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

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**Abstract**

The Central Mediterranean Sea is among the most dangerous crossings for irregular migrants in the world. 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 exogenous variation from rapidly varying crossing conditions, we find that smugglers responded by sending boats in more adverse weather and shifting from seaworthy boats to flimsy rafts. As a result, these operations induced more crossings in dangerous conditions, ultimately offsetting their intended safety benefits due to moral hazard and increasing the realized *ex post* crossing risk for migrants. In spite of the increased risk, it is likely that these operations increased migrant welfare in the aggregate; nevertheless, a more successful policy should instead restrict the supply of rafts and expand legal alternatives for migration.

**Keywords**: Moral hazard, Central Mediterranean, sea crossings, international migration, undocumented migration, search and rescue operations, rubber boats, smugglers, migrants, Africa

**JEL codes**: F22 (International Migration); H12 (Crisis Management); K37 (Immigration Law); K42 (Illegal Behavior and the Enforcement of Law).

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# 1 Introduction

Many Western countries are facing increased migratory pressure over both land and 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 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: 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;[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; 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.[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. In many other European countries, the vote shares of similarly-oriented parties have reached double digits. In recent polls, the vote share of the Italian populist anti-immigration parties "Lega" and "Fratelli d'Italia" jumped from roughly 15 percent to more than 40 percent. The enormous gain, at least for the "Lega," is believed to be due to their 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 its short distance,

[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] 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.

[4] Bazzi et al. (2021) 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.

[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.

this is now agreed to be the among the deadliest water crossings 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 high profile shipwrecks, Italy and the EU initiated extensive search and rescue (SAR) operations at sea in the form of operations *Hermes*, *Mare Nostrum*, *Triton* and *Themis*.[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 due to moral hazard, 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 along the journey in practice. Although Italy and the EU reduced the geographic scope of their operations beginning in 2017, several NGOs and private actors have 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 high-frequency data on crossing attempts by country of origin and boat type, the insights of a novel model of smuggling, and plausibly exogenous, high-frequency variation in the physical conditions of each crossing attempt.[10] Under fairly weak assumptions, we show theoretically that if migrant crossing attempts responded systematically differently to crossing conditions

[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 web site (`http://www.marinetraffic.com/`).

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

with and without SAR operations in place, then we can infer that these operations induced more crossing attempts. Hence, instead of attempting to circumvent the empirical obstacles described above, we can focus on the feasible empirical question of identifying the short-run elasticity of crossing attempts to weather and tidal conditions.

We find that more far-reaching SAR operations induced more migrants to attempt crossings in bad weather, and this eventually led smugglers to shift their operations to unsafe, inexpensive boats. We estimate that almost all additional crossings due to SAR were attempted on inflatable boats, which are estimated to be about 20 times more dangerous than sturdy wooden boats. As a result, the safety benefits of SAR were offset through moral hazard, which led to an increase in the *ex post* riskiness of passage during the most intense periods of SAR. We complement these results with direct evidence of crossings attempted on inflatable boats. In the summer of 2017, the Italian government introduced legislation that forced NGO rescue vessels out of Libyan waters. The observed sudden reduction in crossing attempts, mostly on inflatable boats, is exactly in line with the predictions of our model.

Increases in both total crossing attempts and the riskiness of passage implies that SAR operations increased the total number of deaths in transit. However, we must 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 made worse off by SAR-induced changes in prices, migrants were made better off in aggregate since many more could now afford to attempt the journey in the first place on a three to four times cheaper inflatable boat. However, some of the benefits of SAR likely accrued to smugglers to the extent that they enjoyed market power. As rents to smugglers represent losses to social welfare, this further complicates a full welfare analysis of SAR operations that lies beyond the scope of this paper. Our analysis seeks to offer 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.

The intuition behind our model and empirical approach is straightforward. SAR operations plausibly increase the *ex ante* probability of a successful crossing *ceteris paribus* (where success is defined as an arrival into Italy). Because this benefit is greater for migrants attempting to cross on less safe vessels, SAR distorts both the total number of crossing attempts and the ratio of crossing attempts on seaworthy versus unsafe boats due to moral hazard. Because unsafe vessels are more vulnerable to adverse crossing conditions than seaworthy boats, the distortion across vessel types in turn affects the elasticity of total attempts to crossing conditions. Our estimated magnitude of boat-switching from safe to unsafe boats during periods of intense SAR implies a decrease in the *ex post* probability of safe passage.

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 combine this information with careful research of the timing of SAR operations between 2009-2020. For the later years of our sample (2016-2020) we also observe the country of migrant departure which allows us to exploit a sudden and large drop in the availability of NGO rescue boats close to the Libyan coast for additional identification (see Section A.1 in the Appendix). 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 (wave height), data on migrant boat types, and a carefully researched catalog of SAR operations from 2009-2020.

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) demand for smugglers.

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 empirical literature on risk 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.[13] 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. A more detailed description of these operations is provided in the online appendix. We also describe the various sources of data used in our analysis. In Section 3,

[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.

[13] 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.

we present a simple model of human smuggling that highlights the incentives that shape the decisions of smugglers and potential migrants and indicates an empirical strategy to answer our questions of interest. In Section 4 we describe our empirical model to estimate the responsiveness of smugglers and migrants to crossing conditions, and we interpret our results through the lens of our model to identify the effects of SAR on crossings and riskiness of passage. We conclude with a brief discussion in Section 5.

# 2 Background and Data

## 2.1 Historical Background

The Mediterranean Sea has been the home of trade and migration routes for millennia. Italy, with its strategic central position and proximity to African shores, has always been an important trading hub as a well as a major port of entry into Europe. One major migratory route runs from Libya to the Italian island of Lampedusa, which is closer to Africa (167km or about 100 miles from Ras Kaboudja, Tunisia and 296km from Tripoli, Libya) than to the European mainland (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 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. This time may be dramatically shortened if migrants are rescued early and transported to Lampedusa on military or NGO vessels.[14]

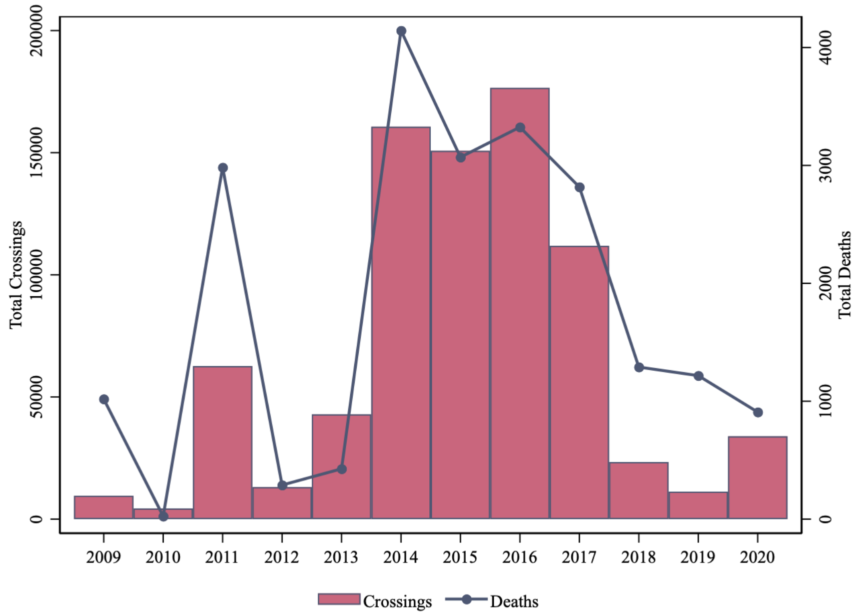
Between 1997 and 2008, the number of irregular crossings from North Africa to Italian shores was stable at around 20,000 per year until Italy and Libya signed a treaty on August 30, 2008 and crossings dropped to roughly 9,500 in 2009 and 4,500 in 2010 (see Figure 1). This established Tunisia as a major point of departure for migrants.[15] Tripoli fell in the August of 2011, which then led to a surge of Libyan refugees. Libyan dictator Muammar Ghaddafi was captured and killed in October 2011 rendering the 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.[16] After two relatively calm years, attempted crossings

[14] 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.

[15] In January 2011, Tunisian President Ben Ali was forced to flee following a month of protests, which kicked off the "Arab Spring". As shown in Appendix Figure C.1, almost half of migrants on the Central-Mediterranean route in 2011 were Tunisians.

[16] The Libyan Army and the police often worked together to force migrants that had been living and working

Figure 1: Crossings and Deaths Along the Central Route, 2009-2020




Note: Bars show the total number of crossings to Italy (on the left axis). Solid line displays the number of deaths in transit along the Central Mediterranean Route (on the right axis). Italian data on total crossings come from the *Polizia di Stato*, the Italian State Police. The data on deaths at sea are from The Migrants File data available at `https://www.themigrantsfiles.com`. The majority of the migrants over the Central Mediterranean route arrived to Italy (and a very small number to Malta). Over the same period Malta registered 24,778 total crossings only.

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.

## 2.2 Data

For our analysis, we combine data from several sources that focus on irregular migration along the Central Route from 2009 to 2020. 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.

### 2.2.1 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

in Libya to leave for Italy (Frontex, 2012).

Table 1: EU Operations

| EU Operations | Dates | Maritime SAR Distance from Italian shores (in km) | Budget per month | Budget total |
|---|---|---|---|---|
| **Hermes - Main operations** | 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 |
| *Extension* | 01 Sep – 31 Mar 12 | 22* | | |
| *Extension* | 01 Nov – 31 Jan 13 | 22* | | |
| | | **Intense SAR** | | |
| **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 Jan 18 | 256 | 18.2 | 437 |
| **Themis** | 01 Feb 18 – 31 Dec 20 | 24 | 22.3 | 721 |
| 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. More intense SAR operations are *Mare Nostrum*, *Triton I*, *Triton II* and *Themis*. Information on the extent of the SAR zone is sometimes hidden in official Frontex Operational Plans (2009-2020). 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). Budget during Themis Operation is retrieved from the Frontex Programming Document 2020 - 2022 (Frontex, 2019). 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).

dates, jurisdiction and budgets in Table 1.[17] We provide a detailed description of each of the major SAR operations in Appendix A.1.

## 2.3 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,

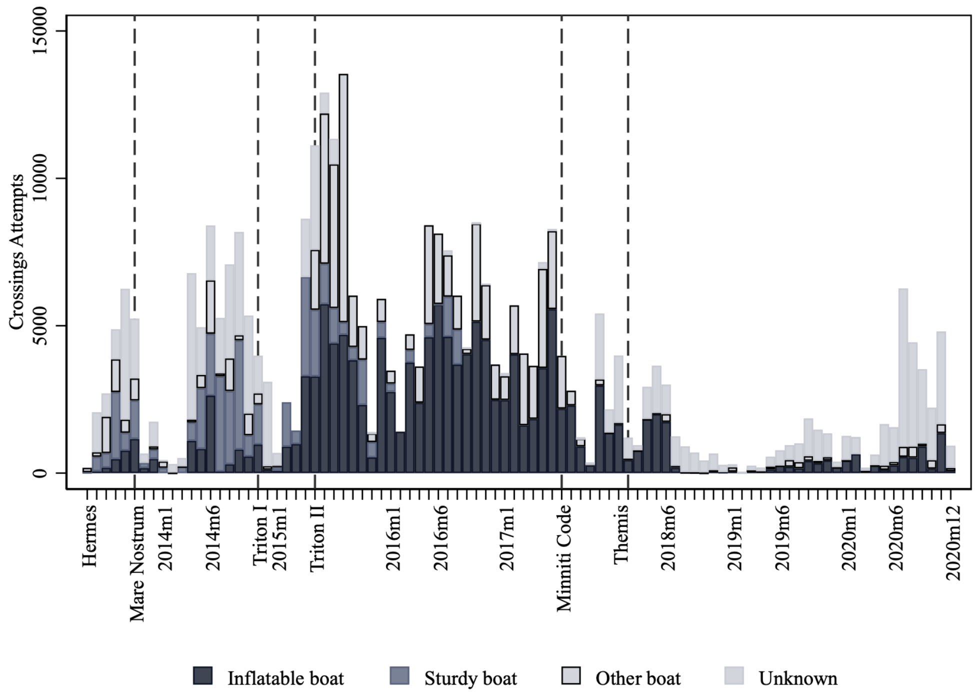
[17] Moreover, in response to the many casualties several Non-governmental organizations started providing aid and emergency medical relief to refugees and migrants. The first vessels of the NGO Migrant Offshore Aid Station (MOAS) started looking for migrant boats in distress close to Libyan shores towards the end of August 2014. Other NGOs followed in later years (a full list is shown in Appendix Table D.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.

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]

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 C.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 such operations were in place only after 2016. Based on our data on crossings merged with UNHCR (2017) data (see Appendix Figure A.1), the fraction of

Figure 2: Types of Vessels Used, 2013-2020




Note: Bars show the monthly total number of crossings attempts to Italy by different types of boats. The information on crossing attempts, which are the sum of crossings and deaths in transit, are disclosed by the European Border and Coast Guard Agency known as Frontex (for the period from 1 January 2013 to October 2017) and by State Police (for the period November 2017 to December 2020). Vertical dotted lines display the start of SAR Operations (Hermes, Mare Nostrum, Triton I, II and Themis) and Minniti Code (August 7, 2017).

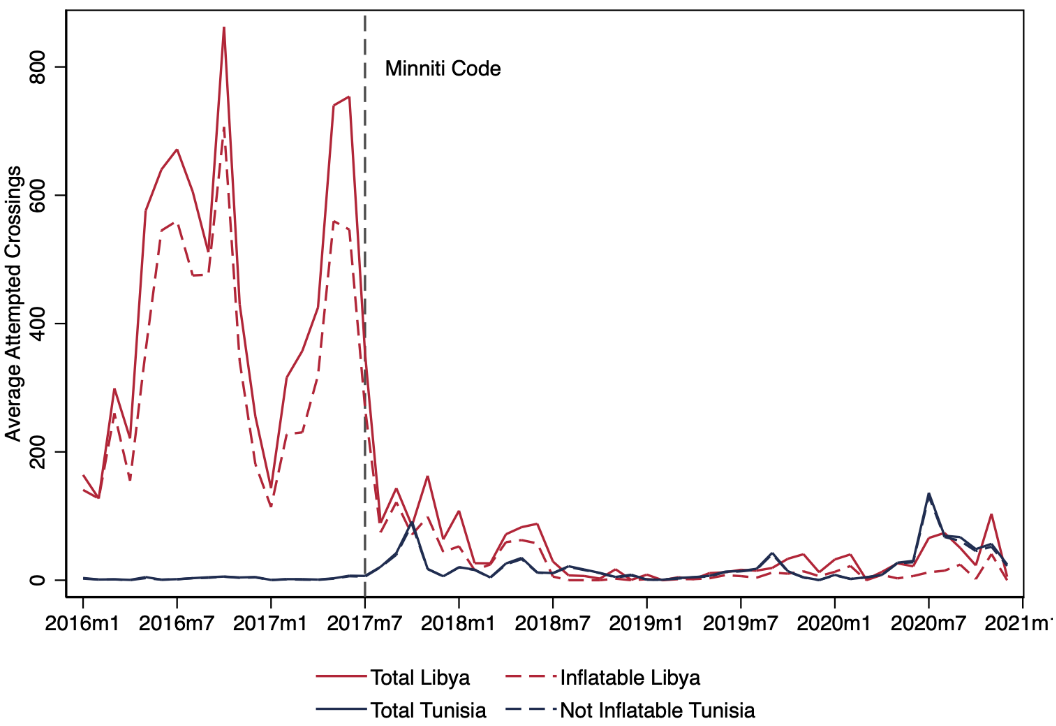
[18] Most of the migrants arrive on the Lampedusa shores (22%), Augusta (20%) and Pozzallo (14%) in Sicily. Beginning in 2016, we observe the country of departure and boat type for each arriving vessel. According to the 2017 Euro Asylum Seeker Survey Bank (2018), which collected information from a random 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 sizable error.

migrants rescued by the LCG is around 10 percent and starts growing only towards the end of 2017. Our results that use data up until 2017 are robust to dropping this period. Later we discuss how LCG interceptions influence the set of results that are based on country of departure-level data.

We also gathered information on vessel type from Frontex for the years 2013-2017, while for the 2016-2020 period we gathered this information by country of departure directly from the *Polizia di Stato*.[19] 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, "other boats" and "unknown boats" become the main vessel used by smugglers. Figure 3 shows that the use of inflatable boats drops again relative terms towards the second half of 2017, after the "Minniti" code and with the beginning of operation *Themis*.

The observed shift in vessel type coincided with a massive increase in rubber boat imports

Figure 3: Attempted Crossings by Ports of Departure, 2016-2020




Note: Red and dark navy blue solid lines display the average attempted crossings by the month and the routes: Libya and Tunisia, respectively. Red and dark navy blue dashed lines display the average attempted crossings with inflatables. The information on crossing attempts, which are the sum crossings and deaths in transit, by different routes (Libya and Tunisia) and types of boats (Inflatable and Not Inflatable boats) are disclosed by *Polizia di Stato*, the Italian State Police (2016-2020). Vertical dotted lines display the start of Minniti Code (August 7, 2017).

[19] We obtained this data via a Freedom of Information Act (FOIA) request. Unfortunately we were denied access to data from 2009-2013.

from China to Malta, Turkey, and Egypt, intermediate stops along the way to Libya. Net-imports of rubber boats and wooden ferries moved roughly in tandem from 2005-2012, after which they sharply diverged (see Appendix Figure C.3). Indeed, in 2014 and 2015 (towards the end of *Mare Nostrum* and the beginning of *Triton II*, two periods of increasing SAR activity) net-imports increase by a factor of 5, followed by another sharp increase in 2017 at the end of *Triton II*. By comparison, imports of other vessels are flat.[20] This pattern is further mirrored by trends in imports of life-jackets to Egypt, Libya and Malta, whose benefits would largely accrue to passengers on unsafe, inflatable vessels.[21]

### 2.4 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.

Our primary source is UNITED for Intercultural Action, the European network in support of migrants, refugees and minorities.[22] 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.[23] We also consider the data from Frontex that spans 2014-2016 and the *Migrants File* dataset that spans 2009-2016.[24]

Given that migrant boats try to navigate the shortest path between the African shore and Lampedusa, we can use the locations of shipwrecks to predict the most likely point of departure. For a given shipwreck, we draw a straight line South from Lampedusa to its location and note where this line intersects the African coastline. We then normalize the angle (-180 degrees

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

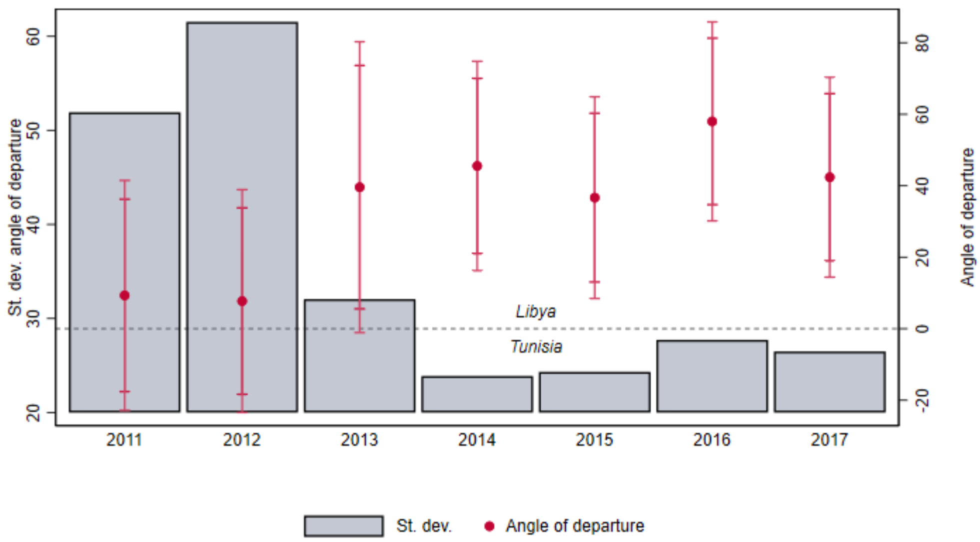
[21] The conjectured use of life-jackets on unsafe boats is also evidence that smugglers are constrained by the safety concerns of migrants through competition.

[22] 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.

[23] 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).

[24] 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 (after this data these data cease to be available). In case of missing information on the number of deaths, we consider the data from IOM, Frontex and *Migrants File*.

Figure 4: Predicted Points of Departure, 2011-2017




Note: The figure shows the average angle of departure based on the locations of shipwrecks and corresponding 90 and 95 percent confidence intervals. The total number of observations is 143. The angles are normalized so that negative values correspond to predicted departures from Tunisia and positive values correspond to predicted departures from Libya. See Appendix Figure C.4 for a detailed map of shipwrecks used to construct this figure.

to 180 degrees) between Lampedusa and the coastal border of Tunisia and Libya to be 0.[25] Negative values of this angle correspond to departures from Tunisia, and positive values of this angle correspond to departures from Libya.[26]

In Figure 4, we plot the average angle of departure along with confidence intervals for each year from 2011-2017. There is a noticeable change in the predicted points of departure in 2013, the first year that *Mare Nostrum* was in place. Most journeys shift from Tunisia to Libya.[27] Moreover, there is a stark decrease in the standard deviation of the angle of departure from about 60 degrees to 30 degrees. Since smugglers tend to be affiliated to local tribesmen who have exclusive control over their territory, we interpret this as evidence of the increasing market concentration of Libyan smugglers who are located close to Tripoli. We discuss the ramifications of market power among smugglers in our model.

## 2.5 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

[25] Using Pozzallo (Sicily) instead of Lampedusa leads to similar patterns. We implement this exercise using a subsample of Frontex data where the locations of shipwrecks are disclosed over the period 2009-2017.

[26] In Appendix Figure C.4, we present a map of fatal sea accidents in the Mediterranean Sea with corresponding angles.

[27] Columns 3 to 7 of Appendix Table C.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.

in the open sea. It combines information on wind, waves and swell, all of which may cause shipwrecks.[28] 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 modeling 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).

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

Table 2: Summary Statistics

| **Sample 2013-2017: 1612 Observations** | *Mean* | *Sd* | *Min* | *Max* |
|---|---|---|---|---|
| Attempted Crossings | 164.483 | 316.160 | 0 | 3051 |
| Wave Height in Tripoli *(33°N 13°30′E)* | 0.787 | 0.498 | 0.108 | 4.164 |
| Max Wave Height in Tripoli (t,t-1) | 0.927 | 0.568 | 0.143 | 4.164 |
| Wave Height in Zuwara *(33°N 12°00′E)* | 0.671 | 0.376 | 0.101 | 3.071 |
| Wave Height in Al Huwariyah *(37°25′N 11°25′E)* | 1.015 | 0.743 | 0.070 | 5.274 |
| Wave Height in Monastir *(36°N 11°25′E)* | 0.865 | 0.601 | 0.073 | 4.173 |
| Wave Height in Djerba *(34°N 11°00′E)* | 0.746 | 0.434 | 0.084 | 2.848 |
| Wave Height in Annaba *(37°5′N 7°30′E)* | 0.966 | 0.727 | 0.145 | 5.580 |
| Fraction of Inflatable Boats | 0.395 | 0.374 | 0 | 1 |
| Fraction of Inflatable+Unknown Boats | 0.586 | 0.422 | 0 | 1 |
| Fraction of Inflatable+Unknown+Other Boats | 0.656 | 0.396 | 0 | 1 |

| **Sample 2016-2020: 3654 Observations (1827 by Route)** | *Mean* | *Sd* | *Min* | *Max* |
|---|---|---|---|---|
| Route: **Lybia** | | | | |
| Attempted Crossings | 168.547 | 511.015 | 0 | 5504 |
| Wave Height | 0.928 | 0.618 | 0.120 | 5.506 |
| Fr. of Inflatable Boat | 0.565 | 0.370 | 0 | 1 |
| Route: **Tunisia** | | | | |
| Attempted Crossings | 17.284 | 51.733 | 0 | 580 |
| Wave Height | 0.786 | 0.588 | 0.091 | 4.403 |
| Fraction of Inflatable Boats | 0.152 | 0.283 | 0 | 1 |

Note: The two subsamples consist of daily crossings from 1 January 2013 to 31 December 2017 and daily crossings disaggregated by country of departure (Libya and Tunisia) from 1 January 2016 to 31 December 2020. Crossing attempts include successful crossings and deaths in transit. Significant wave height is measured in meters and in different locations: Tripoli and Zuwara, Libya; Al Huwariyah, Monastir and Djerba, Tunisia; Annaba, Algeria. 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.

[28] Appendix Table C.2 describes wave and swell in terms of height and length.

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 and Zuwara, Libya; Al Huwariyah, Monastir and Djerba, Tunisia; Annaba, Algeria. Figure C.5 shows the density of the significant wave height by season.

Given the large number of data sources covering different sample periods that we combine for our analysis, we are able to conduct our main analysis on the period from 2013 to 2020, and we present auxiliary results when possible using data from other time periods. We summarize all of our main variables over the primary sample period in Table 2. There are about 160 attempted crossings per day in the 2013-2017 period. The average for the 2016-2020 period is also close to 160, but only for Libya. The average for Tunisia is an order of magnitude smaller. Average wave heights vary between 0.8 and 1 meter and tend to be slightly higher in Libya. Finally, it is worth highlighting the fact that even though Libya is much farther away from Italy than Tunisia, departures from there are considerably more likely to take place on inflatable boats, which is consistent with Frontex assets (and later on NGO rescue boats) locating primarily in Libyan waters.

# 3 Model

We present a simple model of irregular migration that highlights the important incentives faced by smugglers and potential migrants to guide our empirical analysis. Because many features of this market are incompletely observed at best (e.g., prices, vessel types), the implications of our model help us to infer 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.

### Case 1: Single Boat Type

We start with a model of smuggling in which only a single type of boat is available, and we explore how SAR affects migrants' decisions. This roughly corresponds to the pre-*Mare Nostrum* period before inflatable boats became an integral part of the market for passage on the Central Route. On the demand side, we assume a unit mass of potential migrants. Migrant $i$ has utility

$$u_i = \alpha_i \sigma^R(h) - p \tag{1}$$

where $\alpha_i$ is an individual specific parameter that reflects the intensity of $i$'s desire to cross and is distributed according to the continuous density $f$, $\sigma^R$ is the probability of successful passage, and $p$ is the price of passage.[29]

[29] 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 is close to US$2,250 and includes the cost of reaching the African coast, which is roughly 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).

We make a standard monotone likelihood ratio assumption on $f$ that can be easily expressed in terms of the hazard function $\lambda(\cdot)$:

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

Because only a minority of potential migrants attempts to cross, we probably observe the behavior of individuals in the right tail of the distribution of $\alpha$, which makes assumption A1 quite plausible. $\sigma^R$, which represents the probability of successful passage, is a decreasing function of crossing conditions (wave height), $h$, and it should differ if an extensive SAR is in place ($R = 1$) or not ($R = 0$). As such, we make the following assumptions on $\sigma^R$:

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

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

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 relax this assumption later on).[30]

**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 $\alpha_i$ of the marginal migrant who attempts to cross. This result, combined with Assumptions A1 and A3 immediately yield the second part of Proposition 1.

*Remark 1* Our ultimate goal is to empirically assess whether SAR increases total crossing attempts (part 1 of Proposition 1, but this effect is difficult to identify in the absence of exogenous variation in SAR. Under weaker assumptions on the exogeneity of crossing conditions, we can instead test the second part of Proposition 1. The following corollary allows us to connect this to our primary objective:

**Corollary 1.** *Under Assumptions A2 and A3, if total attempted crossings become less elastic to crossing conditions under SAR, then total attempted crossings will increase under SAR.*

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.

[30] It is straightforward to incorporate dynamic considerations into the model; we opt not to in the interest of simplicity. If we interpret $\alpha_i$ as the surplus enjoyed by a migrant who successfully crosses (relative to one who perishes en route), and we consider the alternative condition that migrant $i$ will attempt passage if $u_{it} > \delta E[u_{it+1}]$ where $\delta$ is the discount rate, then we can simplify this to $\alpha_i \left(\sigma_b^R(h) - \delta E(\sigma_b^R(h)\right) > (1-\delta)p_b$. The remainder of the analysis follows as before with slight modifications to the formulas for $\underline{\alpha}$ and $\overline{\alpha}$ given in Lemma 1.

### Case 2: Multiple Boat Types

We now consider an environment in which 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 Appendix Figure C.6). This corresponds to the post-*Mare Nostrum* period in which both wooden boats and inflatable boats were employed in large numbers. We generalize equation (1) as

$$u_i = \alpha_i \sigma_b^R(h) - p_b \tag{2}$$

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

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

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

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

Assumption A4 simply states that irrespective of weather conditions "safe" boats are more likely to complete the journey than "unsafe" boats. Assumption A5 states that 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.[31]On the supply side, smugglers offer passage to migrants at prices $p_b$ and at costs $c_b$ respectively, and we denote by $M_s^R$ and $M_u^R$ the fractions of migrants who attempt to cross on safe and unsafe boats respectively. We assume that seats on safe boats are more costly to provide than seats on unsafe boats ($c_s > c_u$).

We begin our analysis of this market by noting that a less motivated migrant 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.*

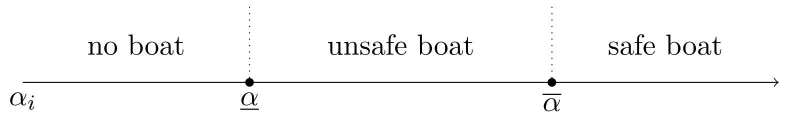
Lemma 1 imposes an ordering on migrants' $\alpha_i$ that allow us to pin down the number of attempted crossings. We illustrate this result in Figure 5. The two thresholds, $\underline{\alpha}$ and $\overline{\alpha}$ fully characterize the equilibrium of the market.

For simplicity, we first consider the case in which the market for smuggling is perfectly competitive, i.e. prices are set to marginal cost.[32] We define crossing risk $\rho$ as the *ex ante*

[31] 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.

[32] 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 among themselves when storing boats,

Figure 5: Migrant's Crossing Decisions




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:*

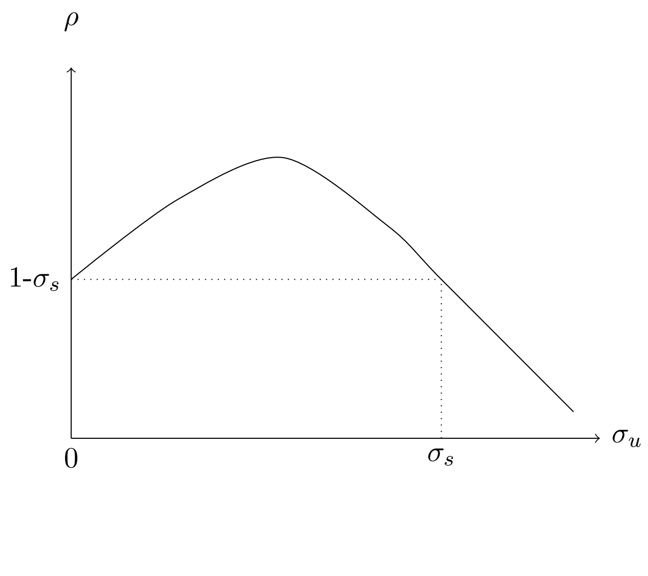
1. *Increases in total attempted crossings and attempted crossings on unsafe boats; decreases in attempted crossings on safe boats.*

2. *An ambiguous effect on crossing risk.*

3. *Total attempted crossings becoming more elastic to crossing conditions if $\sigma_u^0$ 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 $\sigma_u$ 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.

Figure 6: *Ex Ante* Crossing Risk




and by steering information 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.

As before, it is straightforward to show that under the assumptions of Proposition 2, if part 3 holds, then part 1 must hold. This analog to Corollary 1 in the single boat case allows us to test empirically the effects of SAR on total attempted crossings.

Perhaps surprisingly, when $\sigma_u$ is small, it is more likely that SAR operations will increase the crossing risk, and only when $\sigma_u$ 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 $\sigma_u$ grows larger, an increasing amount of travel occurs on unsafe boats, so $\rho$ 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 $\sigma_u$, $\rho$ will be decreasing.

We can also consider the polar case in which smugglers are monopolists and hence can set prices freely depending on the extent of SAR. Details of this exercise are available in the appendix. The results from Proposition 2 still hold under monopoly, and we obtain additional results on price changes which we summarize in Figure 7. 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 $\alpha_i$. Intuitively, the increased safety of the journey offsets any increase in price. All migrants close to this threshold are made better off by search and rescue operations (indicated in blue). In this region, migrants with greater $\alpha_i$ 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 $\alpha_i$ since there is less of a safety premium to taking the safe boat (and it may have gotten more expensive as well). If smugglers enjoy 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 additional structure on $f_\alpha$, we can approximate the relative safety of boats, $\theta = \frac{\sigma_U}{\sigma_S}$, from the semi-elasticities of crossings to weather conditions and relative prices. Formally, if we replace assumption A1 with the stronger parametric assumption

Figure 7: Incidence of Search and Rescue Operations on Migrants

(a) Perfect Competition


(b) Monopolist Smuggler


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.

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

we obtain the following result

**Proposition 3.** *Under assumptions A6 and A7,*

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

*where* $\omega_b^R = \frac{\partial \, Total \; Crossings_b}{\partial h}$

Since only a small fraction of potential migrants attempt a crossing, approximating $f_\alpha$ with a single tailed distribution is appropriate. Moreover, Assumption A7 implies a constant hazard of $\lambda$. Hence, under this assumption, our qualitative assumptions are unlikely to vary under different market structures.

*Remark 2* With information on relative prices, Proposition 3 provides us an approach to use estimates of $\omega_s^R$ and $\omega_u^R$, which are identified under the assumption that crossing conditions are exogenous, to determine the quantitative effect of SAR on crossing risk (note that low values of $\theta$ imply that SAR increases crossing risk per Figure 6).

*Remark 3* The model with two types of boats is a straightforward extension of the model with a single type of boat. 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:

**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: an environment with only one type of boat can be thought of as equivalent to one in which there are two types of boats and the crossing risks on safe and unsafe boats are similar ($\theta = 1$). In this case, most of the crossings that would have occurred on unsafe boats if they were available will now occur on safe boats. In an environment with two types of boats, i.e. one in which safe boats are much safer than unsafe boats, most of the crossings that would have occurred on unsafe boats if they were available are no longer attempted.

# 4 Results

Our model implies that the elasticities of crossing attempts with respect to crossing conditions during periods of differing intensities of SAR are informative of the unintended consequences of SAR. *Remark 1* indicates that we can use these elasticities to infer the effects of SAR on attempted crossings. *Remark 2* indicates that we can use these elasticities to infer the effects of SAR on crossing risk. Moreover, we should remain cognizant of whether a single or multiple type of boat is available to migrants and smugglers. As shown earlier, the availability of multiple boats coincides with the beginning of *Mare Nostrum*, when EU vessels started patrolling close to Libyan waters.

Identification of these elasticities relies on the assumptions of the exogeneity and stationarity of weather and tidal conditions, which are supported by the literature on maritime waves (Kharif et al., 2008). This literature and our model lead to our choice of specification of estimating equation follows. Following the model, the *daily* number of crossing attempts, $c_t$, can be expressed as a function of $\underline{\alpha}_t = \frac{p_t}{\sigma_t}$ where prices and risk refer to the least safe boat type available (this corresponds to the left threshold in Figures 5 and 7). Assuming that the $\alpha$s are distributed approximately exponentially, $c_t = e^{-\lambda \frac{p_t}{\sigma_t}}$, where $\lambda$ 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.[33]

With this in mind, we specify the following Poisson Quasi-ML regression[34]

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

where crossings depend on wave height interacted with the presence of an (intense)[35] search a rescue operation (Post $\text{SAR}_t$) per official records, and the fraction of unsafe boats, ($\bar{u}_{w(t)}$), deployed in a specific week $w(t)$.[36] Our main parameter of interest is $\omega_3$.[37] A negative estimate of this parameter implies that crossing attempts are more responsive to wave heights when SAR is in place compared to when SAR is not in place and a larger fraction of migrants switches from safe to unsafe boats, i.e. from a market with safe boats to one with multiple types of boats. This is evidence that the marginal crossing is being undertaken on a less safe boat, hence crossing attempts have increased and average *ex post* crossing risk has likely increased as well. We estimate Newey-West standard errors to allow for heteroskedasticity and autocorrelation within 28-day periods. We also perform randomization inference to i) ensure the robustness of this choice, and ii) make sure that the results are not due to a spurious correlation.

Because our model predicts a shift from safe boats to unsafe boats, we include week-by-year

[33] See the proof of Proposition 3 in Appendix B for a derivation of this result. Later we test the extent to which our results are robust to alternative specifications.

[34] The Poisson specification offers two additional advantages. First, it is well suited to analyze discrete data (Santos Silva and Tenreyro, 2006) without biasing estimates, which is useful because a large fraction (48%) of days in our sample have no crossing attempts. Second, the inclusion of fixed effects does not contaminate our estimates due to a general change in the overall number of crossings over time. We are going to see that the results are robust to the use of a linear model.

[35] 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, as well as according to average distance of rescues from Lampedusa, Sicily (see Appendix Table C.1). The details on SAR operations are in Table 1.

[36] $\bar{u}_{w(t)}$ 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 also get very similar results.

[37] All coefficients, particularly when close to zero, can be interpreted as semi-elasticities, as these are equal to $100 * (\exp(\beta) - 1)$ per cent.

fixed effects $\mu_{w(t)}$ that subsume all variation in $\bar{u}_{w(t)}$ in order to control for the endogeneity of boat choice as well as the endogeneity of SAR periods. In an exponential model, these fixed effects also mitigate bias in our parameter estimates that would arise from measurement error in crossings. Although attempts and deaths are likely to be better observed when SAR is in place, our reliance on within-week variation in crossing conditions for identification of $\omega_0 - \omega_3$ eliminates this as a source of bias since SAR do not vary at this frequency. Furthermore, we should stress that only the *relative* size of the semi-elasticities (under SAR and in the absence of SAR) matters for our purposes. Because SAR assets easily withstand rough seas and are *ex-ante* unaware of the type of boats they will encounter, the $\omega$s are unlikely to be differentially influenced by any measurement error.

For the post-2016 period, we are able to observe the country of departure for each daily crossing attempt. This enriches our specification by allowing the elasticities to vary both by the presence of SAR and by country of departure. We estimate

$$\begin{aligned} c_{it} &= \exp\left[h_{it}(\omega_0^T + \omega_1^T \text{SAR}_{it} + \omega_2^T \bar{u}_{w(it)} + \omega_3^T \bar{u}_{w(it)} \times \text{SAR}_{it})\right] \\ &\times \exp\left[L_{it}(h_{it}(\omega_0^L + \omega_1^L \text{SAR}_{it} + \omega_2^L \bar{u}_{w(it)} + \omega_3^L \bar{u}_{w(it)} \times \text{SAR}_{it})) + \mu_{w(it),i} + \epsilon_{it}\right] \end{aligned} \tag{4}$$

where $i$ refers to the country of departure and the superscripts $T$ and $L$ correspond to crossing attempts originating in Tunisia and Libya, respectively. Given the sample period for which equation (4) is relevant, the SAR dummy in this case is equal to one before August 7, 2017 (pre-*Minniti* period), after that, it corresponds to the period in which NGOs were asked to sign and abide by the *Minniti* code of conduct (see Appendix A). $\omega_3^L$ measures the marginal sensitivity to wave conditions in the pre-*Minniti* period (multiple boat types regime), when the fraction of inflatables and waves are higher for Libyan departures as compared with Tunisian departures. The $\mu_{w(it),i}$ now correspond to week-year-country of departure fixed effects.

### 4.1 Time-series Evidence, 2013-2017

Estimated coefficients of Equation 3 are presented in Table 3. Each specification corresponds to a different designation of boats as "unsafe:" Column 1 uses dinghies and inflatable boats only, Column 2 adds the boats that are of unknown type and Column 3 adds boat types that are described as "other." The fraction of crossings on "unsafe" boats are aggregated at the weekly level. The baseline types of boat, the safe ones, tend to be fishing vessels or other motorboats. Our estimates imply that a 0.10 meter increase in wave height reduces the total number of crossings on safe boats by 8.9-14.6 percent. As predicted by the model, when unsafe boats are unavailable ("Frac. Unsafe Boat" is zero), the response to intense SAR is positive, reducing the deterrent effect of waves by about two thirds, though it is not statistically significant (except once, +1.16, in column 2). The coefficient on wave height interacted with the fraction of unsafe boats when more intense SAR operations are not operating is positive but is not significantly different from zero. The issue is that during *Hermes* (the excluded period characterized by a

Table 3: Elasticities of Crossing Attempts to Crossing Conditions

| | (1) | (2) | (3) |
|---|---|---|---|
| | | **Crossing Attempts** | |
| | | **Definition of Unsafe Boat** | |
| | *Inflatable* | *Inflatable + Unknown* | *Inflatable + Unknown + Other* |
| Wave Height * SAR * Frac. Unsafe 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 * Frac. Unsafe Boat | 2.13 | 1.91 | 1.63 |
| | (1.81) | (1.34) | (1.13) |
| Wave Height * SAR | 0.21 | 1.16* | 1.00 |
| | (0.46) | (0.65) | (0.73) |
| Observations | 1,612 | 1,612 | 1,612 |
| Week-Year FE | ✓ | ✓ | ✓ |
| *Pre SAR Period Statistics* | | | |
| Mean Total Attempt | 120.34 | 120.34 | 120.34 |
| Mean Wave Height | 0.63 | 0.63 | 0.63 |
| Mean Frac. Unsafe Boat | 0.07 | 0.27 | 0.29 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR, when multiple boat types were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level. We define three different categories of unsafe boats based on the main vessels used. The share of crossing attempts using "inflatable" rubber boats over the total; we then add the "unknown boats" and "other boats", excluding any sturdy and motor boats. All regressions control for week-by-year fixed effects. Regressions are estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

single boat type) only 7% of crossings were attempted on inflatable boats, and these may have been triggered by unusual circumstances.

Importantly, in all specifications, we find that adverse crossing conditions lead to a greater number of departures with more intense SAR operations when there is a greater shift from unsafe boats to safe boats. We find that in the presence of intense SAR and large fraction of unsafe boats (close to one), there is an additional reduction of 65-41 percent. While the coefficients give rise to very large negative elasticities (6.6 times the coefficients), one has to keep in mind that small changes in significant wave have a large impact on the likelihood of encountering rouge waves, that is waves that are at least twice as high as the significant wave. Appendix Figure C.7 shows the probability of encountering maximum waves of different height within a couple of hours depending on whether the significant wave height is 0.63 meters (the pre-*Mare Nostrum* average significant wave height) or 0.73 meters, as well as the corresponding log difference (as in a Poisson model).[38]

The likelihood of facing waves up to 2 meters is about 50 percent larger when significant

[38] These calculations follow from the discussion of statistical models of rogue waves in (Kharif et al., 2008).

wave height increases by 10 centimeters, and is almost twice as large for maximum waves that are up to 2.7 meters tall. This implies that if we measured the elasticity of crossing with respect to the risk of facing very large waves, the elasticities would be much smaller in absolute value.

We perform a number of robustness checks to ensure the validity of our findings and summarize them here, while all the corresponding Tables and Figures are in the Appendix. In Appendix Table C.3 we show that OLS estimation of equation (3) yields similar results to Poisson Quasi-ML regression. In Appendix Table C.4, we show a list of robustness based on the type of clusters. We present the estimates using clusters at the month of the year and week of the year level (in parentheses and squared brackets). In addition, we implement the heteroskedasticity- and autocorrelation-robust standard errors using Newey-West changing the bandwidth, instead of 7 days, we propose 21 and 14 days (in curly brackets and vertical bars, respectively). Our main coefficients of interest keep on being significant no matter the standard errors. In Appendix Table C.5, we replicate our analysis by incorporating information on crossing conditions from earlier days to allow journeys to last more than a day. Again, the results are qualitatively similar when using lagged values or the maximum wave height between t-1 and t, though they tend to generate coefficients that are closer to 0. In Appendix Table C.6, we present results specifying significant wave height quadratically (as in the Appendix Equation 11), and our findings are substantively unchanged. In Appendix Table C.7, we measure crossing conditions as significant wave height from five different locations, one of which is in Libya, three of which are in Tunisia and one from Algeria. Libyan sea conditions appear to be better proxies for the conditions that migrant boats are facing. Finally, in Appendix Table C.8, we show the results using different definitions of for bad (extreme) weather and along the whole distribution of fractions of unsafe boats with the confidence interval (Figure C.10).

As a randomization inference exercise, we estimate 644 versions of Equation 3 under the conservative classification that only inflatable boats are unsafe. In each of these versions, we use wave height at time $t-k$ in place of wave height at time $t$, choosing $k$ to be sufficiently large (28 to 336 days) so as to not affect the journey.[39] The top panels of Appendix Figure C.8 plot the resulting distributions of our two main parameters of interest, $\omega_0^k$s and the $\omega_3^k$s; the bottom panels plot the resulting distributions of the other two semi-elasticities. In line with the standard errors shown in Table 3, the estimated coefficients of $\omega_0^k$ and $\omega_3^k$s lie in the far left tails, with p-values that are close to one percent.

## 4.2 Panel Evidence, 2016-2020

In Table 4 we present coefficient estimates from equation 4 using panel data with different specifications of fixed effects and the pre-enactment period of the code of conduct, which in this case turns to be the period of more intense SAR (pre-*Minniti*) with multiple types of boats. As shown in column 1, attempted crossings are positively related to departures from Libya (0.5 log points), while before the introduction of the code of conduct attempts from Libya were 4.4

[39] Using leads instead of distant lags Appendix Figure C.9 provides similar results but forces us to truncate our sample as our wave height data are only available until the end of 2017.

Table 4: Elasticities of Crossing Attempts to Crossing Conditions by Country of Departure

| | (1) | (2) |
|---|---|---|
| | **Crossing Attempts** | |
| From Libya * SAR | 4.4113*** | |
| | (0.2017) | |
| From Libya | 0.5031*** | |
| | (0.1241) | |
| Wave Height | | -2.2953*** |
| | | (0.3761) |
| Wave Height * Frac. Inflatable Boat | | -2.3742 |
| | | (2.7744) |
| Wave Height * SAR | | -0.7638 |
| | | (0.7255) |
| Wave Height * SAR * Frac. Inflatable Boat | | 4.0147 |
| | | (3.1772) |
| Wave Height * From Libya | | 1.8074** |
| | | (0.7290) |
| Wave Height * From Libya * Frac. Inflatable Boat | | 2.3157 |
| | | (2.8668) |
| Wave Height * From Libya * SAR | | 2.8209* |
| | | (1.6472) |
| Wave Height * From Libya * Frac. Inflatable Boat * SAR | | -6.9742* |
| | | (3.7072) |
| Observations | 3,402 | 2,952 |
| Week-Year FE | ✓ | |
| Week-Year-From Libya FE | | ✓ |

Note: The sample consists of daily observations from 1 January 2016 to 31 December 2020. SAR dummy is equal to one for all observations before August 7, 2017, when multiple boat types were used more frequently. This corresponds to pre-*Minniti* periods, i.e. before the Code of Conduct was enacted restricting *de-facto* the use of unsafe boats. Crossing attempts sum crossings and deaths in transit. Significant wave height is measured in meters in Tripoli, Libya and Tunis, Tunisia depending on the departure location. The dummy "From Libya" takes value one if the migrants departed from Libya (treated units). Frac. Inflatable Boat measures the share of attempted crossings using inflatable boats aggregated at the week-year level. Crossing attempts sum crossings and deaths. In column 1 we control for week-by-year fixed effects. In column 2 we add the interaction with the dummy "From Libya", causing a drop in observations (450) because of zero attempted crossings both from Libya and Tunisia. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are cluster at the week of the year level. * p<.10 ** p<.05 *** p<.01.

log points larger than attempted crossings from Tunisia.[40] In column 2 we control for these level effects with the inclusion of week-year-country of departure fixed effects. Given that this specification leverages a sudden change in the availability of NGO rescue boats, it subsumes any smooth change in demand and supply factors of crossings (beyond those that are already captured by the many fixed effects). Yet, $\omega_3^1$ is remarkably similar to the $\omega_3$ estimated in the time-series specification (-6.97 vs. -6.55), which indicates that in the presence of any SAR (EU or NGO) taking place close to the Libyan coast, i.e. when crossing on unsafe boats become feasible, Libyan crossings in inflatable boats become highly responsive to crossing conditions.

As predicted by the model, the opposite response is observed when there is no substitution from sturdy boats to inflatables, the coefficient on wave height interacted with departure from

[40] The corresponding event study coefficients, using July 2017 (when the *Minniti* code was introduced) as the excluded month, are shown in Appendix Figure C.11. Although not a formal proof, this test is usually interpreted as supportive of the parallel trend assumption.

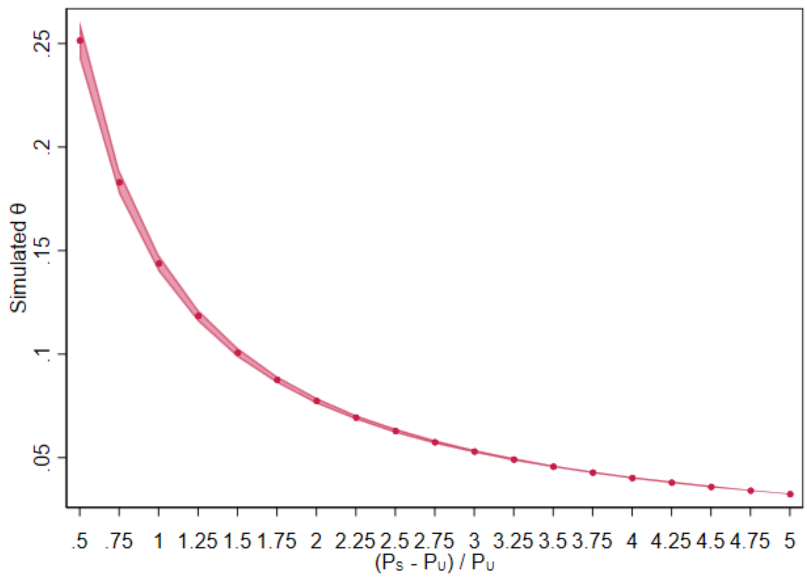
Libya and SAR indicator function is positive (2.8) and significant at the 10 percent level. As for the rest of the coefficients, attempted crossings in the absence of intense SAR operations, namely in the period after the code of conduct is enacted, tend to be highly responsive to crossing conditions when they originate from Tunisia, and even more so when they happen on inflatable boats (2.3 though this difference is not significant). This is in line with the inflatable boats being able to cover the 70km stretch between Tunisia and Italy.[41]

Compared to Tunisia, in the absence of intense SAR, all boats leaving from Libya tend to be less susceptible to wave height. This, again, seems to be driven by the different distance that needs to be covered. Both types of boats, when originating from Libya, tend to carry a lot more migrants, and thus are presumably much larger vessels, and larger vessels are able to withstand rougher sea.[42]

We leverage our model to translate our parameter estimates into estimates of $\theta$, which allows us to make inferences on the effect of SAR on crossing risk. For a given $\frac{p_S - p_U}{p_U}$, Proposition 3 provides a method to simulate $\theta$ as a function of these parameter estimates, since $\omega_u = \omega_0 + \omega_1 + \omega_2 + \omega_3$ and $\omega_s = \omega_0 + \omega_1$ as estimated in equation 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 29), $\hat{\theta}$ is between 5 and 10%. Notice that this is an *ex ante* unobserved risk ratio, which is likely to be very different from the *ex post* risk ratio that one would calculate from observed crossings and deaths, which

Figure 8: Simulated Probability of Success on Unsafe Boat vs. Safe Boat by Relative Price




Note: The $\hat{\theta} = \frac{\sigma_U}{\sigma_S}$s are simulated using the semi-elasticities estimated in Column (1) of Table 3. 95% confidence intervals are shown with standard errors computed using the $\delta$-method.

[41] In spite of this, most attempted crossings from Tunisia happen on sturdy boats (see Figure 3 ).

[42] Frontex data show that the average number of crossings per safe vessel is 164 when leaving from Libya and 23 when leaving from Tunisia. The corresponding numbers for unsafe vessels are 43 and 7.

is endogenously realized in equilibrium only after migrants decisions have been made. Indeed, for any plausible price ratio, we deduce that $\theta$ is likely to be less than 10%, i.e., inflatable boats are about 10 times less safe than all other boats.

The implications of this finding are clear. 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 increase in raw differences in crossing risk estimated in Column 2 of Appendix Table C.1. Given the very low magnitude of $\hat{\theta}$, any bias due to remaining measurement error would need to differ highly heterogeneously by boat type to overturn our results and force us to infer that SAR decreased crossing risk.

The predictions of interest in our model relate to low-frequency boat switching in response to changing SAR conditions; to circumvent endogeneity arising from these decisions, we test these predictions empirically by leveraging high-frequency boat switching in response to changing to crossing conditions, as the $\omega$ semi-elasticities are identified using week-by-year fixed effects.

Nevertheless, we can test directly whether low-frequency boat switching does occur in Table 5. Although our data is limited to SAR periods (since this is when boat type is potentially observable) and, as mentioned, is incomplete (the type of boat is recorded as "unknown" or "other" on 27% and 4% fraction of crossings) there is a clear and systematic pattern: the market for smuggling looks very different during periods of *intensive* SAR operations, which are characterized by increasing use of inflatable craft and decreasing use of sturdier motor and fishing boats.[43]

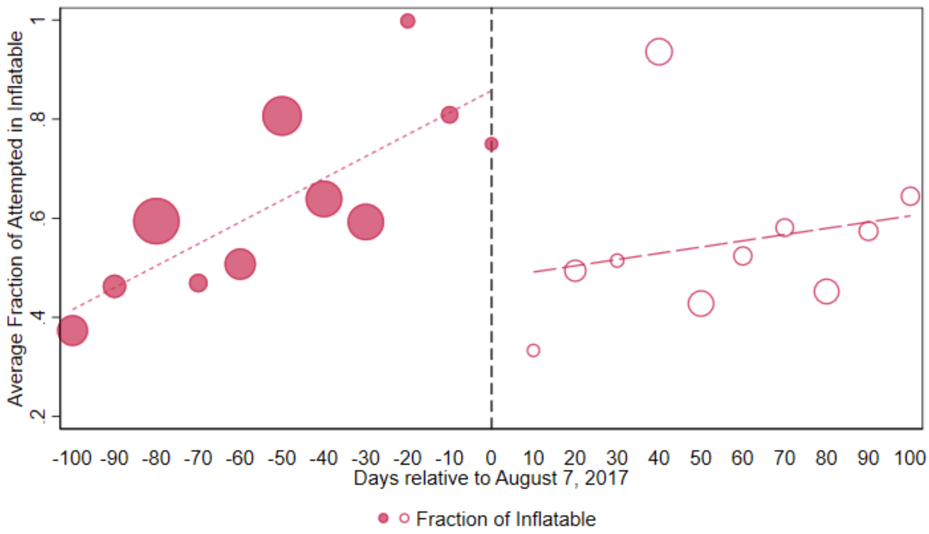
Table 5: Fraction of Migrants by Boat Types

| Fraction of Attempted Crossings | (1) Inflatable | (2) Inflatable + Unknown | (3) Inflatable + Unknown + Other | (4) Fishing | (5) Motor |
|---|---|---|---|---|---|
| Mare Nostrum | 0.06 | -0.07 | 0.10 | 0.05 | -0.15** |
| | (0.05) | (0.06) | (0.08) | (0.07) | (0.06) |
| Triton I | 0.30*** | 0.14 | 0.32*** | 0.04 | -0.35*** |
| | (0.10) | (0.09) | (0.08) | (0.07) | (0.08) |
| Triton II | 0.61*** | 0.55*** | 0.53*** | -0.16*** | -0.37*** |
| | (0.04) | (0.05) | (0.05) | (0.04) | (0.05) |
| Constant | 0.11*** | 0.39*** | 0.41*** | 0.20*** | 0.39*** |
| | (0.03) | (0.04) | (0.05) | (0.04) | (0.05) |
| Observations | 768 | 768 | 768 | 768 | 768 |
| Pre MN Mean Outcome | 0.11 | 0.38 | 0.42 | 0.22 | 0.36 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations were in place (164 days). More intense SAR (i.e. Mare Nostrum (MN), Triton I and II) dummies are equal to one over the periods defined in Table 1. We show the fractions of attempted crossings using "inflatable" rubber boats over the total; adding the category "unknown boats" and then the "other boats". Last two columns show the fraction of attempted crossings using sturdy boats, i.e. fishing and motor boats, respectively. All regressions control for 52 weeks of the year fixed effects. The 768 observations correspond to days with at least one crossing during SAR periods. Regressions estimated using OLS. Cluster standard errors at the weekly level. * p<.10 ** p<.05 *** p<.01.

[43] Using a fractional Probit model to estimate the probability of using a specific type of boat, or using a Poisson model to estimate how crossings on specific types of boats change with more intense SAR operations leads to similar findings (see Appendix Table C.9).

Figure 9: Fraction of Inflatable Boats around the Introduction of the "Minniti Code"




Note: The Minniti Code of Conduct was introduced on the August 7, 2017. Circle size is proportional to the number of attempted crossings.

In Figure 9 we exploit the second set of data, and the sharp changes in attempted crossings around the time the "Minniti Code" became operational and NGO rescue vessels were required to leave the Libyan waters (Figure 3). This change forced Libyan smugglers to use more safe boats (the single boat regime).[44] The fraction of attempted crossing that take place on inflatable boats dropped from about 80 percent pre "Minniti Code" (0 corresponds to the period August 7 to 16) to about 40 percent post. In both sample periods the observed boat switching is consistent with Propositions 2 and 4.

## 5 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 and whose internal politics have been riven by this issue.

After analyzing more than a decade of data on daily crossings, we find that while search and rescue operations have no doubt saved lives directly, they may have had adverse unintended consequences that should be considered. First, by reducing the risk of crossing, they seem to have 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, they induced a large substitution away from seaworthy wooden vessels and towards

[44] The size of the circles in the figure is proportional to the number of attempted crossings.

flimsy, inflatable boats. Thus, the benefits of search and rescue operations have been, to some extent, captured by human smugglers.[45]

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" suggests that this is an ethical 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.[46]

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.[47] One way to do so would be 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 crafts are produced in China, and Appendix Figure C.3 suggests that they may still enter Libya through Egypt and Turkey. That said, there are clear and systematic, albeit indirect, effects of intense SAR operations on these smuggling markets. Ensuring that future SAR policies inadvertently promote activity in these markets as little as possible is thus critical to their success.

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

[45] 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.

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

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

## References


Aksoy, C.G., Poutvaara, P., 2019. Refugees' Self-Selection into Europe: Who Migrates Where? Ifo Working Paper 289.

Allen, T., Dobbin, C.d.C., Morten, M., 2018. Border Walls. NBER Working Paper 25267.

Arcand, J.L., Mbaye, L., 2013. Braving the Waves: the Role of Time and Risk Preferences in Illegal Migration from Senegal. IZA Discussion Paper 7517.

Bank, W., 2018. Asylum Seekers in the European Union: Building Evidence to Inform Policy Making. World Bank Washington, DC.

Battiston, G., 2020. Rescue on Stage: Border Enforcement and Public Attention in the Mediterranean Sea.

Battjes, J.A., Groenendijk, H.W., 2000. Wave Height Distributions on Shallow Foreshores. Coastal Engineering 40, 161–182.

Bazzi, S., Hanson, G., John, S., Roberts, B., Whitley, J., 2021. Deterring illegal entry: Migrant sanctions and recidivism in border apprehensions. American Economic Journal: Economic Policy 13, 1–27.

Bratti, M., Deiana, C., Havari, E., Mazzarella, G., Meroni, E.C., 2020. Geographical proximity to refugee reception centres and voting. Journal of Urban Economics 120, 103290.

Breines, M., Collyer, M., Lutterbeck, D., Mainwaring, C., Mainwaring, D., Monzini, P., 2015. A Study on Smuggling of Migrants: Characteristics, Responses and Cooperation with third Countries. Case Study 2: Ethiopia–Libya–Malta/Italy. Technical Report. European Commission DG Migration & Home Affairs.

Campana, P., 2017. The Market for Human Smuggling into Europe: a Macro Perspective. Policing: A Journal of Policy and Practice 11, 448–456.

Cornelius, W.A., 2001. Death at the Border: Efficacy and Unintended Consequences of US Immigration Control Policy. Population and Development Review 27, 661–685.

Credendino, E., 2017. EUNAVFOR MED Operation SOPHIA. Technical Report. Italian Navy.

Dee, D.P., Uppala, S., Simmons, A., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M., Balsamo, G., Bauer, d.P., et al., 2011. The ERA-Interim Reanalysis: Configuration and Performance of the Data Assimilation System. Quarterly Journal of the Royal Meteorological Society 137, 553–597.

Doleac, J., Mukherjee, A., 2018. The Moral Hazard of Lifesaving Innovations: Naloxone Access, Opioid Abuse, and Crime. IZA Discussion Paper 11489.

Evans, W.N., Lieber, E.M., Power, P., 2019. How the Reformulation of OxyContin Ignited the Heroin Epidemic. Review of Economics and Statistics 101, 1–15.

Fasani, F., Frattini, T., 2019. Border Policies and Unauthorized Flows: Evidence from the Refugee Crisis in Europe.

Feigenberg, B., 2020. Fenced Out: Why Rising Migration Costs Matter. American Economic Journal: Applied Economics 12, 106–39.

Friebel, G., Guriev, S., 2013. Human Smuggling, in: International Handbook on the Economics of Migration. Edward Elgar Publishing. chapter 6, pp. 121–134.

Friebel, G., Manchin, M., Mendola, M., Prarolo, G., 2017. Human Smuggling and Intentions to Migrate: Global Evidence from a Supply Shock along Africa-to-Europe Migration Routes. Centro Studi Luca d'Agliano, University of Milano Working Paper 432.

Frontex, 2009. Frontex Evaluation Report 2009. Technical Report. European Union.

Frontex, 2010. Frontex Evaluation Report 2010. Technical Report. European Union.

Frontex, 2012. Frontex Evaluation Report 2012. Technical Report. European Union.

Frontex, 2014. Frontex General Report 2014. Technical Report. European Union.

Frontex, 2016. Budget. Technical Report. European Union.

Frontex, 2018. Budget. Technical Report. European Union.

Frontex, 2019. Programming Document 2020-2022. Technical Report. European Union.

Gathmann, C., 2008. The Effects of Enforcement on Illegal Markets: Evidence from Migrant Smuggling along the Southwestern Border. Journal of Public Economics 92, 1926–1941.

Hanson, G., McIntosh, C., 2016. Is the Mediterranean the New Rio Grande? US and EU Immigration Pressures in the Long Run. Journal of Economic Perspectives 30, 57–82.

Hatton, T.J., 2016. Refugees, asylum seekers, and policy in oecd countries. American Economic Review 106, 441–45.

Hatton, T.J., 2017. Refugees and asylum seekers, the crisis in europe and the future of policy. Economic Policy 32, 447–496.

Hatton, T.J., 2020. Asylum migration to the developed world: Persecution, incentives, and policy. Journal of Economic Perspectives 34, 75–93.

Heller, T., Pezzani, L., Studio, S., 2012. Report on the "Left-To-Die Boat". Technical Report. London: Forensic Architecture Project Goldsmiths University of London.

Kharif, C., Pelinovsky, E., Slunyaev, A., 2008. Rogue waves in the ocean. Springer Science & Business Media.

Kniveton, D.R., Smith, C.D., Black, R., 2012. Emerging Migration Flows in a Changing Climate in Dryland Africa. Nature Climate Change 2, 444.

Mannocchi, F., 2018. Meeting the Libyan Smugglers Getting Rich Dealing in Migrant Lives. TheNewArab.

McAuliffe, M., Laczko, F., 2016. Migrant Smuggling Data and Research: A Global Review of the Emerging Evidence Base. International Organization for Migration.

McAuliffe, M., Ruhs, M., 2017. World Migration Report 2018. Technical Report. International Organization for Migration.

Micallef, M., 2017. The Human Conveyor Belt: Trends in Human Trafficking and Smuggling in Post-Revolution Libya. Technical Report. The Global Initiative Against Transnational Organized Crime.

MOAS, 2014. Annual Report MOAS 2014. Technical Report. Migrant Offshore Aid Station.

MOAS, 2015. Annual Report MOAS 2015. Technical Report. Migrant Offshore Aid Station.

MOAS, 2016. Annual Report MOAS 2016. Technical Report. Migrant Offshore Aid Station.

MOAS, 2017. Annual Report MOAS 2017. Technical Report. Migrant Offshore Aid Station.

Orrenius, P., Zavodny, M., 2015. Undocumented Immigration and Human Trafficking, in: Handbook of the Economics of International Migration. volume 1, pp. 659–716.

Parliament's Committee, 2017. Report on Mafias, Migrants and Human Trafficking and New Forms of Slavery. Technical Report. Italian Government.

Pastore, F., Monzini, P., Sciortino, G., 2006. Schengen's Soft Underbelly? Irregular Migration and Human Smuggling across Land and Sea Borders to Italy. International Migration 44, 95–119.

Peltzman, S., 1975. The Effects of Automobile Safety Regulation. Journal of Political Economy 83, 677–725.

Porsia, N., 2015. Smuggling Networks in Libya, in: Heller, C., Pezzani, L. (Eds.), Death by Rescue – the Lethal Effects of the EU's Policies of Non-Assistance. Forensic Oceanography, London.

Santos Silva, J.M.C., Tenreyro, S., 2006. The Log of Gravity. The Review of Economics and Statistics 88, 641–658.

Senate Statistical Office, 2015. Report on Immigration. Technical Report. Italian Government.

Tamura, Y., 2010. Migrant Smuggling. Journal of Public Economics 94, 540–548.

UNHCR, 2017. Libya: Activities at Disembarkation. Technical Report. United Nations High Commissioner for Refugees.

UNODC, 2018. Global Study on Smuggling of Migrants 2018. Technical Report. United Nations Office on Drug and Crime.

Winston, C., Maheshri, V., Mannering, F., 2006. An Exploration of the Offset Hypothesis using Disaggregate Data: the Case of Airbags and Anti-lock Brakes. Journal of Risk and Uncertainty 32, 83–99.

Woodland, A.D., Yoshida, C., 2006. Risk Preference, Immigration Policy and Illegal Immigration. Journal of Development Economics 81, 500–513.

# Appendix A: Institutional Background

## A.1 Search and Rescue Operations

Search and rescue operations usually begin with distress calls to "Marine Rescue Coordination Centers (MRCC)," which takes immediate action to rescue the migrant boat in need. For the bulk of our sample period, migrant and civil rescue boats in the Central Mediterranean 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 had officially established their SAR area.[48] This implies that no single country was 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 were transferred almost exclusively to Italy (overall less than 5 percent of migrants who chose the central-Mediterranean route end up on Malta).

#### 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 operation 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 in the Central Mediterranean Sea with an explicit humanitarian aim.

The SAR force included both personnel and sea and air assets of the Navy, the Air Force, the *Carabinieri*, the State and the Financial Police, and the Coastal Guard (Italian Parliament,

[48] Libya established its SAR area in June of 2018.

2017). Once rescued, "irregular" migrants were generally channelled to the existing reception system for asylum seekers (Bratti et al., 2020).[49]

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 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 criticized 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.[50]

[49] Hatton (2016, 2017) discuss the different asylum seeker policies across OECD countries and, importantly, highlight the limitations of the European asylum policy.

[50] 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 late 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.

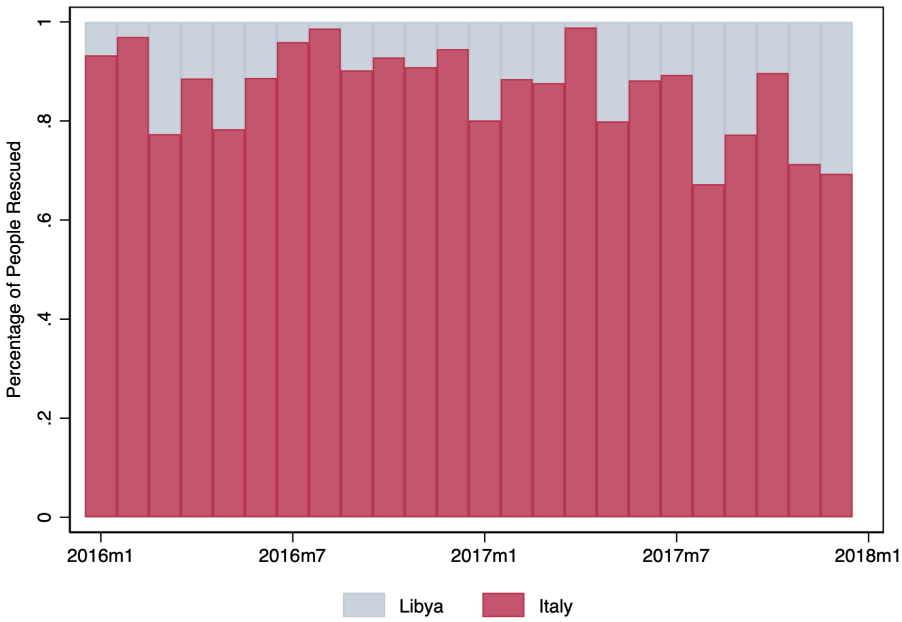
### The Minniti Code and NGOs

In response to an increased presence of NGO vessels near the Libyan shore, former interior ministry Marco Minniti asked NGOs to sign a code of conduct in July 2017.[51] NGO vessels were required to: i) avoid Libyan waters unless to avoid serious and imminent danger, ii) not interfere with the activity of the Libyan Coast Guard, iii) not communicate with migrants to facilitate the departure of boats, and iv) allow Italian police officers onboard their vessels.[52]

Seven out nine NGOs refused to sign the code of conduct, which put their vessels at risk of confiscation. Following strong pressure from the Libyan coast guard, most of these NGOs decided to pull out of Libyan waters. The percentage of irregular migrants intercepted by Tripoli's Government of National Accord (GNA) Coast Guard rose from 10% to 20% by the end of 2017, resulting in a growing fraction of migrants who were returned to Libya (Figure A.1).

However, this alone does not explain the enormous reduction of Libyan arrivals seen in Figure 3, in the middle of the summer, when crossing conditions are ideal. The average daily number of attempted crossings from Libya dropped from around 700 to about 100. This drop was driven by a reduction in crossings on inflatable boats.[53]

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




Note: Data are from the United Nations High Commissioner for Refugees (UNHCR, 2017) that provides the monthly number of migrants intercepted at sea by the coast guards. Red and grey bars show the percentages of the people rescued by Libyan and Italian coast guards, respectively.

[51] We discuss the role of NGOs in more detail in Appendix D.

[52] The code of conduct comprises thirteen rules and is available at `http://www.interno.gov.it/sites/default/files/codice_condotta_ong.pdf`.

[53] Although there was some substitution between Libya and Tunisia, where the average daily crossings rose from under 10 to a maximum of around 100 in September, this does not come close to offsetting the reduction in

**Themis**

In February 2018, operation *Triton* was replaced by Operation *Themis*, which focused on law enforcement and security, including efforts to collect intelligence to stop terrorists and foreign fighters from entering the EU. Under *Themis*, the patrol area shrank considerably to 24 miles from the Italian coast (without covering the Maltese waters). Because vessels under the EU mandate could not operate in waters beyond this mark, *Themis* mandated migrants to be brought to the closest safe harbor.

Libyan crossings. Moreover, daily crossings dropped in Tunisia as well in the later months of 2017. It is worth noting that almost all crossings from Tunisia, which is considerably closer to Italian shores, occurred on sturdy boats.

## Appendix B: 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 $\alpha_i$ than in the absence of SAR. The claim follows.

2. By Assumption A3, the $\alpha_i$ 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. Corollary* 1 By assumption A2, we can let $\alpha^R = \frac{p}{\sigma^R(h)}$ represent the $\alpha_i$ of the marginal migrant who is willing to cross under SAR $R$. If total crossings are less elastic to $h$ under SAR, then

$$\frac{\partial \alpha^1}{\partial h}\frac{h}{\alpha^1} < \frac{\partial \alpha^0}{\partial h}\frac{h}{\alpha^0} \tag{5}$$

since both of these elasticities are negative by assumption A3. A simple rearrangement of equation (5) yields $\frac{\alpha^0}{\alpha^1} > 1$ which, under assumption A2, completes the proof. □

*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 (2) 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 (2). □

*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 $\rho$ will decrease. If not, then $\rho$ 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

$$f\left(\frac{p_u}{\sigma_u^1}\right)\frac{p_u}{(\sigma_u^1)^2}\frac{\partial\sigma_u^1}{\partial h} < f\left(\frac{p_u}{\sigma_u^0}\right)\frac{p_u}{(\sigma_u^0)^2}\frac{\partial\sigma_u^0}{\partial h} \tag{6}$$

We need to specify $\frac{\partial\sigma_b^R}{\partial h}$. Given that significant wave height follows a Rayleigh distribution, a boat that can safely resist waves up to height $H$ will cross safely when meeting $t$ waves with crossing conditions equal to $h$ with probability $\sigma_u = \left(1 - e^{\frac{-2H^2}{h^2}}\right)^t$. Using the approximation that $\log(1-\sigma) = -\sigma$ for the *ex ante* $\sigma$ sufficiently small, the inequality in Eq. 6 simplifies to

$$f\left(\frac{p_u}{\sigma_u^1}\right)\frac{1}{\sigma_u^1} > f\left(\frac{p_u}{\sigma_u^0}\right)\frac{1}{\sigma_u^0}, \tag{7}$$

If we can demonstrate that $\alpha f(\alpha)$ is decreasing at $\alpha = \underline{\alpha}$ , then we establish inequality (7). In other words, we wish to show that $f(a)$ decreases at least as fast as $\frac{1}{\alpha}$. Note that Assumption A1 states that $f(\alpha)$ decreases at least as fast as $1 - F(\alpha)$. Hence it suffices to show that $\alpha\,(1 - F(\alpha)) \to 0$ as $\alpha \to \inf$. Note that $\alpha\,(1 - F(\alpha)) = \alpha - \alpha F(\alpha)$ and $\alpha F(\alpha) \to \alpha$ as $\alpha \to \inf$ since $F$ is a CDF.

Hence, for sufficiently small $\sigma_u^0$, inequality (7) will hold. For example, if $\alpha$ is exponentially distributed, it is easy to show that condition 7 is already satisfied for $\alpha$ larger than the mean of $\alpha$.

□

*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

$$\underline{\alpha}' = \left(\overline{\alpha}\,(\sigma_s - \sigma_u) + p_u\right)\frac{1}{\sigma_s} \tag{8}$$

$$= \frac{\sigma_s - \sigma_u}{\sigma_s}\overline{\alpha} + \frac{\sigma_u}{\sigma_s}\frac{p_u}{\sigma_u} \tag{9}$$

$$= \theta\underline{\alpha} + (1-\theta)\overline{\alpha} \tag{10}$$

□

*Proof. Proposition 3.*

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

$$\sigma_b^{SAR} \approx \left(\frac{2H^2}{h^2}\right)^t \tag{11}$$

$$\approx \frac{1}{\gamma_b^{SAR} + \delta_b^{SAR} h}, \tag{12}$$

where the second line follows from a linear approximation with fixed $t$ to match our empirical specification.[54]

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

$$A^{SAR} = e^{-\lambda \frac{p_u}{\sigma_u^{SAR}}} \tag{13}$$

Noting that $\theta = \frac{\sigma_u}{\sigma_s}$ and $\overline{\alpha} = \frac{p_s - p_u}{\sigma_s - \sigma_u}$, equation (12) implies that

$$\overline{\alpha} = \frac{\theta \left(p_s - p_u\right)}{1-\theta} \left(\gamma_u^{SAR} + \delta_u^{SAR} h\right) \tag{14}$$

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

$$\frac{\omega_s}{\omega_u} = \frac{\theta}{1-\theta} \frac{p_s - p_u}{p_u}, \tag{15}$$

which completes the proof.

□

### Monopolist Smuggler

We now consider the case in which a monopolist smuggler operates and sets prices to maximize profits. For 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 $\sigma_b^R$. The smuggler's problem can thus be written as

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

[54] Appendix Table C.6 shows that using the quadratic function to avoid such approximation gives similar results.

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

**Proposition 4.** *Under Assumptions A1, 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 $\sigma_u^0$ is small.*
3. *An increase in smuggler's profits.*

*Proof. Proposition 4.*

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

$$\frac{\partial M_s^R}{\partial p_s^R}(p_s^R - c_s) + M_s^R + \frac{\partial M_u^R}{\partial p_s^R}(p_u^R - c_u) = 0 \tag{16}$$

$$\frac{\partial M_s^R}{\partial p_u^R}(p_s^R - c_s) + \frac{\partial M_u^R}{\partial p_u^R}(p_u^R - c_u) + M_u^R = 0 \tag{17}$$

Note that prices and crossings are now allowed to vary by $R$. Adding equations (16) and (17) together, we obtain

$$\left(\frac{\partial M_s^R}{\partial p_s^R} + \frac{\partial M_s^R}{\partial p_u^R}\right)(p_s^R - c_s) + \left(\frac{\partial M_u^R}{\partial p_s^R} + \frac{\partial M_u^R}{\partial p_u^R}\right)(p_u^R - c_u) + M_s^R + M_u^R = 0 \tag{18}$$

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

$$\begin{aligned} p_u^R &= c_u + \frac{M_s^R + M_u^R}{\frac{1}{\sigma_u^R} f\left(\frac{p_u^R}{\sigma_u^R}\right)} \\ &= c_u + \frac{\sigma_u^R}{\lambda\left(\frac{p_u^R}{\sigma_u^R}\right)} \end{aligned} \tag{19}$$

The second term in equation (19) 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 (19), we can write

$$\frac{p_u^1}{\sigma_u^1} - \frac{p_u^0}{\sigma_u^0} = \left[\frac{1}{\lambda\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{1}{\lambda\left(\frac{p_u^0}{\sigma_u^0}\right)}\right] + \left[c_u\left(\frac{1}{\sigma_u^1} - \frac{1}{\sigma_u^0}\right)\right] \tag{20}$$

A1 implies that the first term of equation (20) is negative, and A6 implies that the second term of equation (20) is negative, hence the total number of crossings increases.

Now, substituting from equation (16), we obtain

$$M_s^1 - M_s^0 = \frac{\partial M_s^1}{\partial p_s^1}(p_s^1 - c_C) + \frac{\partial M_u^1}{\partial p_s^1}(p_u^1 - c_u) - \left[\frac{\partial M_s^0}{\partial p_s^0}(p_s^0 - c_C) + \frac{\partial M_u^0}{\partial p_s^0}(p_u^1 - c_u)\right] \quad (21)$$

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 (21) 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 $\rho$ 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 (19), we have

$$p_u^1 - p_u^0 = \frac{M_s^1 + M_u^1}{\frac{1}{\sigma_u^1} f\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{M_s^0 + M_u^0}{\frac{1}{\sigma_u^0} f\left(\frac{p_u^0}{\sigma_u^0}\right)} = \frac{\sigma_u^1}{\lambda\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{\sigma_u^0}{\lambda\left(\frac{p_u^0}{\sigma_u^0}\right)} \quad (22)$$

This combined with A1 implies that the right hand side of equation (22) is greater than zero, so $p_u$ increases under SAR.

Rearranging equation (16) yields

$$M_s^R = -\left[\frac{\partial M_u^R}{\partial p_s^R}(p_u^R - c_u) + \frac{\partial M_s^R}{\partial p_s^R}(p_s^R - c_s)\right] \quad (23)$$

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 (23) to express $p_s^R$ as

$$p_s^R = c_s + \left[(p_u^R - c_u) + \frac{\sigma_s^R - \sigma_u^R}{\lambda\left(\frac{p_s^R - p_u^R}{\sigma_s^R - \sigma_u^R}\right)}\right] \quad (24)$$

from which the markup on $p_s^R$ is given in the second term. Using equation (24), we can write

$$p_s^1 - p_s^0 = (p_u^1 - p_u^0) + \left[ \frac{\sigma_s^1 - \sigma_u^1}{\lambda\left(\frac{p_s^1 - p_u^1}{\sigma_s^1 - \sigma_u^1}\right)} - \frac{\sigma_s^0 - \sigma_u^0}{\lambda\left(\frac{p_s^0 - p_u^0}{\sigma_s^0 - \sigma_u^0}\right)} \right] \tag{25}$$

$p_u$ was shown to increase under SAR, so the first term of equation (25) 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 (25) is greater than zero, hence $p_s$ increases under SAR. Finally, if we move the first term on the right hand side of equation (25) 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.

□

We can express the markups that monopolists charge as follows:

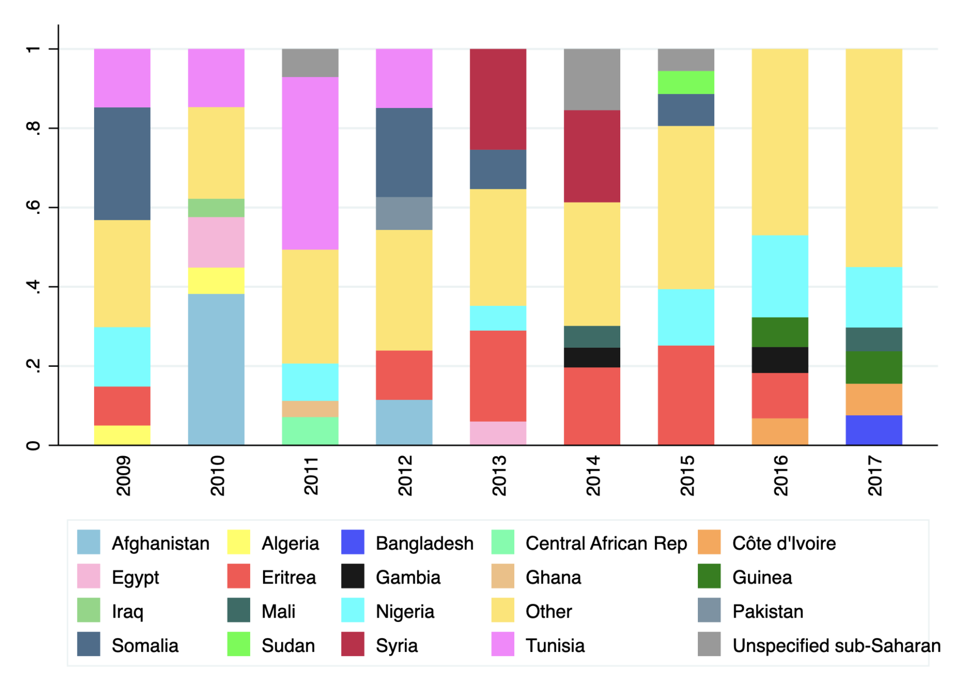
$$p_u^R = c_u + \frac{\sigma_u^R}{\lambda\left(\underline{\alpha}\right)} \tag{26}$$

$$p_s^R = c_s + \left[ (p_u^R - c_u) + \frac{\sigma_s^R - \sigma_u^R}{\lambda\left(\overline{\alpha}\right)} \right] = c_s + \left[ \frac{\sigma_u^R}{\lambda\left(\underline{\alpha}\right)} + \frac{\sigma_s^R - \sigma_u^R}{\lambda\left(\overline{\alpha}\right)} \right] \tag{27}$$

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.

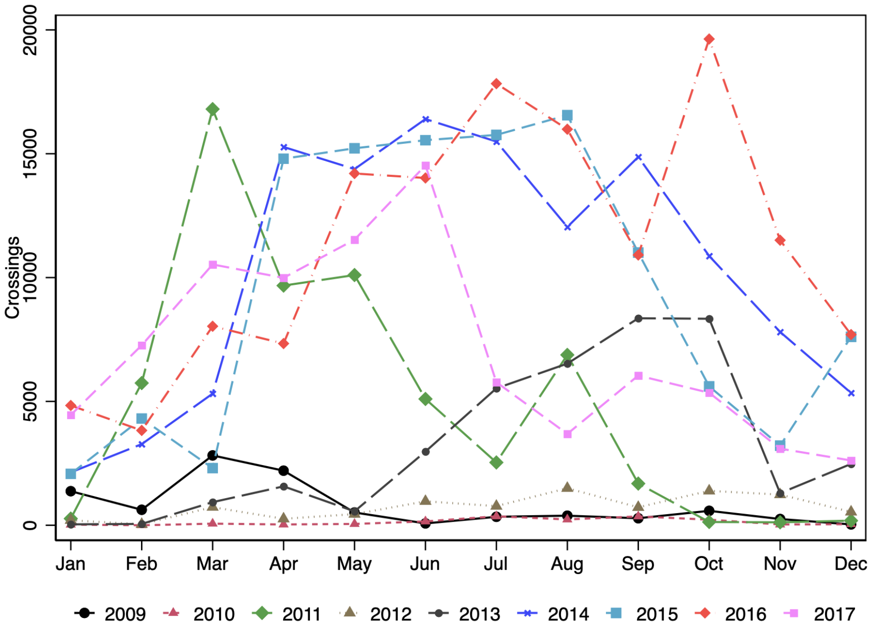
# Appendix C: Additional Tables and Figures

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




Note: Data are collected by the European Border and Coast Guard Agency and are based on detections at the border. Our subset is based on detections along the Central Mediterranean Route and the figures show the fraction of detections for the top six nationality from 2009 to 2017.

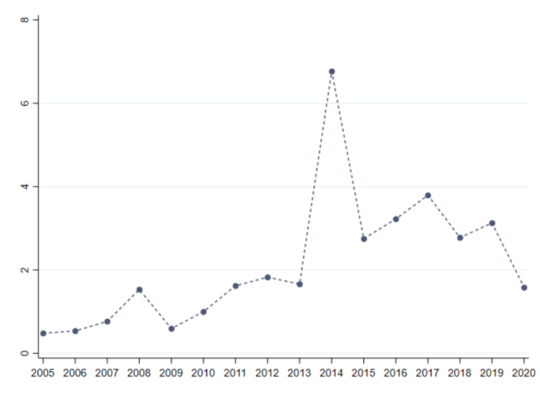
Figure C.2: Monthly Crossing Attempts




Data on crossings are provided by *Polizia di Stato*, the Italian State Police. Data on deaths at sea are described in Section 2.4. The figure shows the total number of monthly crossing attempts that sum the crossings and the deaths in transit.

Figure C.3: Net-Imports of Rubber Boats, Wooden Ferries and Life Jackets

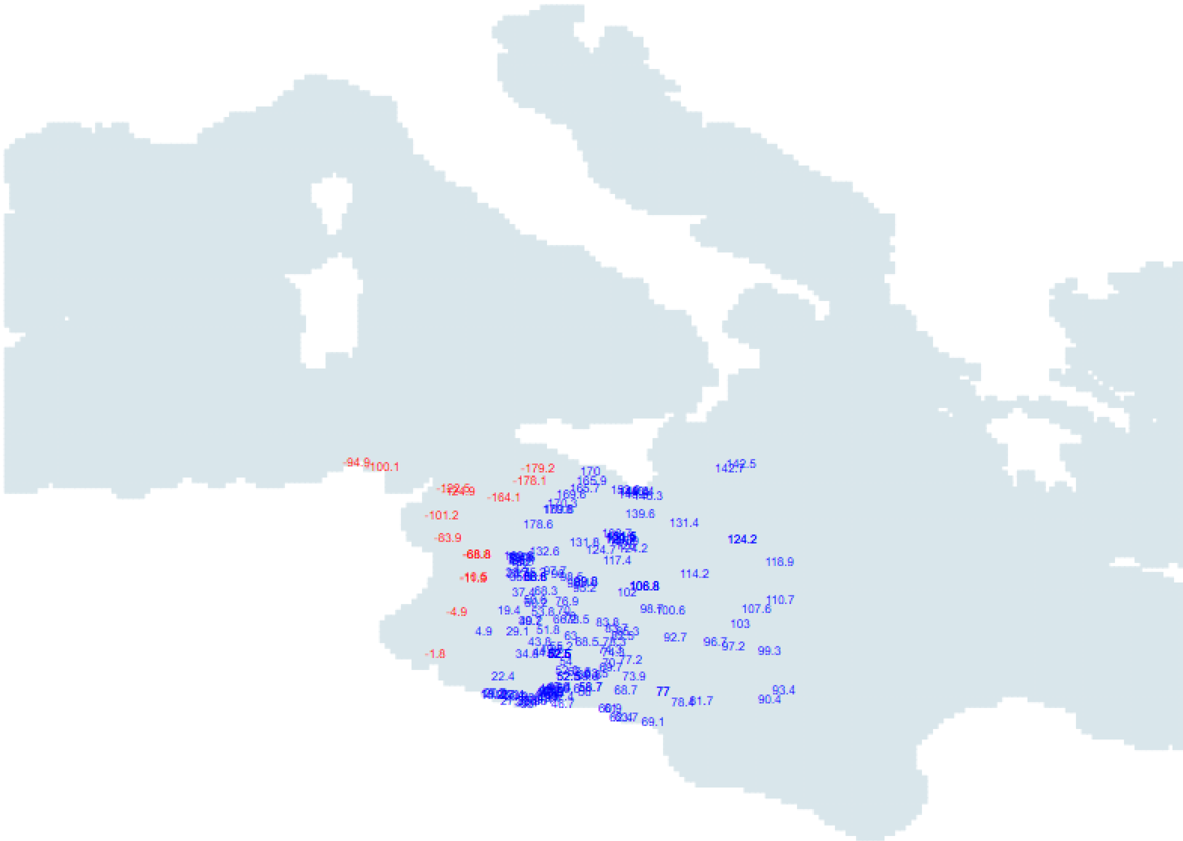

Rubber Boats, Wooden Ferries




Life Jackets

Note: Data come from UN Comtrade over the period 2005-2020. The series show net-imports of rubber boats and ferries (left panel) and Life Jackets (right panel) to countries near Libya for which data are available (Malta, Turkey, and Egypt). Both series are normalized to 1 in 2010.

Figure C.4: Map of Angles



Note: The figure shows the location of shipwrecks and the corresponding angle with respect to Lampedusa. The angle is normalized to be zero between Lampedusa and the shore at the border between Tunisia and Libya, close to the island of Djerba. The angle becomes more negative moving west towards Tunisia and more positive moving East towards Libya. The total number of observations is 143.

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

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | **Crossing 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 SAR Period Statistics* | | | | | | | |
| Pre Mean Outcome | 24 | 0.03 | 325 | 784 | 259 | 206 | 134 |
| Pre Median Outcome | 0.00 | 0.00 | 306 | 787 | 233 | 223 | 168 |
| Estimator | PPML | OLS | OLS | OLS | OLS | OLS | OLS |

Note: The sample in column (1) consists of daily observations from 1 January 2009 to 31 December 2017 (3,287). The sample in column (2) consists of daily observations from 1 January 2009 to 31 December 2017 (1,579), i.e. when deaths and total attempts are simultaneously different from zero. The sample in column (3)-(7) consists of 503 geo-localized rescue events from 18 January 2009 to 22 December 2017. SAR coefficients (Hermes, Mare Nostrum, Triton I and II) are estimated relative to the baseline period in which no SAR operations were in place. Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. Crossing Risk is defined as the number of deaths over total attempts. Distances, expressed in Km, measures the shortest linear distance between different locations (Tripoli, Bengazi (Libya), Al Huwariyah (Tunisia) and Lampedusa (Italy) and the latitude and the longitude of the casualties at sea. All regressions control for 52 weeks of the year fixed effects. Regressions estimated with PPML and OLS. Standard errors clustered by month of the year * $p<.10$ ** $p<.05$ *** $p<.01$.

Table C.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 provides significant wave height that describes the combined height of the sea and the swell that mariners experience on open waters. See `http://www.bom.gov.au/marine/knowledge-centre/reference/waves.shtml`

Table C.3: Crossing Attempts: Robustness using OLS

| | (1) | (2) | (3) |
|---|---|---|---|
| | | **Crossing Attempts** | |
| | | **Definition of Unsafe Boat** | |
| | *Inflatable* | *Inflatable + Unknown* | *Inflatable + Unknown + Other* |
| Wave Height * SAR * Frac. Unsafe Boat | -257.33 | -305.54*** | -273.08*** |
| | (252.35) | (96.35) | (83.64) |
| Wave Height | -76.95** | -104.78*** | -111.96*** |
| | (39.14) | (40.08) | (41.06) |
| Wave Height * Frac. Unsafe Boat | 74.52 | 94.50 | 93.44 |
| | (245.66) | (83.68) | (74.22) |
| Wave Height * SAR | -15.94 | 62.10 | 70.49 |
| | (45.38) | (44.34) | (44.83) |
| Observations | 1,612 | 1,612 | 1,612 |
| Week-Year FE | ✓ | ✓ | ✓ |
| *Pre SAR Period Statistics* | | | |
| Mean Total Attempt | 120.34 | 120.34 | 120.34 |
| Mean Wave Height | 0.63 | 0.63 | 0.63 |
| Mean Frac. Unsafe Boat | 0.07 | 0.27 | 0.29 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level. We define three different categories of unsafe boats based on the main vessels used. The share of crossing attempts using "inflatable" rubber boats over the total; we then add the "unknown boats" and "other boats", excluding any sturdy and motor boats. All regressions control for week-by-year fixed effects. Regressions are estimated using OLS. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table C.4: Crossing Attempts: Robustness on Cluster Standard Errors

<table>
<tr><td></td><td>(1)</td><td>(2)</td><td>(3)</td></tr>
<tr><td></td><td></td><td>Crossing Attempts</td><td></td></tr>
<tr><td></td><td></td><td>Definition of Unsafe Boat</td><td></td></tr>
<tr><td></td><td>Inflatable</td><td>Inflatable +<br>Unknown</td><td>Inflatable +<br>Unknown +<br>Other</td></tr>
<tr><td>Wave Height * SAR * Frac. Unsafe Boat</td><td>-6.55***</td><td>-5.45***</td><td>-4.17***</td></tr>
<tr><td></td><td>(1.63)</td><td>(1.31)</td><td>(1.37)</td></tr>
<tr><td></td><td>[2.97]</td><td>[1.74]</td><td>[1.50]</td></tr>
<tr><td></td><td>{1.95}</td><td>{1.42}</td><td>{1.31}</td></tr>
<tr><td></td><td>|2.13|</td><td>|1.58|</td><td>|1.43|</td></tr>
<tr><td>Wave Height</td><td>-0.89**</td><td>-1.43**</td><td>-1.46**</td></tr>
<tr><td></td><td>(0.38)</td><td>(0.61)</td><td>(0.69)</td></tr>
<tr><td></td><td>[0.41]</td><td>[0.78]</td><td>[0.78]</td></tr>
<tr><td></td><td>{0.39}</td><td>{0.65}</td><td>{0.66}</td></tr>
<tr><td></td><td>|0.39|</td><td>|0.73|</td><td>|0.74|</td></tr>
<tr><td>Wave Height * Frac. Unsafe Boat</td><td>2.13</td><td>1.91</td><td>1.63</td></tr>
<tr><td></td><td>(1.47)</td><td>(1.25)</td><td>(1.20)</td></tr>
<tr><td></td><td>[2.89]</td><td>[1.69]</td><td>[1.35]</td></tr>
<tr><td></td><td>{1.85}</td><td>{1.37}</td><td>{1.17}</td></tr>
<tr><td></td><td>|2.04|</td><td>|1.54|</td><td>|1.29|</td></tr>
<tr><td>Wave Height * SAR</td><td>0.21</td><td>1.16*</td><td>1.00</td></tr>
<tr><td></td><td>(0.48)</td><td>(0.65)</td><td>(0.78)</td></tr>
<tr><td></td><td>[0.49]</td><td>[0.82]</td><td>[0.89]</td></tr>
<tr><td></td><td>{0.46}</td><td>{0.68}</td><td>{0.77}</td></tr>
<tr><td></td><td>|0.46|</td><td>|0.76|</td><td>|0.84|</td></tr>
<tr><td>Observations</td><td>1,612</td><td>1,612</td><td>1,612</td></tr>
<tr><td>Week-Year FE</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Pre SAR Period Statistics</td><td></td><td></td><td></td></tr>
<tr><td>Mean Total Attempt</td><td>120.34</td><td>120.34</td><td>120.34</td></tr>
<tr><td>Mean Wave Height</td><td>0.63</td><td>0.63</td><td>0.63</td></tr>
<tr><td>Mean Frac. Unsafe Boat</td><td>0.07</td><td>0.27</td><td>0.29</td></tr>
</table>

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level. We define three different categories of unsafe boats based on the main vessels used. The share of crossing attempts using "inflatable" rubber boats over the total; we then add the "unknown boats" and "other boats", excluding any sturdy and motor boats. All regressions control for week-by-year fixed effects. Regressions are 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 a bandwidth equal to 7 days and 14 days in curly brackets and vertical bars, respectively. * p<.10 ** p<.05 *** p<.01.

Table C.5: Crossing Attempts: Robustness on Wave Height

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | **Crossing Attempts** | | | | | |
| | **Definition of Unsafe Boat** | | | | | |
| | *Inflatable* | *Inflatable + Unknown* | *Inflatable + Unknown + Other* | *Inflatable* | *Inflatable + Unknown* | *Inflatable + Unknown + Other* |
| Wave Height * SAR * Frac. Unsafe Boat | -0.85 | -2.10** | -1.84* | -2.27 | -3.23*** | -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 * Frac. Unsafe 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 * 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) |
| | **Wave Height in Tripoli (t-1)** | | | **Max Wave Height in Tripoli (t and t-1)** | | |
| Observations | 1,612 | 1,612 | 1,612 | 1,612 | 1,612 | 1,612 |
| Week-Year FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Pre SAR Period Statistics* | | | | | | |
| Mean Total Attempt | 120.34 | 120.34 | 120.34 | 120.34 | 120.34 | 120.34 |
| Mean Wave Height | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 |
| Mean Frac. Unsafe Boat | 0.07 | 0.27 | 0.29 | 0.07 | 0.27 | 0.29 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. In columns 1-3, we use one-day lag ($t-1$); in columns 4-6 the maximum values between wave height at time $t$ and $t-1$. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level. We define three different categories of unsafe boats based on the main vessels used. The share of crossing attempts using "inflatable" rubber boats over the total; we then add the "unknown boats" and "other boats", excluding any sturdy and motor boats. All regressions control for week-by-year fixed effects. Regressions are estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table C.6: Crossing Attempts on Wave Height Squared

| | (1) | (2) | (3) |
|---|---|---|---|
| | | **Crossing Attempts** | |
| | | **Definition of Unsafe Boat** | |
| | *Inflatable* | *Inflatable + Unknown* | *Inflatable + Unknown + Other* |
| Wave Height Sq.* SAR * Frac. Unsafe Boat | -5.93*** | -3.76*** | -2.73*** |
| | (1.56) | (0.82) | (1.00) |
| Wave Height Sq. | -0.48** | -0.64* | -0.84** |
| | (0.21) | (0.34) | (0.41) |
| Wave Height Sq. * Frac. Unsafe Boat | 1.65 | 0.76 | 1.09 |
| | (1.50) | (0.77) | (0.80) |
| Wave Height Sq. * SAR | 0.37 | 0.68* | 0.72 |
| | (0.23) | (0.35) | (0.46) |
| Observations | 1,612 | 1,612 | 1,612 |
| Week-Year FE | ✓ | ✓ | ✓ |
| *Pre SAR Period Statistics* | | | |
| Mean Total Attempt | 120.34 | 120.34 | 120.34 |
| Mean Wave Height | 0.63 | 0.63 | 0.63 |
| Mean Frac. Unsafe Boat | 0.07 | 0.27 | 0.29 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height squared in Tripoli (Libya) is measured in meters. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level. We define three different categories of unsafe boats based on the main vessels used. The share of crossing attempts using "inflatable" rubber boats over the total; we then add the "unknown boats" and "other boats", excluding any sturdy and motor boats. All regressions control for week-by-year fixed effects. Regressions are estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table C.7: Crossing Attempts with Different Locations

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | | | **Crossing Attempts** | | |
| | | | **Definition of Unsafe Boat** | | |
| | | | *Inflatable + Unknown + Other* | | |
| Wave Height * SAR * Frac. Unsafe Boat | -4.436** | -3.256*** | -2.096** | -1.749 | -0.191 |
| | (1.821) | (0.952) | (0.936) | (1.605) | (0.971) |
| Wave Height | -1.511* | -1.478*** | -1.069* | -0.737 | -0.459 |
| | (0.796) | (0.451) | (0.594) | (0.567) | (0.453) |
| Wave Height * Frac. Unsafe Boat | 1.818 | 2.313*** | 1.762** | 1.237 | 0.0573 |
| | (1.558) | (0.723) | (0.834) | (1.339) | (0.875) |
| Wave Height * SAR | 0.314 | 0.587 | 0.403 | -1.231 | -0.391 |
| | (0.964) | (0.615) | (0.673) | (0.867) | (0.568) |
| Observations | 1,612 | 1,612 | 1,612 | 1,612 | 1,612 |
| Week-Year FE | ✓ | ✓ | ✓ | ✓ | ✓ |
| Wave measured in | **Zuwara** | **Monastir** | **Al Huwariyah** | **Djerba** | **Annaba** |
| | Libya | | Tunisia | | Algeria |
| *Pre SAR Period Statistics* | | | | | |
| Pre Mean Outcome | 120.341 | 120.341 | 120.341 | 120.341 | 120.341 |
| Pre Mean Frac. Unsafe Boat | 0.292 | 0.292 | 0.292 | 0.292 | 0.292 |
| Pre Mean Wave | 0.581 | 0.674 | 0.761 | 0.68 | 0.771 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in the different locations (Zuwara and Monastir, Libya; Al Huwariyah and Djerba, Tunisia; and Annaba, Algeria) is measured in meters. The different coordinates are reported in Table 2. Frac. Unsafe Boat measures the share of attempted crossings using "inflatable" rubber boats, "unknown boats" and "other boats" boats aggregated at the week-year level. All regressions control for week-by-year fixed effects. Regressions are estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table C.8: Crossing Attempts on Bad Weather Dummies

| | (1) | (2) | (3) |
|---|---|---|---|
| | | **Crossing Attempts** | |
| | | **Definition of Unsafe Boat** *Inflatable* | |
| **1**[Bad weather] * SAR * Frac. Unsafe Boat | -3.05*** | -4.54 | -9.47** |
| | (0.91) | (3.60) | (4.32) |
| **1**[Bad weather] | -0.59*** | -0.42 | -0.64 |
| | (0.21) | (0.43) | (0.63) |
| **1**[Bad weather] * Frac. Unsafe Boat | 1.57* | 1.67 | 3.85 |
| | (0.84) | (3.54) | (3.52) |
| **1**[Bad weather] * SAR | 0.10 | -0.23 | -0.05 |
| | (0.28) | (0.51) | (0.78) |
| Observations | 1,612 | 1,612 | 1,612 |
| Percentile of Wave Height | >**50** | >**75** | >**90** |
| *Pre SAR Period Statistics* | | | |
| Mean Total Attempt | 120.34 | 120.34 | 120.34 |
| Mean Frac. Unsafe Boat | 0.07 | 0.07 | 0.07 |

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple boat types were used). Crossing attempts sum crossings and deaths in transit. The variable **1**[Bad weather] is equal to one if the significant wave height is higher than median one (column 1), is in the top quartile (column 2) or in the top decile (column 3). Frac. Unsafe Boat measures the share of attempted crossings using inflatable boats aggregated at the week-year level. All regressions control for week-by-year fixed effects. Regressions are estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

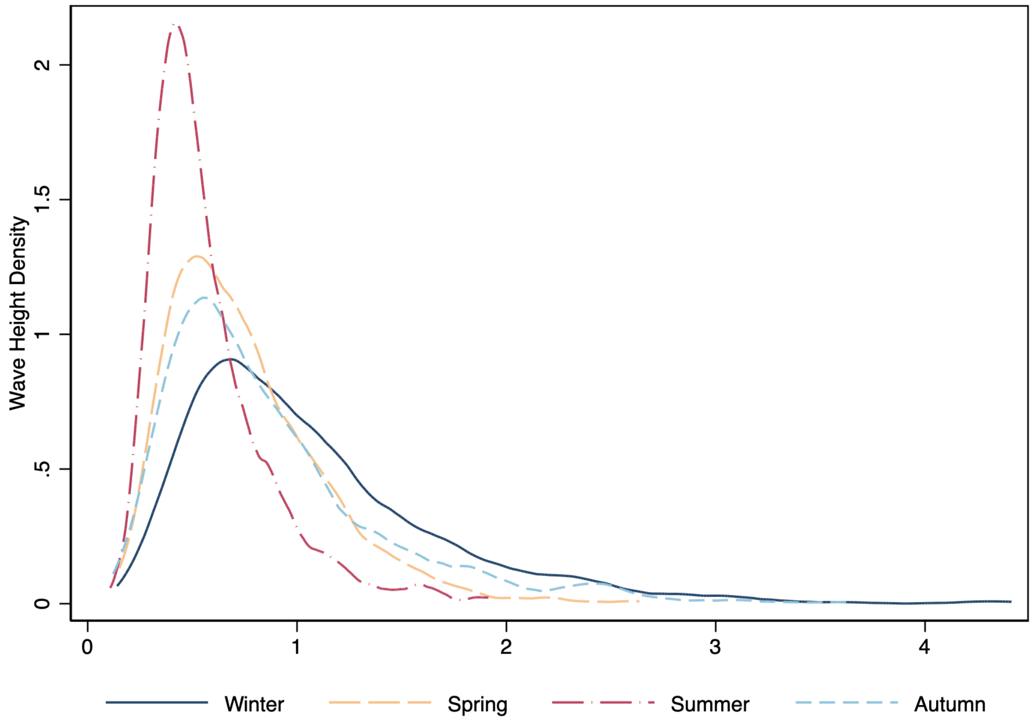
Table C.9: Fraction of Migrants by Boat Types: Robustness

| **Panel A**: Fraction of Attempted Crossings | (1)<br>Inflatable | (2)<br>Inflatable +<br>Unknown | (3)<br>Inflatable +<br>Unknown +<br>Other | (4)<br>Fishing | (5)<br>Motor |
|---|---|---|---|---|---|
| | | | **Fractional Probit model (marginal effects)** | | |
| Mare Nostrum | 0.08 | -0.05 | 0.06 | 0.04 | -0.09*** |
| | (0.06) | (0.04) | (0.05) | (0.04) | (0.03) |
| Triton I | 0.30*** | 0.07 | 0.20*** | 0.06 | -0.24*** |
| | (0.10) | (0.07) | (0.06) | (0.06) | (0.06) |
| Triton II | 0.54*** | 0.42*** | 0.43*** | -0.16*** | -0.31*** |
| | (0.04) | (0.03) | (0.03) | (0.03) | (0.03) |
| Observations | 768 | 768 | 768 | 768 | 768 |
| Pre MN Mean Outcome | 0.11 | 0.38 | 0.42 | 0.22 | 0.36 |

| **Panel B**: Count of Attempted Crossings | (1)<br>Inflatable | (2)<br>Inflatable +<br>Unknown | (3)<br>Inflatable +<br>Unknown +<br>Other | (4)<br>Fishing | (5)<br>Motor |
|---|---|---|---|---|---|
| | | | **PPML** | | |
| Mare Nostrum | 0.47 | 0.10 | 0.74** | 0.96*** | -0.73** |
| | (0.51) | (0.37) | (0.34) | (0.27) | (0.32) |
| Triton I | 1.29** | 0.59 | 1.17*** | 1.97*** | -2.18*** |
| | (0.53) | (0.39) | (0.36) | (0.55) | (0.62) |
| Triton II | 2.20*** | 1.75*** | 1.68*** | -0.34 | -2.62*** |
| | (0.41) | (0.27) | (0.28) | (0.30) | (0.59) |
| Constant | 2.64*** | 3.57*** | 3.63*** | 3.21*** | 4.55*** |
| | (0.41) | (0.26) | (0.27) | (0.24) | (0.22) |
| Observations | 1,612 | 1,612 | 1,612 | 1,383 | 1,397 |
| Pre MN Mean Outcome | 14.10 | 36.94 | 41.44 | 28.37 | 55.25 |

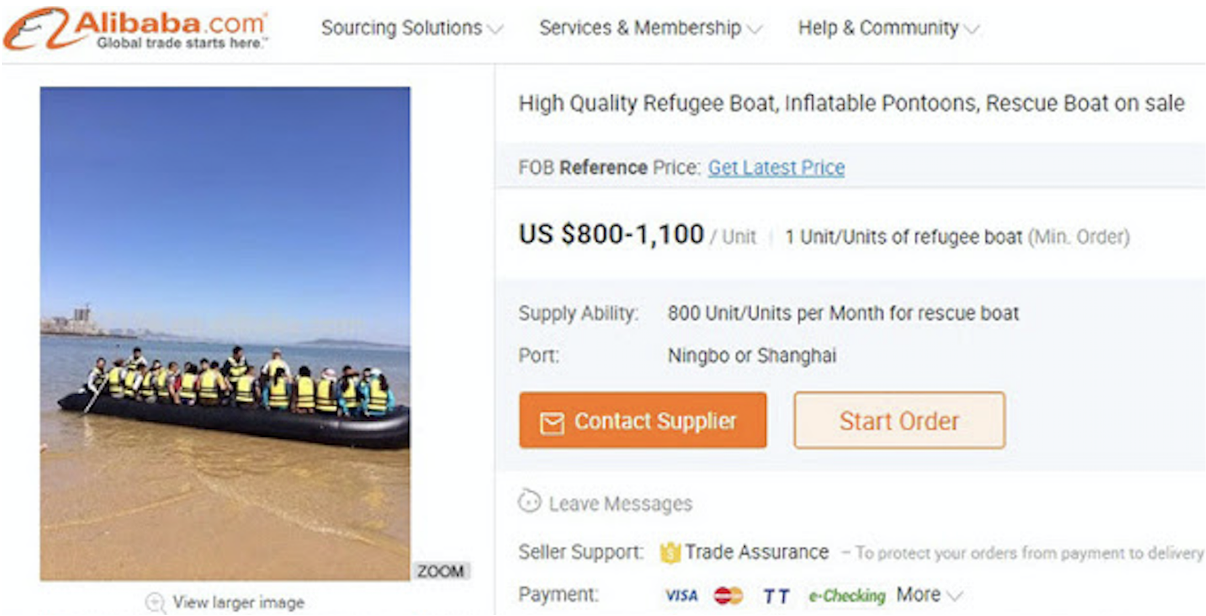
Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations were in place (164 days). More intense SAR (i.e. Mare Nostrum (MN), Triton I and II) dummies are equal to one over the periods defined in Table 1. In Panel A we estimate a fractional Probit model of the share of attempted crossings using different types of boats for each column. The 768 observations correspond to days with at least one crossing. In Panel B the depend variables are the number of attempted crossings using specific types of boats. The sample consists of 1,612 observations (1,383 and 1,397 for fishing and motor boats due to the fixed effects). All regressions control seasonality by adding 52 weeks of the year fixed effects. Cluster standard errors at the weekly level. * p<.10 ** p<.05 *** p<.01.

Figure C.5: Density of Wave Height in Tripoli by Season



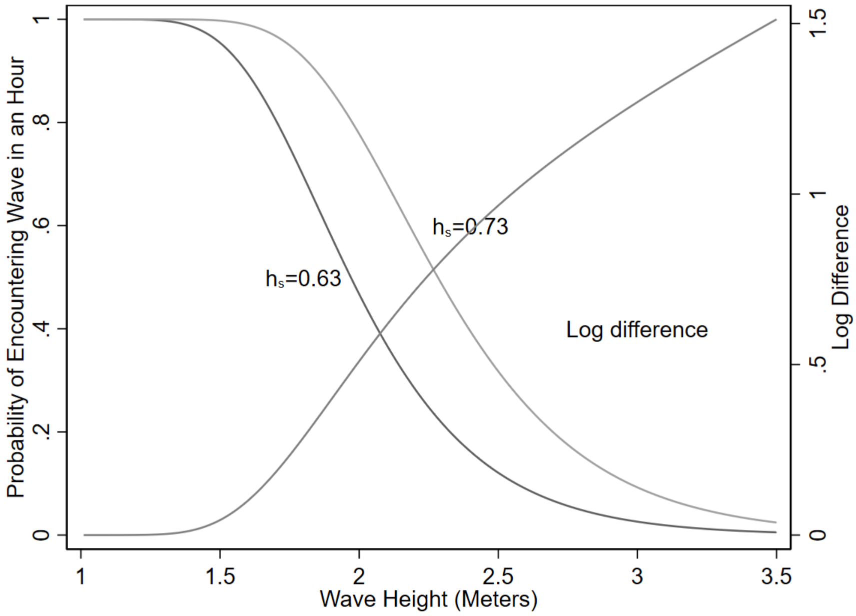

Note: We gather the data on significant wave height from the European Centre for Medium-Range Weather Forecasts (ECMWF). The density functions show the wave conditions by seasons in Tripoli.

Figure C.6: A Typical Inflatable Boat



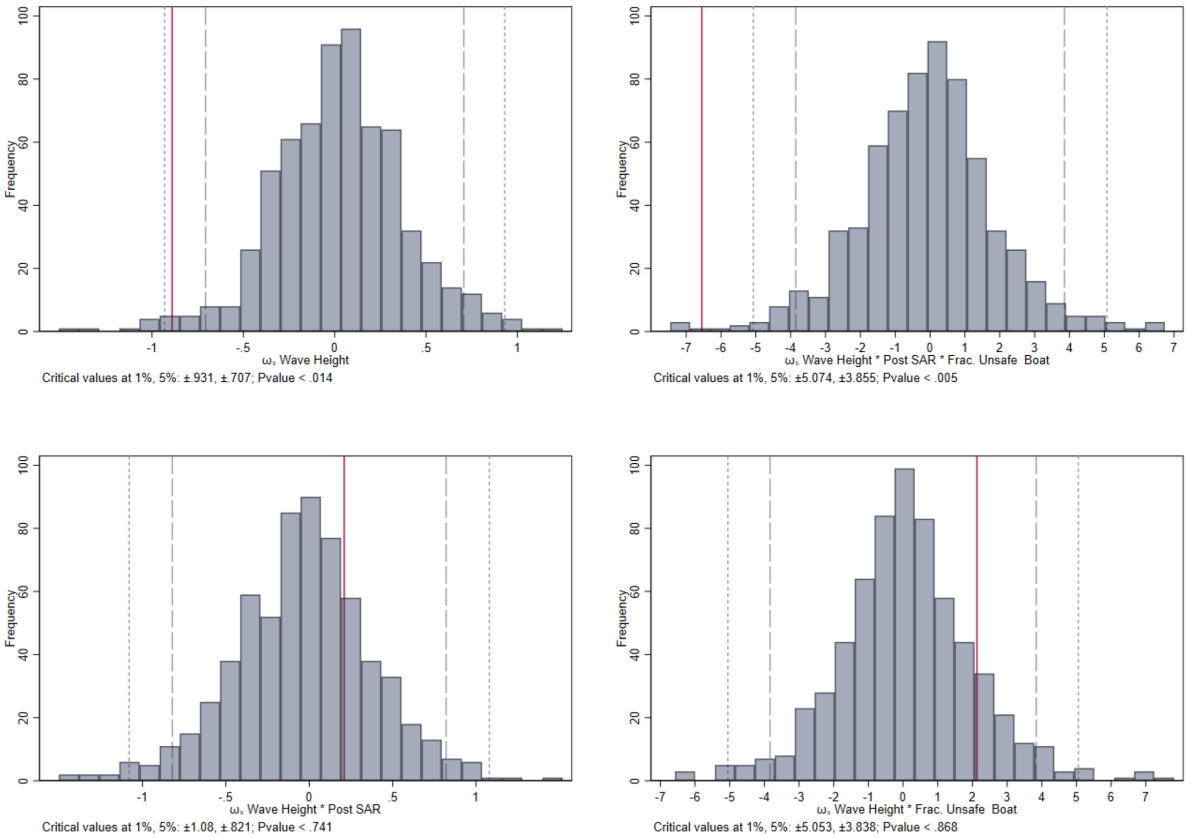

Note: The figure is taken from `https://www.alibaba.com` where Chinese-made dinghies were advertised as "refugee boats" and were transshipped to Libya through other countries, i.e. Malta and Turkey.

Figure C.7: Probability of Encountering Large Waves



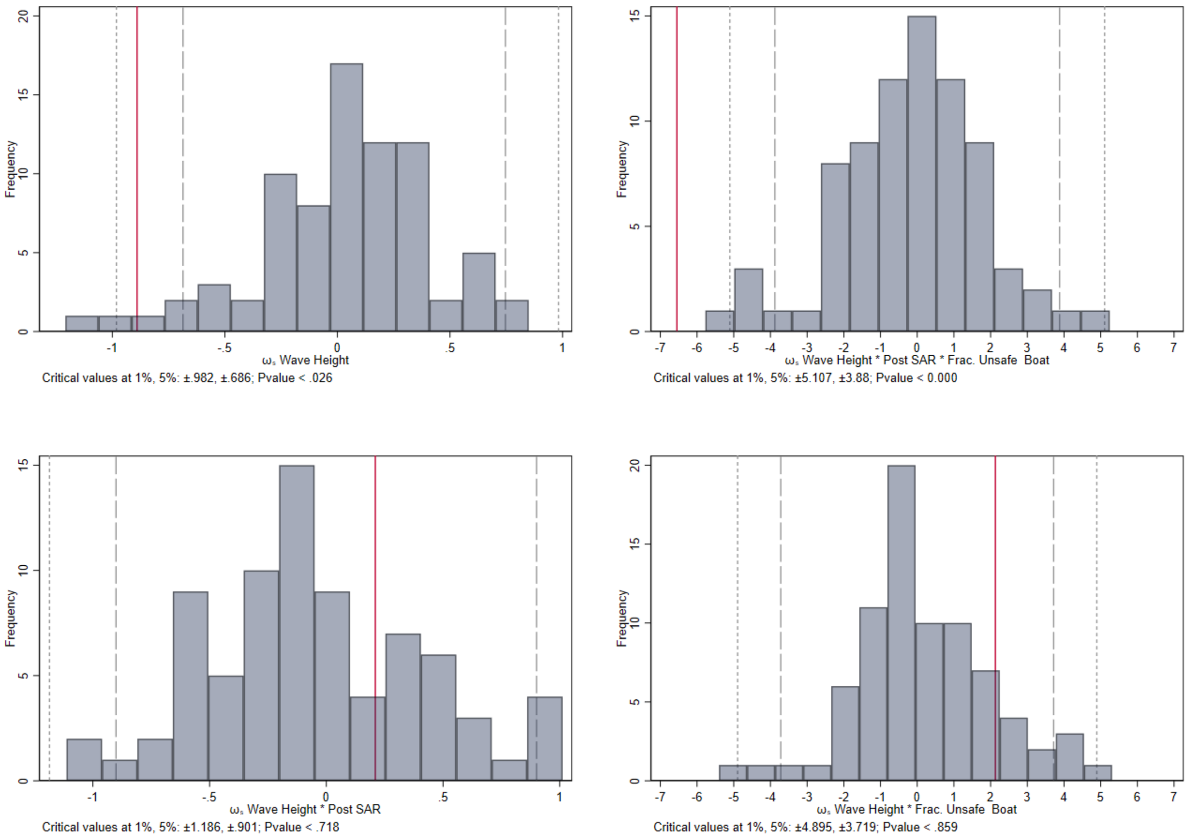

Note: The figure shows the probability of encountering waves up to "Wave Height" when the significant wave height is either 0.63 or 0.73 meters, as well as the corresponding relative difference.

Figure C.8: Randomization Inference Using Former Wave Conditions



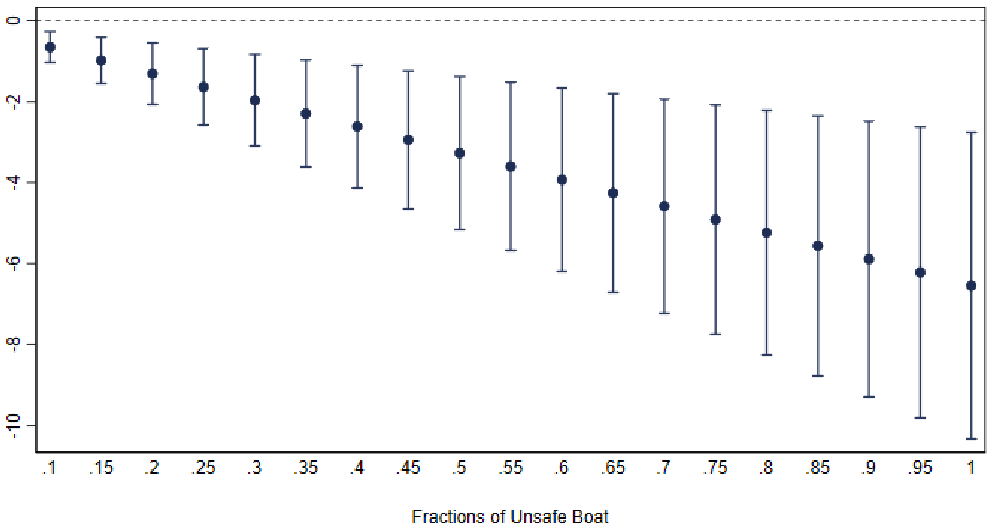

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. We estimate Equation 3 644 times, using wave height at time $t-k$ instead of time $t$, with $k$ ranging from 28 to 672 days. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level, i.e. the share of crossing attempts using "inflatable" rubber boats over the total. All regressions control for week-by-year fixed effects. Left-top panel shows the placebo for the coefficients of the wave height, right-top panel the triple interaction terms between Frac. Unsafe Boat, post Mare Nostrum period and the wave height in Tripoli. Left-bottom panel shows the placebo for the coefficients of the interaction between wave height in Tripoli and Post SAR, right-bottom panel the double interaction terms between Frac. Unsafe Boat and the wave height in Tripoli. Regressions are estimated using Poisson quasi-maximum likelihood models. The solid red line indicates the estimated coefficients, while the dotted and dashed line indicate the 1% and 5% critical values (computed based on the estimated standard deviation).

Figure C.9: Randomization Inference Using Future Waves



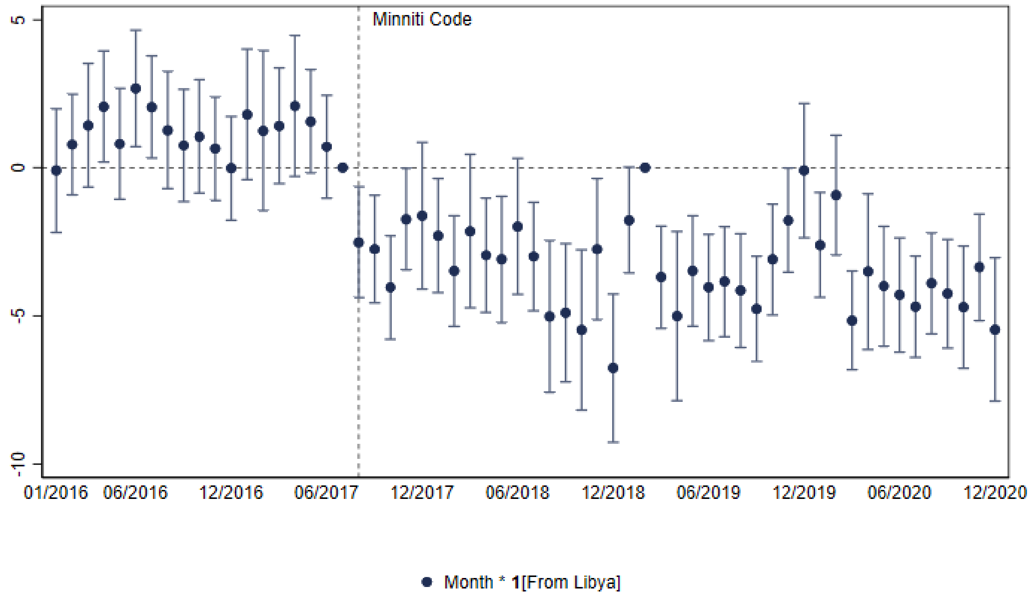

Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. We estimate Equation 3 80 times, using wave height at time $t+k$ instead of time $t$, with $k$ ranging from 7 to 87 days. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level, i.e. the share of crossing attempts using "inflatable" rubber boats over the total. All regressions control for week-by-year fixed effects. Left-top panel shows the placebo for the coefficients of the wave height, right-top panel the triple interaction terms between Frac. Unsafe Boat, post Mare Nostrum period and the wave height in Tripoli. Left-bottom panel shows the placebo for the coefficients of the interaction between wave height in Tripoli and Post SAR, right-bottom panel the double interaction terms between Frac. Unsafe Boat and the wave height in Tripoli. Regressions are estimated using Poisson quasi-maximum likelihood models. The solid red line indicates the estimated coefficients, while the dotted and dashed line indicate the 1% and 5% critical values (computed based on the estimated standard deviation).

Figure C.10: Crossing Attempts to Crossing Conditions along Fraction of Unsafe Boats




Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations (single boat type regime) were in place (164 days). Post SAR dummy is equal to one for all observations after October 18, 2013 (the beginning of the intense SAR when multiple types of boats were used). Crossing attempts sum crossings and deaths in transit. Significant wave height in Tripoli (Libya) is measured in meters. Frac. Unsafe Boat measures the share of attempted crossings using unsafe boats aggregated at the week-year level. We use the unsafe boats defined as the share of crossing attempts using "inflatable" rubber boats over the total. We provide the estimate of semi-elasticity along different fractions of unsafe boat. All regressions control for week-by-year fixed effects. Regressions are estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with a bandwidth equal to 28 days (5% levels).

Figure C.11: Event Study around the Minniti Code




Note: The sample consists of daily observations from 1 January 2016 to 31 December 2020. SAR dummy is equal to one for all observations before August 7, 2017, when multiple boat types were used more frequently. This corresponds to pre-*Minniti* periods, i.e. before the Code of Conduct was enacted restricting *de-facto* the use of unsafe boats. The Libyan route is considered as treated unit. Time indicate the month of the year. Crossing attempts sum crossings and deaths. All regressions control for week-by-year fixed effects. In February 2019 no crossing attempts occurred so no coefficient is estimated (it is absorbed by week-by-year fixed effects). Regressions estimated using Poisson quasi-maximum likelihood models. Figure shows the dynamic effect of the main result in Table 4, i.e. the interaction between $Wave\ Height * From\ Libya * Frac.\ Inflatable\ Boat * SAR$. Each coefficient represents the interaction between the dummy-month of the year and the treatment, i.e. if the crossings attempts come from Libya. Baseline period is July, 2017. Standard errors are cluster at the week of the year level. (5% confidence interval).

# Appendix D: 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 D.1).

Table D.1: NGO Vessels and Operational Period

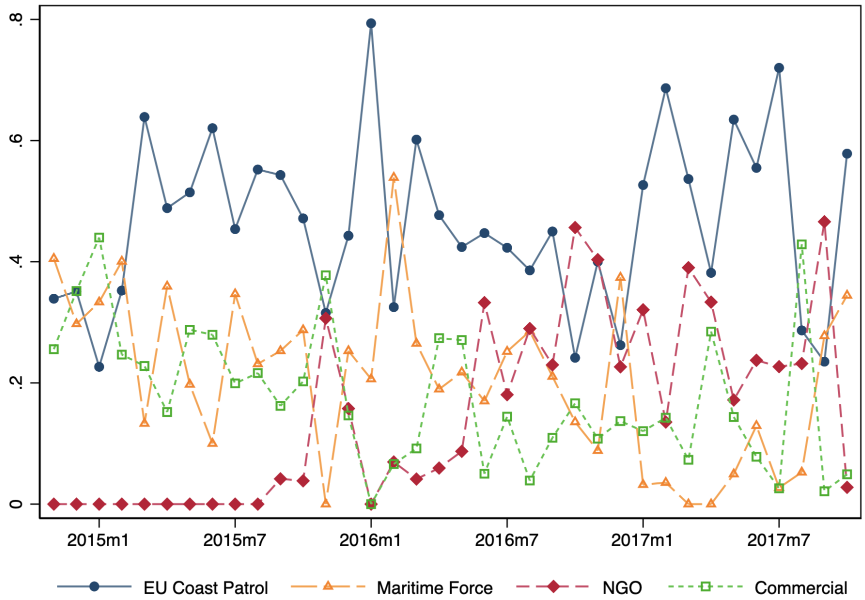
| NGO | Country | Flag | Vessel | Operational Period |
|---|---|---|---|---|
| Jugend Rettet | Germany | The Netherlands | Iuventa | Jul 2016 - Nov 2016 |
| LifeBoat | Germany | Germany | Minden | Jun 2016 - Nov 2016 |
| Médecins Sans Frontières (MSF) | France | Italy | Vos Prudence | Mar 2017 - Oct 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: The list of NGOs operating in the Mediterranean Sea is available in the Italian Navy report (2017). The table distinguishes between the country and flag of the boat, the vessel type and the operational period.

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 D.1, 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.

Figure D.1: Rescue Activity by Organization 2014-2017




Note: Data provided by the European Border and Coast Guard Agency known as Frontex. The information is disclosed by Frontex for the period from January, 2015 to December, 2017. Each line represents the fraction of monthly crossings that are intercepted by any given organization (EU coast patrol, Maritime force, NGOs and Commercial boats). Their sum is always one.