American Economic Journal: Economic Policy 2024, 16(2): 335–365
https://doi.org/10.1257/pol.20220014

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

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Many countries are facing and resisting strong migratory pressure, fueling irregular migration. In response to mounting deaths in the Central Mediterranean, European nations intensified rescue operations in 2013. We develop a model of irregular migration to identify the effects of these operations. We find that smugglers responded by sending boats in adverse weather and utilizing flimsy rafts, thus inducing more crossings in dangerous conditions and ultimately offsetting intended safety benefits due to moral hazard. Despite the increased risk, these operations likely increased aggregate migrant welfare; nevertheless, a more successful policy should instead restrict supply of rafts and expand legal alternatives. (*JEL* D82, J15, J18, K37, K42)

Many Western countries are facing increased migratory pressure over both land and sea.[1] For instance, annual migratory flows from Africa to Italy alone have jumped from a few hundred to almost 200,000 over the past quarter century, and these flows are expected to increase further due to high African population growth, coupled with increasing desertification.[2] This global development has prompted a variety of reactions in destination countries: Europe's Border and Coast Guard agency (Frontex), often in cooperation with the EU member states, patrols Europe's borders to detect (and ostensibly deter) undocumented migrants, most of whom try to cross the Mediterranean Sea to reach Italy, Malta, Greece, or

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† Go to https://doi.org/10.1257/pol.20220014 to visit the article page for additional materials and author disclosure statement(s) or to comment in the online discussion forum.

[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 United Nations 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.

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 United States illegally and has built barriers along the Mexican border.[4]

Recently, European populist or nationalist parties in a number of countries (Hungary, Austria, Italy, Estonia, Poland, and Switzerland) have won seats in government by running primarily on anti-immigration platforms, and the United Kingdom's referendum on Brexit was fueled in part by anti-immigration appeals. This has sent shock waves through European politics and has made immigration one of the most salient political issues. In many other European countries, the vote shares of similarly oriented parties have reached double digits. In recent polls, the vote share of the Italian populist anti-immigration parties Lega and Fratelli d'Italia jumped from roughly 15 percent to more than 40 percent. The enormous gain, at least for the Lega, is believed to be due to their attempts to ban refugee boats, including NGO rescue vessels, from entering Italian ports.

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

The reaction to this slowly unfolding tragedy has been inconsistent at best. In the wake of high-profile shipwrecks, Italy and the European Union initiated extensive search and rescue (SAR) operations at sea in the form of operations Hermes, Mare Nostrum, Triton, and Themis.[8] Despite intensifying efforts, some of the deadliest years on record followed. While these well-intentioned operations ostensibly reduced the risk of death ceteris paribus, they may have also induced greater numbers of migrants to attempt crossing due to moral hazard, leading to an ambiguous effect

[3] Indeed, the Mediterranean Sea has been dubbed the "New Rio Grande" (Hanson and McIntosh 2016). Fasani and Frattini (2019) test whether Frontex deters migrants from attempting to enter Europe and find evidence that deterrence is high for land routes but not sea routes.

[4] Bazzi et al. (2021) find that the increased sanctions have lowered recidivism in illegal entry, while Feigenberg (2020) and Allen et al. (2018) find that the border wall reduced entry, though at a very high cost.

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

[6] See "Up to One Million Poised to Leave Libya for Italy," *ANSAmed*, March 6, 2015.

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

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

on total migrant deaths.[9] Moreover, to the extent that these additional crossings were made on flimsier boats in a cost-saving measure, the operations may have unintentionally increased the risk of death along the journey in practice. Although Italy and the European Union reduced the geographic scope of their operations beginning in 2017, several NGOs and private actors have stepped in by sending rescue vessels to newly unpatrolled areas.

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

In light of these obstacles, standard approaches to estimate the effect of a policy change are unsuitable. Instead, we pursue an indirect identification strategy that combines unique high-frequency data on crossing attempts by country of origin and boat type; the insights of a novel model of smuggling; and plausibly exogenous, high-frequency variation in the physical conditions of each crossing attempt.[10] Under fairly weak assumptions, we show theoretically that if migrant crossing attempts responded systematically differently to crossing conditions with and without SAR operations in place, then we can infer that these operations induced more crossing attempts. Hence, instead of attempting to circumvent the empirical obstacles described above, we can focus on the feasible empirical question of identifying the short-run elasticity of crossing attempts to weather and tidal conditions.

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

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

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

crossing attempts, mostly on inflatable boats, is exactly in line with the predictions of our model.

Increases in both total crossing attempts and the riskiness of passage imply that SAR operations increased the total number of deaths in transit. But we must stress that our findings *do not* imply that SAR operations should be curtailed or eliminated. Indeed, SAR almost certainly led to an increase in total migrant welfare: while some migrants could have been made worse off by SAR-induced changes in prices, migrants were made better off in aggregate since many more could now afford to attempt the journey in the first place on a three-to-four-times-cheaper inflatable boat. However, some of the benefits of SAR likely accrued to smugglers to the extent that they enjoyed market power. As rents to smugglers represent losses to social welfare, this further complicates a full welfare analysis of SAR operations that lies beyond the scope of this paper. Our analysis seeks to offer some nuance for any evaluation of the costs and benefits of SAR operations, as even a well-intentioned policymaker who is faced with balancing such difficult-to-enumerate costs and benefits would be wise to consider behavioral responses to their decision.

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

To implement our identification strategy, we rely on daily observation of activity along the Central Route. This is accomplished with the use of unique, restricted, daily data on crossing attempts that we obtained from the Polizia di Stato, the Italian State Police, who are in charge of migration. To the best of our knowledge, these data have not been used in any other analysis of migration along the Central Route, and they offer an unparalleled perspective on how migration changes at high frequency, the ideal frequency to exploit changes in sea conditions. We combine this information with careful research of the timing of SAR operations between 2009 and 2020. For the later years of our sample (2016–2020), we also observe the country of migrant departure, which allows us to exploit a sudden and large drop in the availability of NGO rescue boats close to the Libyan coast for additional identification due to the enactment of the Minniti Code. In July 2017, in response to an increased presence of NGO vessels near the Libyan shore, interior minister Marco Minniti asked NGOs to sign a code of conduct that, de jure, made it harder for NGO vessels to operate in Libyan waters.[11] Seven out nine NGOs refused to sign the code of conduct, which put their vessels at risk of confiscation. Most of these NGOs

[11] NGO vessels were required to (i) avoid Libyan waters unless to avoid serious and imminent danger, (ii) not interfere with the activity of the Libyan Coast Guard, (iii) not communicate with migrants to facilitate the departure of boats, and (iv) allow Italian police officers onboard their vessels.

decided to pull out of Libyan waters, which led to a large drop in crossing attempts on inflatable boats.

We complement this with a robust dataset on migrant deaths that we cross-reference from four high-quality sources as well as daily data on physical crossing conditions (wave height), data on migrant boat types, and a carefully researched catalog of SAR operations from 2009 to 2020.

Despite the importance of this issue, there has been little empirical analysis and formal theoretical modeling of irregular migration along this important route, as pointed out by Friebel and Guriev (2013).[12] Friebel et al. (2017) and Aksoy and Poutvaara (2019) explore who chooses to migrate to Europe and their motivations for doing so.[13] The authors also consider some unintended effects of stricter border regulations on (negative) circular migration and (positive) demand for smugglers.

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

Our paper also builds on a long-standing empirical literature on risk stemming from Peltzman (1975) that argues that the potential safety benefits of new technologies or policies may be offset by the behavioral responses of different agents, be they drivers (Winston et al. 2006), drug users (Doleac and Mukherjee 2018; Evans et al. 2019), or, in this case, smugglers.[14] 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 SAR 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 I, we provide some background on the Central Route and SAR operations that have been implemented by individual countries, the European Union, and various NGOs. A more detailed description of these operations is provided in the online Appendix. We also describe the various sources of data used in our analysis. In Section II, we present a simple model of human smuggling that highlights the incentives that shape the decisions of smugglers and potential migrants and indicates an empirical strategy to answer our questions of interest. In Section III we describe our empirical model to estimate the

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

[13] 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.

[14] 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.

responsiveness of smugglers and migrants to crossing conditions, and we interpret our results through the lens of our model to identify the effects of SAR on crossings and riskiness of passage. We conclude with a brief discussion in Section IV.

I. Background and Data

A. *Historical Background*

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

In calm waters, migrant boats would typically travel at a speed of 11 to 13 kilometers per hour (km/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 12 km/h, it would take 25 hours to travel from Libya to Lampedusa. This time may be dramatically shortened if migrants are rescued early and transported to Lampedusa on military or NGO vessels.[15]

Between 1997 and 2008, the number of irregular crossings from North Africa to Italian shores was stable at around 20,000 per year until Italy and Libya signed a treaty on August 30, 2008, and crossings dropped to roughly 9,500 in 2009 and 4,500 in 2010 (see Figure 1). This established Tunisia as a major point of departure for migrants.[16] Tripoli fell in the August of 2011, which then led to a surge of Libyan refugees. Libyan dictator Muammar G haddafi was captured and killed in October 2011, rendering the treaty with Italy moot; 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.[17] After two relatively calm years, attempted crossings to Italy further skyrocketed with the deepening of civil war in Libya, reaching close

[15] Military vessels tend to travel in excess of 30 km/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 50 km/h. The two Minerva-class corvettes used in the same operation have a top speed of 33 km/h. The patrol boats *Classe Costellazioni/Comandanti* reach a top speed of 46 km/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 17 km/h.

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

[17] 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).

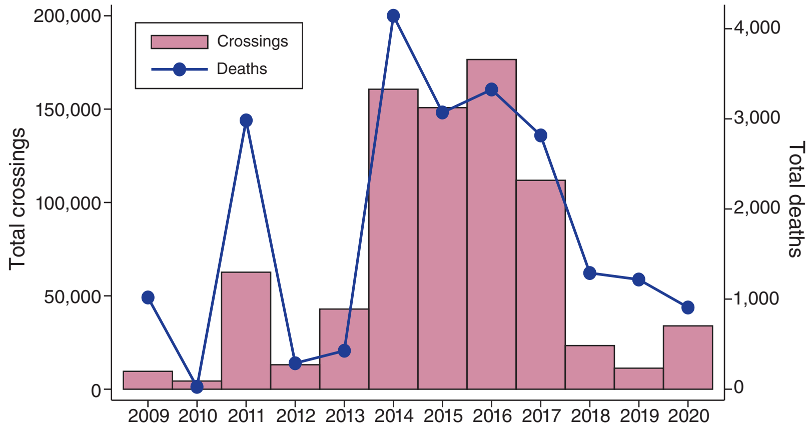

Figure 1. Crossings and Deaths along the Central Route, 2009–2020

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

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.

B. *Data*

For our analysis, we combine data from several sources that focus on irregular migration along the Central Route from 2009 to 2020. Extralegal behavior is by its very nature often difficult to observe. As such, we always rely on multiple sources for those variables that are least well-documented in official statistics. In total, we construct a dataset that includes detailed information on SAR operations alongside daily data on irregular crossings, deaths, and crossing tidal conditions, each of which we describe in further detail.

Search and Rescue Operations.—As irregular migration surged and became more deadly, Italy and the European Union launched a number of SAR operations with specific objectives. We summarize their operating dates, jurisdiction, and budgets in Table 1.[18] We provide a detailed description of each of the major SAR operations in online Appendix A.A.1.

[18] Moreover, in response to the many casualties, several NGOs 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 toward the end of August 2014. Other NGOs followed in later years (a full list is shown in online Appendix Table D.1). Since MOAS was the first NGO to operate close to Libya and discloses all its operational plans, including the exact period of SAR operations, later in the paper we use these dates to proxy for NGO presence.

Table 1—EU Operations

EU Operations	Dates	Maritime SAR Distance from Italian shores (in km)	Budget per month	Budget total
Hermes–Main operations	April 16–Oct. 16, 2009	44	0.9	5.2
	June 14–Oct. 29, 2010	44	0.8	3.3
	Feb. 20–Aug. 31, 2011	44	2.5	15.0
	July 2–Oct. 30, 2012	44	1.0	4.1
	May 6–Oct. 7, 2013	44	1.5	9.0
Extension	Sept. 1–March 31, 2012	22*		
Extension	Nov. 1–Jan. 31, 2013	22*		
		Intense SAR		
Mare Nostrum	Oct. 18, 2013–Oct. 31, 2014	244	9.3	112
Triton I	Nov. 1, 2014–April 30, 2015	56	2.9	27.5
Triton II	May 1, 2015–Jan. 31, 2018	256	18.2	437
Themis	Feb. 1, 2018–Dec. 31, 2020	24	22.3	721
			Fundraising	
NGO Operations	Dates	Maritime SAR Op. Area	per month	total
MOAS	Aug. 25–Oct. 15, 2014	Libyan shore	2.1	4
MOAS	May 1–Oct. 1, 2015	Libyan shore	1.1	5.7
MOAS	June 6–Dec. 31, 2016	Libyan shore	0.86	6
MOAS	April 1–Sept. 1, 2017	Libyan shore	0.55	3.3
		NGO code of conduct		
Minniti	Aug. 7, 2017–	24		

Notes: Budget numbers are in millions of euro. More intense SAR operations are Mare Nostrum, Triton I, Triton II, and Themis. Information on the extent of the SAR zone is sometimes hidden in official Frontex Operational Plans (2009–2020). Information on Mare Nostrum and Triton I are gathered from a report by the Italian Parliament (2017) and Senate Statistical Office (2015). The 2016 and 2018 Frontex budgets provide details on Joint Operations (Frontex 2016, 2018). Budget during Themis Operation is retrieved from the Frontex Programming Document 2020–2022 (Frontex 2019). In these instances our best guess (*) is that surveillance occurred within the territorial sea, as defined by the 1982 UN Convention on the Law of the Sea (12 nautical miles, or 22 km from the coastal state).

C. *Data on Crossings*

We obtained a novel database containing the numbers of daily irregular migrants to Italy from the Polizia di Stato, who operate under the control of the Department of Public Security (Ministry of Interior). The Department oversees all activities related to public order, which include 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 and stay of migrants. We use their data to construct our measure of daily arrivals to the Italian shores, which constitute the bulk (over 75 percent) of all arrivals along the Central Route.[19]

[19] Most of the migrants arrive on the Lampedusa shores (22 percent), Augusta (20 percent), and Pozzallo (14 percent) in Sicily. Beginning in 2016, we observe the country of departure and boat type for each arriving vessel. According to the 2017 Euro Asylum Seeker Survey Bank (2018), which collected information from a random sample of adult migrants in Italian asylum centers, 96 percent of migrants were crossing on boats that were intercepted by Italian or EU naval assets. This implies that the number of daily arrivals is unlikely to be measured with sizable error.

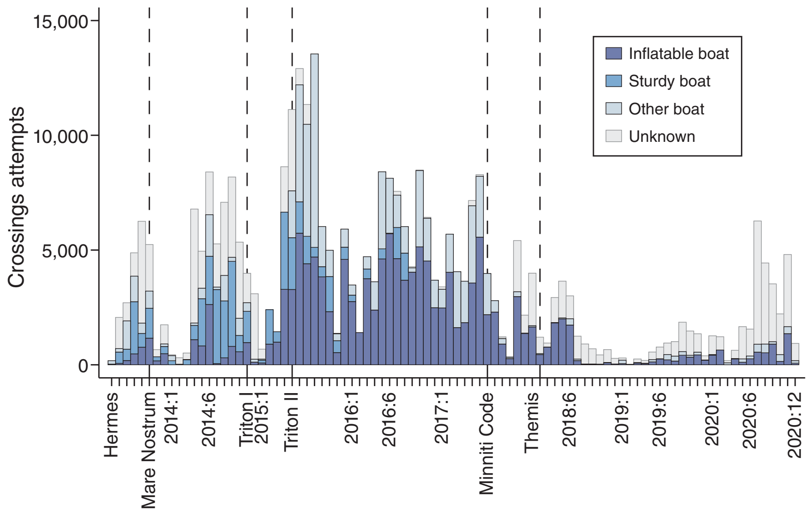

Figure 2. Types of Vessels Used, 2013–2020

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

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 online Appendix Figure C.2. Nevertheless, there is significant variation in seasonality across the different years of our sample.

Unfortunately, we cannot observe daily attempted crossings that are intercepted by the Libyan Coast Guard (LCG), but such operations were in place only after 2016. Based on our data on crossings merged with UNHCR (2017) data (see online Appendix Figure A.1), the fraction of migrants rescued by the LCG is around 10 percent and starts growing only toward the end of 2017. Our results that use data up until 2017 are robust to dropping this period. Later, we discuss how LCG interceptions influence the set of results that are based on country-of-departure-level data.

We also gathered information on vessel type from Frontex for the years 2013–2017, while for the 2016–2020 period we gathered this information by country of departure directly from the Polizia di Stato.[20] We summarize these data in Figure 2. Even though many crossing vessels in that sample period are described as unknown, it is immediate that over time, especially at the start of Triton II operations in mid-2015, inflatable boats, "other boats," and "unknown boats" become the main vessel used by smugglers. Figure 3 shows that the use of inflatable boats drops again in relative

[20] We obtained this data via a Freedom of Information Act request. Unfortunately, we were denied access to data from 2009 to 2013.

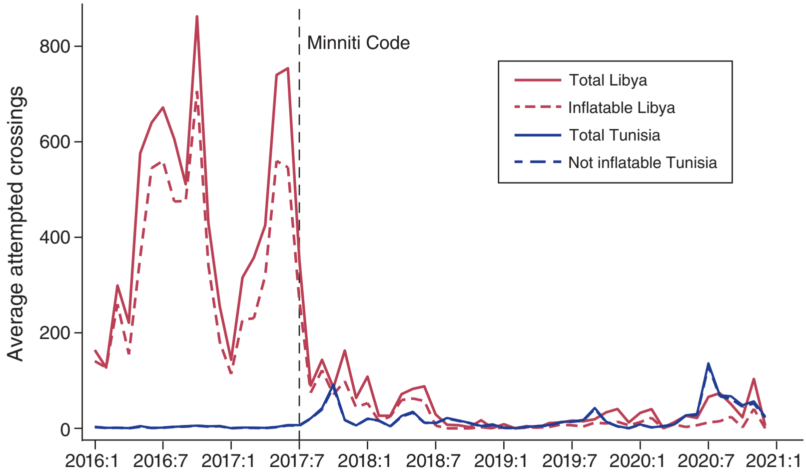

Figure 3. Attempted Crossings by Ports of Departure, 2016–2020

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

terms toward the second half of 2017, after the Minniti Code and with the beginning of operation Themis.

The observed shift in vessel type coincided with a massive increase in rubber boat imports from China to Malta, Turkey, and Egypt, with intermediate stops along the way to Libya. Net imports of rubber boats and wooden ferries moved roughly in tandem from 2005 to 2012, after which they sharply diverged (see online Appendix Figure C.3). Indeed, in 2014 and 2015 (toward the end of Mare Nostrum and the beginning of Triton II, two periods of increasing SAR activity), net imports increase by a factor of five, followed by another sharp increase in 2017 at the end of Triton II. By comparison, imports of other vessels are flat.[21] This pattern is further mirrored by trends in imports of life jackets to Egypt, Libya, and Malta, the benefits of which would largely accrue to passengers on unsafe, inflatable vessels.[22]

D. *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 datasets 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.

[21] In July 2017, the European Union introduced an export ban on inflatable boats and outboard motors to Libya.

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

Our primary source is UNITED for Intercultural Action, the European network in support of migrants, refugees, and minorities.[23] 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, which covers the portion of our sample period in 2017.[24] We also consider the data from Frontex that spans 2014–2016 and the Migrants File dataset that spans 2009–2016.[25]

Given that migrant boats try to navigate the shortest path between the African shore and Lampedusa, we can use the locations of shipwrecks to predict the most likely point of departure. For a given shipwreck, we draw a straight line south from Lampedusa to its location and note where this line intersects the African coastline. We then normalize the angle (-180 degrees to 180 degrees) between Lampedusa and the coastal border of Tunisia and Libya to be 0.[26] Negative values of this angle correspond to departures from Tunisia, and positive values of this angle correspond to departures from Libya.[27]

In Figure 4, we plot the average angle of departure along with confidence intervals for each year from 2011 to 2017. There is a noticeable change in the predicted points of departure in 2013, the first year that Mare Nostrum was in place. Most journeys shift from Tunisia to Libya.[28] Moreover, there is a stark decrease in the standard deviation of the angle of departure: from about 60 degrees to 30 degrees. Since smugglers tend to be affiliated with local tribespeople who have exclusive control over their territory, we interpret this as evidence of the increasing market concentration of Libyan smugglers who are located close to Tripoli. We discuss the ramifications of market power among smugglers in our model.

[23] UNITED has monitored deaths at sea since 1993 with the support of more than 560 organizations and institutions from 46 European countries (including the European Commission, the Council of Europe, OSCE-ODIHR, and Heinrich-Böll-Stiftung). UNITED monitors the number of deaths during border-crossing attempts around the world and counts refugees, asylum seekers, and undocumented migrants who have died through their attempts to enter Europe.

[24] 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).

[25] 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 undercount deaths. Deaths are primarily gathered from the List of Deaths spanning from January 1, 2009, to June 1, 2017 (after this date, these data cease to be available). In case of missing information on the number of deaths, we consider the data from IOM, Frontex, and Migrants File.

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

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

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

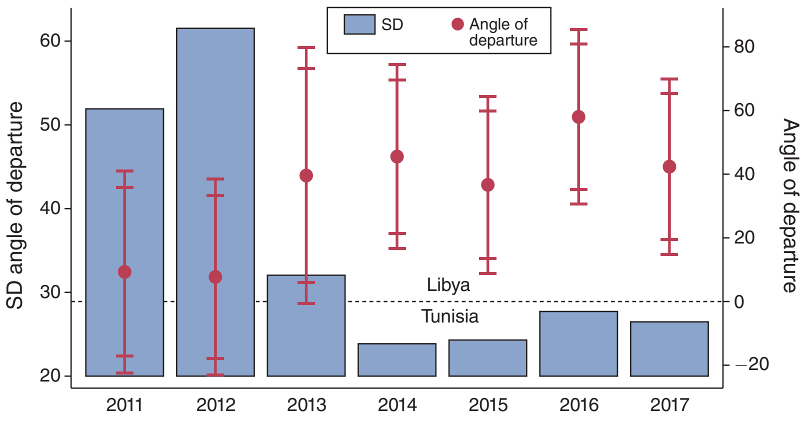

Figure 4. Predicted Points of Departure, 2011–2017

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

E. *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.[29] 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, one in ten waves has 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 (m), a vessel crossing the Mediterranean Sea would most likely encounter waves of up to 3 m of height. Linearity of H (in its exponent) implies that modeling outcomes as linear functions of significant wave height $H^{1/3}$ is empirically equivalent to choosing any other specific wave height $H^{1/k}$ (with coefficients appropriately rescaled).

We obtained detailed data on significant wave height from the European Centre for Medium-Range Weather Forecasts (ECMWF). These data are constructed using high-frequency readings from satellite measurements, surface-based data sources (buoys, radar wind, drop-sonde, and 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

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

TABLE 2—SUMMARY STATISTICS

	Mean	SD	Min	Max
Panel A. Sample 2013–2017: 1,612 Observations				
Attempted Crossings	164.483	316.160	0	3,051
Wave Height in Tripoli (33° N 13° 30′E)	0.787	0.498	0.108	4.164
Max Wave Height in Tripoli $(t, t-1)$	0.926	0.568	0.143	4.164
Wave Height in Zuwara (33° N 12° 00′E)	0.671	0.376	0.101	3.071
Wave Height in Al Huwariyah (37° 25′N 11° 25′E)	1.015	0.743	0.070	5.274
Wave Height in Monastir (36° N 11° 25′E)	0.865	0.601	0.073	4.173
Wave Height in Djerba (34° N 11° 00′E)	0.746	0.434	0.084	2.848
Wave Height in Annaba (37° 5′N 7° 30′E)	0.966	0.727	0.145	5.580
Fraction of Inflatable Boats	0.395	0.374	0	1
Fraction of Inflatable + Unknown Boats	0.586	0.422	0	1
Fraction of Inflatable + Unknown + Other Boats	0.656	0.396	0	1
Panel B. Sample 2016–2020: 3,654 Observations (1,827 by Route)				
Route: Libya				
Attempted Crossings	168.547	511.015	0	5,504
Wave Height	0.928	0.618	0.120	5.506
Fr. of Inflatable Boat	0.474	0.398	0	1
Route: Tunisia				
Attempted Crossings	17.284	51.733	0	580
Wave Height	0.786	0.588	0.091	4.403
Fraction of Inflatable Boats	0.119	0.258	0	1

Notes: The two subsamples consist of daily crossings from January 1, 2013, to December 31, 2017, and daily crossings disaggregated by country of departure (Libya and Tunisia) from January 1, 2016, to December 31, 2020. Crossing attempts include successful crossings and deaths in transit. Significant wave height is measured in meters and in different locations: Tripoli and Zuwara, Libya; Al Huwariyah, Monastir, and Djerba, Tunisia; and Annaba, Algeria. The data on wave height come from the European Centre for Medium-Range Weather Forecasts (ECMWF) from daily runs at 12:00 PM (UTC). The spatial resolution of the dataset is approximately 79 km spacing for the surface around the geographical coordinates.

Djerba, Tunisia; and Annaba, Algeria. Online Appendix Figure C.5 shows the density of the significant wave height by season.

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

II. 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 SAR operations on the various agents involved. For simplicity, we abstract away from any strategic interaction between migrants and smugglers and treat them as consumers and producers, respectively, in the market for crossing attempts.

Case 1 (*Single Boat Type*).—We start with a model of smuggling in which only a single type of boat is available, and we explore how SAR affects migrants' decisions. This roughly corresponds to the pre–Mare Nostrum period before inflatable boats became an integral part of the market for passage on the Central Route. On the demand side, we assume a unit mass of potential migrants. Migrant i has utility

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

where 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, σ^R is the probability of successful passage, and p is the price of passage.[30]

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

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

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

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

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

[30] Migrants pay smugglers very high prices to traverse the Central Route. According to Abdel Jelil et al. (2018), for sub-Saharan Africans the average cost of the entire journey is close to US$2,250 and includes the cost of reaching the African coast, which is roughly equivalent to three years of income. According to Libyan smugglers who have been interviewed by investigative reporters crossing the Mediterranean Sea during this period, passage on inflatable boats costs at least US$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$2,000 and US$2,500.

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

PROPOSITION 1: *Under Assumptions A1, A2, and A3, the introduction of SAR operations will result in:*

(*1*) *Increases in total attempted crossings.*

(*2*) *Total attempted crossings becoming less elastic to crossing conditions.*

All proofs may be found in the online 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 yields the second part of Proposition 1.

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

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

Case 2 (*Multiple Boat Types*).—We now consider an environment in which each migrant may cross on either 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 underpowered outboard motor). This corresponds to the post–Mare Nostrum period, in which both wooden boats and inflatable boats were employed in large numbers. We generalize equation (1) as

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

[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 $\alpha_i\left(\sigma_b^R(h) - \delta E\left[\sigma_b^R(h)\right]\right) > (1-\delta)p_b$. The remainder of the analysis follows as before with slight modifications to the formulas for $\underline{\alpha}$ and $\bar{\alpha}$ given in Lemma 1.

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

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

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

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

Assumption A4 simply states that irrespective of weather conditions safe boats are more likely to complete the journey than unsafe boats. Assumption A5 states that unsafe boats are more susceptible to crossing conditions. Assumption A6 expands on Assumption A2 and captures the fact that SAR increases the safety of unsafe boats more than it increases the safety of safe boats.[32] On the supply side, smugglers offer passage to migrants at prices p_b and at costs c_b, respectively, and we denote by M_s^R and M_u^R the fractions of migrants who attempt to cross on safe and unsafe boats, respectively. We assume that seats on safe boats are more costly to provide than seats on unsafe boats $(c_s > c_u)$.

We begin our analysis of this market by noting that a less motivated migrant will never choose a safer boat than a more motivated migrant, which we formalize in Lemma 1.

LEMMA 1: *Define* $\underline{\alpha} = p_u/\sigma_u^R$ *and* $\bar{\alpha} = (p_s - p_u)/(\sigma_s^R - \sigma_u^R)$. *Under Assumption A4, if* $\alpha_i < \underline{\alpha}$, *then i will not cross. If* $\underline{\alpha} \leq \alpha_i < \bar{\alpha}$ *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 allows us to pin down the number of attempted crossings. We illustrate this result in Figure 5. The two thresholds, $\underline{\alpha}$ and $\bar{\alpha}$, fully characterize the equilibrium of the market.

For simplicity, we first consider the case in which the market for smuggling is perfectly competitive, i.e. prices are set to marginal cost.[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 $1 - \sigma_s$.

[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.

[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 among themselves when storing boats and by steering information to offer mutual assistance. For local, tribal, and community interests, smuggling is sometimes perceived as a way to finance their security in times of civil unrest (Micallef 2017). This is likely to generate some local monopoly power.

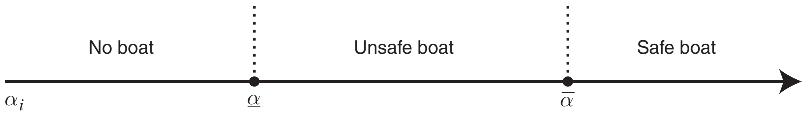

Figure 5. Migrant's Crossing Decisions

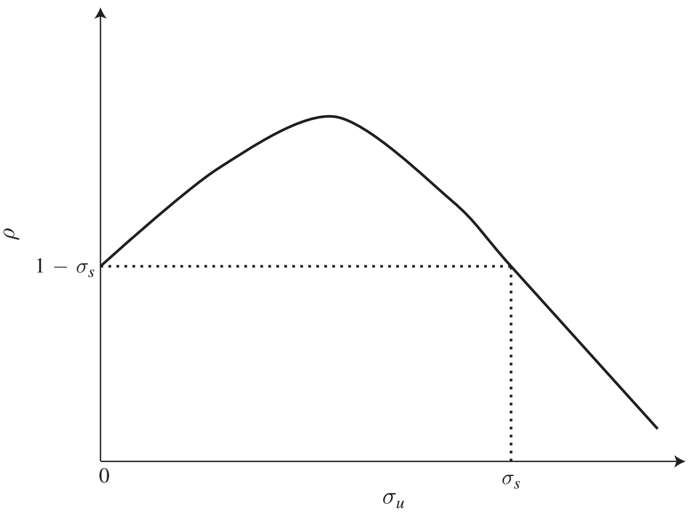

Figure 6. Ex Ante Crossing Risk

PROPOSITION 2: *Under Assumptions A4–A6 and perfect competition, the introduction of SAR 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, and*

(*3*) *total attempted crossings becoming more elastic to crossing conditions if* σ_u^0 *is small.*

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

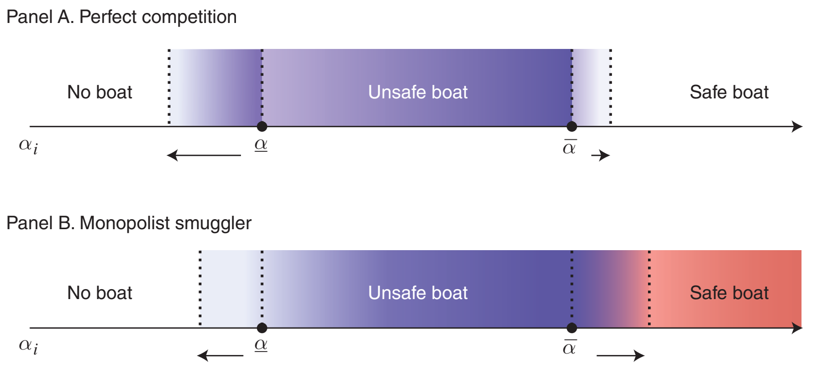

Figure 7. Incidence of Search and Rescue Operations on Migrants

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

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

Perhaps surprisingly, when 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 also consider the polar case in which smugglers are monopolists and hence can set prices freely depending on the extent of SAR. Details of this exercise are available in the online Appendix. The results from Proposition 2 still hold under monopoly, and we obtain additional results on price changes, which we summarize in Figure 7. In the presence of SAR, the migrant who is indifferent between passage on an unsafe boat and no passage at all now has a lower 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 SAR 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 enjoy market power, then all migrants who still take the safe boat will be made worse off by SAR since they pay a higher price but get no added benefit. Moreover, those migrants who are just to the left of this new threshold will also be worse off since they highly value safety but are now priced out of safe boats.

Finally, by placing additional structure on f_α, we can approximate the relative safety of boats, $\theta = \sigma_U/\sigma_S$, from the semielasticities of crossings to weather conditions and relative prices. Formally, if we replace Assumption A1 with the stronger parametric assumption,

$$\alpha_i \sim \mathrm{Exp}(\cdot), \tag{A7}$$

we obtain the following result:

PROPOSITION 3: *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 $\omega_b^R = \partial TotalCrossings_b / \partial h$.

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.

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

Remark 3: The model with two types of boats is a straightforward extension of the model with a single type of boat. In a world where only safe boats are available, as characterized by Proposition 1, there is only a single threshold $\underline{\alpha}'$ describing the marginal migrant who is indifferent between crossing on a safe boat and not attempting to cross. This threshold can be expressed as a convex combination of the two thresholds described in Lemma 1:

LEMMA 2: *Define* $\theta = \sigma_U/\sigma_S$. *Then*

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

Lemma 2 has an intuitive interpretation: an environment with only one type of boat can be thought of as equivalent to one in which there are two types of boats and the crossing risks on safe and unsafe boats are similar ($\theta = 1$). In this case, most of the crossings that would have occurred on unsafe boats, if they were available, will now occur on safe boats. In an environment with two types of boats, i.e. one in which safe boats are much safer than unsafe boats, most of the crossings that would have occurred on unsafe boats, if they were available, are no longer attempted.

III. Results

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

Identification of these elasticities relies on the assumptions of the exogeneity and stationarity of weather and tidal conditions, which are supported by the literature on maritime waves (Kharif et al. 2008).

This literature and our model lead to our choice of specification of estimating equation. Following the model, the daily number of crossing attempts, c_t, can be expressed as a function of $\underline{\alpha}_t = p_t/\sigma_t$, where prices and risk refer to the least safe boat type available (this corresponds to the left threshold in Figures 5 and 7). Assuming that the αs are distributed approximately exponentially, $c_t = e^{-\lambda(p_t/\sigma_t)}$, 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.[34]

With this in mind, we specify the following Poisson quasi-maximum likelihood regression:[35]

$$(3) \qquad c_t = \exp\Big[h_t\big(\omega_0 + \omega_1 PostSAR_t + \omega_2 \bar{u}_{w(t)} + \omega_3 \bar{u}_{w(t)} \times PostSAR_t\big) + \mu_{w(t)} + \epsilon_t\Big],$$

where crossings depend on wave height interacted with the presence of an (intense)[36] SAR operation ($PostSAR_t$) per official records and the fraction of unsafe boats, ($\bar{u}_{w(t)}$), deployed in a specific week $w(t)$.[37] Our main parameter of interest is ω_3.[38] A negative estimate of this parameter implies that crossing attempts are more responsive to wave heights when SAR is in place compared to when SAR is not in place

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

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

[36] We refer to SAR operations as intense in equation (3) because we are only able to observe boat type after January 2013. As a result, the baseline operation in regression refers to *Hermes*, which is the least intense SAR operation according to official operational descriptions, as well as according to average distance of rescues from Lampedusa, Sicily (see online Appendix Table C.1). The details on SAR operations are in Table 1.

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

[38] All coefficients, particularly when close to zero, can be interpreted as semielasticities, as these are equal to $100 \times [\exp(\beta) - 1]$ percent.

and a larger fraction of migrants switches from safe to unsafe boats, i.e. from a market with safe boats to one with multiple types of boats. This is evidence that the marginal crossing is being undertaken on a less safe boat, hence crossing attempts have increased and average ex post crossing risk has likely increased as well. We estimate Newey-West standard errors to allow for heteroskedasticity and autocorrelation within 28-day periods. We also perform randomization inference to (i) ensure the robustness of this choice, and (ii) make sure that the results are not due to a spurious correlation.

Because our model predicts a shift from safe boats to unsafe boats, we include week-by-year 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 semielasticities (under SAR and in the absence of SAR) matters for our purposes. Because SAR assets easily withstand rough seas and are ex ante unaware of the type of boats they will encounter, the ωs are unlikely to be differentially influenced by any measurement error.

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

$$(4) \qquad c_{it} = \exp\Big[h_{it}\Big(\omega_0^T + \omega_1^T SAR_{it} + \omega_2^T \bar{u}_{w(it)} + \omega_3^T \bar{u}_{w(it)} \times SAR_{it}\Big)\Big] \\ \times \exp\Big[L_{it}\Big(h_{it}\Big(\omega_0^L + \omega_1^L SAR_{it} + \omega_2^L \bar{u}_{w(it)} + \omega_3^L \bar{u}_{w(it)} \times SAR_{it}\Big)\Big) \\ + \mu_{w(it),i} + \epsilon_{it}\Big],$$

where i refers to the country of departure and the superscripts T and L correspond to crossing attempts originating in Tunisia and Libya, respectively. Given the sample period for which equation (4) is relevant, the SAR dummy in this case is equal to one before August 7, 2017 (pre-Minniti period); after that, it corresponds to the period in which NGOs were asked to sign and abide by the Minniti Code of Conduct (see online Appendix A). ω_3^L measures the marginal sensitivity to wave conditions in the pre-Minniti period (multiple-boat-types regime), when the fraction of inflatables and waves are higher for Libyan departures as compared with Tunisian departures. The $\mu_{w(it),i}$ now correspond to week–year–country-of-departure fixed effects.

A. *Time Series Evidence*, *2013–2017*

Estimated coefficients of equation (3) are presented in Table 3. Each specification corresponds to a different designation of boats as "unsafe": column 1 uses dinghies and inflatable boats only, column 2 adds the boats that are of unknown type, and column 3 adds boat types that are described as "other." The fraction of crossings

TABLE 3—ELASTICITIES OF CROSSING ATTEMPTS TO CROSSING CONDITIONS

	Definition of Unsafe Boat		
	Inflatable (1)	Inflatable + Unknown (2)	Inflatable + Unknown + Other (3)
Wave Height × Post SAR × Fr. Boat	−6.546	−5.450	−4.168
	(1.929)	(1.397)	(1.293)
Wave Height	−0.891	−1.430	−1.458
	(0.366)	(0.605)	(0.612)
Wave Height × Fr. Boat	2.135	1.907	1.632
	(1.813)	(1.342)	(1.131)
Wave Height × Post SAR	0.209	1.165	1.004
	(0.455)	(0.647)	(0.727)
Week-Year FE	✓	✓	✓
Pre SAR Period Statistics			
Mean Total Attempt	120	120	120
Mean Wave Height	0.63	0.63	0.63
Mean Frac. Unsafe Boat	0.07	0.27	0.29
Observations	1,612	1,612	1,612

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

on unsafe boats is aggregated at the weekly level. The baseline types of boat, the safe ones, tend to be fishing vessels or other motorboats. Our estimates imply that a 0.10 m increase in wave height reduces the total number of crossings on safe boats by 8.9–14.6 percent. As predicted by the model, when unsafe boats are unavailable ("Frac. Unsafe Boat" is zero), the response to intense SAR is positive, reducing the deterrent effect of waves by about two-thirds, though it is not statistically significant (except once, +1.16, in column 2). The coefficient on wave height interacted with the fraction of unsafe boats when more intense SAR operations are not operating is positive but is not significantly different from zero. The issue is that during Hermes (the excluded period characterized by a single boat type) only 7 percent of crossings were attempted on inflatable boats, and these may have been triggered by unusual circumstances.

Importantly, in all specifications, we find that adverse crossing conditions lead to a greater number of departures, with more intense SAR operations when there is a greater shift from unsafe boats to safe boats. We find that in the presence of intense SAR and a large fraction of unsafe boats (close to one), there is an additional reduction of 65–41 percent. While the coefficients give rise to very large negative elasticities (6.6 times the coefficients), one has to keep in mind that small changes in significant wave have a large impact on the likelihood of encountering rogue waves—that is, waves that are at least twice as high as the significant wave. Online Appendix Figure C.6 shows the probability of encountering maximum waves of different height within a couple of hours depending on whether the significant wave height is 0.63 m (the pre–Mare Nostrum average significant wave height) or 0.73 m, as well as the corresponding log difference (as in a Poisson model).[39]

The likelihood of facing waves up to 2 m is about 50 percent larger when significant wave height increases by 10 centimeters, and is almost twice as large for maximum waves that are up to 2.7 m tall. This implies that if we measured the elasticity of crossing with respect to the risk of facing very large waves, the elasticities would be much smaller in absolute value.

We perform a number of robustness checks to ensure the validity of our findings and summarize them here, while all the corresponding tables and figures are in the online Appendix. In online Appendix Table C.3, we show that OLS estimation of equation (3) yields similar results to Poisson quasi-maximum likelihood regression. In online Appendix Table C.4, we show a list of robustness based on the type of clusters. We present the estimates using clusters at the month-of-the-year and week-of-the-year levels (in parentheses and squared brackets, respectively). In addition, we estimate Newey-West heteroskedasticity- and autocorrelation-robust standard errors and vary the bandwidth: instead of 7 days, we propose 14 and 21 days (in vertical bars and curly brackets respectively). Our main coefficients of interest keep on being significant no matter the standard errors. In online Appendix Table C.5, we replicate our analysis by incorporating information on crossing conditions from earlier days to allow journeys to last more than a day. Again, the results are qualitatively similar when using lagged values or the maximum wave height between $t-1$ and t, though they tend to generate coefficients that are closer to 0. In online Appendix Table C.6, we present results specifying significant wave height quadratically (as in the online Appendix equation (B.7)), and our findings are substantively unchanged. In online Appendix Table C.7, we measure crossing conditions as significant wave height from five different locations: one in Libya, three in Tunisia, and one in Algeria. Libyan sea conditions appear to be better proxies for the conditions that migrant boats are facing. Finally, in online Appendix Table C.8, we show the results using different definitions of bad (extreme) weather and along the whole distribution of fractions of unsafe boats with the confidence interval (online Appendix Figure C.9).

As a randomization inference exercise, we estimate 644 versions of equation (3) under the conservative classification that only inflatable boats are unsafe. In each of these versions, we use wave height at time $t-k$ in place of wave height at time t, choosing k to be sufficiently large (28 to 336 days) so as not to affect the journey.[40] The top panels of online Appendix Figure C.7 plot the resulting distributions of our two main parameters of interest, $\omega_0{}^k$ s and the $\omega_3{}^k$ s; the bottom panels plot the resulting distributions of the other two semielasticities. 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 1 percent.

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

[40] Using leads instead of distant lags, online Appendix Figure C.8 provides similar results but forces us to truncate our sample as our wave height data are only available until the end of 2017.

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

	Crossing attempts	
	(1)	(2)
SAR × From Libya	4.411	
	(0.202)	
From Libya	0.503	
	(0.124)	
Wave Height		−2.295
		(0.376)
Wave Height × Frac. Inflatable Boat		−2.374
		(2.774)
SAR × Wave Height		−0.764
		(0.726)
SAR × Wave Height × Frac. Inflatable Boat		4.015
		(3.177)
From Libya × Wave Height		1.807
		(0.729)
From Libya × Wave Height × Frac. Inflatable Boat		2.316
		(2.867)
From Libya × SAR × Wave Height		2.821
		(1.647)
From Libya × SAR × Wave Height × Frac. Inflatable Boat		−6.974
		(3.707)
Week-Year FE	✓	
Week-Year-From Libya FE		✓
Observations	3,402	2,952

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

B. *Panel Evidence, 2016–2020*

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

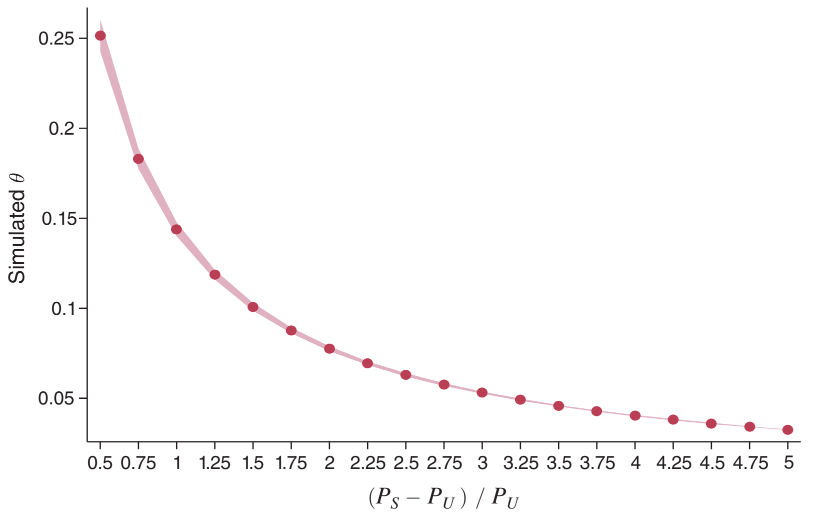

Figure 8. Simulated Probability of Success on Unsafe Boat versus Safe Boat by Relative Price

Note: The $\hat{\theta} = (\sigma_U/\sigma_S)$s are simulated using the semielasticities estimated in column 1 of Table 3. Ninety-five percent confidence intervals are shown with standard errors computed using the δ-method.

larger than attempted crossings from Tunisia.[41] In column 2, we control for these level effects with the inclusion of week–year–country-of-departure fixed effects. Given that this specification leverages a sudden change in the availability of NGO rescue boats, it subsumes any smooth change in demand and supply factors of crossings (beyond those that are already captured by the many fixed effects). Yet ω_3^1 is remarkably similar to the ω_3 estimated in the time series specification (-6.97 versus -6.55), which indicates that in the presence of any SAR (EU or NGO) taking place close to the Libyan coast (i.e., when crossing on unsafe boats become feasible), Libyan crossings in inflatable boats become highly responsive to crossing conditions.

As predicted by the model, the opposite response is observed when there is no substitution from sturdy boats to inflatables; the coefficient on wave height interacted with departure from Libya and SAR indicator function is positive (2.8) and significant at the 10 percent level. As for the rest of the coefficients, attempted crossings in the absence of intense SAR operations, namely in the period after the Code of Conduct is enacted, tend to be highly responsive to crossing conditions when they originate from Tunisia, and even more so when they happen on inflatable boats (2.3, though this difference is not significant). This is in line with the inflatable boats being able to cover the 70 km stretch between Tunisia and Italy.[42]

Compared to Tunisia, in the absence of intense SAR, all boats leaving from Libya tend to be less susceptible to wave height. This, again, seems to be driven by the

[41] The corresponding event study coefficients, using July 2017 (when the Minniti Code was introduced) as the excluded month, are shown in online Appendix Figure C.10. Although not a formal proof, this test is usually interpreted as supportive of the parallel trend assumption.

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

Table 5—Fraction of Migrants by Boat Types

Fraction of Attempted Crossings	Inflatable (1)	Inflatable + Unknown (2)	Inflatable + Unknown + Other (3)	Fishing (4)	Motor (5)
Mare Nostrum	0.058	−0.066	0.099	0.052	−0.151
	(0.047)	(0.065)	(0.078)	(0.065)	(0.065)
Triton I	0.303	0.142	0.316	0.037	−0.353
	(0.103)	(0.089)	(0.083)	(0.072)	(0.081)
Triton II	0.606	0.545	0.532	−0.165	−0.367
	(0.037)	(0.049)	(0.050)	(0.044)	(0.052)
Pre MN Mean Outcome	0.11	0.38	0.42	0.22	0.36
Observations	768	768	768	768	768

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

different distance that needs to be covered. Both types of boats, when originating from Libya, tend to carry a lot more migrants and thus are presumably much larger vessels; larger vessels are able to withstand rougher sea.[43]

We leverage our model to translate our parameter estimates into estimates of θ, which allows us to make inferences on the effect of SAR on crossing risk. For a given $(p_S - p_U)/p_U$, Proposition 3 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 8.

For $p_s \approx 3 \times p_u$, which is in line with media reports (see footnote 30), $\hat{\theta}$ is between 5 and 10 percent. Notice that this is an ex ante unobserved risk ratio, which is likely to be very different from the ex post risk ratio that one would calculate from observed crossings and deaths, which is endogenously realized in equilibrium only after migrants' decisions have been made. Indeed, for any plausible price ratio, we deduce that θ is likely to be less than 10 percent, i.e., inflatable boats are about 10 times less safe than all other boats.

The implications of this finding are clear. First, following Lemma 2, almost all additional crossings induced by SAR took place on unsafe boats. Second, following Figure 6, SAR operations likely increased crossing risk for migrants, which is consistent with the increase in raw differences in crossing risk estimated in column 2 of online Appendix Table C.1. Given the very low magnitude of $\hat{\theta}$, any bias due to remaining measurement error would need to differ highly heterogeneously by boat type to overturn our results and force us to infer that SAR decreased crossing risk.

The predictions of interest in our model relate to low-frequency boat switching in response to changing SAR conditions; to circumvent endogeneity arising from these

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

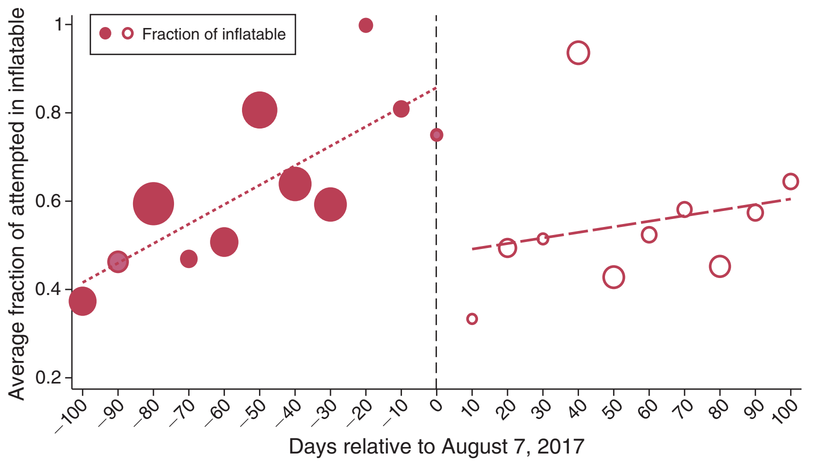

Figure 9. Fraction of Inflatable Boats around the Introduction of the "Minniti Code"

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

decisions, we test these predictions empirically by leveraging high-frequency boat switching in response to changing to crossing conditions, as the ω semielasticities are identified using week-by-year fixed effects.

Nevertheless, we can test directly whether low-frequency boat switching does occur in Table 5. Although our data are 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 percent and 4 percent 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.[44]

In Figure 9 we exploit the second set of data and the sharp changes in attempted crossings around the time the Minniti Code became operational and NGO rescue vessels were required to leave the Libyan waters (Figure 3). This change forced Libyan smugglers to use more safe boats (the single boat regime).[45] The fraction of attempted crossings that take place on inflatable boats dropped from about 80 percent pre–Minniti Code (0 corresponds to the period August 7 to 16) to about 40 percent post–Minniti Code. In both sample periods, the observed boat switching is consistent with Propositions 2 and 4.

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

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

IV. 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 SAR operations and whose internal politics have been riven by this issue.

After analyzing more than a decade of data on daily crossings, we find that, while SAR operations have no doubt saved lives directly, they may have had adverse unintended consequences that should be considered. First, by reducing the risk of crossing, they seem to have induced more migrants to attempt to cross and, in doing so, exposed more people to the risk of death along the passage. Second, by reducing the costs to traffickers of using unsafe boats, they induced a large substitution away from seaworthy wooden vessels and toward flimsy inflatable boats. Thus, the benefits of SAR operations have been, to some extent, captured by human smugglers.[46]

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. However, by intervening along the route, it is likely that more migrants would attempt an extremely dangerous undertaking. Saving a migrant at sea seems to be an obvious decision; weighing that action against the many potential migrants who might be encouraged to undertake such a treacherous passage in the future complicates this immensely. The obvious parallel to well-known "trolley problems" suggests that this is an ethical dilemma with no unambiguous solution. Although our work, unfortunately, does not guide this decision definitively, it does provide clear evidence that migration and smuggling are strategic choices that are made by thoughtful agents in a fraught environment.[47]

In the interest of being constructive, our analysis suggests that a major policy goal of SAR operations should be to limit substitution from seaworthy boats to inflatable ones.[48] One way to do so would be by interceding in the trade of such items to Libya. The European Union's ban on exports of inflatable craft to Libya is a step in the right direction, though most crafts are produced in China, and online Appendix Figure C.3 suggests that they may still enter Libya through Egypt and Turkey. That said, there are clear and systematic, albeit indirect, effects of intense SAR operations on these smuggling markets. Ensuring that future SAR policies inadvertently promote activity in these markets as little as possible is thus critical to their success.

Ultimately, addressing this issue will require interventions that reduce demand for irregular migration. There are two clear margins on which policymakers could act. First, the European Union could reduce demand for immigration out

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

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

[48] This is in line with Spain's decision to ban underpowered (i.e., less than 150 kilowatt-hours) inflatable boats that are longer than 8 m.

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 European Union could facilitate safe, legal migration from home countries to the European Union so that such a vital activity would be taken away from the hands of smugglers and moved 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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