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JEL Classification: F22, K37, K42, H12

Keywords: Central Mediterranean, sea crossings, International Migration, undocumented migration, search and rescue operations, rubber boats, smugglers, migrants, Africa

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

Claudio Deiana[†], Vikram Maheshri[‡], Giovanni Mastrobuoni[§]

May 14, 2021

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1 Introduction

Many Western countries are facing increased migratory pressure be it over land or sea.[1] For instance, annual migratory flows from Africa to Italy alone have jumped from a few hundred to almost 200,000 over the past quarter century, and these flows are only expected to increase further due to high African population growth coupled with increasing desertification.[2] This global development has prompted a variety of reactions in destination countries: 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 of the day. In most other European countries, the vote shares of similarly-oriented parties have frequently reached double digits. According to recent polls, the Italian party "Lega," a populist anti-immigration party, jumped from about 10 percent to 30 percent of the vote share. The enormous gain is believed to be due to his attempts to ban refugee boats, including NGO rescue vessels, from entering Italian ports.

The renewed focus on immigration in Italian politics follows directly from the fact that a major European migratory route is the "Central Route" along which irregular migrants board vessels on the North African coast en route to Italy.[5] In March 2015, the executive director of Frontex told the Italian Associated Press National Agency (ANSA), "Anywhere between 500,000 to a million people are ready to leave from Libya," and from 2009 to 2017 over 750,000 irregular migrants and refugees reached Italy along this route.[6] Despite it is short distance, this is now

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[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. (forthcoming) find that the increased sanctions have lowered recidivism in illegal entry, while Feigenberg (2020) and Allen et al. (2018) find that the border wall reduced entry, though at a very high cost.

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

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

agreed to be the deadliest water crossing in the world (McAuliffe and Ruhs, 2017). Between 2009 and 2017, roughly 11,500 people are believed to have perished in the Central Mediterranean, with countless others dying along the journey through the Sahara desert (UNODC, 2018). In comparison, annual deaths along the US-Mexico border range in the low hundreds.[7]

The reaction to this slowly unfolding tragedy has been inconsistent at best. In the wake of large, high profile shipwrecks, Italy and the EU established extensive search and rescue (SAR) operations at sea in the form of operations *Hermes*, *Mare Nostrum* and *Triton*.[8] Despite intensifying efforts, some of the deadliest years on record followed. While these well-intentioned operations ostensibly reduced the risk of death *ceteris paribus*, they may have also induced greater numbers of migrants to attempt crossing, leading to an ambiguous effect on total migrant deaths.[9] Moreover, to the extent that these additional crossings were made on flimsier boats in a cost-saving measure, the operations may have unintentionally increased the risk of death itself. While in 2017 Italy and the EU have reduced the geographic scope of their operations, 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 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] We find that more far-reaching SAR operations induced more migrants to attempt crossings in bad weather and eventually led smugglers to shift to unsafe boats. We estimate that almost all additional migrants who attempted the journey did so on unsafe, inflatable boats,

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

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

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

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

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

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

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

To implement our identification strategy, we rely on daily observation of activity along the Central Route. This is accomplished with the use of unique, restricted daily data on crossing attempts that we obtained from the *Polizia di Stato*, the Italian State Police in charge of migration. To the best of our knowledge, these data have not been used in any other analysis of migration along the Central Route, and they offer an unparalleled perspective on how migration changes at high frequency, the ideal frequency to exploit changes in sea conditions. We complement this with a robust dataset on migrant deaths that we cross-reference from four high quality sources, daily data on physical crossing conditions, data on migrant boat types, and a carefully researched catalog of SAR operations from 2009-2017.

Despite the importance of this issue, there has been little empirical analysis and formal theoretical modeling of irregular migration along this important route, as pointed out by Friebel and Guriev (2013).[11] Friebel et al. (2017) and Aksoy and Poutvaara (2019) explore who chooses to migrate to Europe and their motivations for doing so.[12] The authors also consider some unintended effects of stricter border regulations on (negative) circular migration and (positive)

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

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

demand for smugglers.

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

Our paper also builds on a long standing literature stemming from Peltzman (1975) that argues that the potential safety benefits of new technologies or policies may be offset by the behavioral responses of different agents, be they drivers (Winston et al., 2006), drug users (Doleac and Mukherjee, 2018; Evans et al., 2019), or in this case, smugglers.[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. We also describe the various sources of data used in our analysis. In Section 3, we present a simple model of human smuggling that highlights the incentives that shape the decisions of smugglers and potential migrants. In Section 4 we develop the empirical model. In Section 5 we estimate the responsiveness of smugglers and migrants to crossing conditions, which we combine with our model to identify the effects of SAR on crossings and riskiness of this passage. We conclude in Section 6.

2 Background and Data

The Mediterranean Sea has been the home of trade and migration routes for millennia. Italy, with its strategic central position and proximity to African shores, has always been an important trading hub as a well as a major port of entry into Europe. One major migratory route runs from Libya to the Italian island of Lampedusa, which is closer to Africa (167km or about 100 miles from Ras Kaboudja, Tunisia and 296km from Tripoli, Libya) than to Italy itself (205km to Sicily and 395km to continental Italy). Another common port of entry is Pantelleria, which is just 71km away from Kelibia (Tunisia).

In calm waters migrant boats would typically travel at a speed of 11 to 13km/h (Heller et al., 2012), meaning that on the shortest path from Tunisia it would take about 6 hours to reach Pantelleria and about 14 hours to reach Lampedusa. When leaving from Libya the boat trip would usually take more than a day. At a speed of 12km/h, it would take 25 hours to

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[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.

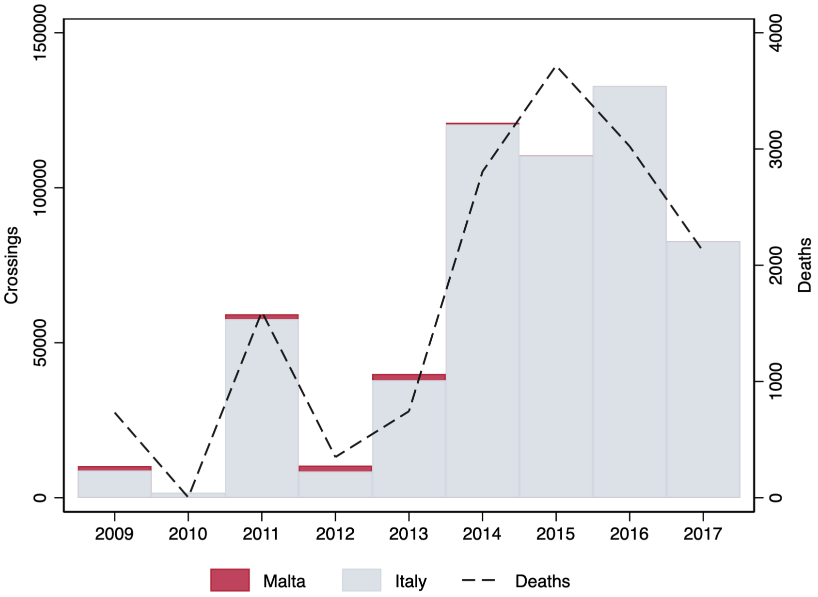
travel from Libya to Lampedusa. The trip may be much shorter if migrants are rescued early and transported to Lampedusa on military or NGO vessels.[14]

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. This established Tunisia as a major point of departure for migrants, particularly after the pro-democracy uprisings during the "Arab Spring" of 2011.

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

As result the Italian government quickly signed a readmission agreement, which allowed a maximum of 100 Tunisian per week to be returned to Tunisia. This slowed down crossings from Tunisia, but Tripoli fell in August of 2011, leading to a surge in refugees from Libya. Libyan dictator Muammar Ghaddafi was captured and killed in October 2011, rendering the

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



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

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[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.

previously signed treaty with Italy moot, and instability quickly travelled to Egypt and the Middle East, bringing with it further waves of refugees. Unsavory actors with ties to Al Qaeda quickly controlled parts of the market for human smuggling into Europe, which by then was largely organized out of Libya. By the end of 2011, almost 60,000 immigrants from North Africa had reached European shores, and Italy became the main port of disembarkation on the Central Route.[15] After two relatively calm years, attempted crossings to Italy further skyrocketed with the deepening of civil war in Libya, reaching close to 150,000 in 2016. This escalation was accompanied by a sharp increase in the number of people dying along the sea route from North Africa with death rates of about 2 percent (see Figure 1).

For our analysis, we combine data from several sources that focus on irregular migration along the Central Route from 2009 to 2017. Extralegal behavior is by its very nature often difficult to observe. As such, we always rely on multiple sources for those variables that are least well documented in official statistics. In total, we construct a dataset that includes detailed information on search and rescue operations alongside daily data on irregular crossings, deaths and crossing tidal conditions each of which we describe in further detail.

2.1 Search and Rescue Operations

As irregular migration surged and became more deadly, Italy and the EU launched a number of search and rescue (SAR) operations with specific objectives. We summarize their operating dates, jurisdiction and budgets in Table 1.[16]

Search and rescue operations usually begin with distress calls to "Marine Rescue Coordination Centers (MRCC)," which take immediate action to rescue the migrant boat in need. In the Central Mediterranean, migrant and civil rescue boats would traditionally call the Italian MRCC located in Rome even if they were closer to Tunisian or Libyan territorial waters because even though both African countries are signatories to the 1979 International Convention on Maritime Search and Rescue, neither one had officially established their SAR area.[17] 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 would be transferred almost exclusively to Italy (see Figure 1).

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

[16] Moreover, in response to the many casualties several Non-governmental organizations started providing aid and emergency medical relief to refugees and migrants. The first vessels of the NGO Migrant Offshore Aid Station (MOAS) started looking for migrant boats in distress close to Libyan shores towards the end of August 2014. Other NGOs followed in later years (a full list is shown in Table C.1). Since MOAS was the first NGO to operate close to Libya and discloses all its operational plans, including the exact period of SAR operations, later in the paper we use these dates to proxy for NGO presence.

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

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
Extension	01 Sep – 31 Mar 12	22*		
Extension	01 Nov – 31 Jan 13	22*		
	06 May – 07 Oct 13	44	1.5	9.0
Mare Nostrum	18 Oct 13 – 31 Oct 14	244	9.3	112
Triton I	01 Nov 14 – 30 Apr 15	56	2.9	27.5
Triton II	01 May 15 – 31 Dec 17	256	10.7	343

NGO Operations	Dates	Maritime SAR Op. Area	Fundraising per month	Fundraising total
MOAS	25 Aug – 15 Oct 14	Libyan shore	2.1	4
MOAS	01 May – 01 Oct 15	Libyan shore	1.1	5.7
MOAS	06 Jun – 31 Dec 16	Libyan shore	0.86	6
MOAS	01 Apr – 01 Sep 17	Libyan shore	0.55	3.3

Note: Budget numbers are in millions of Euro. Information on the extent of the SAR zone is sometimes hidden in official Frontex Operational Plans (2009-2014). Information on *Mare Nostrum* and *Triton I* are gathered from a report by Italian Parliament(2017) and Senate Statistical Office (2015). The 2016 and 2018 Frontex budgets provide details on Joint Operations (Frontex, 2016, 2018). In these instances our best guess (*) is that surveillance occurred within the territorial sea, as defined by the 1982 United Nations Convention on the Law of the Sea (12 nautical miles, or 22 km from the coastal state).

Hermes

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

The main objectives of *Hermes* as laid out by Frontex were (i) border surveillance, (ii) early detection of crossings to inform third countries and seek cooperation (iii) information gathering on crossings, (iv) identification and return of third country nationals, and (v) prevention and fight of smuggling of migrants and trafficking of human beings. Its geographical operational area extended up to 24 nautical miles (approximately 44km) from Sicily, which corresponds to Italian territorial waters plus contiguous zones. Frontex extended the operations twice.

Mare Nostrum

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

Unlike *Hermes*, *Mare Nostrum* had the explicit goal of safeguarding human life at sea. The force included personnel as well as sea and air assets of the Navy, the Air Force, the Carabinieri, the State and the Financial Police, and the Coastal Guard (Italian Parliament, 2017). Once rescued, "irregular" migrants were generally channelled to the existing reception system for asylum seekers (Bratti et al., 2020).[18]

Operationally, *Mare Nostrum* consisted of permanent patrols in the SAR zones of Libya, Malta and Italy. Patrols were supposed to extend up to 120 nautical miles from the Italian territorial waters (about 244km south of Lampedusa) but often reached Libyan territorial waters and included naval and aircraft deployments carried out by military personnel. The monthly cost of this *extensive* operation was around €9.5 million, dwarfing that of *Hermes*. Despite seemingly broad public support, the operation was criticized as an unfair burden for Italy to bear alone. *Mare Nostrum* was also criticised by UK's former foreign office minister, Lady Anelay, who described it as, "an unintended 'pull factor', encouraging more migrants to attempt the dangerous sea crossing and thereby leading to more tragic and unnecessary deaths."

Triton

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

Triton's initial operational area shrunk to only 30 nautical miles (56km) from the Italian and Maltese coasts. However, after two more high profile shipwrecks in a single week in April 2015 resulted in over one thousand migrant deaths, the funding and operational power of *Triton* expanded dramatically. The second phase of *Triton* expanded the SAR area up to 138 miles (256km) south of Lampedusa and tripled its operational budget. In addition, Frontex began to destroy migrant smuggler vessels to prevent them being reused, which might have further prompted smugglers to switch from seaworthy but expensive vessels to inflatable rafts, which

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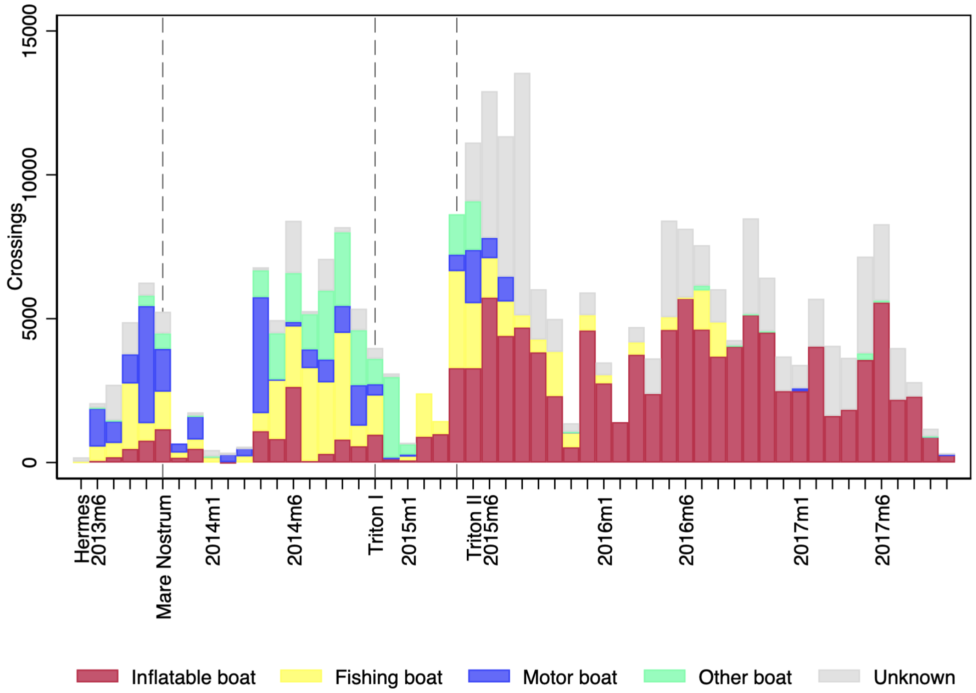
[18] Hatton (2016, 2017) discuss the different asylum seeker policies across OECD countries and, importantly, highlight the limitations of the European asylum policy.

are an order of magnitude cheaper.[19] Operation *Triton* ended in February 2018.[20]

2.2 Data on Crossings

We obtained a novel database containing the numbers of daily irregular migrants to Italy from the *Polizia di Stato* (State Police) who operates under the control of the Department of Public Security (Ministry of Interior). The Department oversees all activities related to public order, which includes operational support for SAR missions. In addition to collecting information on irregular migration, they are tasked with controlling the flow of migrants into Italy and enforcing regulations regarding the entry of and stay of migrants. We use their data to construct our

Figure 2: Types of Vessels Used, 2013-2017



Note: Data provided by the European Border and Coast Guard Agency known as Frontex. The information is disclosed by Frontex for the period from 1 January 2013 to 31 December 2017. Vertical dotted lines display the start of SAR Operations: Hermes, Mare Nostrum, Triton I and II.

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[19] 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.

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

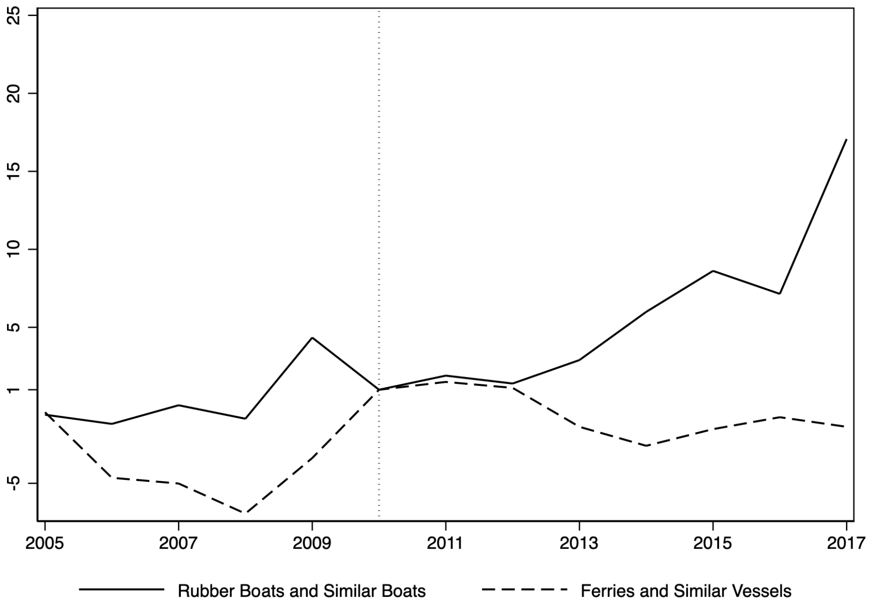
measure of daily arrivals to the Italian shores, which constitutes the bulk (over 75%) of all arrivals along the Central Route.[21] According to the 2017 Euro Asylum Seeker Survey Bank (2018), which collected information from a random sample of adult migrants in Italian asylum centers, 96 percent of migrants were crossing on boats that were intercepted by Italian or EU naval assets. This implies that the number of daily arrivals is unlikely to be measured with sizeable error.

We then compute total crossings as the sum of arrivals and deaths in transit. Attempted crossings have increased over the sample period, peaking in 2016 (see Figure 1). There are on average 170 attempted crossings per day along the Central Route, and they follow a strong seasonal pattern as shown in Figure B.2. Nevertheless, there is significant variation in seasonality across the different years of our sample.

Unfortunately, we cannot observe daily attempted crossings that are intercepted by the Libyan Coast Guard (LCG), but during our period 2009-2017 such operations were in place only after 2016. Based on our data on crossings merged with UNHCR (2017) data (see Appendix Fig. C.2), the fraction of migrants rescued by the LCG is around 10 percent and starts growing only towards the end of 2017. Our results are robust to dropping this period.

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

Figure 3: Rubber Boats against Wooden Ferries



Note: The series show net-imports of rubber boats and ferries to countries near Libya for which data are available (Malta, Turkey, and Egypt). The data source is the United Nations Comtrade. Both series are normalized to 1 in 2010.

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

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. The use of fishing boats and motorboats, the more sturdy boats, becomes less common.

This increase coincides with a massive increase in imports of rubber boats from China to Malta, Turkey, and Egypt, from where rubber boats are believed to reach Libya. According to Figure 3 between 2005 and 2012 imports are fairly flat. There is some increase by 2013, but the large one happens in 2014 and 2015 (between the end of Mare Nostrum and the beginning of Triton II). In those two years net-imports increase by a factor of 5. Another large increase happens towards the end of Triton II, in 2017. By comparison, imports of other vessels are flat.[22] This pattern is further supported by trends in imports of life-jackets to Egypt, Libya and Malta, which we present in Appendix Figure B.3. Indeed, a sharp increase in imports of these inexpensive safety devices, whose benefits would largely accrue to passengers on unsafe, inflatable vessels, is indirect evidence that traffickers offset the safety benefits of SAR.[23]

2.3 Data on Deaths

Although official statistics on deaths in transit are difficult to come by, a number of large transnational organizations make great efforts to document these deaths. We cross-reference these data sets to create a comprehensive single measure of daily deaths. The average number of daily deaths is 4.5, which corresponds to a crossing risk (of death) of 9 percent.

Our primary source is UNITED for Intercultural Action, the European network in support of migrants, refugees and minorities.[24] 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.[25] We also consider the data from Frontex that spans 2014-2016 and the *Migrants File* dataset that spans 2009-2016.[26]

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

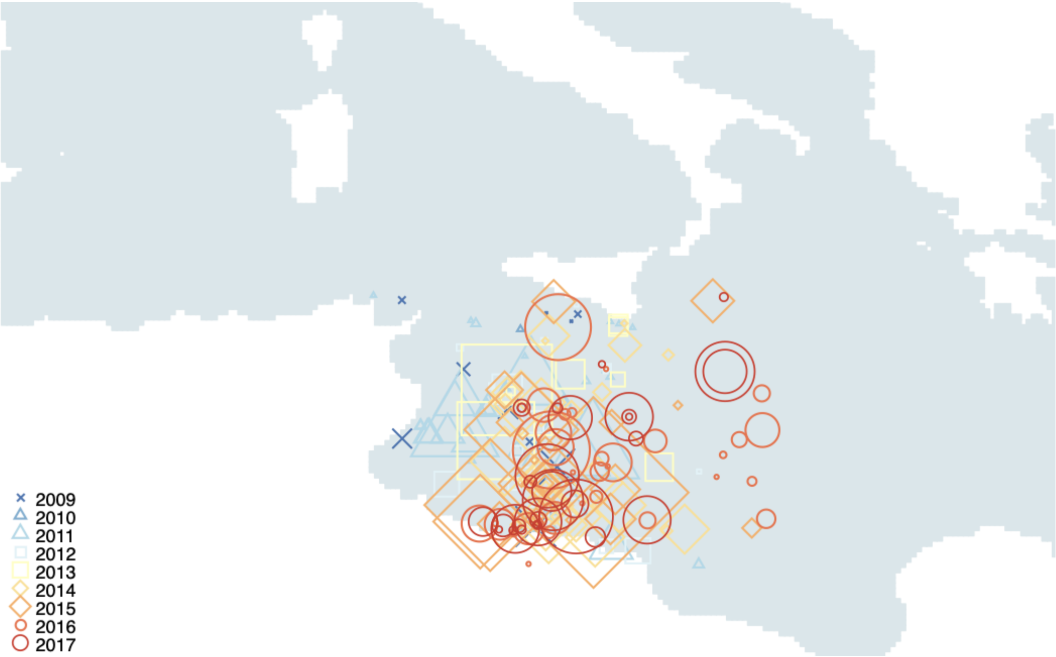
[23] The conjectured use of life-jackets on unsafe boats is also evidence that traffickers are constrained by the safety concerns of migrants through competition.

[24] 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-Bll-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.

[25] 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).

[26] The *Migrants File* database collects information from Puls, a project run by the University of Helsinki, Finland and commissioned by the Joint Research Center of the European Commission. See `http://www.themigrantsfiles.com/`. Relative to other official sources, this seems to under-count deaths. Deaths are primarily gathered from the *List of Deaths* spanning from Jan 1st, 2009 to Jun 1st, 2017. In case of missing information

Figure 4: Migrant Deaths by Location and Year



Note: The map displays the fatal sea accidents from 2009 for which data are available. The description of data on the deaths at sea is in Section 2.3.

In Figure 4, we present a map of fatal sea accidents in the Mediterranean Sea. Larger indicators correspond to more deadly shipwrecks. Not only does the number of deaths increase over time, deaths also appear to occur closer to the Libyan shore.[27]

2.4 Data on Crossing Conditions

We proxy for crossing conditions with significant wave height, $H^{1/3}$, a widely used measure in maritime navigation that corresponds to the average height of the largest tercile of waves in the open sea. It combines information on wind, waves and swell, all of which may cause shipwrecks.[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 modelling outcomes as linear functions of significant wave height $H^{1/3}$

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on the number of deaths, we consider the data from IOM, Frontex and *Migrants File*.

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

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

Table 2: Summary Statistics

	All Sample				Post Mare Nostrum				Pre Mare Nostrum			
	Mean	*Sd*	*Min*	*Max*	*Mean*	*Sd*	*Min*	*Max*	*Mean*	*Sd*	*Min*	*Max*
Attempted Crossings	164	316	0	3051	169	329	0	3051	120	162	0	879
Significant Wave Height												
Tripoli	0.787	0.498	0.108	4.164	0.804	0.513	0.108	4.164	0.630	0.301	0.157	1.580
Max Tripoli (t, t-1)	0.927	0.568	0.143	4.164	0.949	0.585	0.143	4.164	0.724	0.328	0.296	1.580
Zuwara	0.671	0.376	0.101	3.071	0.681	0.386	0.101	3.071	0.581	0.250	0.163	1.335
Annaba	0.966	0.727	0.145	5.580	0.988	0.751	0.145	5.580	0.771	0.425	0.202	2.240
Al Huwariyah	1.015	0.743	0.070	5.274	1.044	0.759	0.070	5.274	0.761	0.523	0.105	3.303
Monastir	0.865	0.601	0.073	4.173	0.887	0.614	0.073	4.173	0.674	0.427	0.130	2.102
Djerba	0.746	0.434	0.084	2.848	0.754	0.441	0.084	2.848	0.680	0.353	0.159	2.028
Combined Tripoli/Al Huwariyah	0.787	0.499	0.108	4.164	0.805	0.514	0.108	4.164	0.629	0.298	0.157	1.555
Fraction of Boats												
Inflatable	0.395	0.374	0.000	1.000	0.432	0.376	0.000	1.000	0.073	0.114	0.000	0.418
Inflatable+Unknown	0.586	0.422	0.000	1.000	0.621	0.421	0.000	1.000	0.271	0.269	0.000	0.875
Inflatable+Unknown+Other	0.656	0.396	0.000	1.000	0.697	0.386	0.000	1.000	0.292	0.282	0.000	0.875
Observations	1612				1448				164			

Note: The sample consists of daily observations from 1 January 2013 to 31 December 2017. Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. The data on wave height come from the European Centre for Medium-Range Weather Forecasts (ECMWF) from daily runs at 12 UTC. The spatial resolution of the data set is approximately 79 km spacing for the surface around the geographical coordinates. The wave height from Tripoli has latitude 33 and longitude 13.5 which is roughly 16 nautical miles (30km) off the principal seaport in Tripoli and 10 nautical miles (18km) from the shortest route to the Libyan coast. The location in Zuwara (33, 12) is close by the main port. The wave height from Annaba (Algeria) has latitude 37.5 and longitude 7.5 The location in Al Huwariyah (37.25, 11.25) is 20 nautical miles (35km) from the Tunisian coast and 50 nautical miles (90km) far way from Pantelleria Island (Italy), while Monastir has latitude 36 and longitude 11.25 which is 1.5 nautical miles (2.88km) from the coast and Djerba is half mile away from the coast.

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 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 B.4 shows the density of the significant wave height by season.

The multiple types and sources of data that we obtain are observed over various periods; as such, we are able to conduct our analysis on the period from 2013 to 2017. We summarize all of our main variables over this period in Table 2.

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. We start with a simple baseline in which only a single type of boat is available, and we explore how SAR affects migrants' decisions (as noted in Section 2.2, this roughly corresponds to the pre-*Mare Nostrum* period). We then introduce heterogeneity in boats and obtain more nuanced predictions of smuggler and migrant behavior.

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

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

where α_i is an individual specific parameter that reflects the intensity of i's desire to cross and is distributed according to the continuous density f, and p is the price of passage.[29] We make a standard monotone likelihood ratio assumption on f that can be easily expressed in terms of the hazard function $\lambda(\cdot)$:

$$\lambda(\cdot) = \frac{f(\cdot)}{1 - F(\cdot)} \text{ is non-increasing.[30]} \qquad \text{(A1)}$$

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

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

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

Assumption A2 states that SAR increases the likelihood of successful passage. Assumption A3 states that adverse crossing conditions (higher h) reduce the likelihood of successful passage, and SAR mitigates this effect. Without loss of generality, we assume that migrant i will attempt passage if $u_i > 0$ and that smugglers are price takers (we will relax this assumption later on).[31]

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

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

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

[31] It is straightforward to incorporate dynamic considerations into the model; we opt not to in the interest of simplicity. If we interpret α_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 δ 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.

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

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

We now generalize this model by positing that each migrant may cross either on a safe boat ($b = s$, e.g., a sturdy, wooden boat) or an unsafe boat ($b = u$, e.g., a crowded inflatable raft with an under-powered outboard motor, see Figure B.5 in the Appendix) at a price of p_b. Migrant i's utility can now be written as

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

where the probability of successful passage and price of passage 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. According to Assumption A5, unsafe boats are more susceptible to crossing conditions. Assumption A6 expands on Assumption A2 and captures the fact that SAR increases the safety of unsafe boats more than it increases the safety of safe boats.[32]

On the supply side, smugglers offer passage to migrants at prices p_b and at costs c_b respectively. Seats on safe boats are more costly to provide than seats on unsafe boats ($c_s > c_u$). Let M_s^R and M_u^R represent the fractions of migrants who attempt to cross on safe and unsafe boats respectively

We begin by noting that less motivated migrants (lower α_i) will never choose a safer boat than a more motivated migrant, which we formalize in Lemma 1.

Lemma 1. *Define* $\underline{\alpha} = \frac{p_u}{\sigma_u^R}$ *and* $\overline{\alpha} = \frac{p_s - p_u}{\sigma_s^R - \sigma_u^R}$ *Under Assumption A4, if* $\alpha_i < \underline{\alpha}$*, then* i *will not cross. If* $\underline{\alpha} \leq \alpha_i < \overline{\alpha}$ *then* i *will cross on an unsafe boat. Otherwise,* i *will cross on a safe boat.*

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

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[32] 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.

Figure 5: Migrant's Crossing Decisions

The model with a two types of boat 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: in an environment in which the crossing risks on safe and unsafe boats are similar ($\theta = 1$) most of the crossings that would occur on unsafe boats if they were available will stilloccur on safe boats anyway. In an environment in which the safe boats are much safer than unsafe boats, most of the crossings that would occur on unsafe boats if they were available would not have occurred otherwise. The former scenario corresponds to the early portion of our sample, when trips largely originated in Tunisia and were very short; The latter scenario corresponds to the later portion of our sample, when trips largely originated in Libya, and were much longer.

For simplicity, we first consider the case in which the market for smuggling is perfectly competitive, i.e., prices are set to marginal cost.[33] We define crossing risk ρ as the *ex ante* probability that a migrant dies along the journey, which is a weighted sum of $1-\sigma_u$ and $1-\sigma_s$.

Proposition 2. *Under Assumptions A4-A6 and perfect competition, the introduction of search and rescue operations will result in:*

1. *Increases in total attempted crossings and attempted crossings on unsafe boats; decreases in attempted crossings on safe boats.*
2. *An ambiguous effect on crossing risk.*
3. *Total attempted crossings becoming more elastic to crossing conditions if* σ_u^0 *is small.*

---

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

The first two parts of Proposition 2 follow immediately from Lemma 1. Because prices remain at $p_u = c_u$ and $p_s = c_s$ irrespective of whether SAR is in place, the resulting decrease in σ_u and increase in $\sigma_s - \sigma_u$ shift $\underline{\alpha}$ and $\overline{\alpha}$ to the left and right respectively in Figure 5 (part 1). These shifts may or may not outweigh the increased safety from SAR (part 2). The third part of Proposition 2 follows from the fact that if unsafe journeys are unlikely to be successful without SAR, then its introduction provides an additional margin along which smugglers and migrants may adjust their decisions.

We now consider the polar case in which smugglers are monopolists and hence can set prices freely depending on the extent of SAR.[34] The smuggler's problem can thus be written as

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

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

Proposition 3. *Under Assumptions A1 and A4-A6, for a monopolist smuggler, the introduction of search and rescue operations leads to:*

1. *The same results as under perfect competition as listed in Proposition 2.*
2. *Increases in p_u, p_s and $p_s - p_u$ if σ_u^0 is small.*
3. *An increase in smuggler's profits.*

We can express the markups that monopolists charge as follows:

$$p_u^R = c_u + \frac{\sigma_u^R}{\lambda(\underline{\alpha})} \tag{1}$$
$$p_s^R = c_s + \left[(p_u^R - c_u) + \frac{\sigma_s^R - \sigma_u^R}{\lambda(\overline{\alpha})}\right] \tag{2}$$

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

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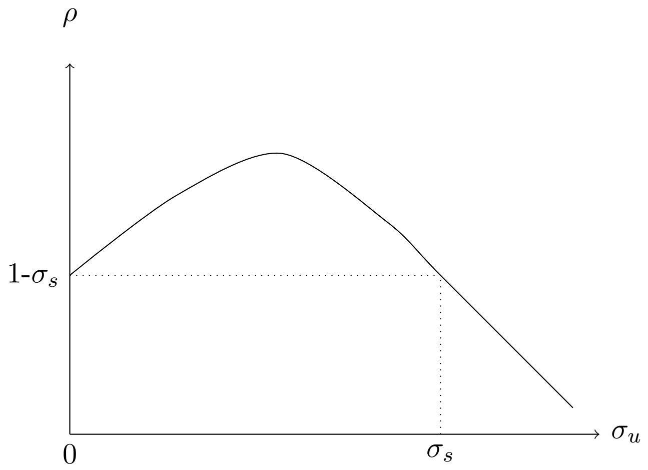
[34] For expositional simplicity, we assume that are unable to adjust their prices to short run fluctuations in crossing conditions (h). This could be relaxed with the introduction of additional technical assumptions on the ordering of the marginal effects of crossing conditions on successful passage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

Figure 6: Net Crossing Risk



Perhaps surprisingly, when σ_u is small, it is more likely that SAR operations will increase the crossing risk, and only when σ_u is large will the crossing risk decrease. The intuition for this is conveyed in Figure 6. When $\sigma_u = 0$, all travel occurs on safe boats, hence $\rho = 1 - \sigma_s$. As σ_u grows larger, an increasing amount of travel occurs on unsafe boats, so ρ increases. When $\sigma_u \geq \sigma_s$, all travel occurs on unsafe boats, so $\rho = 1 - \sigma_u$. The continuity of the objective function implies that in some range of large but not too large σ_u, ρ will be decreasing.

We can illustrate the effect of SAR and its incidence on migrants in Figure 7. The analysis is qualitatively the same whether smugglers face competition or not. In the presence of SAR, the migrant who is indifferent between passage on an unsafe boat and no passage at all now has a lower α_i. Intuitively, the increased safety of the journey offsets any increase in price. All migrants close to this threshold are made better off by search and rescue operations (indicated in blue). In this region, migrants with greater α_i enjoy greater benefits from SAR since they value safety more.

The migrant who is indifferent between passage on a unsafe boat and a safe boat now has a higher α_i since there is less of a safety premium to taking the safe boat (and it may have gotten more expensive as well). If smugglers have any market power, then all migrants who still take the safe boat will be made worse off by SAR since they pay a higher price but get no added benefit. Moreover, those migrants who are just to the left of this new threshold will also be worse off since they highly value safety but are now priced out of safe boats.

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

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

we obtain the following result

Proposition 4. *Under assumptions A6 and A7,*

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

where $\omega_b^R = \frac{\partial total\ crossings_b}{\partial h}$

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

4 Empirical Model

Our main empirical task is to determine whether crossings respond more strongly to crossing conditions (significant wave height measured in meters, $h_t = H_t^{1/3}$) when search and rescue operations are in place *and* migrants are capable of switching from sturdy to inflatable crafts. If we find this to be the case, then we can infer that SAR operations (1) induced additional crossings, and (2) shifted crossings from safe to unsafe boats.

Following the model, the *daily* total number of crossings c_t is a function of $\underline{\alpha}_t = \frac{p_t}{\sigma_t}$, where prices and risk refer to the least safe boat type available. Assuming that the αs are distributed approximately exponentially, $c_t = e^{-\lambda \frac{p_t}{\sigma_t}}$, where λ is the constant hazard. Since h_t is known to follow the Rayleigh distribution, then if risk depends on the likelihood of encountering tall outlier waves, the number of arrivals will also be an exponential function of wave height.[35]

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.

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

The identification of the ωs, the marginal effects of wave height on crossing attempts, rests on the exogeneity and stationarity of weather conditions. The need to identify the marginal effects depending on the presence of EU naval assets, distinguishing safe from unsafe boats indicates the following Poisson Quasi-ML regression[36]

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

where crossings depend on wave height interacted with the presence of an (intense)[37] search a rescue operation (SAR_t) per official records, and the fraction of unsafe boats, ($\bar{u}_{w(t)}$), deployed in a specific week $w(t)$.[38] 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 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 analysis. Because SAR assets easily withstand rough seas and are ex-ante unaware of the type of boats they will encounter, the ωs are unlikely to be differentially influenced by any measurement error.

5 Results

Results are presented in Table 3. Each specification corresponds to a different designation of boats as "unsafe". In all specifications, we find that adverse crossing conditions lead to a greater shift from unsafe boats to safe boats under more intense SAR operations. A 0.10 meter increase in wave height reduces the total number of crossings by 8.9-14.6 percent; in the presence of intense SAR, there is an additional reduction of 41-65 percent. As predicted by the model, when unsafe boats are unavailable, the response to intense SAR is positive, reducing the deterrent effect of waves by about two thirds, though it is not statistically significant (except

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[36] The Poisson specification offers two additional practical advantages. First, it is well suited to analyze discrete data (Santos Silva and Tenreyro, 2006) without biasing estimates when a high fraction (48%) of days have no crossings. Second, our estimates are not contaminated with a size effect due to a general change in the overall number of crossings over time with the inclusion of fixed effects. Nevertheless, later we are also going to use a linear model for robustness.

[37] 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.

[38] $\bar{u}_{w(t)}$ 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.

Table 3: Crossing Attempts

	(1)	(2)	(3)
		Crossing Attempts	
		Wave Height in Tripoli (t)	
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-6.55***	-5.45***	-4.17***
	(1.93)	(1.40)	(1.29)
Wave Height	-0.89**	-1.43**	-1.46**
	(0.37)	(0.60)	(0.61)
Wave Height * Fr. Boat	2.13	1.91	1.63
	(1.81)	(1.34)	(1.13)
Wave Height * Post SAR	0.21	1.16*	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 Fr. 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 were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. Fr. Boat is aggregated at the week of the year level. All regressions control for week-by-year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

once). 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. One has to consider, though, that during Hermes (the excluded period) the fraction of inflatable boats was only 7 percent (bottom row).

As a randomization inference exercise, we estimate 644 versions of Equation 3 under the conservative classification of only inflatable boats as 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 Figure 8 plot the resulting distributions of our two main parameters of interest, ω_0^ks and the ω_3^ks; 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 ω_0^k and ω_3^ks lie in the far left tails, with p-values that are close to one percent.

For a given $\frac{p_S-p_U}{p_U}$, Proposition 4 provides a method to simulate θ 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 9.

For $p_s \approx 3 \times p_u$, which is in line with media reports (see footnote 29), $\hat{\theta}$ is less than 5%. Notice that this is an ex-ante unobserved risk ratio, which is likely to be very different from the

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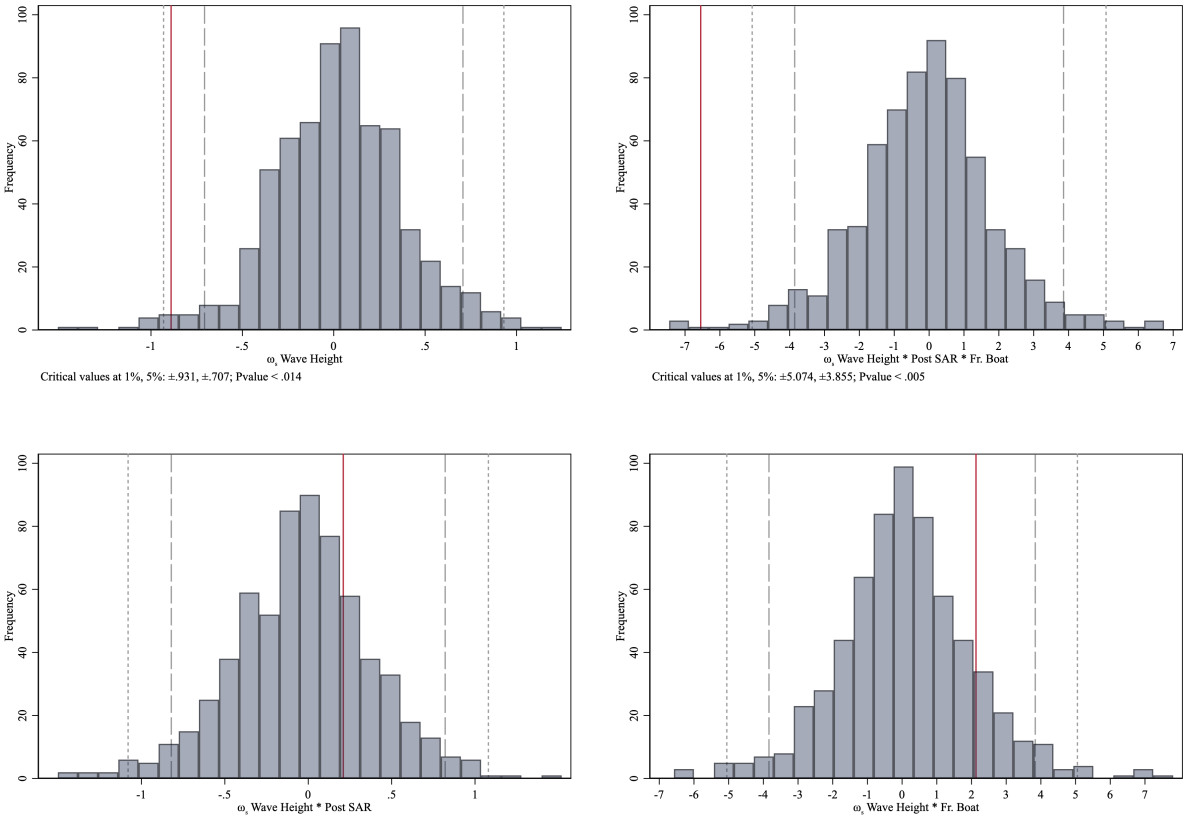
[39] Using leads instead of distant lags Appendix Figure B.6 leads to similar results but forces us to truncate our sample as our wave height data are only available until the end of 2017.

Figure 8: Randomization Inference Using Former Wave Conditions



Critical values at 1%, 5%: ±.931, ±.707; Pvalue < .014

Critical values at 1%, 5%: ±5.074, ±3.855; Pvalue < .005

Critical values at 1%, 5%: ±1.08, ±.821; Pvalue < .741

Critical values at 1%, 5%: ±5.053, ±3.838; Pvalue < .868

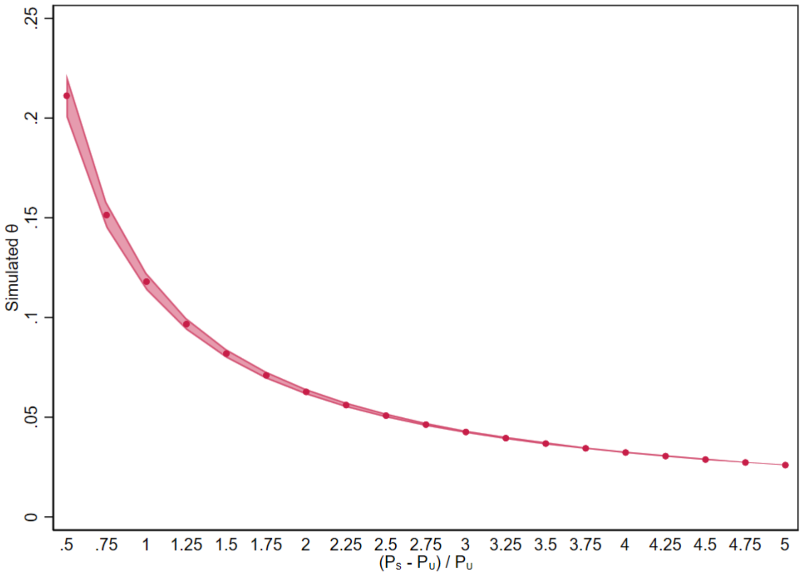
Notes: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. We estimate Equation 3 644 times, using wave height at time $t - k$ instead of time t, with k ranging from 28 to 672. Fr. Boat is aggregated at the week of the year level. All regressions control for week by year fixed effects. Left panel shows the placebo for the coefficients of the wave height and right panel the triple interaction terms between Fr. Boat, post Mare Nostrum dummy and the wave height. Regressions 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).

endogenously realized one after decisions have been made. Indeed, for any plausible price ratio, we can conclude that θ is likely to be less than 10%, implying that inflatable boats are between 10 and 20 times less safe than all other boats. Results of this magnitude also imply that any bias due to remaining measurement error would need to differ highly heterogeneously by boat type in order to undo this result.

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 B.1.

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

Figure 9: Simulated Likelihood of a Successful Journey on Unsafe vs. Safe Boats ($\hat{\theta}$)



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

predictions empirically by leveraging high-frequency boat switching in response to changing to crossing conditions, as the ω semi-elasticities are identified using week-by-year fixed effects. Nevertheless, we can test directly whether low-frequency boat switching does occur in Table 4. 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.

We perform a number of robustness checks to ensure the validity of our findings and summarize them here. Detailed results are presented in the Appendix. In Appendix Table B.3 we show that estimating equation (3) by OLS instead of Poisson Quasi-ML generates similar results. In Appendix Table B.4, we reestimate our main regression with standard errors clustered at different levels in order to ensure that our results are not simply artifacts of serial or spatial autocorrelation. In Appendix Table B.5, we replicate our analysis by adding information on crossing conditions from earlier days in case journeys take more than one day. In Appendix Table B.6, we present results specifying significant wave height quadratically (as in the Appendix Equation 19), and our findings are substantively unchanged. In Appendix Table B.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.

6 Conclusion

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

After analyzing nearly a decade of data on crossings, we find that while SAR has no doubt saved lives directly, it may have had adverse unintended consequences that must be considered. First, by reducing the risk of crossing, SAR likely induced more migrants to attempt to cross, and in doing so, exposed more people to the risk of death along the passage. Second, by reducing the costs to traffickers of using unsafe boats, SAR induced a large substitution away from seaworthy wooden vessels and towards flimsy, inflatable boats. Thus, the benefits of SAR have been, to some extent, captured by human smugglers.[40]

Well-intentioned policymakers who are motivated to take action face a genuine dilemma. By failing to act, it is likely crossings would continue and deaths would continue to mount. But by intervening along the route, it is likely that more migrants would attempt an extremely dangerous undertaking. Saving a migrant at sea seems to be an obvious decision; weighing that action against the many potential migrants who might be encouraged to undertake such a treacherous passage in the future complicates this immensely. The obvious parallel to well-known "trolley problems" in philosophy suggests that this is a moral dilemma with no unambiguous solution. Although our work, unfortunately, does not guide this decision definitively, it does provide clear evidence that migration and smuggling are strategic choices that are made by thoughtful agents in a fraught environment.[41] In the interest of being constructive, our analysis suggests that a

Table 4: Fraction of People by Boat Types

Fraction of Migrants	(1) Inflatable	(2) Inflatable + Unknown	(3) Inflatable + Unknown + Other	(4) Fishing	(5) Motor
Mare Nostrum (MN)	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: SAR coefficients are estimated relative to a baseline in which Hermes operations were in place. 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.

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[40] 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.

[41] European policy makers would also have to consider the conditions that migrants face in Libya while

major policy goal of SAR operations should be to limit substitution from seaworthy boats to inflatable ones.[42] One way to do so would by interceding in the trade of such items to Libya. The EU's ban on inflatable craft exports to Libya is a step in the right direction, though most craft are produced in China and Figure 3 suggests that they may still enter Libya through Egypt and Turkey.

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

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attempting to cross the sea.

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

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Appendix A: Proofs

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

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

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

□

Proof. Lemma 1. Consider two migrants i and j, and assume $i < j$. We first establish an ordering on crossing decisions. Specifically, we seek to prove:

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

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

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

For (2), suppose j takes an unsafe boat. Then a rearrangement of equation (3) implies that $\alpha_j < \frac{p_s - p_u}{(\sigma_s - \sigma_u)}$. Now suppose i took a safe boat. Then $\alpha_i > \frac{p_s - p_u}{(\sigma_s - \sigma_u)}$. But $\alpha_j > \alpha_i$, so this contradicts Assumption A4.

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

Proof. Proposition 2.

1. By A6, $\frac{p_u}{\sigma_u^1} < \frac{p_u}{\sigma_u^0}$, so Lemma 1 implies that total attempted crossings will increase under SAR. Also by A6 $\frac{p_s - p_u}{\sigma_s^1 - \sigma_u^1} > \frac{p_s - p_u}{\sigma_s^0 - \sigma_u^0}$, so Lemma 1 implies that attempted crossings on safe boats will decrease under SAR. It follows that attempted crossings on unsafe boats will increase under SAR.

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

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

$$f\left(\frac{p_u}{\sigma_u^1}\right)\frac{p_u}{(\sigma_u^1)^2}\frac{\partial \sigma_u^1}{\partial h} < f\left(\frac{p_u}{\sigma_u^0}\right)\frac{p_u}{(\sigma_u^0)^2}\frac{\partial \sigma_u^0}{\partial h} \tag{4}$$

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

$$\sigma_u^{SAR} \approx \frac{2H^2}{h^2},$$

and, therefore, $\frac{\partial \sigma_b^R}{\partial h} = -\frac{2H^2}{h^4} = -\frac{1}{2H^2}\left(\sigma_b^R\right)^2$

The inequality in Eq. 11 simplifies to

$$f\left(\frac{p_u}{\sigma_u^1}\right) > f\left(\frac{p_u}{\sigma_u^0}\right), \tag{5}$$

or, given Assumption A1, we need $\sigma_u^1 > \sigma_u^0$; this is true under Assumption A2.

□

Proof. Proposition 3.

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

$$\frac{\partial M_s^R}{\partial p_s^R}(p_s^R - c_s) + M_s^R + \frac{\partial M_u^R}{\partial p_s^R}(p_u^R - c_u) = 0 \tag{6}$$

$$\frac{\partial M_s^R}{\partial p_u^R}(p_s^R - c_s) + \frac{\partial M_u^R}{\partial p_u^R}(p_u^R - c_u) + M_u^R = 0 \tag{7}$$

Note that prices and crossings are now allowed to vary by R. Adding equations (6) and (7) together, we obtain

$$\left(\frac{\partial M_s^R}{\partial p_s^R} + \frac{\partial M_s^R}{\partial p_u^R}\right)(p_s^R - c_s) + \left(\frac{\partial M_u^R}{\partial p_s^R} + \frac{\partial M_u^R}{\partial p_u^R}\right)(p_u^R - c_u) + M_s^R + M_u^R = 0 \tag{8}$$

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

$$p_u^R = c_u + \frac{M_s^R + M_u^R}{\frac{1}{\sigma_u^R} f\left(\frac{p_u^R}{\sigma_u^R}\right)} = c_u + \frac{\sigma_u^R}{\lambda\left(\frac{p_u^R}{\sigma_u^R}\right)} \tag{9}$$

The second term in equation (9) 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 (9), we can write

$$\frac{p_u^1}{\sigma_u^1} - \frac{p_u^0}{\sigma_u^0} = \left[\frac{1}{\lambda\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{1}{\lambda\left(\frac{p_u^0}{\sigma_u^0}\right)}\right] + \left[c_u\left(\frac{1}{\sigma_u^1} - \frac{1}{\sigma_u^0}\right)\right] \tag{10}$$

A1 implies that the first term of equation (10) is negative, and A6 implies that the second term of equation (10) is negative, hence the total number of crossings increases.

Now, substituting from equation (6), we obtain

$$M_s^1 - M_s^0 = \frac{\partial M_s^1}{\partial p_s^1}(p_s^1 - c_C) + \frac{\partial M_u^1}{\partial p_s^1}(p_u^1 - c_u) - \left[\frac{\partial M_s^0}{\partial p_s^0}(p_s^0 - c_C) + \frac{\partial M_u^0}{\partial p_s^0}(p_u^1 - c_u)\right] \tag{11}$$

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 (11) is less than zero, hence the total number of crossings on safe boats decreases with SAR.

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

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

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

2. Substituting from equation (9), we have

$$p_u^1 - p_u^0 = \frac{M_s^1 + M_u^1}{\frac{1}{\sigma_u^1} f\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{M_s^0 + M_u^0}{\frac{1}{\sigma_u^0} f\left(\frac{p_u^0}{\sigma_u^0}\right)} = \frac{\sigma_u^1}{\lambda\left(\frac{p_u^1}{\sigma_u^1}\right)} - \frac{\sigma_u^0}{\lambda\left(\frac{p_u^0}{\sigma_u^0}\right)} \tag{12}$$

This combined with A1 implies that the right hand side of equation (12) is greater than zero, so p_u increases under SAR.

Rearranging equation (6) yields

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

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 (13) to express p_s^R as

$$p_s^R = c_s + \left[(p_u^R - c_u) + \frac{\sigma_s^R - \sigma_u^R}{\lambda\left(\frac{p_s^R - p_u^R}{\sigma_s^R - \sigma_u^R}\right)}\right] \tag{14}$$

from which the markup on p_s^R is given in the second term. Using equation (14), we can write

$$p_s^1 - p_s^0 = (p_u^1 - p_u^0) + \left[\frac{\sigma_s^1 - \sigma_u^1}{\lambda\left(\frac{p_s^1 - p_u^1}{\sigma_s^1 - \sigma_u^1}\right)} - \frac{\sigma_s^0 - \sigma_u^0}{\lambda\left(\frac{p_s^0 - p_u^0}{\sigma_s^0 - \sigma_u^0}\right)}\right] \tag{15}$$

p_u was shown to increase under SAR, so the first term of equation (15) 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 (15) is greater than zero, hence p_s increases under SAR. Finally, if we move the first term on the right hand side of equation (15) to the left hand side, the same logic implies that $p_s - p_u$ increases under SAR.

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

□

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

$$\underline{\alpha}' = \left(\overline{\alpha}\left(\sigma_s - \sigma_u\right) + p_u\right)\frac{1}{\sigma_s} \tag{16}$$

$$= \frac{\sigma_s - \sigma_u}{\sigma_s}\overline{\alpha} + \frac{\sigma_u}{\sigma_s}\frac{p_u}{\sigma_u} \tag{17}$$

$$= \theta\underline{\alpha} + (1-\theta)\overline{\alpha} \tag{18}$$

□

Proof. Proposition 4.

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

$$\sigma_b^{SAR} \approx \left(\frac{h^2}{2H^2}\right)^{-1} \tag{19}$$

$$\approx \frac{1}{\gamma_b^{SAR} + \delta_b^{SAR} h}, \tag{20}$$

where the second line follows from a linear approximation to match our empirical specification.[43]

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

$$A^{SAR} = e^{-\lambda \frac{p_u}{\sigma_u^{SAR}}} \tag{21}$$

Noting that $\theta = \frac{\sigma_u}{\sigma_s}$ and $\overline{\alpha} = \frac{p_s - p_u}{\sigma_s - \sigma_u}$, equation (20) implies that

$$\overline{\alpha} = \frac{\theta\,(p_s - p_u)}{1-\theta}\left(\gamma_u^{SAR} + \delta_u^{SAR} h\right) \tag{22}$$

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

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

Taking the ratio, we get that

$$\frac{\omega_s}{\omega_u} = \frac{\theta}{1-\theta}\frac{p_s - p_u}{p_u}, \tag{23}$$

which completes the proof.

□

---

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

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

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	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	0.00	306	787	233	223	168
Estimator	PPML	OLS	OLS	OLS	OLS	OLS	OLS

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

Table B.2: Wave and Swell Explanations

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

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

Note: The Bureau of Meteorology 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 B.3: Crossing Attempts: Robustness using OLS

	(1)	(2)	(3)
		Crossing Attempts	
		Wave Height in Tripoli (t)	
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. 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 * Fr. Boat	74.52	94.50	93.44
	(245.66)	(83.68)	(74.22)
Wave Height * Post 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 Fr. 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 were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using OLS. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

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

	(1)	(2)	(3)
		Crossing Attempts	
		Wave Height in Tripoli (t)	
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-6.55***	-5.45***	-4.17***
	(1.63)	(1.31)	(1.37)
	[2.97]	[1.74]	[1.50]
	{1.95}	{1.42}	{1.31}
	|2.13|	|1.58|	|1.43|
Wave Height	-0.89**	-1.43**	-1.46**
	(0.38)	(0.61)	(0.69)
	[0.41]	[0.78]	[0.78]
	{0.39}	{0.65}	{0.66}
	|0.39|	|0.73|	|0.74|
Wave Height * Fr. Boat	2.13	1.91	1.63
	(1.47)	(1.25)	(1.20)
	[2.89]	[1.69]	[1.35]
	{1.85}	{1.37}	{1.17}
	|2.04|	|1.54|	|1.29|
Wave Height * Post SAR	0.21	1.16*	1.00
	(0.48)	(0.65)	(0.78)
	[0.49]	[0.82]	[0.89]
	{0.46}	{0.68}	{0.77}
	|0.46|	|0.76|	|0.84|
Observations	1,612	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 Fr. 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 were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are clustered at the month of the year and week of the year level in parentheses and squared brackets, respectively. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 21 days and 14 days in curly brackets and vertical bars, respectively. * p<.10 ** p<.05 *** p<.01.

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

	(1)	(2)	(3)	(4)	(5)	(6)
	Crossing Attempts					
	Wave Height in Tripoli (t-1)			**Max Wave Height in Tripoli (t and t-1)**		
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*	*Inflatable*	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-0.85	-2.10**	-1.84*	-2.27	-3.23***	-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 * Fr. Boat	-1.68	0.41	0.35	-0.90	0.86	0.73
	(2.40)	(0.78)	(0.81)	(1.92)	(0.84)	(0.73)
Wave Height * Post SAR	0.17	0.52	0.58	0.13	0.79**	0.92*
	(0.45)	(0.48)	(0.56)	(0.35)	(0.39)	(0.49)
Observations	1,612	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 Fr. 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 were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table B.6: Crossing Attempts on Wave Height Squared

	(1)	(2)	(3)
	Crossing Attempts		
	Wave Height in Tripoli (t)		
	Inflatable	*Inflatable + Unknown*	*Inflatable + Unknown + Other*
Wave Height * Post SAR * Fr. Boat	-5.93***	-3.76***	-2.73***
	(1.56)	(0.82)	(1.00)
Wave Height	-0.48**	-0.64*	-0.84**
	(0.21)	(0.34)	(0.41)
Wave Height * Fr. Boat	1.65	0.76	1.09
	(1.50)	(0.77)	(0.80)
Wave Height * Post SAR	0.37	0.68*	0.72
	(0.23)	(0.35)	(0.46)
Observations	1,612	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 Fr. Boat	0.07	0.27	0.29

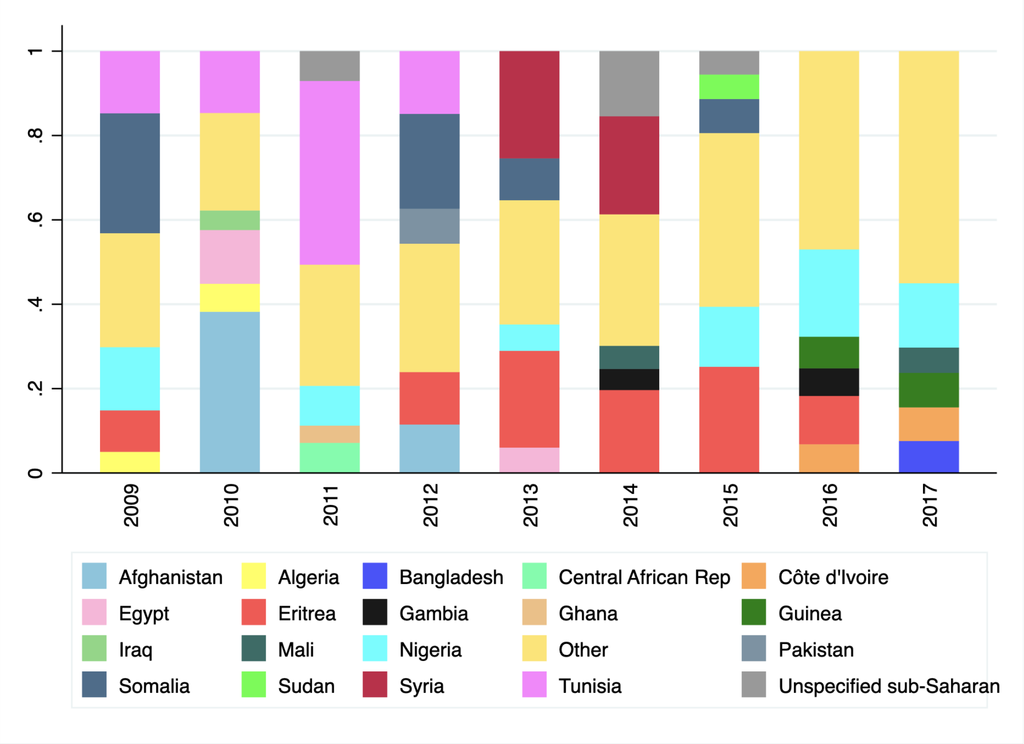
Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. All regressions control for week by year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

Table B.7: Crossing Attempts with Different Locations

	(1)	(2)	(3)	(4)	(5)
			Crossing Attempts		
			Wave Height in Tripoli (t)		
			Inflatable + Unknown + Other		
Wave Height * Post SAR * Fr. 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 * Fr. Boat	1.818	2.313***	1.762**	1.237	0.0573
	(1.558)	(0.723)	(0.834)	(1.339)	(0.875)
Wave Height * Post 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	**Zuwara**	**Monastir**	**Al Huwariyah**	**Djerba**	**Annaba**
	Libya		Tunisia		Algeria
Pre SAR Period Statistics					
Pre Mean Oucome	120.341	120.341	120.341	120.341	120.341
Pre Mean Boat	0.292	0.292	0.292	0.292	0.292
Pre Mean Wave	0.581	0.674	0.761	0.68	0.771

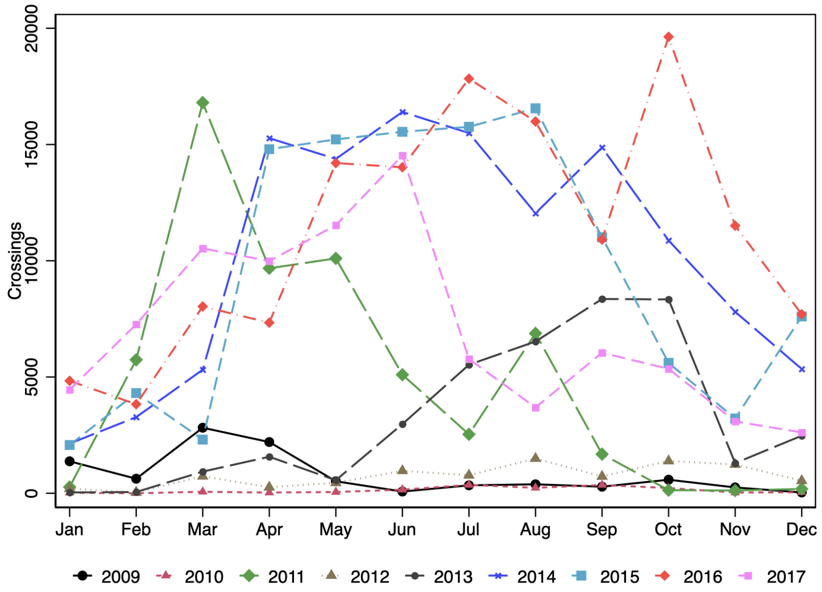
Note: The sample consists of daily observations from 7 May 2013 to 4 October 2017. SAR coefficients are estimated relative to a baseline in which Hermes operations were in place (164 days). Crossing attempts sum crossings and deaths. Significant wave height is measured in meters. Fr. Boat is aggregated at the week of the year level. All regressions control for week-by-year fixed effects. Regressions estimated using Poisson quasi-maximum likelihood models. Standard errors are heteroscedasticity- and autocorrelation-robust using Newey-West with bandwidth equal to 28 days. * p<.10 ** p<.05 *** p<.01.

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



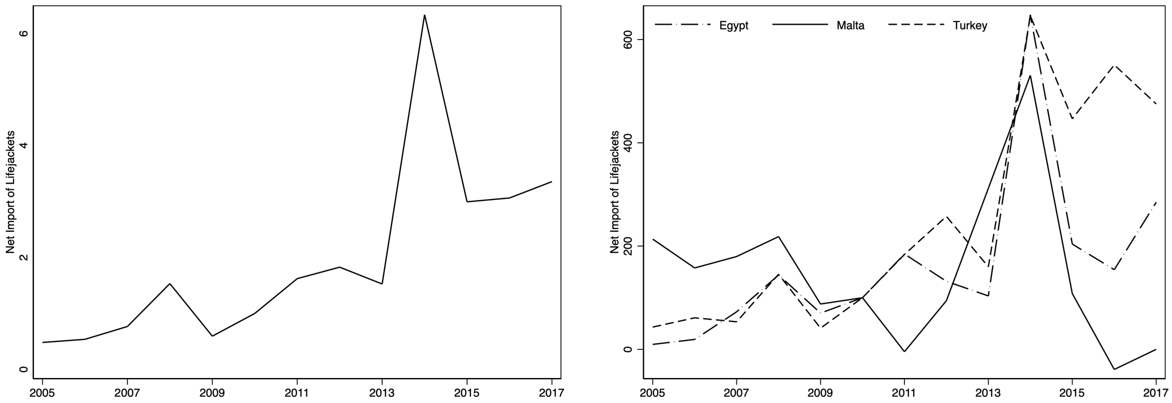
Note: Data are collected by the European Border and Coast Guard Agency and are based on detections at the border. Our subset is based on detections along the Central Mediterranean Route and the figures show the fraction of detections for the top six nationality from 2009 to 2017.

Figure B.2: Monthly Crossing Attempts



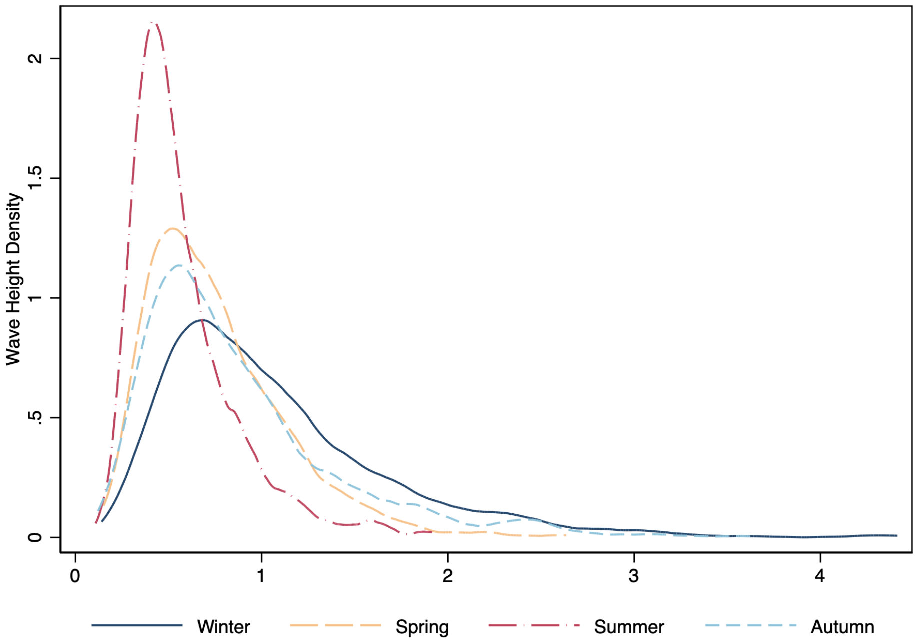
Data on crossings are provided by the *Polizia di Stato* (State Police, Ministry of Interior). Data on deaths at sea are described in Section 2.3. The figure shows the total number of monthly crossing attempts (sum of crossings and deaths).

Figure B.3: Net Import of Life Jackets



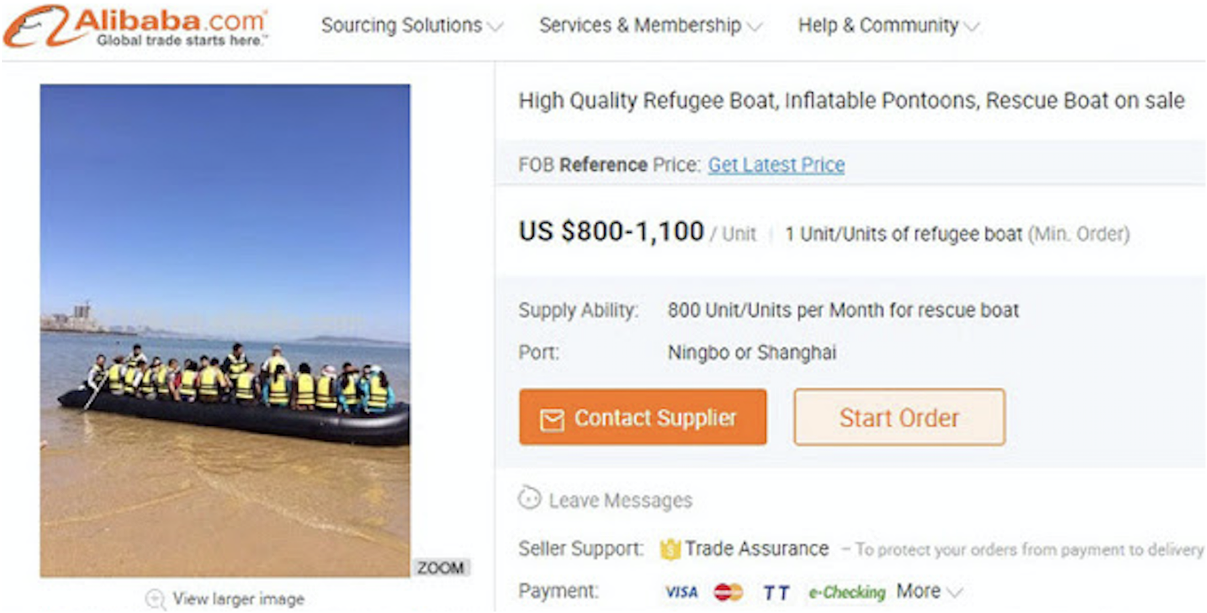
Note: The series show net-imports of life jackets to countries near Libya for which data are available (Malta, Turkey, and Egypt). The data source is the United Nations Comtrade. Both series are normalized to be equal to 100 in 2010.

Figure B.4: 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 B.5: A Typical Inflatable Boat



High Quality Refugee Boat, Inflatable Pontoons, Rescue Boat on sale

FOB **Reference** Price: Get Latest Price

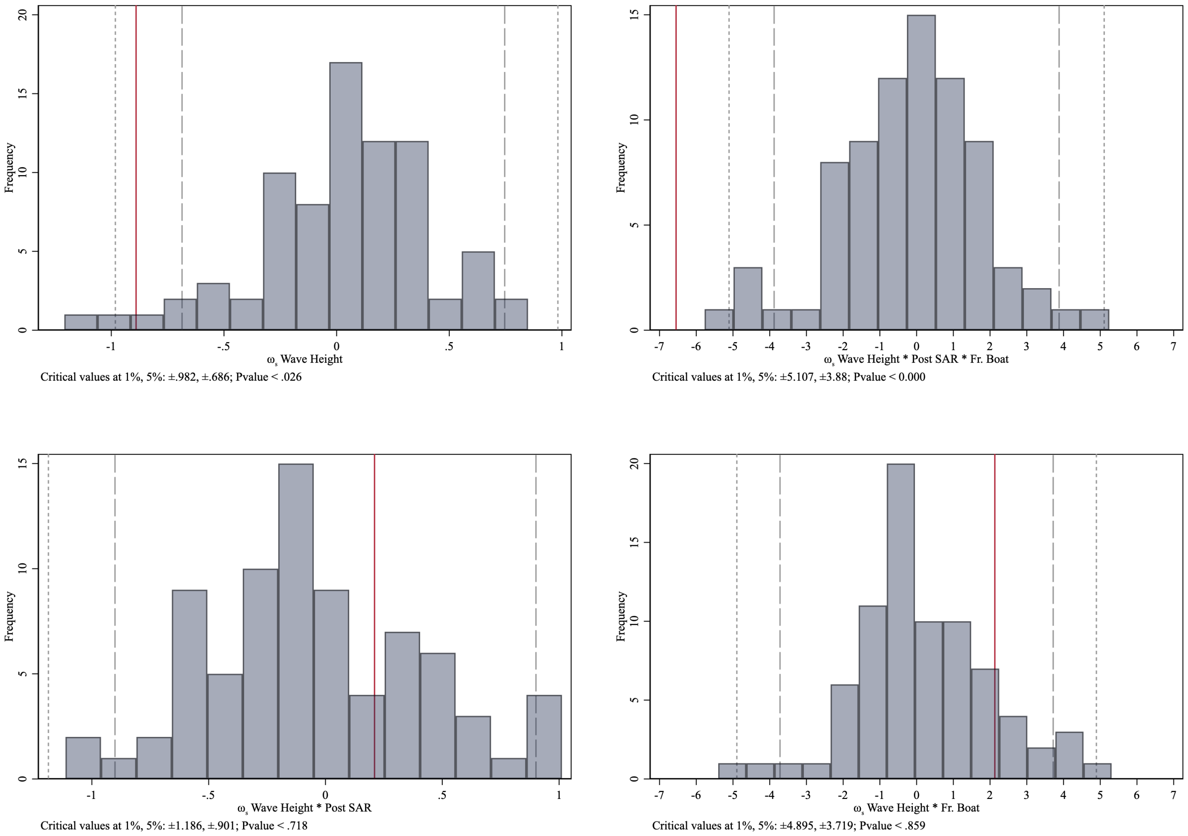
US $800-1,100 / Unit | 1 Unit/Units of refugee boat (Min. Order)

Supply Ability: 800 Unit/Units per Month for rescue boat
Port: Ningbo or Shanghai

Seller Support: Trade Assurance – To protect your orders from payment to delivery
Payment: VISA TT e-Checking More

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 B.6: Randomization Inference Using Future Waves



Critical values at 1%, 5%: ±.982, ±.686; Pvalue < .026

Critical values at 1%, 5%: ±5.107, ±3.88; Pvalue < 0.000

Critical values at 1%, 5%: ±1.186, ±.901; Pvalue < .718

Critical values at 1%, 5%: ±4.895, ±3.719; Pvalue < .859

Notes: 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). Crossing attempts sum crossings and deaths. Significant wave height 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. Fr. Boat is aggregated at the week of the year level. All regressions control for week by year fixed effects. Left panel shows the placebo for the coefficients of the wave height and right panel the triple interaction terms between Fr. Boat, post Mare Nostrum dummy and the wave height. Regressions 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).

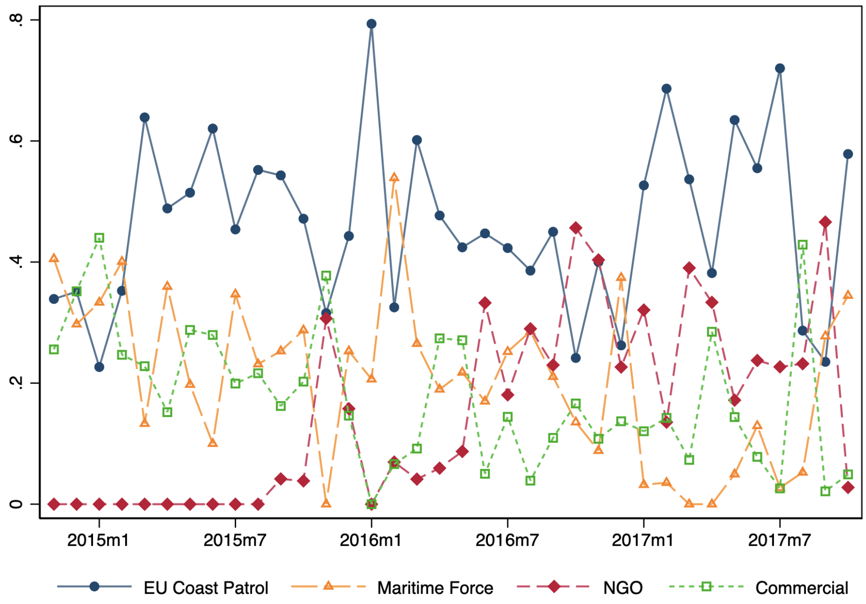
Appendix C: NGO Operations (For Online Publication Only)

In addition to official operations by the EU government, several humanitarian operations were conducted by NGOs during our sample period; however these were much smaller in scope and intensity than official operations. The most active NGO, Malta-based Migrant Offshore Aid Station (MOAS), deployed fishing vessels and two drones (MOAS, 2014, 2015, 2016, 2017). MOAS offered an example that was later been imitated by other NGOs. In 2015, the Brussels and Barcelona branches of Médecins Sans Frontiéres (MSF) developed their own SAR capabilities using their own vessels; German NGO Sea-Watch also purchased a vessel to search for migrant boats in distress in 2015. In February 2016, SOS Mediterranee chartered a 77 meter ship to conduct operations in partnership with the Amsterdam branch of MSF (see Table C.1).

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

In Figure C.1, we see that NGO activity only constituted a substantial portion of all SAR

Figure C.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 2015 to 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.

Table C.1: NGO Vessels and Operational Period

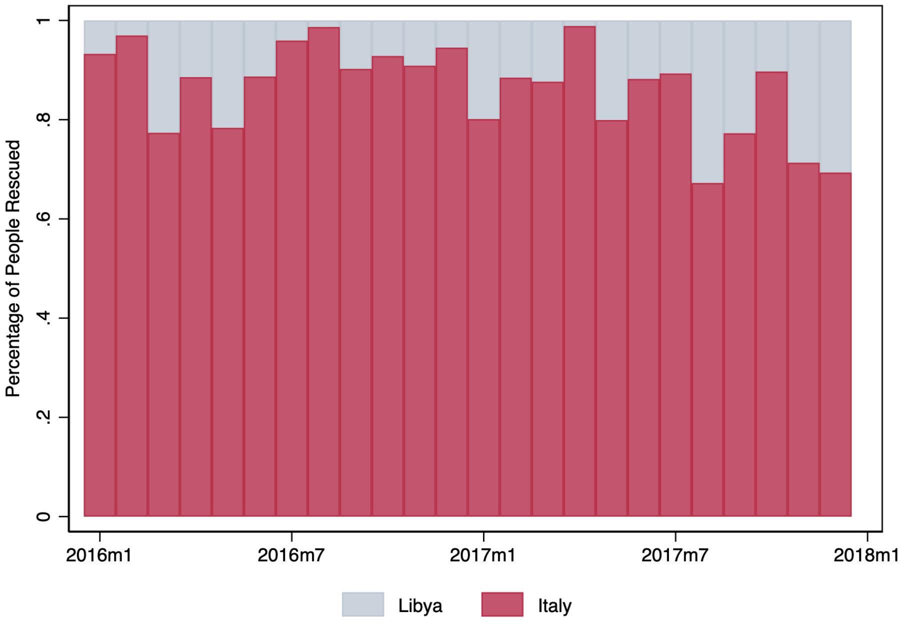
NGO	Country	Flag	Vessel	Operational Period
Jugend Rettet	Germany	The Netherlands	Iuventa	Jul 2016 - Nov 2016
LifeBoat	Germany	Germany	Minden	Jun 2016 - Nov 2016
Mdecins Sans Frontires (MSF)	France	Italy	Vos Prudence	Mar 2017 - Oct 2017
Mdecins Sans Frontires (MSF)	France	Panama	Dignity I	May 2015 - Dec 2016
Mdecins Sans Frontires (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 Mditerrane	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.

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.

In response to the NGOs SAR activity, former interior ministry Marco Minniti established a code of conduct for NGO vessels that the organizations were asked to sign. NGO vessels were required to: i) stay out of Libyan waters, except in situations of serious and imminent danger; ii) not interfere with the activity of the Libyan Coast Guard; iii) not send any communications to facilitate the departure of boats carrying migrants; and iv) allow Italian police officers to be

Figure C.2: 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 monthly data on the number of migrants intercepted at sea by Lybian and Italian coast guards. We construct the percentage of people rescued by types.

onboard of their vessels. Seven out nine NGOs refused to sign the code of conduct, putting their vessels at risk of confiscation.[44]

The interaction between SWH and a post code of good conduct dummy has a positive but not significant effect on crossings, deaths and crossing risks (columns 4-6), while the rest of the coefficients are almost unchanged. Our results are also robust to alternative functional form specifications. In columns 7-10 we use the inverse hyperbolic sine transformation of daily crossings $\log(Y_t + (Y_t^2 + 1)1/2)$ to make sure that the results are not simply driven by differences in the number of crossings between SAR and non-SAR periods.

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[44] The code of conduct comprises thirteen rules and is available at `http://www.interno.gov.it/sites/default/files/codice_condotta_ong.pdf`. As a matter of fact, we observe that the percentage of irregular migrants intercepted by Tripoli's Government of National Accord (GNA) Coast Guard increases by ten percentage points throughout the end of 2017 (from 10% to 20%) meaning that migrants were brought back to Libya (Figure C.2). Over the same period, it occurred that some inflatable boats were sent a few miles off the Libyan coast to be rescued and then Libyan smugglers stole the outboard engine of their dinghy to be reused or to sell it on land.