sigma_s^1 - \sigma_u^1}\right)} - \frac{\sigma_s^0 - \sigma_u^0}{\lambda\left(\frac{p_s^0 - p_u^0}{\sigma_s^0 - \sigma_u^0}\right)} \right] \tag{22}$$

p_u was shown to increase under SAR, so the first term of equation (22) is greater than zero. Similarly, total safe crossings were shown to decrease under SAR, so A6 and A1 together imply that the second term of (22) is greater than zero, hence p_s increases under SAR. Finally, if we move the first term on the right hand side of equation (22) 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.

□

Proof. Lemma 2. From Lemma 1, $\underline{\alpha} = \frac{p_u}{\sigma_u}$ and $\overline{\alpha} = \frac{p_s - p_u}{\sigma_s - \sigma_u}$. The same logic implies that $\underline{\alpha}' = \frac{p_s}{\sigma_s}$. It follows that

$$\underline{\alpha}' = \left(\overline{\alpha}\left(\sigma_s - \sigma_u\right) + p_u\right)\frac{1}{\sigma_s} \tag{23}$$

$$= \frac{\sigma_s - \sigma_u}{\sigma_s}\overline{\alpha} + \frac{\sigma_u}{\sigma_s}\frac{p_u}{\sigma_u} \tag{24}$$

$$= \theta\underline{\alpha} + (1-\theta)\overline{\alpha} \tag{25}$$

□

Proof. Proposition 4.

Under the assumption that significant wave height follows a Rayleigh distribution, a boat of type b that can safely resist waves up to height H will cross safely on a day with crossing conditions equal to h with probability $\sigma_b = 1 - e^{\frac{-2H^2}{h^2}}$. Using the approximation that $\log(1-\sigma) = 1 - \sigma$ for σ close to 0, then under a given SAR, we obtain

$$\sigma_b^{SAR} \approx \left(\frac{h^2}{2H^2}\right)^{-1} \tag{26}$$

$$\approx \frac{1}{\gamma_b^{SAR} + \delta_b^{SAR} h}, \tag{27}$$

where the second line follows from a linear approximation to match our empirical specification.[42]

[42] Appendix Table B.7 shows that using the quadratic function to avoid such approximation gives similar results.

Combining Assumption A7 and Lemma 1, we can write the total number of crossing attempts under a given SAR operation as

$$A^{SAR} = e^{-\lambda \frac{p_u}{\sigma_u^{SAR}}} \tag{28}$$

Noting that $\theta = \frac{\sigma_u}{\sigma_s}$ and $\overline{\alpha} = \frac{p_s - p_u}{\sigma_s - \sigma_u}$, equation (27) implies that

$$\overline{\alpha} = \frac{\theta \left(p_s - p_u\right)}{1 - \theta} \left(\gamma_u^{SAR} + \delta_u^{SAR} h\right) \tag{29}$$

Defining $\omega_u = \omega_0 + \omega_1 + \omega_2 + \omega_2$ and $\omega_s = \omega_0 + \omega_1$ to be the semi-elasticities for safe and unsafe boats estimated in equation (3), it implies that

$$\begin{aligned} \omega_s &= -\lambda \frac{\theta \left(p_s - p_u\right)}{1 - \theta} \delta_u^{SAR} \\ \omega_u &= -\lambda p_u \delta_u^{SAR} \end{aligned}$$

Taking the ratio, we get that

$$\frac{\omega_s}{\omega_u} = \frac{\theta}{1 - \theta} \frac{p_s - p_u}{p_u}, \tag{30}$$

which completes the proof.

□

Appendix B: Additional Tables and Figures (For Online Publication Only)

Table B.1: Irregular Migration During Search and Rescue Operations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total Attempts	Crossing Risk	Distance (in km) to:				
			Tripoli	Bengazi	Al Huwariyah	Min (Tripoli Bengazi & Al Huwariyah)	Lampedusa)
Hermes 2011	2.21***	0.00	-34.20	-49.70**	38.01	-5.16	0.71
	(0.38)	(0.03)	(28.78)	(21.43)	(27.20)	(20.71)	(25.13)
Hermes 2011a	-0.26	0.03	-32.63	-120.59**	120.10**	37.41	66.97
	(0.49)	(0.05)	(32.88)	(47.01)	(58.85)	(26.82)	(53.77)
Hermes 2012	0.23	0.03	-22.27	-7.75	-1.34	5.57	-32.66
	(0.34)	(0.02)	(50.06)	(42.10)	(56.00)	(27.39)	(52.36)
Hermes 2013	1.70***	0.00	47.34	-61.76*	26.28	95.94***	-17.00
	(0.35)	(0.02)	(38.77)	(36.19)	(34.14)	(21.38)	(31.53)
Hermes 2013a	0.49	0.06	-47.91*	-20.13	44.60	-19.75	16.76
	(0.50)	(0.06)	(26.48)	(28.60)	(29.93)	(18.82)	(26.47)
Mare Nostrum	2.55***	0.07***	-107.55***	-106.34***	123.25***	-29.17	66.64***
	(0.30)	(0.03)	(33.61)	(22.86)	(28.03)	(25.08)	(21.06)
Triton I	2.42***	0.08**	-180.60***	-102.92***	160.50***	-63.95***	83.78***
	(0.37)	(0.03)	(26.52)	(25.92)	(25.70)	(17.96)	(16.50)
Triton II	2.56***	0.10***	-171.17***	-101.38***	167.25***	-77.34***	106.63***
	(0.29)	(0.02)	(25.27)	(18.77)	(23.67)	(15.82)	(17.14)
Observations	3,287	1,579	503	503	503	503	503
Pre Mean Outcome	24	0.03	325	784	259	206	134
Pre Median Outcome	0	0.00	306	787	233	223	168
Estimator	PPML	OLS	OLS	OLS	OLS	OLS	OLS

Notes: SAR coefficients are estimated relative to a baseline in which no SAR operations were in place. Crossing Risk is defined as the number of deaths per total attempts. Distances are measured for crossing with casualties. All regressions control for 52 weeks of the year fixed effects. Regressions estimated with OLS. Standard errors clustered by month times year * p<.10 ** p<.05 *** p<.01.

Table B.2: 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`

Table B.3: Summary Statistics

	All			No Operation			Hermes			Mare Nostrum			Triton		
	Obs	Mean	St. Dev	Obs	Mean	St. Dev	Obs	Mean	St. Dev	Obs	Mean	St. Dev	Obs	Mean	St. Dev
Attempted Crossings	3287	175.15	403.02	654	30.33	130.22	1097	83.18	222.02	379	308.10	519.49	1157	300.66	525.05
Deaths	3287	4.59	33.29	654	1.59	19.24	1097	2.18	21.26	379	7.23	30.20	1157	7.71	46.82
Crossing Risk	1579	0.09	0.26	166	0.05	0.19	443	0.04	0.17	217	0.09	0.26	753	0.13	0.31
Wave in Tripoli	3287	0.82	0.51	654	0.92	0.50	1097	0.77	0.48	379	0.79	0.47	1157	0.82	0.53
Max Wave in Tripoli (t, t-1)	3287	0.96	0.57	654	1.09	0.54	1097	0.90	0.55	379	0.93	0.54	1157	0.97	0.61
Wave in Bengazi	3287	0.92	0.60	654	1.07	0.66	1097	0.86	0.56	379	0.84	0.50	1157	0.91	0.60
Wave in Al Huwariyah	3287	1.08	0.76	654	1.29	0.79	1097	0.98	0.72	379	1.06	0.72	1157	1.06	0.78
Wave Combined Tripoli	3287	0.82	0.51	654	0.92	0.50	1097	0.77	0.48	379	0.79	0.47	1157	0.82	0.53
Wave Combined Tripoli/Al Huwariyah	3287	0.90	0.60	654	1.20	0.73	1097	0.84	0.56	379	0.79	0.47	1157	0.82	0.53
Distance to Tripoli	503	186.27	136.69	38	314.20	139.69	75	297.49	109.55	50	196.30	130.18	340	145.96	119.38
Distance to Bengazi	503	253.51	143.93	38	395.28	139.37	75	374.86	115.74	50	266.64	132.47	340	208.97	124.77
Distance to Lampedusa	503	215.87	93.09	38	152.00	93.42	75	136.79	97.10	50	207.50	94.24	340	241.69	77.58

Note: Crossing Risk is estimated as total daily deaths divided by total daily attempted crossings. The data on wave height come from the European Centre for Medium-Range Weather Forecasts (ECMWF) from daily runs at 12 UTC. The spatial resolution of the data set is approximately 79 km spacing for the surface around the geographical coordinates. The wave height from Tripoli has latitude 33 and longitude 13.5 which is roughly 16 nautical miles (30km) off the principal seaport in Tripoli and 10 nautical miles (18km) from the shortest route to the Libyan coast. The location in Al Huwariyah (37.25, 11.25) is 20 nautical miles (35km) from the Tunisian coast and 50 nautical miles (90km) far way from Pantelleria Island (Italy), while Bengazi (Lybia) wave height is close by the coast.

Table B.4: Attempted Crossings: Robustness using OLS

	(1)	(2)	(3)
		Total Attempts	
		Wave Height in Tripoli (t)	
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-288.51	-337.57***	-290.80***
	(249.29)	(93.06)	(85.89)
Wave Height	-92.08**	-135.06***	-144.90***
	(39.96)	(35.60)	(35.91)
Wave Height * Fr. Boat	138.43	146.55**	143.44**
	(237.78)	(74.30)	(67.97)
Wave Height * Post SAR	-26.59	74.22	73.91
	(51.73)	(45.76)	(49.29)
Observations	1,469	1,469	1,469
Week-Year FE	X	X	X
Pre Mean Outcome	131.573	131.573	131.573

Note: SAR coefficients are estimated relative to a baseline in which Hermes operations were in place. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using OLS. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table B.5: Attempted Crossings: Robustness on Cluster Standard Errors

	(1)	(2)	(3)
		Total Attempts	
		Wave Height in Tripoli (t)	
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-6.55***	-5.45***	-4.17***
	(1.63)	(1.31)	(1.37)
	[2.97]	[1.74]	[1.50]
	{1.95}	{1.42}	{1.31}
	|2.13|	|1.58|	|1.43|
Wave Height	-0.89**	-1.43**	-1.46**
	(0.38)	(0.61)	(0.69)
	[0.41]	[0.78]	[0.78]
	{0.39}	{0.65}	{0.66}
	|0.39|	|0.73|	|0.74|
Wave Height * Fr. Boat	2.13	1.91	1.63
	(1.47)	(1.25)	(1.20)
	[2.89]	[1.69]	[1.35]
	{1.85}	{1.37}	{1.17}
	|2.04|	|1.54|	|1.29|
Wave Height * Post SAR	0.21	1.17*	1.00
	(0.48)	(0.65)	(0.78)
	[0.49]	[0.82]	[0.89]
	{0.46}	{0.68}	{0.77}
	|0.46|	|0.76|	|0.84|
Observations	1,469	1,469	1,469
Week-Year FE	X	X	X
Pre Mean Outcome	131.573	131.573	131.573

Note: SAR coefficients are estimated relative to a baseline in which Hermes operations were in place. Squared Significant wave height squared is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are clustered at the month of the year and week of the year level in parentheses and squared brackets, respectively. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 21 days and 14 days in curly brackets and vertical bars, respectively. * p<.10 ** p<.05 *** p<.01.

Table B.6: Attempted Crossings: Robustness on Wave Height

	(1)	(2)	(3)	(4)	(5)	(6)
	Total Attempts					
	Wave Height in Tripoli (t-1)			**Max Wave Height in Tripoli (t and t-1)**		
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*	*Inflatable*	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-0.85	-2.10**	-1.84*	-2.27	-3.24***	-2.79***
	(2.46)	(0.90)	(0.97)	(1.98)	(0.91)	(0.88)
Wave Height	0.21	-0.10	-0.09	-0.24	-0.69**	-0.70**
	(0.37)	(0.39)	(0.39)	(0.30)	(0.34)	(0.35)
Wave Height * Fr. Boat	-1.68	0.41	0.35	-0.90	0.86	0.73
	(2.40)	(0.78)	(0.81)	(1.92)	(0.84)	(0.73)
Wave Height * Post SAR	0.17	0.52	0.58	0.13	0.79**	0.92*
	(0.45)	(0.48)	(0.56)	(0.35)	(0.39)	(0.49)
Observations	1,469	1,469	1,469	1,469	1,469	1,469
Week-Year FE	X	X	X	X	X	X
Pre Mean Oucome	131.57	131.57	131.57	131.57	131.57	131.57

Note: SAR coefficients are estimated relative to a baseline in which Hermes operations were in place. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table B.7: Attempted Crossings on Wave Height Squared

	(1)	(2)	(3)
	Total Attempts		
	Wave Height in Tripoli (t)		
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-5.93***	-3.76***	-2.73***
	(1.56)	(0.82)	(1.00)
Wave Height	-0.48**	-0.64*	-0.84**
	(0.21)	(0.34)	(0.41)
Wave Height * Fr. Boat	1.65	0.76	1.09
	(1.50)	(0.77)	(0.80)
Wave Height * Post SAR	0.37	0.68*	0.72
	(0.23)	(0.35)	-0.46
Observations	1,469	1,469	1,469
Week-Year FE	X	X	X
Pre Mean Outcome	131.573	131.573	131.573

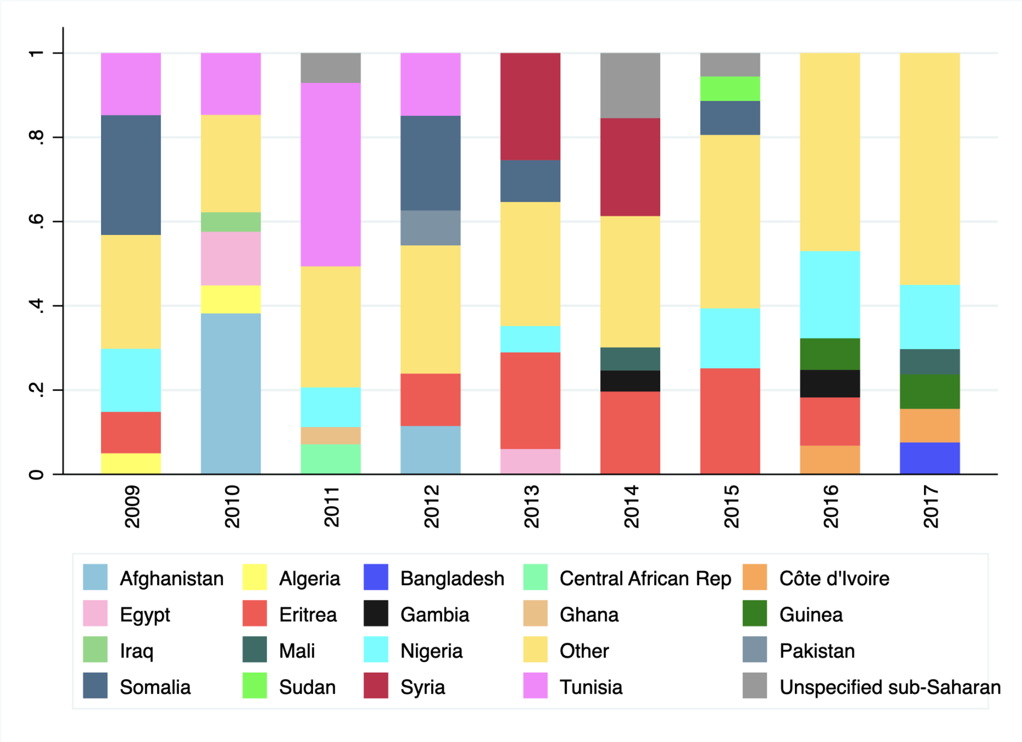
Note: SAR coefficients are estimated relative to a baseline in which Hermes operations were in place. Squared Significant wave height squared is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table B.8: Effects of Crossing Conditions on Crossing Attempts

	(1)	(2)	(3)	(4)	(5)	(6)
			Total Attempts			
Wave Height	-1.70***	-2.14***	-1.61***	-1.35***	-1.96***	-2.46***
	(0.46)	(0.28)	(0.22)	(0.18)	(0.20)	(0.28)
Wave Height * Hermes	0.44	0.23	-1.18***			
	(0.49)	(0.38)	(0.36)			
Wave Height * Mare	0.25	0.68	0.70	-0.11	0.51	1.55***
	(0.60)	(0.49)	(0.45)	(0.44)	(0.45)	(0.48)
Wave Height * Triton I	-0.25	0.18	0.16	-0.61**	0.00	1.02*
	(0.49)	(0.34)	(0.58)	(0.27)	(0.28)	(0.61)
Wave Height * Triton II	-1.14**	-0.70*	1.13***	-1.49***	-0.88***	1.98***
	(0.52)	(0.38)	(0.28)	(0.31)	(0.33)	(0.33)
Lag Wave Height			-1.24**			0.37
			(0.58)			(0.37)
Lag Wave Height * Hermes			2.03***			
			(0.60)			
Lag Wave Height * Mare			0.02			-1.60***
			(0.71)			(0.55)
Lag Wave Height * Triton I			-0.05			-1.66***
			(0.75)			(0.60)
Lag Wave Height * Triton II			-1.40**			-3.02***
			(0.63)			(0.44)
$\omega_0 + \omega_{Hermes}$	-1.263***	-1.911***	-2.784***			
	(0.187)	(0.248)	(0.297)			
$\omega_0 + \omega_{Mare}$	-1.454***	-1.454***	-0.908***	-1.454***	-1.454***	-0.908***
	(0.397)	(0.397)	(0.390)	(0.397)	(0.397)	(0.390)
$\omega_0 + \omega_{TritonI}$	-1.956***	-1.956***	-1.442***	-1.956***	-1.956***	-1.442***
	(0.192)	(0.192)	(0.541)	(0.192)	(0.192)	(0.541)
$\omega_0 + \omega_{TritonII}$	-2.839***	-2.839***	-0.478***	-2.839***	-2.839***	-0.478***
	(0.255)	(0.255)	(0.175)	(0.255)	(0.255)	(0.175)
Lag $\omega_0 + \omega_{Hermes}$			0.788***			
			(0.313)			
Lag $\omega_0 + \omega_{Mare}$			-1.223***			-1.223***
			(0.402)			(0.402)
Lag $\omega_0 + \omega_{TritonI}$			-1.287***			-1.287***
			(0.468)			(0.468)
Lag $\omega_0 + \omega_{TritonII}$			-2.641***			-2.641***
			(0.234)			(0.234)
Wave Height type:	Combined Tripoli & Al Huwariyah	Combined Tripoli	No Combined Tripoli	Combined Tripoli & Al Huwariyah	Combined Tripoli	No Combined Tripoli
Observations	2,900	2,900	2,899	2,900	2,900	2,899
Week-Year FE	X	X	X	X	X	X

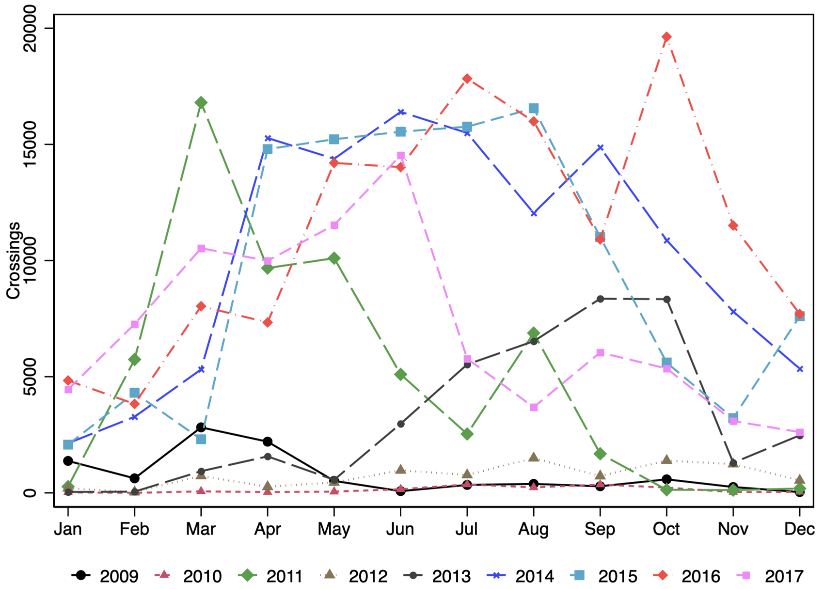
Note: SAR coefficients are estimated relative to a baseline in which No Operations were in place (column 1 to 3). SAR coefficients are estimated relative to a baseline in which No Operations and Hermes were in place (column 4 to 6). All regressions include week-by-year fixed effects. In Column 1 and 4 we use the combined wave from Tripoli and Al Huwariyah meaning that we take wave at time t from Al Huwariyah for the pre-Gheddaffi period and wave at time t-1 from Tripoli otherwise. In Column 2 and 5 we consider the combined wave condition from Tripoli meaning that we take wave at time *t* fot the pre-Gheddaffi period and wave at time t-1 otherwise. In Column 3 and 6 we consider the wave condition from Tripoli. Results in italics demonstrate the total effect. Standard errors clustered by month times year. * p<.10 ** p<.05 *** p<.01.

Figure B.1: Nationalities of Migrants on the Central Route by Year



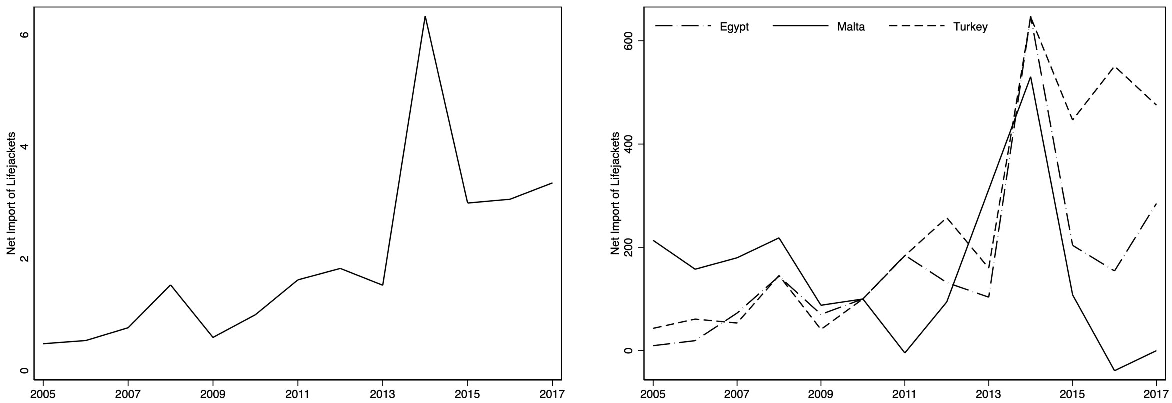
Source: EU-Frontex Data on detections at the border.

Figure B.2: Monthly Crossings



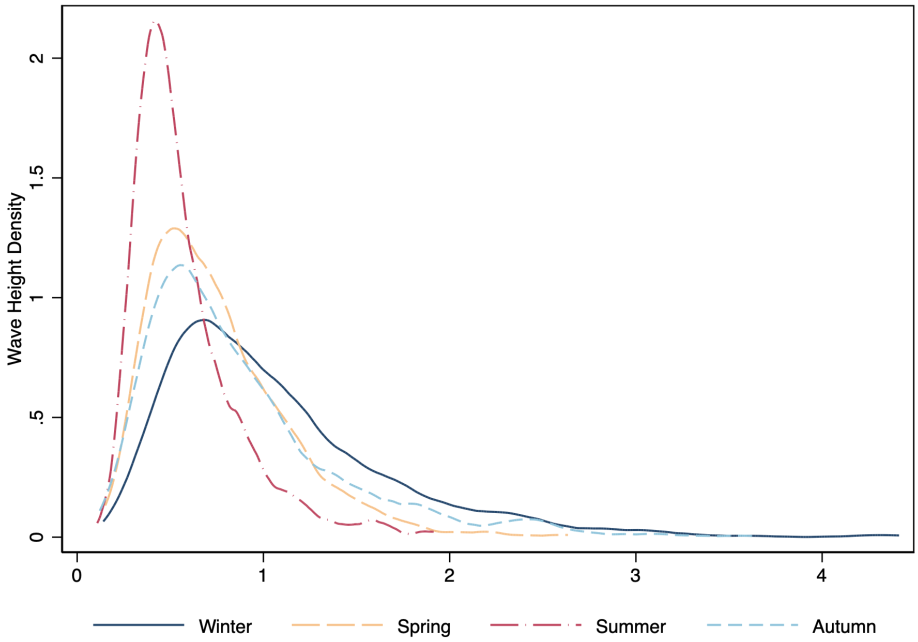
Source: Italian Ministry of Interior.

Figure B.3: Net Import of Life Jackets



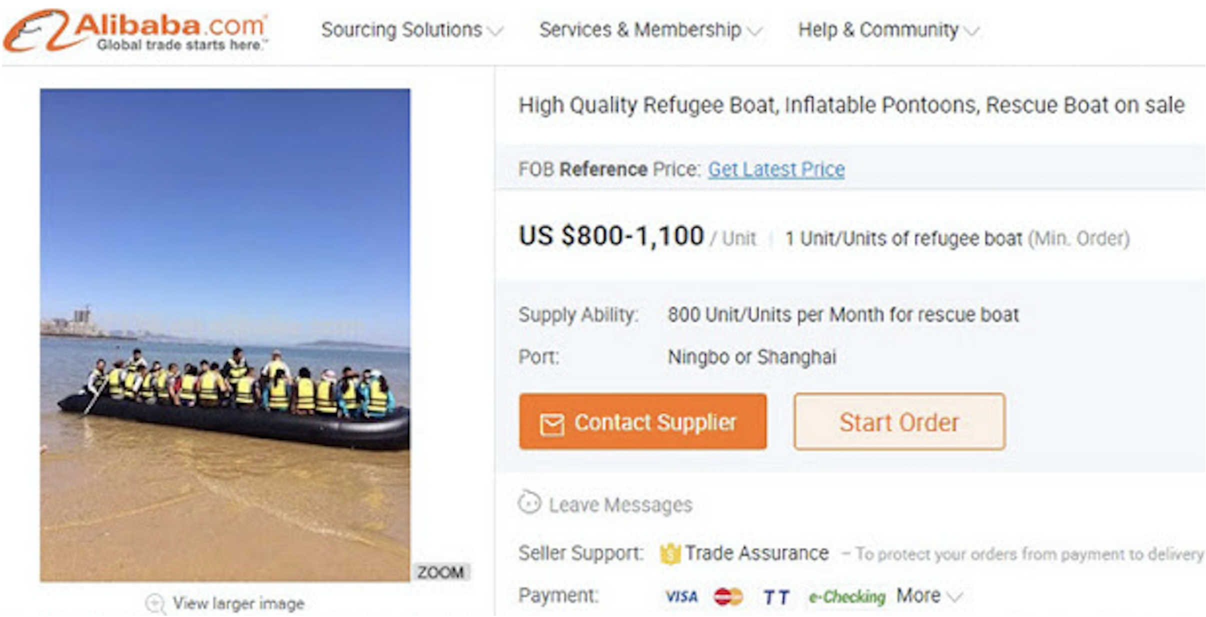
Note: The series show net-imports of life jackets to countries near Libya for which data are available (Malta, Turkey, and Egypt). The data source is the United Nations Comtrade. Both series are normalized to 100 in 2010.

Figure B.4: Density of Significant Wave Height by Season



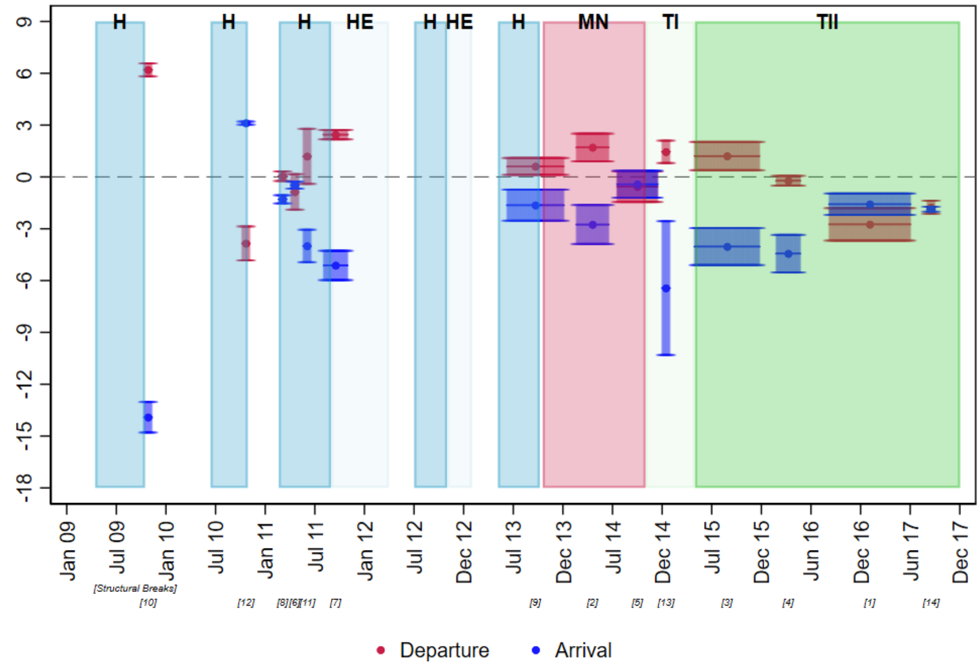
Source: European Centre for Medium-Range Weather Forecasts (ECMWF). Wave from Tripoli.

Figure B.5: A Typical Inflatable Boat



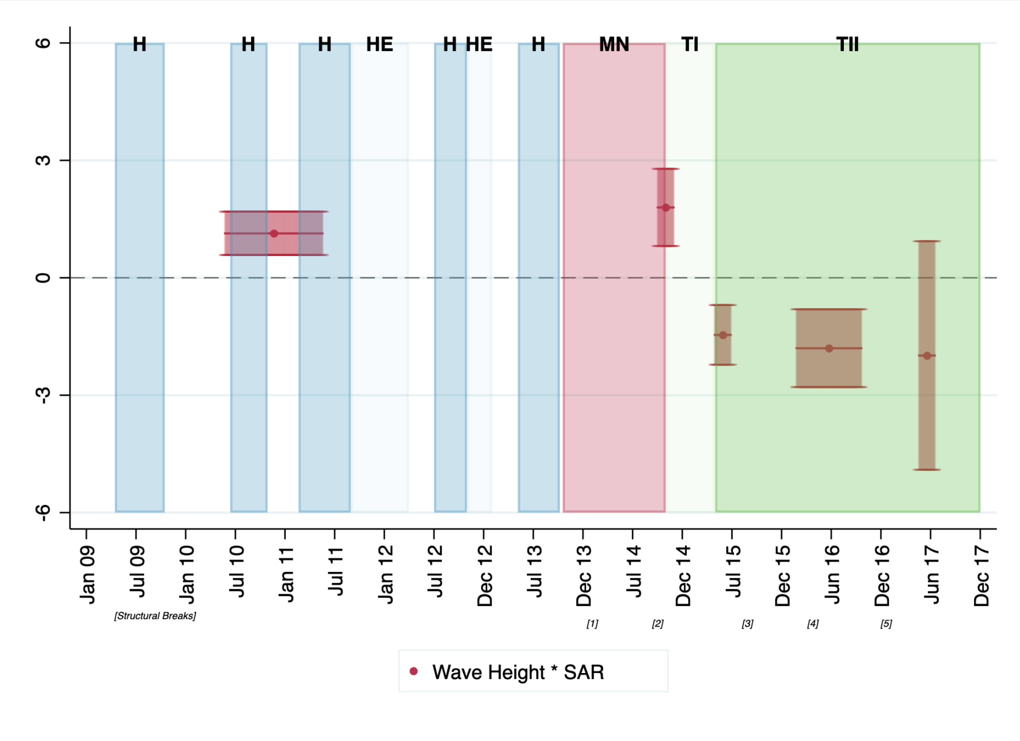
Source: `https://www.alibaba.com`.

Figure B.6: Effects of Crossing Conditions on Crossing Attempts When Searching for Structural Breaks - 15 days



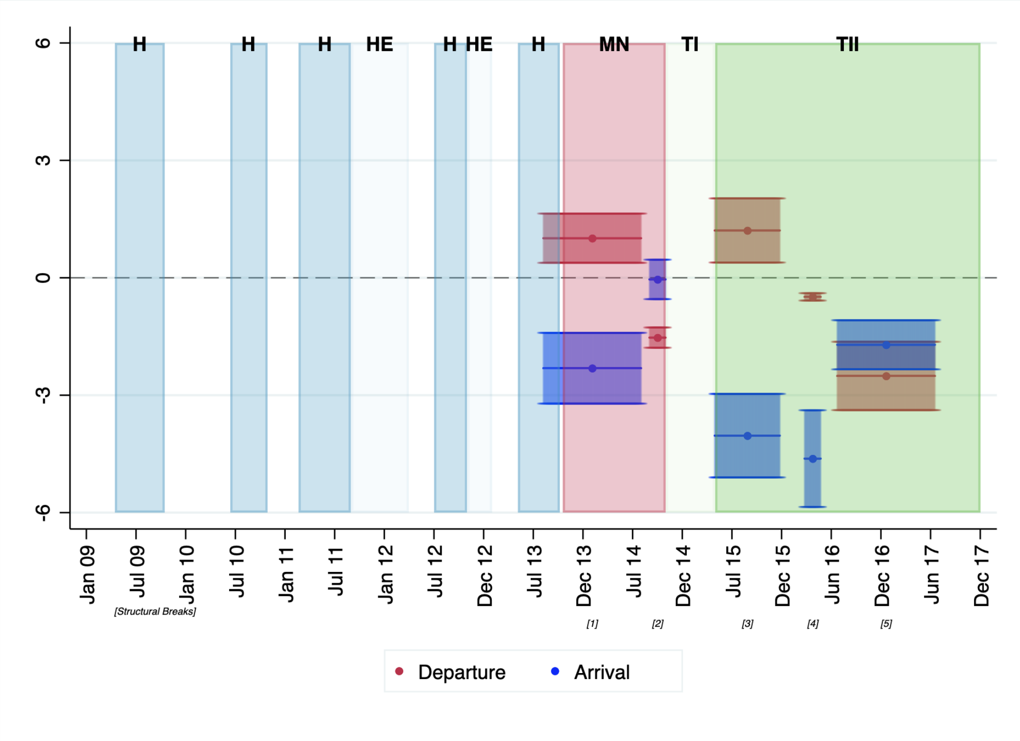
Structural breaks are identified using the procedure outlined in the text. We use the combined wave from Tripoli and Al Huwariyah meaning that we take wave at time t from Al Huwariyah for the pre-Gheddaffi period and wave at time t-1 from Tripoli otherwise. Estimates in red correspond to the effects of conditions at departure ($\omega_0^D + \omega_k^D$) and estimates in blue correspond to the effects of conditions upon arrival ($\omega_0^A + \omega_k^A$). 95% confidence intervals shown are calculated with month of the year standard errors. Differently colored regions representing different official SAR operations are provided for reference.

Figure B.7: Effects of Crossing Conditions on Crossing Attempts: Structural Break Search - 30 days



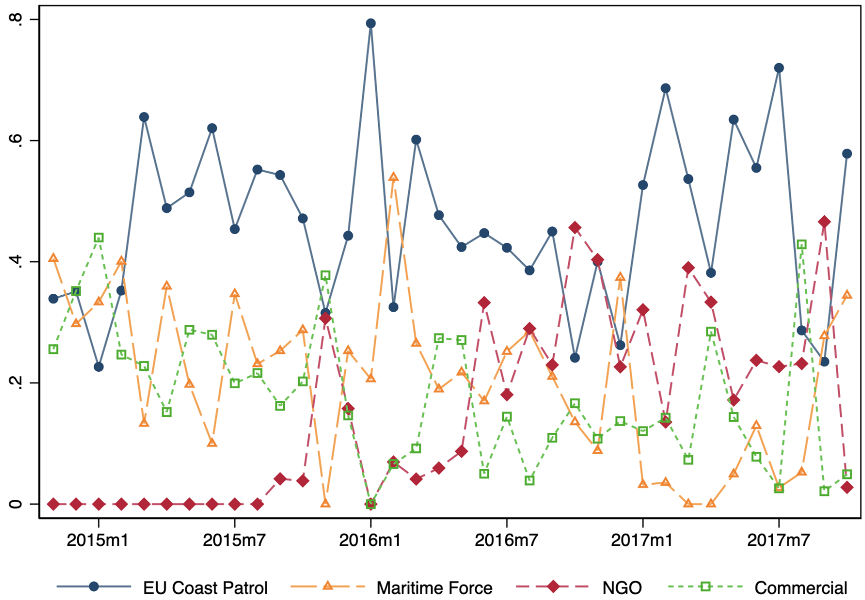
Structural breaks are identified using the procedure outlined in the text. We use the combined wave from Tripoli and Al Huwariyah meaning that we take wave at time t from Al Huwariyah for the pre-Gheddaffi period and wave at time t-1 from Tripoli otherwise. Estimates correspond to the interaction effects of crossing conditions (ω_k). 95% confidence intervals shown are constructed with standard errors clustered by month of the year. Differently colored regions represent different SAR operations.

Figure B.8: Effects of Crossing Conditions on Crossing Attempts When Searching for Structural Breaks - 30 days



Structural breaks are identified using the procedure outlined in the text. We use the combined wave from Tripoli and Al Huwariyah meaning that we take wave at time t from Al Huwariyah for the pre-Gheddaffi period and wave at time t-1 from Tripoli otherwise. Estimates in red correspond to the effects of conditions at departure ($\omega_0^D + \omega_k^D$) and estimates in blue correspond to the effects of conditions upon arrival ($\omega_0^A + \omega_k^A$). 95% confidence intervals shown are calculated with month of the year standard errors. Differently colored regions representing different official SAR operations are provided for reference.

Figure B.9: Rescue Activity by Organization 2014-2017



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

Appendix C: NGO Operations (For Online Publication Only)

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 capabilities 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 (see Table C.1).

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 B.9, 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 C.2 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

Table C.1: 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 C.2: Effects of Crossing Conditions on Crossing Attempts, NGO and Minniti periods

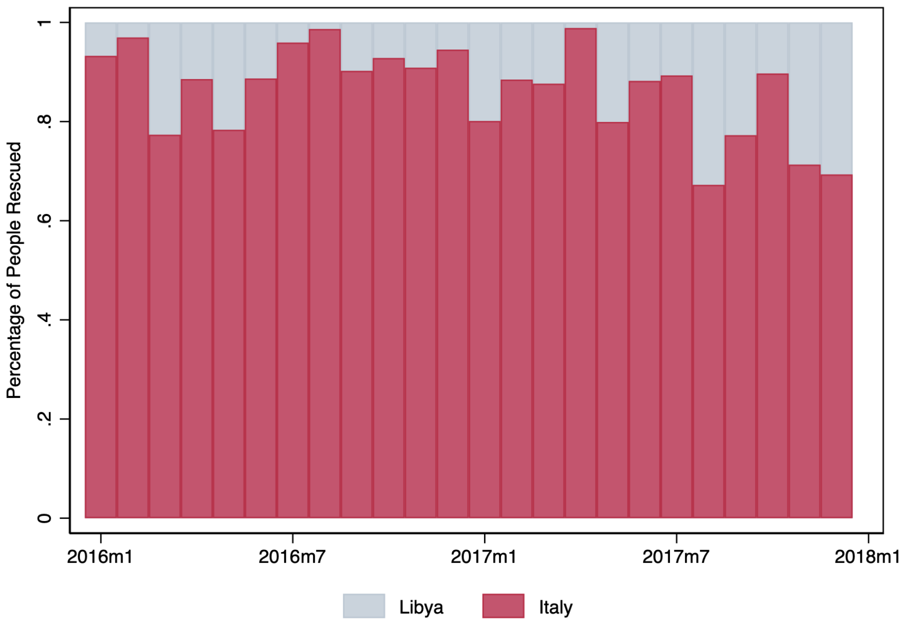
	(1)	(2)
	Total Attempts	
Wave Height	-1.62***	-1.62***
	(0.22)	(0.22)
Lag Wave Height	-1.25**	-1.25**
	(0.58)	(0.58)
Wave Height * Hermes 2009	-0.12	-0.12
	(0.66)	(0.66)
Wave Height * Hermes 2010	-1.86	-1.86
	(1.58)	(1.58)
Wave Height * Hermes 2011	-1.27***	-1.27***
	(0.38)	(0.38)
Wave Height * Hermes 2011a	-1.67	-1.67
	(1.27)	(1.27)
Wave Height * Hermes 2012	0.15	0.15
	(1.09)	(1.09)
Wave Height * Hermes 2013	-1.03	-1.03
	(0.96)	(0.96)
Wave Height * Hermes 2013a	-0.20	-0.20
	(0.36)	(0.36)
Wave Height * Mare Nostrum	0.67	0.66
	(0.42)	(0.42)
Wave Height * Triton I	0.17	0.17
	(0.58)	(0.58)
Wave Height * Triton II	0.92***	0.81***
	(0.30)	(0.31)
Wave Height * MOAS	0.36	0.46
	(0.34)	(0.35)
Wave Height * NGO Code of Conduct		0.66
		(0.44)
Lag Wave Height * Hermes 2009	1.55**	1.55**
	(0.62)	(0.62)
Lag Wave Height * Hermes 2010	2.43	2.43
	(1.53)	(1.53)
Lag Wave Height * Hermes 2011	2.29***	2.29***
	(0.64)	(0.64)
Lag Wave Height * Hermes 2011a	2.45**	2.45**
	(1.21)	(1.21)
Lag Wave Height * Hermes 2012	0.94	0.94
	(1.06)	(1.06)
Lag Wave Height * Hermes 2013	1.53**	1.53**
	(0.63)	(0.63)
Lag Wave Height * Hermes 2013a	-1.84**	-1.84**
	(0.82)	(0.82)
Lag Wave Height * Mare Nostrum	0.02	0.01
	(0.72)	(0.72)
Lag Wave Height * Triton I	-0.04	-0.04
	(0.75)	(0.75)
Lag Wave Height * Triton II	-1.41**	-1.55**
	(0.70)	(0.73)
Lag Wave Height * MOAS	-0.00	0.12
	(0.46)	(0.50)
Lag Wave Height * NGO Code of Conduct		0.62
		(0.67)
Observations	2,899	2,899
Week-Year FE	X	X
Estimator	PPML	PPML

Note: SAR coefficients are estimated relative to a baseline in which No Operations were in place. All regressions control for week-year fixed effects. Standard errors clustered by month of the year. * p<.10 ** p<.05 *** p<.01.

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.[43]

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 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.

Figure C.1: Percentage of Migrants Intercepted at Sea by Libyan and Italian Coast Guards



Source: Authors calculations from UNHCR data (2017).

[43] 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 C.1). 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.