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The impact of the EU-Turkey agreement on the number of lives lost at sea

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The European Union is facing a major challenge: irregular migration. Our aim in this paper is to shed light on a past EU migration policy through the lens of a rigorous analysis of its impact. To this end, we look at the EU-Turkey statement, an agreement reached in March 2016 to contrast irregular migration from Turkey to the EU. Despite the intention to curb migration flows, combat smuggling and improve border security, the implementation of the EU-Turkey deal has raised questions about its effectiveness and humanitarian impact. Drawing on existing literature and empirical data, this study examines the impact of the EU-Turkey statement on migration patterns and fatalities in the Mediterranean. Using a Matrix Completion estimator for panel data, we assess the effect of the agreement by quantifying the number of migrants diverted to alternative routes and estimating the lives lost at sea as a result. Our results show a significant diversion effect from the Eastern Mediterranean to the Central Mediterranean route, which undermines the core objective of the agreement to reduce border crossings. We estimate an increase of around 2000 migrants on the Central Mediterranean route due to the agreement from April to December 2016. We also find a correlation between the diversion effect and the risk of death on the main migration routes, resulting in a net increase of 45 ± 3 lives lost at sea. Our work highlights the unintended consequences of bilateral migration agreements and emphasizes the need for a broader perspective when designing future policies.

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Introduction

In recent years, the European Union (EU) has faced a formidable challenge as irregular migration flows to its shores reached unprecedented levels between 2014 and 2018, leading to what is commonly referred to as the “migration crisis” (European Commission and Directorate-General for Communication, 2017). This increase in migration has attracted public attention and led to a focus on emergency measures to counter irregular border crossings. In response to the migration crisis, policy-makers have pursued various strategies, including the conclusion of agreements with transit countries and the adoption of measures to externalize border controls. These efforts reflect an approach that aims to manage migration flows and mitigate the immediate challenges of irregular migration. Despite the limitations of such an approach, agreements with transit countries are increasingly becoming the norm. On March 17, 2024, for example, the EU announced a substantial pledge of over €5 billion in grants and loans to Egypt, the latest of many Mediterranean countries to receive support to improve its border security measures (Directorate-General for Neighborhood and Enlargement Negotiations, 2024). These initiatives follow precedents set by agreements with countries such as Turkey in 2016, which served as a model for similar deals. The declaration signed between the EU and Turkey in March 2016 is an important agreement with far-reaching implications (Council of the European Union, 2016). Although the declaration aims to address the problem of irregular migration, it has raised questions about its effectiveness and the impact on human lives (European Asylum Support Office, 2020).

One of the most important points was Turkey’s commitment to strengthen border security and prevent refugees and migrants from entering the EU. In return, the EU promised Turkey financial support for the care and accommodation of refugees within its borders. Despite the intentions expressed in the declaration, 2016 saw the highest number of deaths among migrants attempting to reach Europe via the dangerous Mediterranean routes, which include the Western, Eastern, and Central routes (the terms “Western Mediterranean route” and “Western route” are used interchangeably, as are “Central Mediterranean route” with “Central route”). Shockingly, 5143 people lost their lives on this perilous journey, an increase of more than 1000 deaths compared to the previous year (International Organization for Migration (IOM), 2023). Remarkably, this happened while the number of refugees arriving in Europe fell by more than 60% (United Nations High Commissioner for Refugees (UNHCR), 2023a). While the European Commission claims that the agreement between the EU and Turkey has led to tangible results in reducing irregular and dangerous crossings as well as in reducing the number of fatalities in the Aegean Sea, there are still numerous reasons to doubt the overall effectiveness of the declaration when considering the entire Mediterranean migration region (European Commission, 2019). These facts underline the need to assess the impact of migration agreements more precisely at the regional level and in the long term, which raises important research questions: Has the EU–Turkey deal significantly reduced the number of migrants arriving in the European Union? Has EU funding and the EU–Turkey statement helped to prevent the tragic loss of life in the Mediterranean? Or, on the contrary, has the deal contributed to increasing the risk of deaths in the Mediterranean? In light of these crucial questions, in this paper we examine whether the EU–Turkey statement has inadvertently contributed to an increase in migrant crossings on alternative and riskier routes, leading to an increase in the risk of death.

In recent years, researchers have studied irregular migration in the Mediterranean, focusing on the determinants, patterns, and impacts. However, to our knowledge, no published study has attempted to conduct a causal analysis of the diversion effect of any

policy in the region. In our study, the term diversion refers to the phenomenon of some migrants choosing alternative routes instead of the route targeted by the policy. Most studies focus on the Central Mediterranean route, as it is the one with the highest migration flow and the highest number of fatal events (GMDAC Briefing Series, 2015). In particular, most studies examine the impact of EU-funded Search and Rescue (SAR) operations on the increase or decrease of migration flows. SAR operations in the Mediterranean are coordinated efforts to locate and rescue people in distress at sea in the region to save lives and ensure the safety of migrants and others facing dangerous conditions during sea crossings. Battiston (2017) emphasizes that a more humanitarian rescue policy correlates with an increase in future crossing attempts, while stricter border control measures are associated with a higher risk of death for migrants. Deiana and coworkers (2022) developed a model of irregular migration to determine the impact of SAR operations. They found that these operations inadvertently led smugglers to use more dangerous methods, such as sending boats out in bad weather and using flimsy rafts. In contrast, Cusumano and Villa (2020) and other researchers (Amenta et al. 2021; Rodríguez Sánchez et al. 2023) have found that SAR operations conducted by European authorities and non-governmental organizations (NGOs) have effectively reduced the number of deaths at sea without significantly encouraging irregular migration.

When it comes to examining the impact of a policy or agreement on migration flows and the associated risk of death for migrants, the existing body of research is limited to a few papers (Fasani and Frattini, 2019; Zambiasi and Albarosa, 2023). It is an emerging field of research characterized by its novelty and the scarcity of available data. The ongoing work of Zambiasi and Albarosa (2023) represents a pioneering attempt to study the impact of an agreement in the Mediterranean region. They focus on assessing the impact of a specific migration agreement between Italy and Libya on the security of migration routes and the decision-making processes of migrants and smugglers. Their research provides important insights suggesting that migrants and smugglers responded strategically to this policy change. In particular, they changed their routes and redirected a significant part of the illegal migration flow to the Western Mediterranean route. Another interesting approach is the analysis of the effects of conflicts on migration behavior (Weisser, 2023). Weisser (2023) has found that conflicts and the resulting forced displacement of people can have far-reaching repercussions, such as increasing migration hazards on distant migration routes due to a spillover effect on the affected region. Overall, recent studies highlight the complex dynamics and unintended consequences associated with migration deals, particularly in terms of route security and the adaptability of migration patterns in response to policy changes. These results support our hypothesis regarding the chronic problem of redistribution of migrants via alternative routes. We argue that policies that focus solely on enforcing controls on a single route prove ineffective, potentially exacerbating the problem by displacing it to another area and delivering counterproductive results. It is indeed proven that changing the accessibility or enforcement of borders along migration routes can cause a significant shift in migrant flows. Guido Friebel et al. (2017) have shown that the opening of the Central Mediterranean route in 2011 has changed the dynamics of migration flows. Another remarkable work (Steinhilper and J. Gruijters, 2018) contributes to the understanding of deaths at the Mediterranean borders by evaluating recent data sources, providing a descriptive statistical analysis of mortality risks from 2010 to 2016, and assessing the link between European border policies and deaths. The findings challenge the narrative of deterrence and highlight the limits of the EU’s strategy to address the current

humanitarian crisis. Despite their efforts, most empirical analyses lack statistical relevance. For example, many analyses claim that there has been no immediate redistribution of migrants following the agreement between the EU and Turkey, based solely on the total number of crossings and the shift in the composition of migrants using the Central Mediterranean route (Presidency of the Council of the European Union, 2016; Steinhilper and J. Gruijters, 2018). However, as we will show, this claim is misleading, since we find a significant diversion effect towards alternative routes. Nonetheless, the International Organization for Migration (IOM) acknowledges an unusual increase in border crossings in December 2016, possibly related to the signing of the EU–Turkey statement. A review of the existing literature reveals a lack of in-depth quantitative research on the impact of the EU–Turkey statement. The online article by Spijkerboer (2016), for example, claims that the EU–Turkey statement had no causal impact on the decline in migration flows on the Eastern Mediterranean route, without presenting any econometric analysis to substantiate his hypothesis. As Steinhilper (Steinhilper and J. Gruijters, 2018) notes, despite the high death toll and ongoing public debates, the academic community has shown little interest in conducting thorough quantitative analyses of border deaths. Indeed, the existing literature often approaches the subject from a legal or critical theoretical standpoint and generally neglects to engage with the available quantitative information. This is even true of the literature on the EU–Turkey agreement, as most academic work aims to highlight the various legal shortcomings and perceived immorality of the agreement (Yilmaz Elmas, 2020). The literature on irregular migration in the Mediterranean Sea reveals a diverse range of analyses. However, there is still a lack of in-depth research on the implications of the EU–Turkey statement.

Our research aims to unravel the complexity of the implications of the EU–Turkey statement and assess its impact on irregular migration and human lives. Through an examination of existing data, reports, and incidents, we seek to uncover the diversion effect of the EU–Turkey deal by using a Matrix Completion estimator for panel data (Athey et al. 2021). Furthermore, we intend to estimate the potential number of lives lost at sea due to the implementation of the EU–Turkey deal. With this project, we investigate the impact of migration agreements on diversion phenomena on the main routes in the Mediterranean. We emphasize the need for a broader perspective when drafting migration agreements within the European Union and argue that while the detour of migrants via alternative routes may be beneficial for individual states, from the EU's perspective, it is a dangerous development that undermines the original intention of the agreement. Using a novel causal method, we can not only detect a significant detour effect from the Eastern to the Central route but also quantify the number of migrants forced to take this alternative route. This allows a numerical estimate of the lives lost at sea due to the implementation of the EU–Turkey statement. It is important to be aware that our results are approximate and likely underestimate the actual impact. Numerous IOM reports highlight the dangers of the Central route due to its length of several hundred kilometers, political instability and dangerous smuggling strategies (Global Migration Data Analysis Centre, 2016). Our analysis is divided into two parts. First, we examine the impact of the agreement on migration flows in the Mediterranean. Then, we focus on the derivation of the risk of death caused by the deal.

The EU–Turkey Agreement

The EU–Turkey deal, which was formally agreed on March 18, 2016, was created as a strategic response to the migration crisis of

2015 (Council of the European Union, 2016). This initiative was part of the Joint Action Plan presented in October 2015 and endorsed by the European Council on November 29. The main objective of the agreement was to tackle the Syrian migration crisis by reducing the flow of irregular migrants traveling from Turkey to Greece (European Commission, 2015b). Once the number of border crossings was significantly reduced, a voluntary humanitarian reception system was to be set up in cooperation with Turkey (European Commission, 2015a). The agreement was intended to curb irregular migration flows, dismantle smuggling networks, and reduce the burden on the EU frontline states, particularly Greece. Under the agreement, Turkey committed to take back all irregular migrants who entered Greece after March 20 2016, while the EU, in return, pledged to resettle one Syrian refugee from Turkey for every person sent back (the so-called “1:1 mechanism”). A key issue with this provision is that Turkey has reportedly not processed asylum applications from non-Syrian refugees, leaving Afghans, Iraqis, and Pakistanis (three of the main nationalities crossing the Eastern Mediterranean route) with limited access to international protection in Turkey or Europe. This approach raised concerns, as the EU prioritizes protection based on nationality rather than actual need. In addition, the EU promised Turkey €6 billion in financial aid to support refugee-hosting efforts, accelerated visa liberalization for Turkish nationals, and the revival of Turkey's stalled EU accession negotiations. Although the agreement has contributed to a significant reduction in crossings across the Aegean and the number of deaths in the region, there is no conclusive evidence of a link between the agreement and these outcomes. Some researchers argue that the decline would have occurred independently of the agreement (Spijkerboer, 2016). In addition, the deal has been heavily criticized for its legal and ethical implications. Human rights organizations have condemned it for undermining asylum protection and exacerbating the precarious conditions for refugees in both Greece and Turkey. Furthermore, the agreement has strengthened Turkey's geopolitical leverage over the EU, as Ankara has regularly threatened to open its borders to gain political and financial concessions. The deal remains a cornerstone of EU migration policy, but its long-term sustainability and ethical legitimacy remain the subject of intense academic and political debate.

Methods

Data. To carry out our analysis, we rely on two main sources of information. For our impact analysis, we need data on entry flows into the EU via different Mediterranean routes. At the same time, we collect detailed information on casualties at sea to assess the risk of crossing the Mediterranean. For the first part of our study, we use data sets provided by Frontex, while for the second part, we also rely on data from the Missing Migrants project. Frontex, officially known as the European Border and Coast Guard Agency, is an agency of the European Union responsible for coordinating and supporting border control and migration management between EU Member States. Frontex collects and analyses migration and border control data to help manage migration flows and improve security at the EU's external borders (European Border and Coast Guard Agency (Frontex), 2009). Frontex compiles statistics on irregular border crossings detected at the EU's external borders. It also records the nationalities of migrants apprehended attempting to cross the borders irregularly and groups them according to migration routes. The dataset provided by the Missing Migrants project is compiled by the IOM and is available online (International Organization for Migration (IOM), 2023). This dataset represents the most comprehensive record of migration incidents worldwide and contains data on

incidents leading to the death or disappearance of one or more migrants. It comes from various sources, including media, institutions, and non-governmental organizations (NGOs), and contains important information, such as the number of fatalities and missing persons per incident, the locations of the incident, and the data sources. In the previous two datasets, both border crossings and missing migrants are categorized into different coherent migration routes based on the point of interception.

In our impact analysis, the primary dependent variable of interest is the monthly number of attempted crossings from 2011 to early 2017 across five major migration routes in the Mediterranean: the Western Mediterranean, the Western African, the Central Mediterranean, the Eastern Border, and the Eastern Mediterranean. The Western Mediterranean route connects ports in Algeria and Morocco with Spain, while the Western African route links the western coast of Africa with the Canary Islands. The Central Mediterranean route connects Italy and Malta with Libya, as well as Tunisia and Egypt. The Eastern Border route stretches across Eastern Europe and connects it with Turkey by land. Finally, the Eastern Mediterranean route connects Greece, Turkey, and Cyprus and represents an important link between Europe, the Middle East, and Asia. The recognition of these routes has received international approval from leading humanitarian organizations such as IOM (International Organization for Migration (IOM), 2023), Frontex (European Border and Coast Guard Agency (Frontex), 2009) and UNHCR (United Nations High Commissioner for Refugees (UNHCR), 2023b).

To take into account the economic and political conditions in the migrants' countries of origin, we include GDP (Kummu et al. 2024) per capita and the Fragile State Index (Fund for Peace, 2007) as control variables. GDP per capita serves as an indicator of economic prosperity and helps to capture the extent of economic hardship that influences migration decisions. The Fragile State Index, which measures state stability using indicators such as political legitimacy, public services, and human rights, provides information on the role of governance and institutional fragility in the emergence of migration flows. We also examined the use of conflict-related data as a potential determinant of migration. In particular, we considered conflict fatalities from the Armed Conflict Location and Event Data (ACLED) (Raleigh et al. 2010) dataset, but problems with data availability prevented their inclusion in this analysis. Similarly, we examined the UCDP dataset (Uppsala Conflict Data Program, 2023), but its country-level data proved too sparse to provide meaningful variation, dropping the total number of observations from 73,440 to 20,208. The Frontex dataset provides the nationality of migrants and allows us to construct our data matrix for the first analysis such that each unit of observation represents the total number of migrants of a given nationality crossing one of the five routes at a given time, as well as the economic and political conditions in their country of origin.

In our second analysis of the change in route risk induced by the EU–Turkey agreement, we use monthly data on fatalities and disappearances documented for the four Mediterranean routes, as we have excluded the Eastern Border due to a lack of data. As the dataset on missing migrants does not include nationality information, we aggregate the data at the route level. This particular analysis focuses on a narrower time frame from 2015 to 2017. In this analysis, which aims to provide evidence of the existence of a positive correlation between the number of missing migrants and the change in the number of migrants caused by the EU–Turkey agreement, we also use the ACLED dataset since, in this case, we did not encounter any data availability problem. ACLED is a publicly available dataset on conflict events, created specifically for detailed conflict analysis and crisis mapping. This dataset contains details on the dates and locations of all

documented incidents of political violence in more than 70 developing countries, with a focus on regions such as Africa, Asia, and the Middle East. We use this data in our regression analysis to control for the political instability in the countries of departure of the sea crossings: Lybia for the Central Mediterranean route, Morocco for the Western routes, and Turkey for the Eastern Mediterranean route. All the data we collected and the code we used for the analysis are available in an open repository, as described in the Data Availability section.

Counterfactual estimation and causal implication. The aim of our main analysis is to assess the impact that the agreement between the EU and Turkey had on the redistribution of nationalities that constituted the majority of migrants crossing the Aegean Sea before the signing of the declaration. The method we used to assign a nationality to either the treated or control group was to examine the distribution of nationalities across routes. If the median number of migrants of a nationality in the pre-treatment period was above the aggregate median of all nationalities on the treated Eastern Mediterranean route, then that nationality was considered as treated. If it was below the median, it was assigned to the control group (for a complete list of nationalities in the control and treatment groups, see Tables S1 (a, b) in the Supplementary Materials). In addition to using the median as the threshold, we also performed checks with alternative thresholds. For the imputation of treated nationality status, we consider all nationalities except Syrians, as they benefited from the exclusive privileges laid down in the agreement.

In our main analysis, we estimate the average treatment effect on the treated

$$ATT = E[Y_{D=1} - Y_{D=0} | D = 1] \quad (1)$$

where D_{it} denotes the treatment status, $Y_{it}(1)$ and $Y_{it}(0)$ the potential outcomes of the unit i in the period t if $D_{it} = 1$ or $D_{it} = 0$. We consider the nationalities that mainly used the Eastern Mediterranean route to enter the EU as the treated entities, as they were more affected by the agreement after March 2016. Therefore, D_{it} is set to 1 after the signing of the agreement, starting in April 2016. Although the Syrians belonged to the group of treated nationalities, their privileges limited the diversion effect. Some border crossings were still possible for Syrians under the 1:1 rule, and special funds were provided to improve conditions for refugees in Turkey, so there were 3.6 million Syrian refugees in Turkey in 2020. We have therefore excluded Syrians from our main analysis. The results of an alternative analysis, including the Syrians in the treated group, are presented in the Supplementary Material as a robustness check. To assess the impact of the agreement on nationalities that predominantly used the Eastern Mediterranean route, we use a causal machine learning approach. Specifically, we rely on the Matrix Completion estimator (MC) (Athey et al. 2021) to predict migration patterns in a counterfactual scenario without the EU–Turkey agreement. This method, originating from the computer science literature, serves as a generalization of factor-augmented models. MC treats a causal inference problem as a task to complete an $N \times T$ matrix with missing entries, where missing entries occur when $D_{it} = 1$. Mathematically, MC assumes that the $N \times T$ matrix can be approximated by a matrix of lower rank $L(N \times T)$, i.e.: $Y(0) = X\beta + L + \epsilon$. In this context, Y is a $(N \times T)$ matrix of untreated outcomes; X is a $(N \times T \times k)$ array of covariates, and ϵ represents a $(N \times T)$ matrix of idiosyncratic errors. Matrix Completion then attempts to estimate L directly by

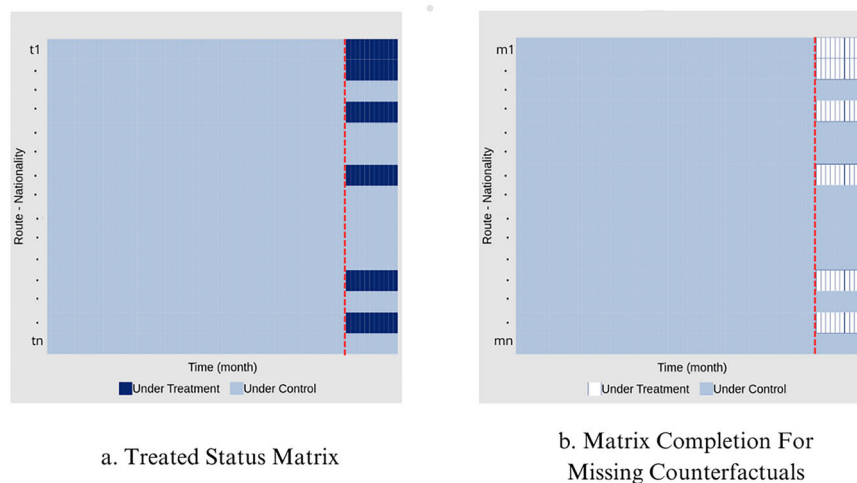


Fig. 1 The figure describes our causal machine-learning approach. **a** The treated status matrix (TSM) illustrates the relationship between route-nationality pairs on the y-axis and time represented on a monthly basis on the x-axis. For example, t_1 here represents the Eastern Mediterranean route-Bangladesh nationality unit, which belongs to our treatment group (dark blue cells), while t_n represents the Western Mediterranean route-Zambia unit, which belongs to the control group (light blue). The red dashed line indicates the start of treatment in April 2016. **b** Starting from our TSM, we can obtain our Matrix Completion matrix (MCM), which is obtained by removing the treated entries (i.e. t_{1j} , where j is a post-treatment column index) and interpreting them as missing counterfactuals (white cells). The goal of the Matrix Completion estimator is to estimate the missing counterfactual values of our treated units accurately.

solving the following minimization problem

$$L = \operatorname{argmin}_L \left(\sum_{(i,t) \in O} \frac{1}{|O|} (Y_{it} - L_{it})^2 + \lambda_L \cdot \operatorname{norm}(L) \right), \quad (2)$$

where $O = \{(i, t) | D_{it} = 0\}$, $\operatorname{norm}(L)$ is the chosen matrix norm of L and λ_L is a tuning parameter. In our analysis, we define two models: one including covariates and one without. The latter incorporates only time-fixed effects and unit-fixed effects for nationality-route pairs, allowing the algorithm to minimize errors within the space of unobserved characteristics. A visual representation of our methodological approach is provided in Fig. 1, which shows different units t_1 to t_n , each representing a unique combination of route and nationality, whose state is evolving through time; some of them become treated after the signing of the agreement in March 2016 (dark blue). These dark blue cells are the ones that will be considered as missing observations by our Matrix Completion estimator.

A comparison was made between the Generalized Synthetic Control (SC) method proposed by Yiqing Xu (2017) and the Matrix Completion approach, both of which are widely used in causal inference studies. Matrix Completion has been used extensively in various fields in imputation tasks and causal inference, and in our analysis, it consistently provided coherent results for both standardized and non-standardized data. This method provided robust estimates and insightful results, underlining its suitability for our study. Conversely, our application of the SC method initially led to contradictory results. While the SC is known for its effectiveness in causal inference, we observed that it exhibited a high sensitivity to the pronounced spike in migration flows in 2015, leading to an overestimation of the average treatment effect and consequently to misleading conclusions (see Supplementary Material). This problem could be due to the violation of the parallel trends assumption or to a known limitation of SC in panel data contexts where the number of observations significantly exceeds the number of time periods, as in our case with over 70,000 observations and about 70 time periods (Athey et al. 2021). While Generalized Synthetic Control relies on parallel trends to construct a counterfactual situation, Matrix Completion instead assumes a low-rank structure, which

is a more flexible condition. This flexibility allows Matrix Completion to capture complex, nonlinear relationships in the data that SC, with its linear weighting of control units, may struggle to account for. Following this reasoning, when the data were standardized, the results of SC matched those of Matrix Completion. This suggests that preprocessing can help to mitigate methodological limitations by making the underlying assumptions more comparable. Given these limitations of the SC method, we opted for a different estimator, namely the Interactive Fixed Effect (IFE) method (Liu et al. 2024). IFE and Matrix Completion are both methods used for imputing missing data and estimating causal effects, but they differ in how they deal with noise and structure in the data. IFE relies on a hard impute approach, where a fixed number of singular values are selected to capture the underlying patterns, while the rest are discarded. This rigid factor selection can make IFE highly sensitive to spikes and structural breaks, as it lacks a regularization mechanism to smooth out fluctuations. In contrast, MC applies a soft impute technique by applying an L1 penalty to all singular values and gradually shrinking them instead of making a binary selection. This allows MC to adapt more flexibly to complex data structures, reduce volatility, and mitigate the effects of outliers. Our analysis confirms this difference: before the intervention, IFE produced more volatile estimates and was more sensitive to the pronounced spike in migration flows in 2015, while MC provided smoother and more stable estimates (see Supplementary Materials). This discrepancy likely results from the assumption of a fixed structure with a low rank in IFE and the parallel trend assumption. Based on our results, Matrix Completion seems to be the more robust method as it copes better with high-dimensional settings and irregular trends.

The effect of the EU-Turkey deal on missing migrants. In the second step of our analysis, we take the change in migrant flows along the four routes most affected by the agreement, as measured by the ATT, as an indicator to quantify the impact of the agreement on lives lost at sea. To this end, we run a two-way fixed effects regression to test the relationship between the monthly ATT of the EU-Turkey agreement on the number of crossings of

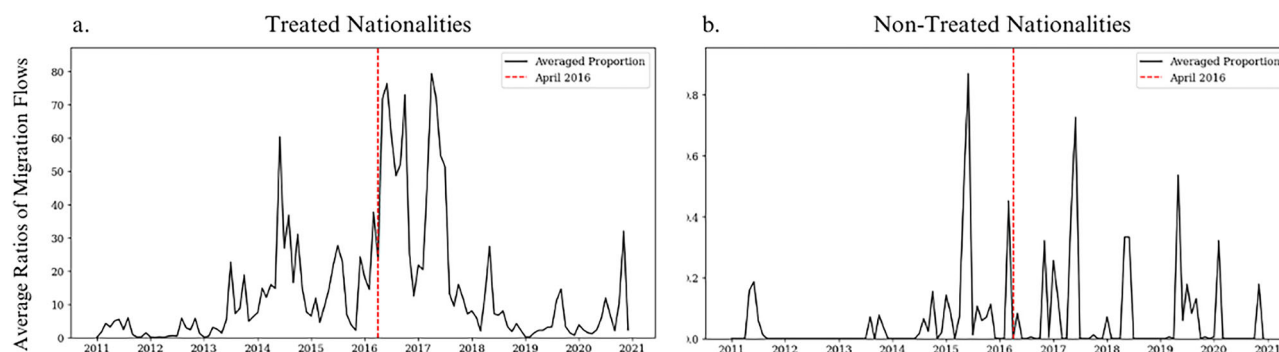


Fig. 2 This figure shows the evolution of migration flows along the Central and Eastern Mediterranean routes, distinguishing between treated and non-treated nationalities. If the median number of migrants of a nationality in the pre-treatment period was higher than the overall median of all nationalities on the Eastern Mediterranean route, this nationality was considered treated. The left panel (a) illustrates the average ratio of migration flows for treated nationalities and shows a notable increase around 2016, followed by sharp fluctuations and a subsequent decline. The right panel (b), showing non-treated nationalities, exhibits a more volatile pattern with periodic peaks, albeit with lower overall intensity. The red dashed line marks April 2016, a critical point related to the EU-Turkey agreement affecting migration dynamics. The observed differences indicate a significant impact of this agreement on migration routes, especially for treated nationalities, which appear to have changed their routes or migration strategies in response to the EU-Turkey deal.

different routes and the number of migrants missing at sea on the same routes. The inclusion of monthly fixed effects allows us to take out the effects of unobservable variables that vary over time, while the inclusion of route fixed effects allows us to remove time-invariant, route-specific variables that we do not observe. In addition to the basic framework, we add a control variable to account for departure country instability as a critical time-varying factor affecting route risk. We decided to measure the instability of Turkey, Libya, and Morocco by the number of deaths from violence against civilians, as the literature points out that the instability of a country is mainly related to the emergence of illegal markets such as smuggling, where the goal is to maximize profit at the expense of migrants' lives (Europol and INTERPOL, 2016).

Thus, the equation of our model is

$$MM_{i,t} = \alpha_i + \gamma_{t-1} + \beta_1 \text{crossings}_{i,t-1} + \beta_2 \text{ATT}_{i,t-1} + \beta_3 \text{politicalfatalities}_{i,t-1} + \epsilon_{i,t-1} \quad (3)$$

where $MM_{i,t}$ is the number of missing migrants along route i in month t , α_i and γ_{t-1} are route and time fixed effects, while $\text{ATT}_{i,t-1}$ is our variable of interest, which measures the change in the number of treated migrants along route i at time $t-1$ induced by the EU-Turkey agreement, and which we estimated in the first step of our analysis using our MC method.

Results

Descriptive statistics. First, we present descriptive statistics to assess the potential diversion effect of the EU-Turkey agreement on the most affected nationalities. Second, we provide an overview of the data on missing migrants by comparing a one-year period before and after the EU-Turkey agreement. This analysis focuses, in particular, on the Central Mediterranean and the Eastern Mediterranean migration routes. Figure 2 shows the average proportions of migrants who chose the Central Mediterranean route over the Eastern Mediterranean route for different nationalities. This visual representation is intended to provide an initial insight into the potential diversion effect that has unfolded following the adoption of the EU-Turkey statement. This effect consists of migrants, mainly from the Middle East, Asia, and some African countries, being diverted from the Eastern Mediterranean route to the Central route. Figure 2 clearly shows a shift from the Eastern Mediterranean route to the Central Mediterranean route for the treated nationalities following the implementation of the EU-Turkey statement. While this shift is

evident for the treated nationalities, there is no evidence that the non-treated nationalities have changed their route. In fact, there has been no noticeable change in trends for non-treated nationalities since April 2016. Despite the evidence of a change in migration patterns, previous descriptive studies have indicated that the diversion effects were not large enough, as highlighted, for example, by the Council of Europe (Varvitsiotis, 2017) and in other research articles (Steinhilper and J. Gruijters, 2018). However, a thorough analysis of the effects of this policy has yet to be conducted, as previous studies have only compared the distribution of nationalities from populous and war-torn countries before and after the signing of the agreement and provided corresponding results that did not yield any rerouting evidence. Through our causal machine learning analysis, we draw attention to the impact of a migration agreement between the EU and its neighboring countries and emphasize that descriptive statistics alone may not be sufficient for a thorough assessment of such a pivotal policy.

Figure 3 examines the mortality rates and again compares the Central route with the Eastern Mediterranean route. As can be seen from Fig. 3 and is generally acknowledged, the Central route is characterized by an alarmingly high mortality rate. Figure 3 shows a remarkable increase in mortality rates following the adoption of the EU-Turkey statement. Of particular significance is an unusual increase in the winter months of 2016, a phenomenon pointed out by the IOM. The IOM attributes this spike to the closure of the Eastern Mediterranean route. These initial analyses shed light on the increased risks migrants face when choosing the Central Route. In the upper part of Fig. 3, we present the localized reports of missing migrants and compare the years before and after the agreement. The sub-graphs (a) and (b) visually illustrate the decrease in accidents on the Eastern Mediterranean route and the simultaneous rise of accidents along the Central Mediterranean route. Before the agreement, reports of missing migrants on the Central route mainly were isolated incidents involving small numbers, apart from one major accident. After the agreement, while small-scale accidents continued, there was a noticeable rise in large shipwrecks, which appeared more spread out along the entire Libyan coast. It is important to emphasize that due to the unreported or undetected deaths of migrants at sea, caution should be exercised when interpreting the estimated mortality rates. The uncertainty regarding the number of missing migrants and the number of crossings used for the calculation leads to potential limitations in the accuracy of these statistics. In

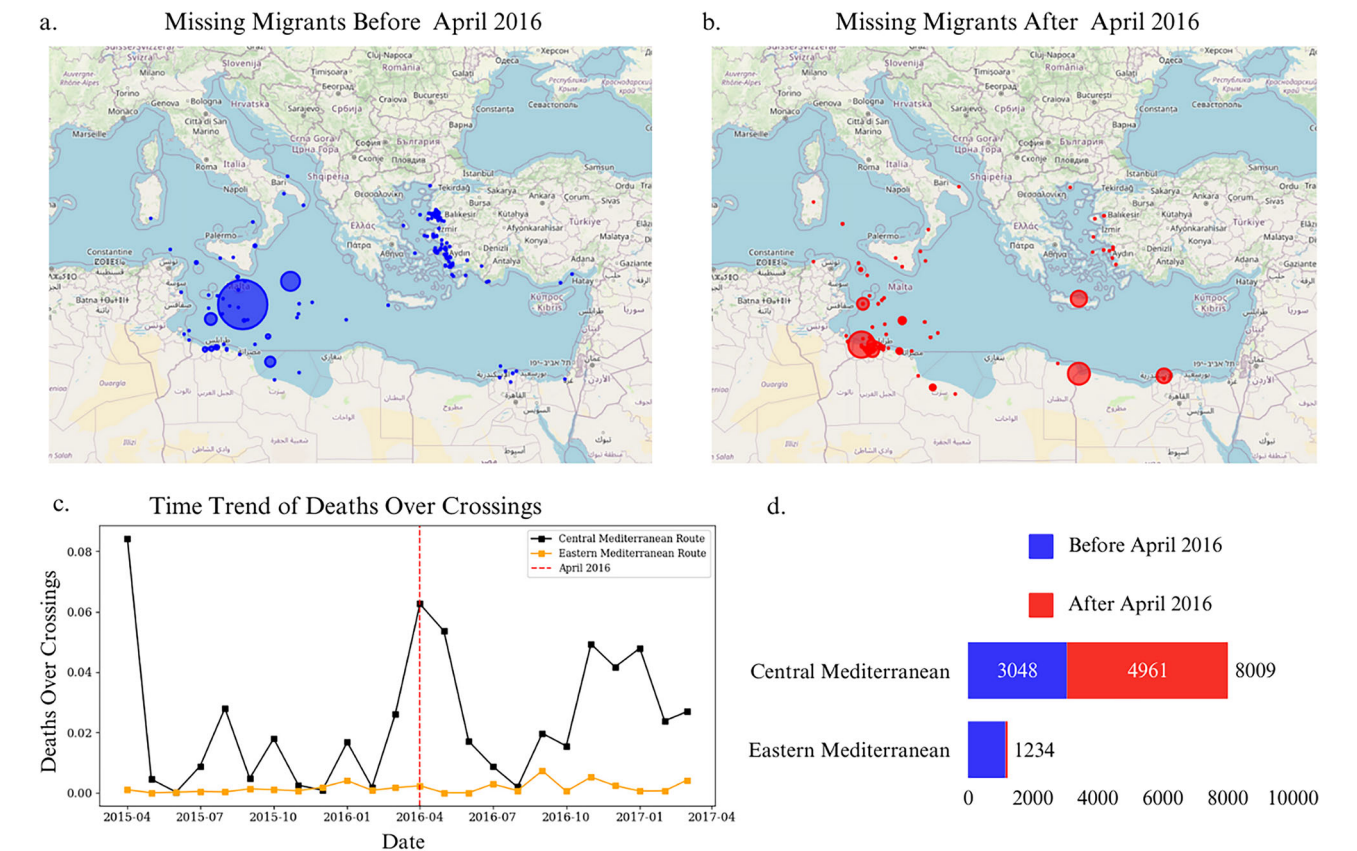


Fig. 3 The maps in panels. **a** and **b** Show the geographical distribution of missing migrants in the Mediterranean before and after April 2016, marked in blue and red respectively, with a time window that goes from April 2015 to April 2017. A notable shift can be observed, with incidents in the Central Mediterranean becoming more dispersed and frequent after April 2016. Panel **(c)** shows the time trend of reported deaths over the number of crossings along the Central and Eastern Mediterranean routes. These trends indicate a higher risk of crossing on the Central Mediterranean route. Finally, panel **(d)** quantifies the number of recorded deaths and shows an increase in deaths in the Central Mediterranean after April 2016, while the numbers in the Eastern Mediterranean appear comparatively lower.

Table 1 Estimated monthly average treatment effects on the treated (ATTs) and <i>p</i> -values for total migration flows and specific routes.												
Route	Median				First quartile				Third Quartile			
	No controls		GDP & FSI		No controls		GDP & FSI		No controls		GDP & FSI	
	ATT	<i>p</i> -value	ATT	<i>p</i> -value	ATT	<i>p</i> -value	ATT	<i>p</i> -value	ATT	<i>p</i> -value	ATT	<i>p</i> -value
Central Med.	198	0.0008	193	0.0010	146	0.0010	138	0.0020	257	0.0190	261	0.022
Eastern Bor.	1	0.4646	−3	0.3279	2	0.3069	−2	0.2489	−6	0.0169	−8	0.034
Eastern Med.	−66	0.0800	−80	0.1263	−42	0.0815	−55	0.0924	−133	0.065	−158	0.059
Western Afr.	1	0.1927	−4	0.3736	3	0.2339	−4	0.2862	−5	0.051	−9	0.031
Western Med.	6	0.0323	1	0.8394	7	0.0357	0	0.8967	0	0.9169	−7	0.1502
Overall effect	11	0.4802	3	0.8671	10	0.3869	1	0.9004	−4	0.8840	−14	0.6840
No. of obs.	73,440		62,796		73,440		62,796		73,440		62,796	
Results are presented using three different specifications, each with and without controls for GDP per capita and the fragile states index (FSI).												

addition, the calculation of the mortality rate does not take into account deaths that occur before embarkation for the sea journey. As a result, the value of the mortality rate is likely to be underestimated. This is particularly true for the Central route, where the likelihood of human trafficking and exploitation is higher than for migrants who have opted for the Eastern Mediterranean route (Galos et al. 2017).

Counterfactual analysis. Our main objective is to investigate the impact of the EU–Turkey agreement on the migration flows of

those nationalities that constituted the majority of migrants crossing the Aegean Sea before the signing of the declaration. The main results of our analysis are summarized in Table 1. Table 1 shows the estimated ATTs grouped by the five routes using different treatment thresholds. These estimates are obtained using the Matrix Completion method with and without covariates. As the Table shows, the results indicate a consistently similar effect of the agreement on migration flows across routes, highlighting the robustness of our approach. The results are consistent with those obtained using the Generalized Synthetic Control and

Interactive Fixed Effects approaches (see Supplementary Material). In all six model specifications, the ATT for the Central Mediterranean route remains positive and significant, with values ranging from 138 to 261. In contrast, for the Eastern Mediterranean route, we see a decrease in crossings, as expected. However, the modest significance of this result is intriguing when interpreting the impact of the agreement on this route. Ultimately, among all these models, we decided to select the first model specification for several reasons. First, using controls reduces the number of observations by 10,000. Second, there is a temporal mismatch between the yearly controls and our monthly dependent variable. Furthermore, the results from the model using the median with controls closely mirror those from the model without controls. We chose the median because it captures the central tendency, offering results that are between the extremes of the first and third quartiles. To further enhance the robustness of our analysis, we implemented an iterative approach. This process began by categorizing nationalities as treated based on the third quartile, which represents the most stringent threshold. Subsequently, one nationality at a time was moved from the control group to the treated group, progressively advancing toward the set of nationalities classified as treated according to the first quartile. In each iteration, we calculated the ATTs using the Matrix Completion method to examine potential discontinuities in the results. As illustrated in Figure S7 of the Supplementary Materials, as nationalities are added to the treated group, the ATT for the Central Mediterranean route begins to decrease smoothly, whereas the ATT for the Eastern Mediterranean route increases. Conversely, the ATT for the Western Mediterranean routes remains stable, suggesting that these routes are unaffected by the changes in the treated group and the deal itself, likely due to their more distant geographical context. Moreover, the significance of the ATT was largely preserved for the Central Mediterranean route, whereas the Eastern and Western Mediterranean routes exhibited only weak significance. The computation of the various thresholds and the treatment allocation took place up to October 2015 to avoid possible pre-trend effects, given the presentation of the Joint Action Plan in October 2015.

Analyzing the outputs of our baseline model, the most striking result pertains to the Central Mediterranean route, where the ATT is positive and statistically significant at the 0.01 level. The positive value of 198 indicates the monthly average of migrants who were forced to take the Central route as a result of the agreement, thus exposing themselves to a higher risk of exploitation, human trafficking, and a higher probability of death during the crossing. Table 1 also contains the ATT value for the Western Mediterranean and African routes. As expected, there was no significant diversion effect on the Western routes between 2011 and 2017. This is likely due to the large distance to the Eastern Mediterranean route. To further illustrate the estimated ATTs at the route level, Fig. 4 presents the ATTs grouped by route and averaged over time, together with the corresponding uncertainty estimates for the Central Mediterranean and the Eastern Mediterranean routes. The confidence intervals shown in the graphs refer to a 95 percent confidence level, where the uncertainty estimates were derived using a block bootstrap with 200 iterations and clustered at the unit level. Figure 4a presents the statistically significant monthly ATT estimates for the Central Mediterranean route. Summing these monthly ATTs from April to November 2016 yields a total of 2090, representing the increase in crossings among migrants of treated nationalities. Furthermore, the figures show that the estimated ATTs during the pre-treatment phase are nearly zero. Indeed, it is important that the ATTs are not significant during the pre-treatment phase to ensure the validity of the assumptions of our model. We find that

the number of treated migrants using the Eastern Mediterranean route decreased after the agreement, and the number of treated migrants using the Central route increased, indicating a statistically significant diversion effect.

Robustness checks. After reviewing our initial results, we sought to assess their robustness. To this end, we conducted both a placebo test in time (using the placebo and equivalence tests) and a pre-trend test (using the *F*-test and equivalence test). Six-month and four-month placebo-in-time tests were conducted to control for the presence of a pre-trend. The 6-month period takes into account possible pre-trends concerning the submission of the Joint Action Plan in October 2015, while the 4-month period begins with the adoption of the Action Plan on November 29. Two different techniques are used in the placebo tests. First, we apply a canonical placebo test, where we calculate the ATT for the selected pre-treatment period and then test whether the “fake” ATT is statistically different from zero (placebo test) and second, whether the “fake” ATT remains within a certain range (equivalence test). The second technique builds on the first but is more rigorous. Here, we test whether each individual “fake” ATT from the pre-treatment period is statistically different from zero by applying both an *F*-test and an equivalence test. In this way, we try to assess the presence of a possible pre-trend in the best possible way.

As illustrated in the lower part of Fig. 4c, the selected model passed all tests except for the *F*-test in the pre-trend test (see also Figs. S1–S6 in the Supplementary Materials). However, the *F*-test is known to be more sensitive to outliers, which makes the equivalence test the more robust of the two methods (Liu et al. 2024). After conducting several experiments to assess the robustness and effectiveness of our model, the results indicate a significant diversion effect on the Central Mediterranean route triggered by the implementation of the EU–Turkey agreement. These results are consistent with the IOM’s hypothesis that efforts to stem migration flows generally only shift them in other directions (Arezo and Davin, 2015). This significant result also prompts us to further investigate the relationship between the diversion effect caused by the agreement and the likelihood that migrants who are diverted to the Central route are at risk of death.

Hazard of crossings. After analyzing the impact of the agreement on the diversion of migrants from the Eastern Mediterranean route to alternative routes, our results indicate a potentially increased risk of death for migrants attempting to cross these alternative routes, particularly the Central route. Therefore, a better assessment of the increased migration risk is needed, even if the available data do not allow a rigorous analysis of the relationship between the agreement and the mortality risk associated with crossing the Mediterranean. We begin our analysis by examining the mortality rate on the Central Mediterranean route, based on the available data on Missing Migrants. This rate is calculated according to the IOM method: dividing the number of deaths at sea by the number of deaths at sea plus the number of crossings (GMDAC Briefing Series, 2015). An initial descriptive analysis reveals a relevant difference between the mean values of the distribution of mortality rates before and after the deal, with the mean value almost doubling in the period after the deal (Fig. 3d). This preliminary observation forms the basis for the development of our hypothesis that the diversion of migrants from the Eastern Mediterranean to the Central route has increased the likelihood of migrants being exposed to a risk of premature death. In addition to our observations, we also have the opportunity to

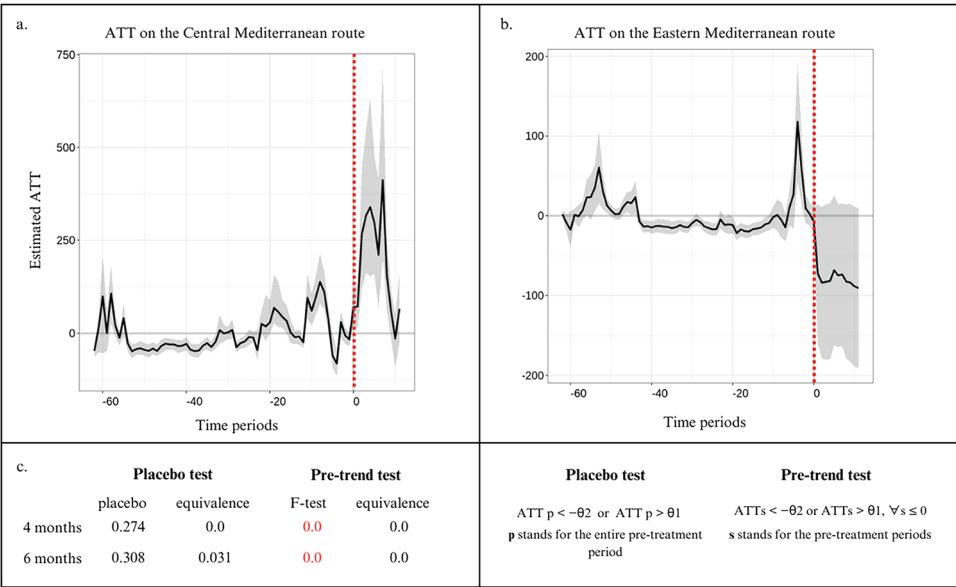


Fig. 4 Estimated average treatment effect on the treated (ATT). We show the ATT for the Central Mediterranean (a) and Eastern Mediterranean (b) migration routes. The solid black line represents the average estimated ATT, while the shaded area indicates the 95% confidence interval. The red dashed vertical line indicates the start of the EU-Turkey deal in April 2016. Below the graph on the left (c), we show the p -values of the placebo and pre-trend tests for the ATTs on the Central Mediterranean route. Our model passes all tests except the F -test. On the right-hand side, you will find a brief explanation of the main differences between the two test families.

corroborate our hypothesis by relying on the results of field-work as found by Galos et al. (2017). In particular, Galos and colleagues examine the vulnerabilities and risks of exploitation and abuse faced by migrants arriving in Europe during their journey. Their report focuses on a comparative analysis between the Eastern Mediterranean route and the Central route, drawing attention to their differences and identifying the main predictors of the likelihood of experiencing violence. They found that the choice of migration route and travel characteristics are more important than socio-demographic background in determining the risks for migrants, as longer journeys, for example, significantly increase the likelihood of abuse, exploitation, and trafficking. They also report that migrants on the Eastern Mediterranean route usually travel for 62 days, while half of the migrants on the Central Mediterranean route travel longer, more than six months and an average of 153 days. Moreover, secondary migration, i.e. departure from a country other than the country of origin, is a significant predictor only in the case of the Central route. These results confirm the increased risks faced by migrants diverted to the Central route during their journey. This journey appears to be significantly longer and the likelihood of secondary migration is high. Moreover, the socio-demographic characteristics turn out to be non-significant, suggesting that vulnerability to exploitation is independent of the country of origin. In light of all these findings, our hypothesis that migrants who choose the Central Mediterranean route rather than the Eastern Mediterranean route are at increased risk is confirmed.

Most importantly, however, we identify a significant relationship between the number of lives lost at sea and the diversion effect induced by the EU-Turkey agreement. To achieve this, we conducted a two-way fixed effects regression analysis. Our results in Table 2 show a significant and positive correlation between the ATTs and the number of migrants missing at sea with an R-squared value of 0.589. Indeed, our results reveal some interesting findings. First, we observe a statistically significant positive correlation between migrant crossings and missing migrants ($\beta = 0.001$, $SE = 0.000$, $t\text{-stat} = 2.543$, $p = 0.012$),

suggesting that higher migration flows correlate with more migrant deaths. In addition, the diversion effect due to the EU-Turkey agreement also seems to contribute to higher migrant death rates, as shown by the positive and highly significant coefficient associated with ATT ($\beta = 0.877$, $SE = 0.298$, $t\text{-stat} = 2.948$, $p = 0.004$). Finally, we included a proxy for the instability of the country of departure—Libya for the Central Mediterranean route, Morocco for the Western route, and Turkey for the Eastern Mediterranean route—in our regression model by considering the number of political deaths. The results show a positive and statistically significant coefficient ($\beta = 0.315$, $SE = 0.137$, $t\text{-stat} = 2.295$, $p = 0.024$), indicating a possible link between political instability in the country of departure and increased migrant deaths. Our analysis shows a significant correlation between the EU-Turkey agreement and the number of deaths on the Central Mediterranean route. These findings deserve careful consideration, as the EU is negotiating similar agreements with other partners in the region (Pignal, 2024), most recently with the Egyptian government.

Given the significant ATT along the Central route and a positive significant correlation between the deal's diversion effect and the number of deaths at sea, our next objective was to quantify the deaths in the Central Mediterranean attributable to the agreement. Our approach involves multiplying the significant monthly estimated ATT for the Central route by the mortality rate for each month between April and December 2016. We obtain a value of 45 ± 3 deaths attributable to the declaration. While the resulting numerical value has only symbolic weight, it confirms that the EU-Turkey agreement has forced many migrants to change their route, exposing them to an increased risk of death.

Discussion and conclusion

The main aim of the agreement between the EU and Turkey was to stop the uncontrolled influx of migrants leaving Turkey and arriving on European shores. At its core, the agreement sought to manage migration more effectively while ensuring a coordinated response between Turkey and the EU. In

Table 2 Two-way fixed effect model.				
Missing migrants = crossings + ATT + political fatalities + unit fixed effects + time fixed effects				
Covariance type: Clustered by route and time				
Coefficients				
	Estimate	Std. error	t-Statistic	p-value
Crossings	0.001	0.000	2.543	0.012
ATT	0.877	0.298	2.948	0.004
Political fatalities	0.315	0.137	2.295	0.024
Included fixed effects				
				Total
Entity				4
Time				37
Summary statistics				
- Number of observations: 142				
- R-squared (incl. FE): 0.589, Within R-squared: 0.161				

particular, the agreement aimed to reduce irregular migration by preventing unsafe crossings in the Aegean Sea and addressing the root causes of displacement through humanitarian aid and development initiatives. It included provisions for the repatriation of all new irregular migrants crossing from Turkey to the Greek islands and the resettlement of Syrian refugees directly from Turkey to the EU under a “1:1 exchange mechanism”. At the same time, the European Union, together with the Turkish government, pledged to “break the business model of the smugglers and to offer migrants an alternative to putting their lives at risk” (Council of the European Union, 2016) while Turkey would “take any necessary measures to prevent new sea or land routes for illegal migration opening from Turkey to the EU” also by cooperating with neighboring countries (Council of the European Union, 2016). Although the main objective of the agreement between the EU and Turkey was not to guarantee a safer life for migrants, it is clear that the two parties also took into account the humanitarian impact of the agreement. This intention is also reflected in the impact assessment prepared by the European Commission in 2018 (European Commission, 2018). Furthermore, in its “Second Report on the progress made in the implementation of the EU–Turkey Statement” (European Commission, 2016), the European Commission expressed its concern about the emergence of new migration routes from Turkey to Europe. Despite these concerns, no evidence of the development of new routes as a result of the agreement was found, but in two months, there was not enough time to assess the impact of the agreement on the safety of migrants or the emergence of new migration routes. The report “EU–Turkey Statement: Four years on” (European Commission, 2020) of March 2020 analyses statistics on the development of refugee flows and the use of the 6 billion euros that the EU has invested in Turkey to provide humanitarian aid to refugees. The data presented refers to a very limited period before the agreement, comparing the peak of the migration crisis in 2015–2016 with the evolution of migration flows in the following 4 years. In our view, this type of comparison could be misleading as no rigorous statistical test has been performed. In our analysis, we find that the decrease in migration flows on the Eastern Mediterranean route is only marginally significant. More importantly for our objective, the 2020 report makes no reference to the emergence of new migration routes due to the agreement, let alone an analysis of a

possible diversion effect on existing Mediterranean routes. To properly assess the impact of the agreement on migrants of different nationalities, we develop a rigorous machine learning framework to evaluate the impact of the EU–Turkey agreement on the migration decisions of those migrants who would have chosen the Eastern Mediterranean route in the absence of the agreement, a route widely recognized for its significantly lower risks compared to the Central Mediterranean route. Overall, a significant diversion effect can be observed, which leads to more migrants of the nationality that would have taken the Eastern Mediterranean route after the agreement choosing the more dangerous Central route. Furthermore, we highlight a positive correlation between the significative diversion effect caused by the EU–Turkey agreement and a higher risk of getting into dangerous situations that lead to the loss of migrants’ lives. Taken together, our results reveal how short-sighted it is to focus exclusively on a single migration route in the Mediterranean: migration patterns are clearly interdependent, and targeted actions need to be coordinated across the region. This is the main policy implication of our study, as this form of agreement has been used as a reference by the European Union when drafting other agreements, such as the recent agreements with Egypt in March 2024. The narrow focus on bilateral agreements will likely overlook the broader impact that migration agreements can have on alternative routes that inevitably intersect with the European community. There is, therefore, an urgent need for a more comprehensive approach that assesses the impact of such policies. This approach would allow for a clearer understanding of the positive and negative effects of migration agreements between the EU and third countries. Although our work takes a broader look at the impact of the EU–Turkey agreement on migration flows in the Mediterranean, there are nevertheless some important limitations that need to be taken into account in future work. First, the impact of all bilateral agreements, including the most recent ones, should be considered as part of a comprehensive analysis of the impact of EU policies. Second, better data is needed, particularly on the nationalities of migrants lost at sea and migration flows along land routes. Better data would allow a more accurate reconstruction of migration flows from countries of origin to Europe. We see our work as a first step towards a transparent and participatory framework for policy impact analysis, which could ensure that all stakeholders contribute to improving the quality of policy evaluation.

Data availability

The code and datasets generated during and/or analyzed during the current study are available in the Github repository: https://github.com/ireneb612/impact_EUTurkey_deal.

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Author contributions

The authors contributed equally to the paper. Both authors have reviewed the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

This article does not contain any studies with human participants performed by the authors.

Additional information

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