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INTERNATIONAL MIGRATION RESPONSES TO NATURAL DISASTERS: EVIDENCE FROM MODERN EUROPE'S DEADLIEST EARTHQUAKE

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ABSTRACT

The Messina-Reggio Calabria Earthquake (1908) was the deadliest earthquake and possibly the most devastating natural disaster in modern European history. It occurred when overseas mass emigration from southern Italy was at its peak and international borders were open, making emigration a readily available and widespread option for disaster relief. We use this singular event and its unique and important context to study the effects of natural disasters on international migration. Using commune-level data on damage and annual emigration, we find that this momentous event did not have, on average, a large positive impact on emigration. There were, however, heterogeneous and offsetting responses to the shock, with a more positive effect on emigration where agricultural day laborers comprised a larger share of the labor force, suggesting that attachment to the land was an impediment to quickly reacting to the disaster through migration. Common alternative explanations for the absence of positive migration responses, such as liquidity constraints, greater exigencies, and a positive shock to the demand for construction labor, are not supported by our data. These findings contribute to literatures on climate-and disaster-driven migration and on the Age of Mass Migration.

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1 Introduction

How do major natural disasters affect international migration? Interest in this question has grown recently, in part due to increased attention to the dangers of climate change. But the answer is both theoretically and empirically ambiguous (e.g., Berlemann and Steinhardt 2017; Black et al. 2013; Mahajan and Yang 2020). International migration can serve as an adjustment mechanism and provide relief in the face of negative economic shocks (e.g., Mahajan and Yang 2020; Ó Gráda 2019; Ó Gráda and O'Rourke 1997). On the other hand, disasters might hinder migration; a variety of mechanisms have been suggested for this effect, including tightened liquidity constraints (Cattaneo and Peri 2016), greater exigencies and economic opportunities at home (Halliday 2006), or remittances or other financial inflows to affected areas (Yang 2008a). Indeed, a number of studies have found that international migration may be unaffected or reduced by natural disasters (e.g., Beine, Noy, and Parsons 2019; Beine and Parsons 2015; Cattaneo and Peri 2016; Nawrotzki and DeWaard 2018). But this evidence comes almost entirely from studies of events occurring in recent decades—a period characterized by stringent legal restrictions on international migration that potentially add a distorting filter to economic incentives. Evidence from events that occurred in the absence of such barriers is still lacking, but is necessary for a complete understanding of the effects of natural disasters on international migration.

In this paper we study, for the first time, the effect of a major natural disaster on international migration in a context with minimal barriers to migration. In particular, we focus on the Messina-Reggio Calabria Earthquake of 1908, which occurred in a unique and historically important setting of open borders and pre-existing mass migration, where reacting to the disaster by moving overseas was a widespread available option. This was the most deadly and destructive earthquake, and possibly the most devastating natural disaster of any kind, in modern European history,[1] killing as many as 120,000 people and causing massive destruction to buildings and infrastructure throughout Sicily and Calabria (Dickie 2008; Dickie and Sayer 2005; Parrinello 2015; Risk Management Solutions 2008). The historical importance of this shock is compounded by the unique setting in which it struck. The earthquake occurred at the peak of the Age of Mass Migration (1840–1914), during which over 50 million Europeans migrated to the New World (Abramitzky and Boustan 2017; Hatton and Ward 2019; Hatton and Williamson 1998), enabled by open borders and cheap transatlantic transportation, and drawn by high expected returns (Abramitzky, Boustan, and Eriksson 2012).[2] Italy was

[1] Another candidate would be the 1755 Lisbon earthquake, which is estimated to have killed between 10,000 and 100,000 people, with most estimates in the lower range (Pereira 2009, p. 468).

[2] Of these, about 30 million were bound for the United States (Abramitzky and Boustan 2017; Hatton and Williamson 1998).

a leading country in this movement, sending hundreds of thousands of migrants each year to the Americas and to other European countries, in what amounted to one of the largest free flows of international migration in world history (Foerster 1919; Gomellini and Ó Gráda 2013; Spitzer and Zimran 2021). The earthquake-affected regions of Sicily and Calabria had just come to the forefront of this movement, with average annual emigration rates of about 26 and 36 per thousand, respectively, in the four years prior to the earthquake—extremely high for voluntary migration by any historical standard. The region thus had sufficient prior exposure to migration to develop thick networks of prior migrants (Spitzer and Zimran 2021). These factors made international migration a familiar, attractive, and relatively easy disaster-relief option for the affected population. We ask whether and under what circumstances this option was used.

Our analysis is based on a dataset of annual emigration rates for every commune in Italy for the pre-World War I period, focusing on the period 1905–1912.[3] This dataset is based on two main sources—passenger manifests of Italians arriving at the Port of New York (Spitzer and Zimran 2018) and official Italian emigration statistics (Spitzer and Zimran 2021). We combine these data with commune-level measures of damage from the earthquake (Guidoboni et al. 2007) and an extensive collection of characteristics of Italian communes and districts,[4] compiled from censuses and other official historical sources. We use difference-in-differences and event study specifications to determine whether the emigration trends of severely damaged communes in Sicily and Calabria differed from those of other communes in those regions following the earthquake.[5]

Our main finding is that there is no evidence of a large positive impact of the earthquake on emigration from affected communes as a whole.[6] Indeed, although they are not statistically significant, our preferred point estimates suggest a small and transitory *decline* in emigration of about 10 percent in the first year after the shock in communes experiencing severe damage relative to other communes in Sicily and Calabria; in the four years after the earthquake, the average severely damaged commune experienced a decline in emigration of about 7 percent. This result is qualitatively robust to using alternative measures of earthquake exposure, to changing the source of migration data, to the manner in which we account for deaths from the earthquake, and to a variety of potential differential time trends on the basis of commune characteristics. Although limited statistical power prevents precise estimation of this effect, we are able to conclude that the impact of the

[3]There were approximately 8,000 communes in Italy, with about 390 in Calabria and 350 in Sicily.

[4]We use the term "district" to refer to the Italian units of *circondario* or *distretto*. These were the next highest administrative unit above the commune, and there were 284 such units in Italy in the study period. The two earthquake-affected regions had only *circondari*, with 24 in Sicily and 11 in Calabria. Above that, there were 69 provinces (3 in Calabria and 7 in Sicily) and 16 regions.

[5]We also present analyses in which the sample includes all of Italy, and in which the unit of analysis is the district rather than the commune.

[6]Similarly, we find no evidence of an impact of the earthquake on the demographic composition of migrants that might indicate a change in the incentives to migrate.

earthquake was, in fact, small as compared to some relevant benchmarks. For instance, the Panic of 1907, which led to a recession in the United States and sharp declines in US immigration from all sources, was associated with at least a 75-percent decline in Italian emigration in the year prior to the earthquake. We can easily rule out such a magnitude for the estimated effect of the earthquake. Our estimates are also small when compared to the estimated impacts on migration of more recent events, such as modern hurricanes (Mahajan and Yang 2020). The lack of a strong positive impact of the earthquake on migration and our finding that any impact of the shock was small or even negative is striking in light of the extreme toll of the earthquake in human lives and physical capital, the disruption of economic activity that it induced, the large (but short-lived) internal refugee movement that it created, the slow reconstruction that followed it, and the ubiquity of mass migration in the affected regions both before and after the shock.

To better understand the reasons for the limited aggregate earthquake response, we test for local characteristics that were associated with heterogeneous responses to the earthquake. Perhaps the most important indicator of an individual's socioeconomic status in this context was his position in the agricultural land tenure system, and we find that communes from districts with a greater share of the labor force employed as agricultural day laborers (as opposed to owner-occupiers, renters, sharecroppers, etc.), whose lack of contractual obligation to the land would have made them most readily able to emigrate in response to a shock, experienced a greater increase in emigration in response to the earthquake.[7] This heterogeneity is robust to controlling for different earthquake reactions by areas with different shares of labor in agriculture of any form (i.e., owners, renters, sharecroppers, etc.), and for heterogeneous responses to the earthquake with respect to a number of other commune- and district-level characteristics. Although we cannot definitively rule out that this result reflects heterogeneity with respect to employment in agriculture more broadly, the evidence strongly suggests that it was specifically the unattached day laboring portion of the agricultural labor force that was prone to react by migration.

In principle, this result is consistent with the *greater exigencies* explanation for reduced migration after natural disasters (Halliday 2006)—that owners of buildings in need of repair were incentivized to remain at home to rebuild them. However, to the extent that we can test this explanation with information on the distribution of property owners, we find that such a channel is not borne out by the data. Instead, we argue that the relationship between individuals and the land *per se* was likely the root cause that prompted those who (among the agricultural classes) were most weakly attached to the land to react quickly through overseas emigration and prevented those who were economically invested and contractually tied to the land

[7] Although our analysis is at the commune level, the district is the finest level at which occupational distributions are available.

from responding with the same ease. Prior work has identified attachment to the land as a factor limiting emigration generally (e.g., Hatton 2010; Hatton and Williamson 1998; Valsecchi 2014), but ours is the first evidence, to our knowledge, that it can also hinder adjustment in the face of shocks.

Another common explanation for a lack of migration increases in response to disasters is that the economic repercussions exacerbate liquidity constraints faced by households with limited access to credit, thus inhibiting them from funding emigration. To test whether this explanation applies in our context, we collected a variety of commune-level measures of access to financial institutions of all tiers, ranging from large joint stock banks and credit unions to more granular postal savings banks, pledge banks (forms of charitable pawnbrokers), and local mutual aid societies. None of these measures appear to be consistently associated with an increased migration response to the earthquake, nor is the size of the migrant network, another potential source for liquidity under stress. These results suggest that even if liquidity constraints impeded migration, they did not become a relatively stronger inhibiting force in severely damaged communes in the aftermath of the earthquake. We also provide evidence that greater reconstruction labor demand capturing potential emigrants was not responsible for our findings, and we argue as well that increased financial inflows are an unlikely explanation.

This paper contributes to three main literatures. Most narrowly, it adds to the literature on the effects of the Messina-Reggio Calabria Earthquake. Given its significance in Italian history, this event has been the object of repeated scholarly investigations over more than a century (e.g., Bertolaso et al. 2008; Dickie 2008; Dickie and Sayer 2005; Mercalli 1909). Debates continue regarding the toll of the earthquake in lives and damage, as well as on the magnitude of internal population movements in its wake (e.g., Caminiti 2009; Mortara 1913; Parrinello 2012; Restifo 1995); an ancillary contribution of our analysis is to shed some light on these debates by lending quantitative support to the revisionist view arguing that death tolls and population movements in the aftermath of the shock have been overstated. Furthermore, because of their importance in the economy of the affected area and the extent of the damage, much of the attention of the authorities at the time of the earthquake, and subsequently of the historical literature and of the popular memory of the event, has focused on the experience of Messina and to a lesser extent of Reggio Calabria. But these cities were just two of the many affected (and 109 severely damaged) communities. The responses of the remaining smaller communes, on the other hand, are poorly documented and understood. Our analysis sheds more light on the aftermath of the earthquake beyond the major cities. Finally, to our knowledge, we are the first to study international migration in response to the disaster—a potentially important margin of response in this context given the high levels of migration prior to the shock. Understanding such a response to the shock is fundamental to a complete history of this important event.

This paper also adds to the literature on the Age of Mass Migration, which has expanded in recent years as new data have been brought to bear on fundamental questions of the economics of migration.[8] However, advances in understanding the determinants of migration in this context have been more limited (c.f., Gray, Narciso, and Tortorici 2019; Karadja and Prawitz 2019; Spitzer 2021; Spitzer and Zimran 2021). We advance the literature on this front by studying the role of sudden shocks to the home economy in generating emigration. This paper also contributes to the important but long-dormant debate over whether migration during the Age of Mass Migration was primarily shaped by push factors inherent to the home economy or by pull factors inherent to the destination (e.g., Gould 1979). By showing that even an enormously destructive shock to the origin had a small impact relative to business-cycle variation in the destination, we add to the body of evidence supporting the primacy of pull factors (e.g., Boustan 2007; Hatton and Williamson 1998; Jerome 1926; Kuznets 1958).

Finally, this paper contributes to the literature on the effects of natural and man-made disasters on migration and thus to the broader literature on climate- and disaster-driven migration (Myers 2002). Our finding, that a shock as cataclysmic as the Messina-Reggio Calabria earthquake had no meaningfully positive impact on international migration, is an important addition to the recent accumulation of evidence demonstrating no or negative effects of natural disasters and other climatic shocks on international migration (e.g., Beine and Parsons 2015; Cattaneo and Peri 2016; Gröschl and Steinwachs 2017; Halliday 2006; Hunter, Murray, and Riosmena 2013). Our evidence regarding attachment to the land as an obstacle to adjustment through migration also adds to the possible explanations for such non-response. Importantly, this paper shows that no-migration responses to natural disasters can occur even when migration is a widely available option and legal restrictions are absent. Indeed, if ever there were a case in which a natural disaster would be expected to generate migration, it is in the context that we study of easy and widespread migration and a devastating shock. Yet the effects of such shocks may be more nuanced than simple intuition implies.

2 Background

2.1 The Earthquake and its Aftermath

The 7.1 magnitude Messina-Reggio Calabria Earthquake struck the Strait of Messina and its surroundings on December 28, 1908. It was followed by a severe tsunami, with waves as high as 40 feet (Risk Management

[8]See Abramitzky and Boustan (2017) and Hatton and Ward (2019) for surveys of this literature.

Solutions 2008), which ravaged coastal communities along the strait. Because of the unprecedented scale of the damage, the earthquake is regarded as one of the most destructive natural disasters in modern European history (Dickie 2008). The area's main cities, Messina and Reggio Calabria, on opposite sides of the strait, were almost entirely destroyed (Baratta 1910). Estimates of the number of deaths caused by the earthquake and the tsunami range from 90,000 to 120,000,[9] most of which were concentrated in the two urban centers. In the municipality of Messina alone (i.e., in the city of Messina and in some outlying *frazioni* within the *comune*), an estimated 30,000 to 60,000 inhabitants were killed relative to a 1901 population of just under 150,000 (Dickie 2008),[10] and about 98 percent of residential structures were destroyed or irreparably damaged (Mercalli 1909, p. 28), leaving tens of thousands injured and homeless. The damage was so unprecedented in its severity that Giuseppe Mercalli, the renowned seismologist who created the widely used measure of material damage caused by an earthquake, added a new intensity degree to his eponymous scale to describe the damage—XI, *catastrofe* (Tertulliani 2014).

Outside of the major urban centers, many smaller communities were reduced to rubble. Figures for Sicily are lacking, but detailed data are available on damage for all communes in the province of Reggio Calabria. In the average commune there (excluding Reggio Calabria itself), about 23 percent of buildings were completely destroyed and another 24 percent were heavily damaged, with more severe damage in the district of Reggio Calabria than in the districts of Palmi and Gerace Marina (Baratta 1910, pp. 198–207; see Figure 1 for a map of districts in the affected area). Palmi, a smaller Calabrian commercial center near the Tyrrhenian coast (pop. 13,346 in 1901), and Sant'Eufemia d'Aspromonte, a nearby uphill town (pop. 6,285 in 1901), were "dead," according to the Bishop of Palmi (Liberti 1993). Palmi had an estimated 700 dead and 1,000 injured; out of 2,221 buildings, 445 houses were completely destroyed, 1,189 irreparably damaged, and 387 more lightly damaged; Sant'Eufemia d'Aspromonte had 839 dead; out of 1,200 buildings, only 100 survived, and were badly damaged (Baratta 1910, pp. 198–207).

The earthquake also led to considerable population displacement. At least 66,000 refugees are estimated to have left Messina in the immediate aftermath of the earthquake, traveling mainly to other large Sicilian cities and to Naples: according to the official refugee census conducted in January and March 1909, there were about 20,000 refugees in Catania, 11,000 in Palermo, 2,600 in Syracuse, and 8,000 in Naples (Parrinello 2012).[11] But there are indications that this flow was short-lived, such that "immediately following the exodus

[9] In comparison, the death toll caused by the 1906 San Francisco earthquake is estimated at around 3,000 individuals (Ager et al. 2020).

[10] Caminiti (2009), Guidoboni and Mariotti (2008), Parrinello (2012), and Restifo (1995, 2008) provide a deeper investigation of these estimates. We provide alternative estimates of the Messina and Reggio Calabria death tolls below.

[11] In Online Appendix E, we attempt to link these individuals to passenger lists, but as we discuss further below, the results of this exercise are inconclusive.

from the scene of the disaster, a counter-exodus began" (Restifo 1995, p. 562). We discuss evidence below that supports this view of a rapid return to the affected area and the ways in which internal displacement may affect the interpretation of our results.

Reconstruction after the earthquake was slow. The new anti-seismic urban regulation plans for the cities of Messina and Reggio Calabria were only approved in 1911, at which point much of the population of Messina still lived in temporary or overcrowded housing, with one temporary settlement alone housing 60,000 people (Farinella and Saitta 2019, p. 113). Even after 1911 reconstruction proceeded slowly. In 1922, 70,000 people in Messina and Reggio Calabria still lived in temporary housing. Of the 28,000 new houses slated to be build in Messina by 1931 according to the reconstruction plan, only 1,482 were completed by the early 1920s. By the 1930s, temporary housing still accounted for about one-third of the Messina housing stock, and the 1936 census of housing reported that about half of the population of Messina lived in overcrowded houses (Farinella and Saitta 2019). Delayed reconstruction also appears to have been the norm in smaller towns in the area. In Palmi, for instance, there were difficulties in obtaining the materials to construct temporary shelters, and the distribution of reconstruction resources was reportedly stifled by a patronage system that was prone to misallocation. In some cases, the frustration with slow reconstruction led to protests and riots, which turned deadly in the Calabrian town of Sinopoli (Teti 2008).

Despite the sluggish reconstruction, the population of the cities of Messina and Reggio Calabria rebounded quickly (Parrinello 2012; Restifo 1995). As shown in Table 1, Messina in 1911 had 126,557 inhabitants relative to 149,778 in 1901 and Reggio Calabria had 43,162 in 1911 relative to 44,415 in 1901. Thus, any immediate outflow of refugees appears to have returned relatively quickly. According to the traditional view of the *Messinesi*, this demographic recovery was largely due to an inflow of newcomers from the hinterland. Indeed, Messinesi call their hometown "a city without memory," in reference to the destruction of almost all historical buildings and to perceptions that internal migrants almost completely replaced the pre-earthquake population (Dickie and Sayer 2005). Such an inflow, if true, is important, as it potentially would have capture individuals who would otherwise have emigrated in response to the shock. But a more detailed examination of Italian census figures from 1901 and 1911 and of data on emigration, return migration, births, and deaths reveals that this local myth is largely untrue, and, indeed, that any internal population movements to the cities of Messina and Reggio Calabria were likely small.

Table 1 presents data on the population of the cities of Messina and Reggio Calabria by place of birth from 1901 and 1911 population census data.[12] Two years after the disaster, 83.8 percent of Messina's 126,557

[12]Unfortunately, similar data are not available for smaller towns in the affected areas.

residents were listed as natives of the city, whereas only 6.2 percent were born elsewhere in the province of Messina, even less than their share in 1901.[13] Thus, in 1911 the number of non-native residents in these cities was too small to be consistent with any large inflow of new internal migrants in the wake of the earthquake. To provide more concrete bounds on the inflow of newcomers that could be attributed to the earthquake, we combine these census figures with annual data on 1901–1911 births, deaths, and emigrants for the communes of Messina and Reggio Calabria, and information on return migration to the provinces of these communes. The rationale of this exercise is that internal migration and the death toll from the earthquake can be determined from the unexplained residual from a calculation of the total population change, taking into account international net migration, births, and deaths. The details of these computations and the underlying assumptions are presented in Appendix A and we report the main findings here. First, as a by-product of these calculations, we compute alternative upper bounds to the death tolls from the earthquake for the two cities: 35,193 in Messina and 9,298 in Reggio Calabria. The upper bound for Messina is well short of the official but long-suspected statistic of over 60,000 killed by the earthquake, increasing our skepticism of the official estimate. Instead, it supports the lower range of estimates that have been offered, which still imply a death toll of about one-fifth of the population of Messina. For Reggio Calabria, however, the upper bound exceeds somewhat the official estimate of 8,000, suggesting that the official toll is plausible. This is consistent with most of the uncertainty in the death tolls of the earthquake coming from questions over the toll for Messina itself.

Our estimated upper bound for the net internal migration to these major cities over the *entire period 1901–1911* is 10,581 for Messina and 7,623 for Reggio Calabria. These estimates pale in comparison to the size of international emigration flows, which averaged over 15,600 per year from the province of Messina over the period 1905–1908 (of which over 13,000 per year were from communes other than Messina) and over 14,300 emigrants per year from the province of Reggio Calabria over the same period. Moreover, as we point out in Appendix A, these upper bounds include both internal migration in response to the earthquake as well as the internal churn of population that would have occurred even in the absence of the earthquake. In fact, our preferred estimate of the true net internal inflow of Italians who were not natives of the city in response to the earthquake is as low as -562 in Messina (i.e., the number of non-native residents of Messina who left the city to another Italian destination *exceeded* the number of new incomers) and 3,492 in Reggio Calabria. Thus, local folk history notwithstanding, internal migration to the two major cities, fueled as it

[13] We are not able to rule out that the replacement was by residents of outlying *frazioni* within the commune of Messina, who would have counted as natives of the commune in the census but might have been considered outsiders by themselves and by natives of the city. We are not aware of any historical evidence suggesting that this is the explanation for the divergence between the folk history and official statistics.

may have been by demand for reconstruction labor, was not sufficiently large to reroute significant flows that would have constituted a positive international migration response had they been directed abroad.

Surprisingly, very little is known about international migration as a response to the earthquake, despite the fact that the area was in the midst of an unprecedented mass emigration at the time of the shock. As we argue below, this option potentially provided cheap and readily available access to relief to the tens of thousands who had lost their homes and their livelihoods. Indeed, according to a survey of refugees from Messina in Naples in April 1909, half of the 1,000 respondents indicated an intention to migrate (either internally or overseas), "especially [to] the United States" (Parrinello 2012, p. 39). Importantly, there is no evidence that the earthquake itself posed a direct obstacle to migration by disrupting travel: although Messina was the sixth most important maritime hub in Italy in terms of yearly traffic, its importance as a point of embarkation for transatlantic migration paled in comparison to that of Palermo, Naples, and Genoa.[14] In any event, the Port of Messina re-opened within two weeks of the earthquake (Royal Society for the Encouragement of Arts and Commerce 1910).[15] Whether the affected population responded to the disaster through international migration remains an open question with important implications for a complete understanding of this event and for the economics of disaster-induced migration.

2.2 Natural Disasters and Migration: Theory and Evidence

Natural disasters can affect migration incentives in a number of conflicting ways. Among other channels, disasters may affect the operation of markets for labor and goods; household decisions on consumption, saving, and insurance; financial flows; private and public investment; and technological change. Despite the basic intuition that negative shocks are bad for the local economy and therefore should strengthen push factors, economic theory does not necessarily predict a positive effect. Consequently, much of our understanding of the effects of natural disasters on migration depends on empirical evidence, most of which comes from a literature motivated by the goal of understanding the effects of climate change on population movements in developing countries in recent decades (see surveys by Berlemann and Steinhardt 2017; Black et al. 2013). This literature has identified several important mechanisms by which natural disasters have been shown to affect migration.

The simplest mechanism is by augmenting push factors. By destroying productive capital, buildings, and infrastructure and by displacing labor, natural disasters hamper productive activity and trade. This

[14] From the Statue of Liberty-Ellis Island Foundation data that we describe below, were were able to determine that only about 4 percent of Italians arriving at Ellis Island between 1904 and 1908 embarked in Messina.

[15] Farinella and Saitta (2019) describe a 16-percent decline in transactions at the port of Messina from 1908–1911, and attribute it to the development of other ports in the area as well as to the earthquake.

can translate into a reduction in household income in the place of origin (Baez and Santos 2008; Banerjee 2007; Cai et al. 2016; Gröger and Zylberberg 2016). More broadly, there is evidence that these shocks have persistent long-run negative effects on individual standards of living (Caruso 2017), on regional economic trajectories (Ager et al. 2020; Hornbeck 2012), and on national economic growth (Hsiang and Jina 2014; Skidmore and Toya 2002). The destruction of residential capital—probably the most notable feature of the Messina-Reggio Calabria Earthquake outside of the loss of life—is a major shock to standards of living and household wealth; moreover, it is a wealth shock that is shared within the community, which makes it harder to cope by employing local informal insurance mechanisms. With incomes reduced, homes damaged or destroyed, and lacking the financial safety provided by the value of private residential real estate, the option of staying becomes less attractive. Indeed, there is ample evidence that natural disasters and climatic shocks have the capacity to cause massive displacement—short-term and short-distance internal migration—much like the well documented but short-lived stream of internal refugees in the wake of the Messina-Reggio Calabria Earthquake (e.g., Gray and Mueller 2012; Gröger and Zylberberg 2016; Penning-Rowsell, Sultana, and Thompson 2013; Robalino, Jimenez, and Chacón 2015)—and permanent long-distance internal migration (Boustan, Kahn, and Rhode 2012; Hornbeck 2012; Hornbeck and Naidu 2014; Sichko 2021). Some studies have also found similar positive effects on international migration (e.g., Drabo and Mbaye 2014; Reuveny and Moore 2009). The most comprehensive evidence for such a positive effect comes from Mahajan and Yang's (2020) worldwide study of the effect of hurricanes on migration to the United States over the period 1980–2000.

However, it is far from clear that these positive effects on international migration characterize all cases of major natural disasters. A number of studies have found negative or no-migration effects, at least for large segments of the population (e.g., Beine and Parsons 2015; Cattaneo and Peri 2016; Gröschl and Steinwachs 2017; Halliday 2006; Hunter, Murray, and Riosmena 2013; Yang 2008b). This is a common finding even for internal migration (Cattaneo and Peri 2016; Gignoux and Menéndez 2016; Nawrotzki and DeWaard 2018; Paul 2005; Penning-Rowsell, Sultana, and Thompson 2013). This frequently observed lack of a positive effect of shocks on migration gives rise to the notions of *trapped populations* (Nawrotzki and DeWaard 2018) and an *immobility paradox* (Beine, Noy, and Parsons 2019), describing a state in which poor populations would have wanted to react by migration, but are locked in by liquidity constraints that are exacerbated by the shock. The role of liquidity constraints in masking or reversing an otherwise positive effect on migration is consistent with findings of heterogeneous effects of shocks on migration with respect to income, wealth, or human capital, and with a greater increase in migration after a shock among better-off households, regions, or countries (Beine and Parsons 2017; Cattaneo and Peri 2016; Gröschl and Steinwachs 2017; Nawrotzki and DeWaard 2018; Sichko 2021; c.f., Halliday 2006).[16]

Another mechanism that could offset the push effect of natural disasters is that reconstruction may increase demand for labor in the construction sector. Part of this effect would be realized through self-employment within the household, such as by repairing or rebuilding damaged property, which becomes a high-net present value project.[17] Such *greater exigencies* at home have been cited by Halliday (2006) as the most likely explanation for the negative effect of the 2001 El Salvador earthquakes on migration to the United States (although this is disputed by Yang 2008b). The effect might also come through demand for construction workers in the local and regional labor markets.[18] Moreover, reconstruction efforts are often fueled by remittances and other forms of financial flows to the affected places (Bettin and Zazzaro 2018; David 2011; Mohapatra, Joseph, and Ratha 2009; Paul 2005; Yang 2008a; c.f., Lueth and Ruiz-Arranz 2008). Beyond the recovery period, post-disaster reconstruction may even produce positive economic effects that persist in the long run by bringing about a wave of (literal) creative destruction (Barone and Mocetti 2014; Gignoux and Menéndez 2016; Hornbeck and Keniston 2017), which may induce more people to stay by strengthening protections against similar future events (Boustan, Kahn, and Rhode 2012), or by hastening institutional reform (Pereira 2009).

Two issues in the rich literature on the relationship between natural shocks and migration highlight the contribution of our study of the Messina-Reggio Calabria Earthquake. First, as mentioned above, the literature has largely focused on climatic shocks. Most of these, such as extreme weather events, are relatively small in comparison to the scale of the devastation wrought by the Messina-Reggio Calabria Earthquake. Evidence on the effects of disasters at that scale is scarce.[19] Second, virtually all studies dealing with international migration have explored events that have occurred since 1960—a period characterized by stringent restrictions on labor mobility across international borders (Hatton and Williamson 2005).[20] The Messina-Reggio Calabria Earthquake occurred in an area that was heavily exposed to overseas migration

[16] Sichko (2021) makes a particularly important contribution in this regard by using individual-level data to show that greater education was associated with greater responsiveness to droughts, a result that he attributes to liquidity constraints. Most other studies rely on aggregate data. See also Sedova and Kalkuhl (2020).

[17] Indeed, in the average commune in the District of Reggio Calabria, roughly half of all buildings were severely damaged or destroyed by the earthquake (Baratta 1910, pp. 198–207).

[18] For instance, in the wake of earthquakes in Calabria prior to the one that we study, there is evidence of an increase in construction wages (Caputo 1908). Similarly, Pereira (2009) documents such a rise in wages after the 1755 Lisbon earthquake. Interestingly, however, Kirchberger (2017) finds that following the 2006 Yogyakarta earthquake in Indonesia, there was no overall change in wages in the worst hit places, but there was greater increase in wages and hours worked by workers who had previously been employed in agriculture, possibly due to a movement of workers from agriculture to construction.

[19] The most obvious exceptions are the studies of earthquakes by Gignoux and Menéndez (2016), Halliday (2006), and Yang (2008b).

[20] Karadja and Prawitz (2019), who use frost shocks as part of an instrument for migration to the US from Sweden during the 1860s, provide evidence from a period of unrestricted migration, but the magnitude of the shock is considerably smaller.

at a time in which the migration choice was effectively unhindered by legal restrictions, and, moreover, could have been aided by large networks of prior migrants. If, for example, poorer populations are more likely to be incentivized to move overseas by a disaster, but are also less likely to be able to overcome the legal restrictions of migration, then the estimates on the effects on the underlying demand for international migration, which is the unobserved measure that really reflects incentives, will be downward biased. This raises the question of whether the trapped populations are not merely trapped by poverty or entrenched by shock-related incentives, but are in part also *banned populations*. Our case study is unique in focusing on a massive shock whose survivors were familiar with a relatively cheap option of overseas migration, were linked to a large proportion of their communities that had already relocated abroad and could assist their migration, and, in most cases, undoubtedly did have a legal path to migrate.

2.3 Italian Emigration

Italy was a latecomer to international mass migration.[21] Whereas Britain, Germany, and Ireland were already the sources of large numbers of migrants as early as the 1840s, Italy, along with other countries in the southern and eastern European periphery, did not begin to experience large-scale international migration until the late 1880s (Hatton and Williamson 1994, 1998; Spitzer and Zimran 2021) even though the United States had maintained an effectively open border to European immigration throughout this period. Once Italian emigration began, however, it accelerated rapidly. The rate of emigration from the entire country exceeded 15 per thousand by 1901, and peaked in 1913 at over 25 per thousand (Ferenczi and Willcox 1929; Hatton and Williamson 1998, p. 97).[22]

Italian migration was mostly divided between three major destinations—North America (primarily the United States), South America (primarily Argentina and Brazil), and Europe (primarily Austria-Hungary, Germany, Switzerland, and France). But the composition of destinations varied across the country, with northerners primarily traveling across the Alps and southerners to North America. In the regions of Sicily and Calabria, the rate of migration to North America regularly exceeded 20 per thousand after 1900. In total, 71 percent of migrants from these regions traveled to North America from 1901 to 1914. The next largest major destination was South America, with just over 22 percent of migrants from these regions.[23]

Three important patterns characterized the Italian migration. First, a relatively large share of this flow

[21] The most comprehensive survey of all aspects of Italian migration remains Foerster (1919). For a recent summary of quantitative evidence see Gomellini and Ó Gráda (2013).

[22] Gomellini and Ó Gráda (2013) and Spitzer and Zimran (2021) also describe the trends in Italian migration.

[23] The figures on emigration by province of origin and destination country are calculated from Table V of the *Statistica della Emigrazione Italiana per l'Estero*, which we describe in more detail below.

consisted of repeat and temporary migrants, or "birds of passage" (Gomellini and Ó Gráda 2013). Bandiera, Rasul, and Viarengo (2013) argue that over 70 percent of Italian migrants to the United States between 1900 and 1910 returned to Italy.[24] Spitzer and Zimran (2018, Table 2, p. 231) find that 44.3 percent of Italians arriving at Ellis Island during the period 1907–1925 had already lived in the United States prior to the observed migration. This may be important in the context of a response to a natural disaster because there is reason to believe that temporary migration might be more responsive to a natural disaster than permanent migration (Bohra-Mishra, Oppenheimer, and Hsiang 2014).

The second feature, which was shared by migratory flows from virtually all European countries, was the considerable year-to-year fluctuation in migration rates in response to business cycles in the destination countries (Hatton and Williamson 1998, ch.4; Jerome 1926; Spitzer 2015). Most importantly in the context of the Messina-Reggio Calabria Earthquake, the Panic of 1907—a financial crisis in the United States that caused a recession in late 1907 and 1908—was followed by a decline in total immigration to the United States from nearly 1.2 million to under 700,000 between fiscal years 1907 and 1908. Immigration remained low in fiscal year 1909 before resurging to over 925,000 in fiscal year 1910 (Barde, Carter, and Sutch 2006). Italian emigration to the United States followed this trend, falling from over 300,000 in calendar year 1907 to about 130,000 in calendar year 1908, before resurging to 289,000 in calendar year 1909.[25] To evaluate the effects of the earthquake on migration, it is crucial that we account for this volatility, which generated a nationwide (or even continent-wide) surge in emigration in the year after the earthquake. This fluctuation in migration in response to the Panic of 1907 also provides a yardstick to which the effects of the earthquake can be compared.

The third important pattern in Italian migration is its spatial expansion. Following Gould (1980), Spitzer and Zimran (2021) show that mass migration from Italy to North America began in a few distinct districts in the late 1870s and early 1880s and spread from there in a process of spatial diffusion to the rest of Italy through immigrants' social networks.[26] In Sicily and Calabria, the nearest *epicenter* districts were Corleone in the province of Palermo (about 200 kilometers west of the Strait of Messina) and Sala Consilina

[24] According to Hatton and Williamson (1998, p. 97), the national emigration rate from Italy net of returns was below 5 per thousand after 1901. The importance of return migration was probably far greater in northern Italy, where seasonal migration across the Alps was much more common.

[25] The Italian emigration statistics are from our transcription of the *Statistica della Emigrazione Italiana per l'Estero*, which we discuss in more detail below. American official immigration statistics are reported by fiscal years whereas the Italian statistics are reported by calendar years. Most migration occurred in the first few months of the calendar year, limiting the divergence between calendar and fiscal year totals. According to the NBER measures, the contraction associated with the Panic of 1907 lasted from May 1907 to June 1908, approximately overlapping with fiscal year 1908 (National Bureau of Economic Research 2020).

[26] There were similar patterns for migration to South America and to Europe, but with different initial epicenters and starting points in time.

in the province of Salerno (about 250 kilometers north), from which sources of mass emigration expanded gradually.[27] By the time of the earthquake, the area around the Strait of Messina had already achieved high rates of emigration. Communes within a radius of 150 kilometers from the earthquake's epicenter experienced an average annual emigration rate of over 35 per thousand in the period 1905–1908—extraordinarily high by any standard. We interpret this as having passed a point of saturation—a previous migrant stock large enough that it was likely that virtually all residents had a connection to prior migrants, and therefore had the option of migration, in which they could be aided by these prior migrants.[28] Emigration trends from saturated areas were reaching a plateau, albeit with considerable volatility around this level. But the provinces of Catania and Siracusa in southeastern Sicily, farther from the emigration epicenters, had lagged behind the rest of Sicily and Calabria, and achieved saturation only in the early 1910s. This meant that the emigration of this area was on a rising trend relative to the area around the Strait of Messina in the period that we analyze (Spitzer and Zimran 2021). In other words, there was an external reason for differential trends in emigration in the regions affected by the earthquake, which is an important factor to consider in our difference-in-differences analysis.

The composition of the flow of Italian migration is also potentially important to understanding the impact of the earthquake. Roughly three-quarters of Italian migrants were male (Hatton and Williamson 1998, p. 102), an imbalance exceeding that of almost any other group of migrants during the Age of Mass Migration. Spitzer and Zimran (2018) show that migrants from southern Italy, including those from Sicily and Calabria, were largely positively selected into migration on the basis of average height, a proxy for human capital. This selection was particularly strong for Calabria (Spitzer and Zimran 2018, Fig. 2, p. 234). The flow of migration also consisted primarily of individuals employed in unskilled occupations (Federico et al. 2021; Pérez 2021; Spitzer and Zimran 2018). According to official Italian emigration statistics, in 1905–1908, 49.9 percent of Calabrian migrants and 38.1 percent of Sicilian migrants were employed in agriculture.[29] As we will show below, the occupational distribution of the affected areas bears heavily on their responses to the earthquake.

Internal migration within Italy may also have been an important margin of response to the earthquake,

[27]The other epicenters identified by Spitzer and Zimran (2021) are Pozzuoli in Naples, Isernia in Campobasso, and Albenga and Chiavari in Genoa.

[28]Spitzer and Zimran (2021) show that connections to networks of prior migrants were the first-order determinant of mass emigration in Italy at the district and commune level from 1876–1920. Spitzer (2021) shows that pogroms in the Russian Empire did not push a significant number of Jews from the affected regions so long as they were not exposed to prior migration.

[29]As we discuss in footnote 85 below, there is reason to believe that a substantial fraction of these were agricultural day laborers. In the relatively urbanized provinces of Reggio Calabria and Messina, the share of migrants who worked in agriculture was smaller, but there were large shares of migrants who were employed in construction, and these individuals were likely unskilled and landless.

and would potentially constitute a substitute for international migration. Although sources on internal migration are very limited in comparison to international migration, we know that, at least in southern Italy in that period, this was a far less common phenomenon than was international migration. As discussed above, there is no evidence of a large inflow to the cities of Messina and Reggio Calabria, indicating that the draw of reconstruction labor to these cities was unlikely to capture any substantial part of the potential international migration flow. More generally, internal migration flows were largely temporary and were dwarfed by international migration, especially after 1900 (Gallo 2012), probably because returns to migration and employment opportunities were far greater in overseas destinations. More broadly, the 1911 census indicates that 93.9 percent of Sicilan-born and 94.1 percent of Calabrian-born individuals living in Italy in 1911 lived in their province of birth, of which 85.0 percent and 84.6 percent, respectively, resided in their commune of birth.[30] There is little doubt that the primary outside option for the earthquake-affected population was overseas migration.

3 Data

3.1 Sources and Construction

Data on earthquake severity are taken from Guidoboni et al. (2007), a source based largely on descriptions of earthquake damage provided by Baratta's (1910) state-of-the-art study.[31] This source reports Mercalli severity scores for various latitude-longitude pairs in the affected region. Whereas the more commonly referenced Richter scale is based on the amount of energy released by the earthquake, the Mercalli scale is defined on the basis of the damage suffered. It ranges from I (not felt) to XII (extreme), with the definitions listed in Online Appendix Table B.1. In some cases, our data include intermediate measures such as IX–X or X–XI, which we score as 9.5 or 10.5. The Mercalli score is helpful in our case, as this is a more direct measure of the impact of the earthquake than the magnitude of shaking, which may translate into damage differently in different areas. Guidoboni et al. (2007) also provide information on the number of reported deaths at each latitude-longitude pair.[32]

[30]These figures are from Table IX.C of the 1911 Italian census. The district-level data from Table IX.B also support this notion, with the fraction of the population of each district that was born in its commune of residence ranging from 83.35 percent in Reggio Calabria to 90.19 percent in the district of Mistretta in the province of Messina. In 1901, Volume II, Table V.B of the census indicates that 94.7 percent of Sicilians and 95.6 percent of Calabrians lived in their birth province. The data to compute the share of individuals living in their commune of birth are not published in the 1901 census.

[31]Guidoboni et al. (2007) also provide data on earlier earthquakes, which we use to construct a measure of earthquake risk later in the paper.

[32]As discussed above, these estimates remain the subject of debate to the present, particularly in the case of the city of Messina. We use the official death toll for this city (67,307 when including some outlying towns that have since been incorporated into Messina) although, as discussed above, we believe that the true toll may be less than half this number. In Online Appendix

To prepare these data for analysis, we first assigned the point-based severity measures to the communes into which they fall. In the absence of a map of Italian communes for the early 20th century, we relied on a shape file of communes as of January 1, 2018 (ISTAT 2018a), which resulted in a small number of historical communes being combined with one another to form larger communes, primarily through the incorporation of adjacent communes into the communes of Messina or Reggio Calabria. In cases where a modern commune had multiple points of severity measures, we first attempted to identify the city center;[33] in other cases, we use the maximum severity recorded in the commune. For communes with no severity measures, we used an inverse-distance-weighted imputation of Mercalli scores. Our benchmark treatment variable is a binary indicator for severe damage from the earthquake: we assigned a commune to the severe group if its severity score was VIII or higher,[34] and assigned all other communes to the non-severe group. In practice, all communes for which we imputed a severity measure fell into the non-severe category (i.e., their imputed Mercalli scores were below VIII), which is consistent with the absence severity information indicating little or no earthquake damage and with the inclusion of all severely affected areas in the damage data. Our choice of the VIII cutoff is based on the fact that this severity level entails substantial damage to ordinary buildings, whereas a VII cutoff implies considerable damage only to poorly built structures. Recognizing that many structures in the study area may have been poorly built, we explore below the consequences of changing the severity cutoff, using dose response models, or avoiding the use of the damage data altogether by using distance from the earthquake epicenter as the treatment measure.

We use two sources of migration data. The first is the Ellis Island arrival records database, which was provided by the Statue of Liberty-Ellis Island Foundation and is described in detail by Spitzer and Zimran (2018). This dataset contains the records of all passenger arrivals at the Port of New York for the period 1897–1924, comprising the vast majority of all arrivals in the United States during the latter decades of the Age of Mass Migration in general and in our study period in particular.[35] In total, there are records of 4.8 million passengers with Italian origin or nationality from the complete Statue of Liberty-Ellis Island Foundation database. The data are compiled from passenger manifests, which were completed by shipping companies upon passengers' embarkation in the port of origin, and which were subsequently verified by immigration agents at Ellis Island. In the case of Italian passengers, the information provided in these

G.2 we show that our results are robust to a number of approaches to addressing potential inaccuracies in the death counts.

[33]That is if there are several observations for Messina, we use the measure for the city of Messina itself rather than for surrounding *frazioni*, or villages, within the same municipality

[34]This cutoff typically corresponds to a Richter scale reading of 7.0 (US Geological Survey 2019).

[35]Spitzer and Zimran (2018, Table D.1) compare the total inflows in this source to those of official statistics of arrivals of Italians to the United States, finding that the coverage of the Ellis Island passenger manifests is nearly complete. The Ellis Island manifests also have partial coverage of arrivals from 1892–1896, but some records were lost to fire.

manifests appears highly accurate, probably as a result of the requirement by Italian authorities to travel abroad with a passport (Foerster 1919, pp. 10–22), which was an official document identifying migrants' communes of origin.

To identify the last place of residence of each passenger arriving at Ellis Island, we used an automated geo-location algorithm, previously used by Spitzer and Zimran (2018), which converted the textual (and often misspelled or incomplete) transcription of the last place of residence in the dataset into latitude and longitude pairs.[36] Spitzer and Zimran (2018) show that this algorithm is highly accurate (i.e., in at least 92 percent of cases in which an individual is assigned to a location, that location is correct), that at least 79.3 percent of records with complete information could be geo-located (with a higher probability of successful geo-location after 1900), and that the subset of individuals whose location could be determined from the algorithm is representative of all passengers. In total, the data include 1,879,365 individuals arriving in the United States in the years 1905–1912 with a listed last place of residence that was determined to possibly be in Italy. Specific latitude and longitude coordinates could be assigned to 1,445,096 passengers (76.9 percent) and were linked to a commune of last residence. For the same reason discussed above, we assigned individuals to the modern commune (as of January 1, 2018) in which their coordinates fall. We then used a variety of sources to determine the historical district and province to which this modern commune belongs.[37] The ultimate product is an annual count of passengers from each commune. The passenger lists also contain a limited number of individual migrant characteristics, including age and gender.[38] We use these data to construct each commune-year's average emigrant characteristics, as well as a count of prime-aged (18–65) male passengers, who may have been more responsive to the labor market consequences of the shock.

Our second and complementary source of migration data is the official commune-level emigration counts published in the *Statistica della Emigrazione Italiana per l'Estero*.[39] This source, which was digitized and described in detail by Spitzer and Zimran (2021), indicates the number of international emigrants from each commune based on the issuance of passports, which were compulsory for international travel after 1901

[36]The passenger manifests also include the passenger's place of birth, but this field was not digitized by the Statue of Liberty-Ellis Island foundation. Spitzer and Zimran (2018, p. 229, fn 14) show that the last place of residence and birth place agree in approximately 98 percent of cases in 1907 and 1912 (when an auxiliary source transcribing birth place is available).

[37]More details of this component of the data cleaning process are presented in Online Appendix C.

[38]The records contain additional personal information, such as height and occupation. But these variables were not digitized for the entire collection of passenger records. Spitzer and Zimran (2018) digitized a sample that enables cross-province comparisons, but the additional transcription required to enable a cross-commune-year comparison of individuals characteristics is infeasibly large. Therefore, we restrict our analysis to the variables that are available for all individuals.

[39]We keep these data at the level of the historical commune at which they are reported, which leads to some minor differences relative to the Ellis Island data described above; however, their geographic location (and thus their earthquake severity) is based on modern borders. This is particularly relevant in the case of communes that have been incorporated into other communes over time; in such cases, the location is based on the location of the modern commune to which they have been incorporated. More details of this data cleaning are provided in Online Appendix C and by Spitzer and Zimran (2021).

(Foerster 1919; Hatton and Williamson 1998). Although these data add information relative to the Ellis Island records and provide coverage of all destinations (rather than just the United States) and ports of entry (rather than just New York), they suffer from some disadvantages. First, they do not enable us to determine the demographic characteristics (e.g., age or gender) of the migrant. Second, records for the districts of Palmi (in the province of Reggio Calabria) and Messina (in the province of Messina) for the fourth quarter of 1908 were destroyed by the earthquake and were imputed based on 1907 figures.[40] There is also the possibility that the earthquake may have disrupted travel plans, leading to a discrepancy between passport issuances and actual emigration. Therefore, we use the Ellis Island data for our benchmark specification, while reporting the same results using the alternative emigration data. The two sources are largely consistent with each other, as are the outcomes of the empirical analysis. Where they are not, we point this out.

One concern with both sources of migration data is whether internal refugees who eventually migrated were reported as coming from their hometowns or from their place of refuge. Unfortunately, we cannot be certain that displaced persons were indeed listed according to the town in which they had been living at the moment the earthquake struck. We are reassured, however, by the evidence that refugees rapidly returned to affected areas (Restifo 1995) and that internal migration rates were low, as discussed above. Further reassurance is provided by sampling and inspecting passenger lists for a mismatch between the last place of residence and the place of birth.[41] This search yields no systematic evidence of Messina-born individuals listing a different locality as the last place of residence.[42]

Finally, we collected data on the characteristics of Italian communes and districts from a variety of official sources. The most important is the 1901 Italian census of population, the last before the earthquake. This source provides commune-level population counts,[43] which enable us to compute rates of emigration, as well as district-level occupational distributions.[44] We are particularly interested in the distribution of the different types of contractual attachment to the land of agricultural workers, which was likely the most important factor differentiating the status of the rural working class that formed the majority of the population and of those who migrated. The least attached were the agricultural day laborers (*giornalieri di campagna*).

[40] The original source states, "Per gli emigranti partiti dai comuni del circondario di [Messina/Palmi] mancano i dati del quarto trimestre 1908, perchè il registro dei passaporti andò disperso nel disastro causato dal terremoto; si è perciò completata la statistica, sostituendovi i dati relativi al quarto trimestre 1907."

[41] The latter field is available in the original manuscripts, but was not transcribed, and so this comparison requires a manual examination.

[42] We randomly sampled a small number of individuals and manifest pages in the passenger manifests emigrating in January, February, and March 1909 whose last place of residence was in the province of Catania, which was the closest and most important refuge for the displaced Messinesi. We then manually inspected these records and found no instance of a Messina-born individual listed as a resident of Catania.

[43] The population data that we use are originally from the 1901 census, but were reported in the *Statistica della Emigrazione Italiana per l'Estero*.

[44] 1901 Census, Volume III, Table C.

Other categories indicate a more rigid attachment: sharecroppers (*mezzadri*), contracted laborers (*contadini obbligati*), renters, lessees, and owner-occupiers. We use these data to compute two measures—the fraction of the male labor force in the district employed in agriculture (of all types of tenure) and the fraction of the male labor force employed as agricultural day laborers. We focus on the latter group because they were the least attached to the land and we therefore suspect that they may have been more responsive to shocks than others. Important as well is employment in construction and in credit and banking—sectors whose size might modulate the effect of the earthquake, as we discuss in section 5.5. We also use district-level information from the 1901 census on the rates of ownership of real estate in the form of land and buildings,[45] as well as literacy and the fraction of the population under age 15.[46] Finally, we collected commune-level indicators on the presence of post offices, telegraphs, and police stations.[47]

To evaluate the suspected role of liquidity constraints in muting a potential earthquake response, we collected and digitized commune-level information on various tiers of the Italian financial system to complement our data on district-level employment in credit and banking. The rationale of this approach is that, if liquidity constraints were important in hindering a migration response to the earthquake, this impact should have been stronger where there was less access to credit to potentially provide liquidity. First, from the Historical Archive of Credit in Italy (Natoli et al. 2016) we have data on the assets of and the short- and long-duration loans provided by banks of various levels. This includes data on the upper and middle tiers of the banking system—ordinary credit or joint-stock banks (*Società Ordinarie di Credito*), cooperative banks (*Banche Popolari*), and savings banks (*Casse di Risparmio Ordinarie*).[48] Probably more accessible and important for the southern peasantry were the lower-tier financial institutions. Natoli et al. (2016) provide data on one such type of institution—pledge banks (*Monti di Pietà*). These were pawn shops that operated as charitable religious institutions. Their origins date to the fifteenth century, and they played an important role in Italy's historical financial development (Pascali 2016). By the end of the nineteenth century they were declining relative to the more modern institutions, but they were widely diffused, particularly in less developed areas such as Sicily and Calabria, and handled much of the country's small scale credit (Carboni and Fornasari 2019). Natoli et al. (2016) show that the coverage of the data within the sectors of the banking system that they study is almost universal in years ending 5 and 0. The most recent year with detailed data

[45] 1901 Census, Volume IV, Table VIII.B.

[46] 1901 Census, Volume II, Table III.B.

[47] *Dizionario dei Comuni del Regno d'Italia*

[48] The Natoli et al. (2016) data do not include, and we were not able to locate, data on the *Casse Rurali*, which were at a level similar to the cooperative banks (*Banche Popolari*). Galassi and Cohen (1994) show that, with the exception of the Province of Palermo, the *Casse Rurali* were largely absent from Sicily and Calabria, meaning that their omission from our data likely does not obscure a significant potential source of credit in the earthquake-affected region.

prior to the earthquake is 1905, and we use the data to compute each commune's log assets per capita and log credit per capita, as well as analogs of these measures capturing assets and credit within a 25-kilometer radius of each commune. Natoli et al.'s (2016) data do not capture two potentially important sources of liquidity. The first is credit provided by postal savings banks (*Casse Postali di Risparmio*), which were perhaps the most important destination for the savings of the working classes.[49] We collected data on these banks, but the most recent available source relative to the earthquake was in 1887.[50] Again, we use this source to produce local per capita and 25-kilometer radius per capita measures. Another such institution was Mutual Aid Societies (*Società di Mutuo Soccorso*). These societies proliferated in the decades following Italian unification, and in our context were likely an instrument for raising funds under stress, as well as, more broadly, an indicator for high social capital that could be used for the same end. We collected data on the membership and endowment of these societies in each commune in 1904 in order to capture potential informal channels of liquidity provision.[51]

Additional sources enable us to characterize communes' agriculture, industry, and transportation. The Jacini Inquiry (1877–1886) published data on agricultural activity for Sicily from 1885.[52] We use this source to compute the fraction of a commune's land devoted to agriculture, the share of trees (citrus, olives, and vineyards) in total cultivated land,[53] and the cultivated hectares per capita. Ciccarelli and Groote (2017) provide data on the Italian rail network, which we use to determine each commune's rail linkage status in 1908. The 1911 Industrial census provides information on total horsepower in manufacturing in each commune, which we use to produce a per capita measure.[54] Finally, we have GIS data on commune area from the Italian statistical agency ISTAT, which we use to compute population density.

3.2 Summary Statistics

Table 2 presents summary statistics for earthquake exposure and emigration for severely damaged and non-severely damaged communes in Calabria and Sicily, as well as for the whole of Italy. The table first presents data on the damage caused by the earthquake. Unsurprisingly, severely damaged communes were closer to the epicenter of the earthquake—just under 40 kilometers on average—and by definition they experienced

[49] *Relazione intorno al servizio delle Casse Postali di Risparmio durante l'anno 1887.*

[50] We also digitized data on pledge banks in 1896 and savings banks in 1875, which we use for robustness checks.

[51] *Le Società di Mutuo Soccorso in Italia al 31 Dicembre 1904.*

[52] *Atti della Giunta per la inchiesta agraria e sulle condizioni della classe agricola*, Roma, 1881–1886.

[53] The distinction between trees and fields in agriculture was among the most important in southern Italian agriculture in this period with implications for the emergence of organized crime (e.g., Acemoglu, de Feo, and de Luca 2020; Dickie 2004; Dimico, Isopi, and Olsson 2017).

[54] A clear concern with this source is that it is from after the earthquake, but no earlier measure is available and we believe that this source provides a stock measure of communes' industrialization which is unlikely to be drastically changed within a short period of time.

more damage as measured by the Mercalli score. By contrast, the average non-severely damaged commune in the regions of Sicily and Calabria had a Mercalli severity of about VI.[55] Severely damaged communes also registered considerably more deaths per capita, on average 17.5 deaths per thousand, which emphasizes that Messina's official death toll (445 per thousand) was an extreme outlier. Figure 2 maps the data on damage from the earthquake. Panel (a) presents the Mercalli score for each commune (excluding those without data in Guidoboni et al. 2007). Panel (b) maps the indicator for whether each commune experienced damage of a Mercalli severity of VIII or greater. Severity is clearly a decreasing function of distance from the earthquake's epicenter (indicated by the large dot), but there is still considerable local variation.

Table 2 also presents various measures of emigration. The rates of emigration according to the Ellis Island data are approximately half those reported in the official emigration data, reflecting their incomplete coverage in terms of international destinations (e.g., migration to South America is not captured by the Ellis Island data), the minority of passengers whose commune of origin could not be determined, and to a lesser degree the absence of data from other ports of entry to the United States. Figure 3 presents the spatial distribution of our main outcome variable—average annual emigration rates at the commune level according to the Ellis Island data.[56] Panel (a) reports average annual emigration rates for the pre-earthquake period 1905–1908. The main pattern evident from this panel is the lower emigration rates from southeastern Sicily relative to the rest of the island and relative to Calabria, consistent with the late arrival of mass migration in this area, as discussed above and by Spitzer and Zimran (2021). Panel (b) reports the change in emigration after the earthquake (the ratio of the average annual emigration rates for 1909–1912 relative to those for 1905–1908). Consistent with the expansion of migration to the southeast of Sicily, the greatest increase over time appears to have been in these areas with previously low migration rates.[57] There is no clear relationship between proximity to the earthquake epicenter and the change in emigration rates other than that a handful of communes around the Strait of Messina, including Messina and Reggio Calabria, are in the bottom quintile of migration growth over the period.

Figure 4 plots the average annual commune-level emigration rate over the period 1905–1912 for severely damaged and non-severely damaged communes in Sicily and Calabria. The dominant pattern in these trends is the large decline in average emigration rates in 1908 in response to the Panic of 1907, from over 15 per

[55] The US Geological Survey (2019) maps a Mercalli severity of VI to a maximum Richter scale reading of 5.9, and a severity of VIII to a minimum Richter scale reading of 7.0—a greater-than-10-fold difference in intensity.

[56] Online Appendix Figure B.1 presents analogous figures based on the Italian official statistics.

[57] In the official emigration statistics, the average annual emigration rates for the southeastern provinces of Siracusa and Catania in the period 1905–1908 were 24.6 and 22.7 per thousand—high by external standards, but the lowest of any provinces in Sicily or Calabria in this period. While Catania (along with every other province in the area except Siracusa) experienced a decline in average annual migration rates in the period 1909–1912, Syracuse experienced an increase in average annual emigration rates by a factor of 1.16 over this period.

thousand to about 5 per thousand in the Ellis Island data (panel a) and from over 40 per thousand to about 20 per thousand in the official statistics over 1906–1908 (panel b). Conversely, the trends for both the severely damaged and other communes in Sicily and Calabria appear similar both before and after the earthquake at the end of 1908—with severely damaged communes always exhibiting slightly lower emigration rates than non-severely damaged ones.

Table 3 presents summary statistics for characteristics of communes and districts.[58] Severely damaged communes were, on average, farther from emigration epicenters than were non-severely damaged communes, and were in districts with a greater share of employment in construction and with fewer property owners per capita. Communes of both groups were in districts with, on average, similar levels of employment in credit and agricultural day labor. Severely damaged communes were also in districts with somewhat lower property ownership. There are some substantial differences in measures of financial development and social capital, but the signs of the differences vary and no group clearly dominates the other.

All of these summary statistics suggest that severely damaged and non-severely damaged communes differed in important ways prior to the earthquake. As our empirical specifications will include commune fixed effects, absorbing any level differences between severely damaged and non-severely damaged communes, this imbalance is not concerning *per se*.[59] The main remaining concern, however, is that the differences in commune characteristics between the two groups might suggest that emigration from the two groups would have evolved along different trends in the counterfactual without an earthquake shock. As pointed out above, the most concrete source for such non-parallel trends is distance from emigration epicenters, for which we control directly, but we cannot rule out the existence of others *a priori*, though we find it unlikely that differing characteristics would drive differing emigration trends after the earthquake but, as our event study specifications will show, not prior to it. We address this concern below by repeating our main results allowing for differential trends based on a large set of observable covariates and find that our results are robust to their inclusion.

Another concrete concern follows from the lower pre-treatment rate of emigration in the treatment (severe) group, as noted above (see also Figure 4). Places that saw more emigration in the past might have been depleted, in the sense that their pool of potential migrants was smaller as a result of greater past migration. This dynamic effect would lead, keeping all incentives equal, to a smaller emigration increase

[58]This table focuses on our main variables of interest. Summary statistics for additional variables are presented in Online Appendix Table B.2.

[59]A major limitation of this discussion of balance is that the only data that we observe at an annual frequency are on migration. As a result, it is not possible to test for differential pre-trends in other characteristics of communes. Reassuringly, as we show below, there we no notable differences in the trends of migration between severely damaged and non-severely damaged communes prior to the earthquake.

where past emigration was greater. In our context this would entail an upward bias in the estimate of the treatment effect. For three reasons, we conclude that this imbalance is not a challenge to our empirical strategy. First, the difference in pre-disaster migration between the two groups, though non-negligible in magnitude, is statistically indistinguishable from zero.[60] Second and most importantly, the upward bias coming from the lower pre-treatment migration rates in severely damaged communes would work against our argument of a non-positive effect of the earthquake, as it would tend to drive *more* future emigration from the treatment group. Finally, Spitzer (2015) has shown that, although areas that experience exogenous increases in migration can produce fewer future migrants, this diminution is gradual and mild.

Finally, our summary statistics provide the first indications of our main finding. Table 2 shows that emigration rates in both severely damaged and non-severely damaged communes declined somewhat over time, but did so slightly more in communes experiencing severe damage. In panel (b) of Figure 3 there is little apparent impact of the earthquake, apart from a drop in emigration rates in the cities of Messina and Reggio Calabria and a few adjacent communes.[61] In Figure 4 the trends both before and after the event are nearly indistinguishable, and certainly so relative to the large temporal fluctuations in migration, such as that induced by the Panic of 1907. Finally, Figure 5 plots the ratio of the post-to-pre (i.e., 1909–1912 to 1905–1908) emigration rates against the pre-earthquake average annual emigration rates, separately for each group. It appears that any impact of the earthquake was of secondary importance as compared to the patterns of convergence in emigration rates discussed above. There is a clear downward slope in the plots, reflecting β-convergence in migration rates, but there is little difference between the trends of the two groups and the trend of the severe group is nowhere higher.[62]

[60] In a cross-section regression of the log of average emigration rates in 1905–1908 on a severe damage indicator, the estimate of the difference in emigration rates is -0.090 with a standard error of 0.120. Even under the extreme assumptions that this difference is fully exogenous and unrelated to differences in incentives, and thus the gap in past migration maps exactly to a greater unobserved pool of prospective migrants of the same size, and that the size of this pool will completely converge back by 1912, this would cause an upward bias to our estimated effect whose absolute size is no greater than that of this difference. More realistically, the convergence would be much more gradual and far from complete after four years (Spitzer 2015)

[61] This decline seen in the Ellis Island data is not mirrored in the official statistics (Online Appendix Figure B.1).

[62] Spitzer (2021) and Spitzer and Zimran (2021) perform similar analyses. There is a natural concern that the negative correlation comes from the fact that the pre-earthquake emigration rate appears on the x-axis and also inversely on the y-axis. To address this concern, we follow Spitzer (2021) and Spitzer and Zimran (2021) in also reporting the correlation between the ratio and the post-earthquake emigration rate. If the negative relationship were solely mechanical, then we would expect a positive correlation in this case of the same magnitude as the negative correlation. As evident in the notes to the figures, there is such a positive correlation, but it is smaller than the negative correlation between the ratio and the pre-earthquake emigration rates. Thus, there is evidence that some but not all of the negative relationship in Figure 5 is spurious.

4 Empirical Strategy

Our empirical analysis is based on emigration data at the commune-year level for the period 1905–1912. Because the earthquake occurred in the last days of 1908 (December 28), it is natural to define 1908 as the last year of the pre-treatment period and 1909 as the first year of the post-treatment period. The length of the period that the analysis covers is motivated by the prior expectation that the impact of the earthquake might evolve over several years, and our event study specifications explore the sensitivity of the findings to changes to the duration of the experiment window. The benchmark sample is limited to the regions of Sicily and Reggio Calabria, in which all affected communes are located. We also report results in which we limit attention to one region in particular or expand it to all of Italy.

Our benchmark empirical approach is the generalized difference-in-differences equation with non-parametric province-specific time trends,

$$\log(e_{it}) = \alpha_{pt} + \alpha_i + \beta(s_i \times q_t) + \gamma(d_i \times q_t) + \varepsilon_{it}, \tag{1}$$

where e_{it} is the emigration rate of commune i in year t, α_{pt} are province-year fixed effects, and α_i are commune fixed effects. The commune fixed effects capture time-invariant differences in emigration rates and other characteristics across communes. The province-year fixed effects capture province-specific year-to-year variations, controlling for time trends and volatility across the study area. The coefficient of interest is β, which is the coefficient on the interaction between an indicator for whether a commune was severely damaged by the earthquake (s_i) and an indicator for the post period of years 1909 and later (q_t). Equation (1) also includes an interaction between the distance from the nearest emigration epicenter (d_i) and the post indicator q_t. We include this interaction in all of our difference-in-differences analyses to account for differential trends stemming from distance from the early sources of emigration, which, as discussed above, is an important source of potentially non-parallel trends.[63] Identification is based on the degree to which severely damaged communes deviated in the post-treatment period from the trend of other communes in the same province, beyond the differential trend implied by their distance from the nearest emigration epicenter.[64]

We take several different approaches to inference. The treatment varies at the level of the commune and it might be natural to cluster standard errors at this level. But such an approach would rule out cross-commune correlation, which we find implausible. Conley (1999) standard errors address this issue by permitting such a correlation. In later analyses, however, we will use variables that vary only at the district level, requiring

[63]We repeat the main results without this control in Online Appendix G.1 with substantially similar results.
[64]We also use this specification with alternative outcomes reflecting the average migrant characteristics of each commune-year.

that we cluster at this more conservative level. Thus, although the online appendix includes a version of our results with commune-clustered and Conley (1999) standard errors (the latter allowing correlation within 3 lags and 150 kilometers), our preferred approach is to cluster at the higher level of the district, which also permits correlation between communes in the same district over different years. This approach, however, is complicated by the challenge that there are only 35 districts in the regions of Sicily and Calabria. To address the small number of clusters, we use Roodman et al.'s (2019) wild bootstrap approach to inference clustering at the district level.[65] We emphasize that clustering at a higher level, which generally yields wider confidence intervals, works against our argument that there was no large positive effect. While wider confidence intervals eliminate the statistical significance of a wider range of positive effects, they also raise the upper bound of the range of likely estimates, such that for any given estimate, the higher this upper bound and the harder it is to rule out large positive effects.

The nature of earthquakes is such that the treatment itself is very geographically clustered, which is one of the important motivations for conservative clustering. It also suggests an alternative method for evaluating the distribution of the estimated effect—one that explicitly incorporates the geographic structure of the shock. We supplement inference based on district clustering with a randomization inference method. Complete details of this method are presented in Online Appendix D. In brief, we simulate 500 randomly placed earthquakes in Sicily and Calabria with the distance-damage relationship estimated from the Messina-Reggio Calabria Earthquake. We then re-estimate our regressions for each of the simulated events. This approach enables us to determine whether the estimates that we derive for the actual earthquake differ from those of the random earthquakes—essentially a placebo analysis that takes into account the spatial distributions of the treatment and the outcome. Specifically, this exercise produces what we call a *tail-mass value*, which is the share of estimates in the randomization inference that are more extreme than the true estimate relative to the median of these estimates. The tail-mass value is a close analog to the ordinary one-sided p-value.

In all of our analyses we weight each commune equally rather than by its population, its share of aggregate emigration, or some other measure of size. Each commune thus constitutes a separate instance. This implies that the cities of Messina and Reggio Calabria, despite their large population, death toll, and refugee streams, are treated as just two of many communes (and we show in Online Appendix G.2 that our results are not sensitive to excluding them). Weighting by population would cause us to derive much of our identification from these two cities, in which the effects of the earthquake may have been idiosyncratic

[65]The bootstrap is not necessary for specifications including all of Italy since there are 284 districts in this case. For such specifications, we use the standard clustered standard errors at the district level.

and unrepresentative.[66] Our equal-weighting approach corresponds to the motivation to understand how a typical commune was affected by the earthquake rather than to quantify the total effect of the earthquake.

Our preferred emigration outcome variable is the logarithm of the emigration rate as measured in the Ellis Island data. We also examine alternative outcome variables, representing different aspects of emigration. These alternatives include an Ellis Island-based measure of migration of prime-aged (18–65) males, which we take as the group that was the most likely to react to labor market incentives, and total emigration rates from the Italian official statistics. We also estimate specifications in which we adjust the emigration rate in the post-earthquake period according to the estimated death toll. In such specifications, we compute the alternative emigration rate $\tilde{e}_{it}$ as

$$\tilde{e}_{it} = \begin{cases} \frac{E_{it}}{N_i} & t \leq 1908 \\ \frac{E_{it}}{N_i - D_i} & t \geq 1909 \end{cases},$$

where E_{it} is the number of emigrants from commune i in year t, N_i is the 1901 population of commune i, and D_i is the death toll in commune i according to Guidoboni et al. (2007). For two reasons, we are comfortable doing this despite our concerns regarding the Messina death toll. First, there is reason to believe that the death tolls in other places were more accurate, in particular because no other commune's death rate approached that of Messina, and our results are insensitive to excluding Messina. Second, we show below that our results are robust to whether or not we adjust the denominator for deaths, and to sequentially dropping communes in order of their death rates.

Finally, to provide a test of the parallel trends assumption required for causal interpretation of estimates of equation (1),[67] to better understand the dynamics of the response (if any) to the earthquake, and to determine if the results are driven by the definition of the experiment window, we also adapt equation (1) into an event study specification. Specifically, we estimate an equation of the form

$$\log(e_{it}) = \alpha_{pt} + \alpha_i + \beta_t s_i + \gamma_t d_i + \varepsilon_{it}, \tag{2}$$

where all terms are defined analogously to equation (1) and the coefficients β and γ are permitted to vary by year. We approach inference in estimating equation (2) in a manner equivalent to our approach for equation (1).

[66] When we do weight our observations by population, there are strong differential pre-trends between severely damaged and non-severely damaged communes, limiting our ability to determine an earthquake effect.

[67] The test of parallel trends also provides a placebo test of changing the timing of the earthquake.

5 Results

In this section we present our main result, the aggregate non-positive effect of the earthquake, and argue that it can be rationalized by heterogeneity of the treatment with respect to the composition of the labor force. These claims are accompanied by various attempts to test their robustness, to assess alternative channels, and to interpret them in this particular context and in comparison to the effects of other shocks.

5.1 Aggregate Effects of the Earthquake

Our benchmark results point toward the conclusion that there was no large positive impact of the earthquake on subsequent emigration flows, and moreover, although our estimates are statistically insignificant, they suggest that any effect was, in fact, negative. Table 4 presents the results of estimating the difference-in-differences specification of equation (1) for a variety of geographic scopes and definitions of the outcome.[68] Our preferred estimates, based on the Ellis Island data with no adjustments and focusing on Sicily and Calabria as the study regions, are in column (1) of Panel A. The estimated coefficient of -0.071 indicates a small relative decline in emigration from affected communes of about 7 percent,[69] and is both statistically insignificant according to the district-clustered wild bootstrap ($p > 0.50$) and does not stand out according to the randomization inference exercise, with more than one-quarter of the placebo estimates more negative than our estimate (and, conversely, nearly three-quarters more positive). The remaining specifications of Table 4 show that this qualitative result is not driven by the source of the emigration date, by the inclusion or exclusion of earthquake deaths in computing emigration rates, or by the geographic scope; the estimated effect in all specifications ranges from a decline of 15 log points to a zero impact, and no estimate is statistically significant.[70]

Figure 6 presents year-specific treatment effects from the event study specification of equation (2) with a variety of dependent variables. As in Panel A of Table 4, the sample includes all communes in Sicily and Calabria. First, these specifications test and lend support to the parallel trends assumption underlying the difference-in-differences analysis. They also show how any effect of the earthquake evolved over time.

[68] Online Appendix Table B.3 repeats these results with commune-clustered and Conley (1999) standard errors. These results are also statistically insignificant, but the implied confidence intervals are all smaller than those in Table 4, enabling us to rule out a greater range of potential positive earthquake effects.

[69] That is, a decline in the average annual emigration rate from about 14 per thousand before the earthquake (Table 2) to about 13 per thousand after.

[70] To evaluate the effect of the earthquake on the demographic composition of emigration, Online Appendix Table B.4 repeats the estimation of equation (1) with the demographic characteristics of migrants as the outcome. For all four characteristics—age, male, prime-aged male, and child (i.e., less than 16 years old)—we find no evidence of a statistically significant effect of the earthquake. The point estimates suggest a small increase in the share of non-labor force participants. For instance, column (2) of panel A indicates that there was a 1.2 percentage-point decline in the male share of migrants relative to a pre-earthquake mean of over 87 percent in the severely damaged communes.

Our preferred results are presented in panel (a), which uses emigration counts from Ellis Island without adjustments. The point estimates show no evidence of meaningfully different emigration trends of severely damaged and other communes prior to the earthquake. In the first year after the shock, there was a slight (just under 10 log points) relative decline in emigration in the severely damaged communes, but according to both the confidence intervals and the randomization inference bands, this change was not statistically significant. This decline then diminished considerably by the second year after the earthquake, remaining small and statistically insignificant thereafter.

The lack of a large positive impact of the earthquake is not due to an idiosyncrasy of our choice of how to measure earthquake damage or emigration. First, both the difference-in-differences results of Table 4 and the event study results of Figure 6 are qualitatively robust to changing the definition of the outcome variable. Second, we repeat the results of Table 4 using either the Mercalli score (Online Appendix Table B.5) or the negative distance (in hundreds of kilometers) from the earthquake epicenter (Online Appendix Table B.6) instead of the severe indicator. Although the coefficients are occasionally statistically significant, mostly hovering just below zero, the interpretation of the point estimates is similar to that of Table 4.[71] Finally, Figure 7 explores the consequences of changing the definition of severe damage to various Mercalli score cutoffs.[72] Given the small number of communes with a severity of IX or greater (25 communes) and our understanding that a Mercalli score of VI or less indicates only negligible damage, the natural alternative cutoff to VIII is VII. In no case does changing the definition of severe damage from VIII to VII materially affect our results.[73] Although in some cases the earthquake effect for a cutoff of VII, which is always negative, is marginally significant, the magnitude of the point estimate is not appreciably different, and the tighter confidence intervals strengthen the case for no large positive effect. Nonetheless, since it is our view that VIII is the most appropriate cutoff, we continue to use it throughout the analysis.

On the whole, we conclude that, regardless of the definition of treatment, the extent of the sample, the source of emigration data, or the approach to inference, there is no statistically significant evidence of a

[71] As shown in Table 2, the difference in the severity of the average severely damaged and average non-severely damaged commune was about 2.5, which according to column (1) panel A of Online Appendix Table B.5 corresponds to a negative effect of severity of about 15 log points. We present these results with the caveat that there is no reason to believe that the Mercalli scores are cardinal and that Online Appendix Figure B.2 shows that some of this estimate may be driven by lower severity levels, where we do not expect to find an effect due to the lack of damage. Similarly, according to Table 2, the difference in the average distance to epicenter between the severely damaged and non-severely damaged communes was 99.5 kilometers, implying that Online Appendix Table B.6's panel A column (1) estimate also corresponds to a negative severe coefficient of about 15 log points. The confidence intervals of the estimates of Online Appendix Tables' B.5 and B.6 are also somewhat tighter than those of Table 4 when converted similarly, again strengthening the case for no large positive effect.

[72] In Figure 7, all communes with missing severity data are set to non-severe. Online Appendix Figure B.3 performs an analogous exercise in which we impute missing Mercalli scores before applying the severity cutoff, again finding evidence of large positive effects.

[73] Due to the small number of communes experiencing severity of IX or above, setting the cutoff to IX or greater results in confidence intervals that are an order of magnitude greater, rendering any inference largely meaningless.

meaningful positive effect of the earthquake on migration. At most, the point estimates attribute to the disaster a small and short-lived relative *decline* in emigration from severely damaged communes.[74]

5.2 Statistical Power and Economic Significance

A challenge to our interpretation of these results as indicating a lack of a large positive effect of the earthquake on migration is that our estimates are statistically imprecise. In the benchmark specification (Table 4, Panel A, column 1), the 95-percent confidence interval for the earthquake effect ranges from a decrease in emigration of 45 log points to an increase of 39 log points.[75] This raises the question of whether we can rule out an economically significant positive migration response to the earthquake. In part, this imprecision is a product of our conservative approach to inference based on the wild bootstrap clustered at the district level. When we use a more liberal approach to inference, as in Online Appendix Table B.3, the confidence intervals are considerably narrower. The upper bound of the 95-percent confidence interval is an increase of 9 log points when using commune-clustered standard errors. When using Conley (1999) standard errors, which are plausible in this case since we do not use district-level variables, the upper bound of the confidence interval is an increase of 20 log points. The conclusion also depends on the yardstick for economic significance. To be sure, the upper bound of the most conservative confidence interval, a 39-log point increase, is not negligible. But it is important to keep in mind the unprecedented magnitude of the disaster and the ubiquity of international migration in the affected region. If there were any case in which we expect a clear and large effect of a natural disaster on emigration, it is this one.

Recent studies and related historical events offer reasonable yardsticks to gauge economic significance. Closest is the decline in emigration resulting from the Panic of 1907, just one year before the earthquake. This short-lived recession greatly reduced US immigration from all European origin countries (Hatton and Williamson 1998, ch. 4), and southern Italy was no exception. Communes severely damaged by the earthquake experienced a decline in average rates of emigration from 1907 to 1908 of 129.3 log points, from 15 per thousand to 4 per thousand (panel a of Figure 4).[76] This is far outside even our most conservative con-

[74] Another attempt to find a direct link between the earthquake and subsequent migration is described in Online Appendix E. We used the list of 20,673 displaced persons in Catania in the refugee census and linked them to the Ellis Island arrival records. We find no evidence that a great number of these internal refugees have subsequently found their way to the US. Unfortunately, we cannot rule out that this pattern is a result of a large rate of false positive matches, and thus judge the added value of this evidence to be very low.

[75] The 90-percent confidence interval for the same estimate ranges from a decline of 36 log points to an increase of 28 log points. The middle 90 percent of the randomization inference replications is a range from a decline of 18.1 log points to a rise of 19.8 log points, which implies that any magnitude in this range would be statistically insignificant according to the randomization inference exercise.

[76] In the official data, the decline over 1906-1908 is from over 45 per thousand to just over 20 per thousand—79 log points lower. Over 1907–1908, the decline is from about 34 per thousand to just over 20 per thousand (49 log points). But the confidence interval for the estimated effect of the earthquake on emigration rates is also smaller when using the official statistics, ranging

fidence intervals,[77] meaning that any likely effect of the earthquake is far smaller, in absolute size, relative to this benchmark effect of US business cycle fluctuations. This particular comparison also bears on the *push-pull* debate of migration (e.g., Gould 1979; Hatton and Williamson 1998; Jerome 1926; Kuznets 1958), which considers whether the size of migratory flows was primarily determined by conditions in the origin or destination countries. The small impact of an undoubtedly cataclysmic event as compared to the much larger effect of a transient shock outside Italy in the form of a US recession, is yet more evidence to the dominance of pull over push factors (Hatton and Williamson 1998, ch. 4).[78]

Another useful yardstick for the effect of the earthquake on migration is provided by Mahajan and Yang's (2020) study of the effects of hurricanes on migration to the US, which emphasizes the role of the stock of previous immigrants in the destination.[79] Applying their estimates (Tables 3 and 5) to a rough estimate of the size of the Calabrian and Sicilian population already present in the US at the end of 1908, the implied effect of what Mahajan and Yang (2020) call a "one standard deviation" hurricane—a far smaller shock than the Messina-Reggio Calabria earthquake—ranges from 43.9 percent to 106 percent increase in annual migration, again outside of our confidence intervals for the effect of the earthquake. The details of how we computed these figures are presented in Online Appendix F.

In sum, although a conservative approach to inference leads to rather wide confidence intervals around our estimates, hindering our ability to definitively conclude that there was no positive effect of the earthquake on international migration, our estimates are nevertheless sufficiently precise to conclude that any likely true increase in migration in response to the earthquake was small as compared to those of similar or weaker

from a decline of 31 log points to a rise of 13 log points.

[77] The 1907–1908 change also exceeds the bounds of our conservative confidence interval for the one-year impact of the earthquake(Figure 6, panel a).

[78] Notably, the small impact of the earthquake relative to that of the business cycle is similar to Boustan's (2007) finding that the Russian Jewish emigration to the United States was primarily determined by the state of the US economy and that pogroms had at most a second-order effect. Similarly, Spitzer (2021) estimates the effect of a pogrom on the emigration of Russian Jews from another "migration-saturated" region—the Pale of Settlement in the Russian Empire around 1905. He finds that exposure to a pogrom led to an increase in emigration of about 20 percent, which is near the upper extreme of the earthquake's 90-percent interval. The Great Irish Famine of 1846–1850 is another useful comparison, in the sense that it was a disaster that had had an immense toll in lives and has been linked to subsequent mass migration (Ó Gráda 2019; Ó Gráda and O'Rourke 1997). Although the effect of the famine has not been formally quantified, the large impact of the shock is evident in the fact that the number of Irish immigrants to the United States more than doubled between 1846 and 1847 (Barde, Carter, and Sutch 2006) when the famine intensified, even as the base population declined dramatically. We can easily rule out changes of this magnitude in our context.

[79] Instances of disaster-induced internal migration in the United States also provide useful points of comparison. Ager et al. (2020, Table 1) find that a one-standard deviation increase in earthquake intensity from the San Francisco Earthquake of 1906—a far smaller shock than the one we consider—reduced the in-migration rate over the period 1900-1910 by 11 percentage points relative to a mean of about 52 percent, or about a 20 percent decline. Long and Siu (2018, Table 2, p. 1009) show that Dust Bowl counties experienced an increase in inter-county emigration rates from 47.2 percent to 51.6 percent from the 1920s to the 1930s while the rest of the country experienced a decline in inter-county migration rates—an increase of about 23 percent. Lange, Olmstead, and Rhode (2009, pp. 713–714) find that the boll weevil caused a decline of population of 30 percent in five years (i.e., an average annual out-migration rate of 6 percent or higher from areas that previously were not engaged in considerable internal migration) in the counties most reliant on cotton prior to the shock. Boustan et al. (2021, Tables 1 and 2) find that a "super-severe" disaster in a county led to an increase in its out migration rate by 3 percentage points relative to an average out migration rate of 1 percentage point.

shocks that have been studied in prior research.

5.3 Spillovers

The preceding analysis has focused on the commune as the unit of analysis. The disadvantage of focusing on such a high resolution is that the no-spillovers assumption inherent in the difference-in-differences and event study analyses is more likely to be violated. Severe damage in one commune could have changed the migration incentives for individuals in adjacent communes that were not severely damaged. If these spillovers operated in the same direction, this would bias our estimates toward zero, limiting our ability to rule out a large effect. We take three approaches to addressing this concern. First, we point out that the analysis of Online Appendix Table B.6, using distance from the earthquake epicenter as the treatment, treats severely damaged and non-severely damaged communes equidistant from the earthquake epicenter equally, obviating concerns about spillovers in this regard. Second, Online Appendix Table B.7 repeats the results of Table 4 but omits any commune that was not severely damaged but was contiguous to a severely damaged commune.[80] There were 105 such communes, and omitting them leads to a more negative (albeit less precise) estimate, inconsistent with a spillover mechanism of this type being responsible for our findings.[81]

Finally, we expand the unit of analysis to the district. Specifically, we estimate versions of equations (1) and (2) in which the unit of observation is the district-year and the province-year fixed effects are replaced with region-year fixed effects (there were 16 regions, or *compartimenti*). An important caveat in this analysis is that focusing on a larger administrative unit considerably reduces the number of observations. For this reason we focus on a specification that includes all Italian districts in the sample. We classify a district as treated if at least 40 percent of its population lived in a commune that was severely damaged by the earthquake.[82] In practice, this results in the five closest districts to the epicenter (Castroreale and Messina in Sicily and Gerace Marina, Palmi, and Reggio Calabria in Calabria) being treated. The small number of

[80] Online Appendix Figure B.4 presents analogous event study results.

[81] Online Appendix Table B.8 tests an alternative spillover mechanism in which the shock led people in places with a high risk of earthquake damage to leave. We determine the number of earthquakes over the period 1808–1908 in which each commune experienced a Mercalli severity of VII or higher and add this as an alternative measure of treatment in addition to severe damage from the Messina-Reggio Calabria earthquake. The VII cutoff is chosen rather than VIII for two reasons—because damage amounting to a Mercalli severity of VIII is quite rare, leaving few places marked as high risk, and because we view a severity of VII as sufficient to indicate to individuals that their place of residence is susceptible to severe earthquake damage. We find no evidence of a statistically significant response of these communes when controlling for severe damage from the Messina-Reggio Calabria Earthquake and there is no systematic sign of these estimates that enables us to draw even less confident conclusions.

[82] We chose this cutoff because it is a natural break in the distribution. The marginal district classified as severely damaged is Gerace Marina in the province of Reggio Calabria, where, 43.5 percent of the population lived in severely damaged communes. The next district with greater damage is Castroreale in the province of Messina, where 47.1 percent of the population lived in severely damaged communes. The marginal district classified as non-severely damaged is Monteleone di Calabria in the province of Catanzaro, where 23.8 percent of the population lived in a severely damaged commune. Alternative results reclassifying the marginal district, Monteleone di Calabria, as severely damaged are presented in Online Appendix Figure B.5 with similar results.

treated units in this analysis raises issues of inference (MacKinnon and Webb 2020). To address this concern, we adjust our main randomization inference approach to the new unit of observation, randomly choosing 500 points in Italy, assigning the five closest districts as treated, and estimating the adapted version of equation (2).

We focus these results, which are presented in Figure 8, on the unadjusted official statistics because they provide more complete coverage of areas outside of southern Italy, which are included in these specifications. In these areas, migration to destinations other than the United States was considerably more important,[83] and therefore the loss of information arising from focusing only on migration to the United States—as the Ellis Island data entail—may be more severe.[84] The point estimate of -0.086 is remarkably similar to our estimates from Table 4, and like those estimates this one does not stand out from the placebo replications. In the event study, unlike the commune-level results, there is some evidence of differential pre-trends between affected and unaffected districts, which complicates interpretation of the difference-in-differences coefficient, but at least from 1906 these are moderated. The point estimate for 1909 is consistent with a transient effect, if any, of the earthquake on emigration, this time a positive one. Any difference between affected and unaffected districts vanishes by 1910. None of these coefficients are statistically significant according to the randomization inference. In sum, we do not find evidence that the commune-level analysis obscures aggregate district-level effects by neglecting to account for spillovers.

5.4 Labor Force Composition and Heterogeneous Responses to the Earthquake

What could explain the absence of a large aggregate positive impact of the earthquake? We approach this question by looking for local conditions that were associated with heterogeneous responses to severe earthquake damage. Such responses may have been meaningful in magnitude and duration, even if they canceled each other out in the aggregate. Guided by the competing hypotheses in the literature discussed in section 2.2 and by the features of the southern Italian economy, we focus on what we consider to be the most likely factors that would limit a positive emigration response to the earthquake—attachment to the land, liquidity constraints, greater exigencies, and demand for reconstruction labor. To be clear, we are not asking what made a commune more likely to send fewer emigrants in general, but what made one react more negatively to the disaster.

We first turn to understanding the role of the composition of the agricultural working class, which formed

[83] In the northern regions of Piedmont, Lombardy, Veneto, and Emilia Romagna, over 77 percent of migrants in the period 1900–1914 traveled to other European countries.

[84] Results for alternative dependent variables are presented in Online Appendix Figure B.6.

the majority of both the labor force and of the migrants themselves.[85] Peasants in the different categories of agricultural labor differed in both their standards of living and in their tenancy status, and moving up the tenancy ladder by leasing or purchasing land was a primary goal of Italian migrants and their households (Hatton 2010; Hatton and Williamson 1998). It is likely that a worker's position in this hierarchy affected his ability and his incentive to respond quickly to a shock through migration. Renters, lessees, and owner-occupiers, who had at least some stake in cultivating and improving the land to which they were attached, could not abandon it costlessly on short notice, and they may have experienced the greater exigency of an incentive to invest in rebuilding and repairing their own property after the earthquake. Day laborers, who comprised about half of the agricultural labor force (Table 3) were relatively unfettered by contractual obligations or vested capital and, for this reason, potentially were better able to quickly react to unexpected shocks, such as damage to their residences.[86] On the other hand, being at the bottom of the socio-economic scale, agricultural day laborers may have faced a greater tightening of their financial constraints to migration. To evaluate these possibilities, we estimate whether districts where agricultural day laborers were a greater share of the labor force were more responsive to damage from the earthquake.

Our empirical approach is to adjust the difference-in-differences specification of equation (1) to the form

$$\log(e_{it}) = \alpha_{pt} + \alpha_i + \beta(s_i \times q_t) + \gamma(d_i \times q_t) + \delta(x_i \times q_t) + \pi(s_i \times x_i \times q_t) + \varepsilon_{it}, \tag{3}$$

where x_i is some characteristic of commune i and π is the interaction coefficient of interest. We standardize the interaction characteristics such that x_i always has mean 0 and standard deviation 1 in the estimation sample for each specification. Similarly, we adjust the event study specification of equation (2) to the form

$$\log(e_{it}) = \alpha_{pt} + \alpha_i + \beta_t s_i + \delta_t x_i + \pi_t(s_i \times x_i) + \gamma_t d_i + \varepsilon_{it}. \tag{4}$$

Table 5 presents the results of estimating equation (3) for unadjusted emigration data for Sicily and Calabria, taking the 1901 district-level share of employment as agricultural day laborers as x_i.[87] Alongside the small and statistically insignificant reaction of communes at the mean to the earthquake, as seen in

[85] There is reason to believe that agricultural day laborers made up the bulk of the flow of immigrants from Italy as a whole, although it is impossible to positively verify this. In Spitzer and Zimran's (2018) sample, 47.8 percent of male migrants over age 22 reported an unskilled job, with another 37.1 percent reporting a farming occupation. However, given the age distribution, it is very likely that some or even most of those listed as farmers were, in fact, farm laborers. That farmers were the shortest occupational group (Spitzer and Zimran 2018, Table A.2, p. 243) is consistent with this. Moreover, it is very likely that those listing an occupation of "laborer" were in fact farm laborers; see also Pérez's (2021, pp. 13–14) argument that the distinction between farmers and unskilled laborers in passenger manifests is not particularly informative.

[86] Hatton (2010), Hatton and Williamson (1998), and Vianello (2014) also argue that attachment to the land might have hindered migration in general.

[87] Results for other dependent variables and geographic scopes are presented in Online Appendix Table B.9.

column (1) (which repeats the result in Table 4),[88] column (2) reports a statistically significant and strongly positive relationship between a district's share of employment in agricultural day labor and the response of communes in that district to the earthquake. A commune with an agricultural day labor share one standard deviation above the mean experienced a relative increase in emigration of over 35 log points in response to the earthquake shock.

To more easily see the differential reaction, Figure 9 estimates the event study specification of equation (4) using an indicator for being in a district above the sample median in terms of the agricultural day labor share as the interaction variable x_i.[89] Panels (a) and (c), which use the Ellis Island data, show that neither group exhibits any differential pre-trend, there is a readily apparent divergence in the effect of the earthquake on severely damaged districts. In the above-median group, there was a relative increase in emigration of 19 log points in 1909, whereas communes in the below-median group share show a relative decrease of 39 log points. The divergence persisted in later years, though it was of a somewhat smaller magnitude. However, we treat these results with some skepticism: based on the official emigration data, the interaction with the share of agricultural laborers is weaker, though still statistically significant (Table 5, column 6) and the event study patterns are no longer as neat as with the Ellis Island data (panels b and d of Figure 9).[90]

Was this heterogeneity indeed linked to the composition of the agricultural labor force, or merely to its size relative to that of other sectors? In column (3) of Table 5, we estimate equation (3) with the standardized share of a district's male labor force employed in agriculture in 1901 as x_i. In column (3), the coefficient is positive, but it is also smaller and its statistical significance weaker. Column (4) allows for heterogeneous earthquake responses by both characteristics, effectively "horse-racing" the two. In column (4), the coefficient on the interaction with general agricultural labor is reduced to zero, while the coefficient on the interaction with the share in agricultural day labor is only slightly reduced and remains statistically significant. Again, performing the same exercise with the official statistics (columns 7 and 8) gives less conclusive results, with estimates that point in the same direction, but which are weaker and statistically insignificant in the horse-race specification.

On the whole, we conclude that the results of Table 5 and Figure 9 strongly suggest that the lack of an average effect of the earthquake masks a more complex heterogeneous response in which the least attached peasants reacted by migrating overseas, whereas the rest remained.

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[88] Because of the randomization involved in the wild bootstrap, the p-values and confidence intervals will not be identical.

[89] In Calabria, 7 districts were above the median and 4 below. In Sicily, 10 districts were above the median and 14 were below.

[90] Results for alternative dependent variables are presented in Online Appendix Figure B.7. Online Appendix Figure G.14 presents results defining severe damage at a cutoff of VII with neater event study results for the official statistics.

5.5 Explaining the Lack of an Aggregate Migration Response

In light of the devastation wrought by the Messina-Reggio Calabria Earthquake and the ubiquity of mass migration in Sicily and Calabria at the time of the shock, our finding that there was no discernible positive impact on migration from the average commune is surprising. It is, however, consistent with findings of no effect or a negative effect of natural disasters on migration in other contexts, as discussed above. Several competing theoretical justifications have been offered for this *immobility paradox* and we proceed to examine them in our context.

A leading potential explanation is that the devastation from the disaster led to a tightening of liquidity constraints that offset any strengthening of push factors arising from the earthquake. Such a mechanism is not easily reconcilable with our finding above that a greater share of agricultural day laborers, who were likely most sensitive to tightening liquidity constraints, was associated with the most positive reactions to this shock. It is also possible to test these mechanisms directly using our data on financial institutions, mutual aid societies, and pre-existing migrant networks. We do this by estimating versions of equation (3) in which the normalized interaction characteristic x_i is some commune-level measure, presenting our results for the interaction coefficient π in Table 6. In general, these results do not support the argument that liquidity constraints were important in determining migration responses to the earthquake. Measures of financial development in rows a–g of this Table are, as a rule, not statistically significantly associated with earthquake responses, and in any event the estimated coefficients are nearly all negative, indicating a *more negative* migration response in places with greater access to credit—the opposite of what we would expect from a liquidity constraints mechanism.

Because the formal financial system was not the only potential source of liquidity, we also focus on two measures of access to more informal support for migration. These are the prevalence of mutual aid societies,[91] capturing general local social capital, and the size of the local migration network,[92] which is both a migration-specific measure of local social capital and a potential source of liquidity in the form of remittances and paid tickets. If increasingly binding liquidity constraints were responsible for limiting a migration response, we would expect a more positive reaction to the earthquake where mutual aid societies and migrant networks were more prevalent. Some of the results in rows h–j of Table 6 are not inconsistent

[91] The province-level density of mutual benefit associations in Italy was previously used as a measure of social capital in Cappelli (2016, 2017), Ciccarelli and Fachin (2017), and Postigliola and Rota (2019). Our paper is the first to use this measure at the commune level.

[92] We define this as the ration of the cumulative flow from the commune over the years prior to 1908 according to each source of emigration data to the 1901 population of a commune. That is, for the Ellis Island data, the network size is based on emigration 1897–1908 whereas for the official statistics it is based on emigration 1884–1908.

with this view, but they are weak and mixed. The coefficients on the interaction with membership in mutual benefit associations in row h are positive when using the Ellis Island data, large in comparison to the results of Table 4, and statistically significant according to the randomization inference. But, they are negative and significant when using the official emigration statistics, and in row i, the coefficient on the alternative measure, these associations' per capita assets, is negative and insignificant in all specifications. The interaction coefficients of the size of the migrant network in row j hover around zero and are statistically insignificant.[93] We conclude that overall, there is no consistent evidence that communes that had better access to credit and social capital were more likely to react to the earthquake by overseas migration, and therefore that liquidity constraints are unlikely to have been the cause for the non-positive average effect of the earthquake.

Another potential explanation for a lack of a response is a rise in reconstruction labor demand that provided an increasingly lucrative alternative to overseas migration.[94] This explanation is inconsistent with the absence of a large population inflow from the hinterland to the heavily damaged cities (Table 1) and with the delays in reconstruction documented above.[95] It is also somewhat inconsistent with our findings of more positive responsiveness of areas with more agricultural day laborers, who were likely the first candidates to switch to unskilled construction jobs. Although we lack detailed data on internal migration and wages,[96] we can test this argument by looking for a heterogeneous earthquake response according to the share of employment in construction in 1901. Notwithstanding the potential shift of labor into construction after the shock, a lesser migration response by areas with a greater construction share would be consistent with a reconstruction mechanism. We repeat equation (3) with a district's standardized share of construction labor as the interaction characteristic x_i, presenting our results in Table 7. In Panel A, the interaction coefficients are negative in all specifications, consistent with the hypothesized mechanism, but the coefficients are small (approximately -0.1) and approach statistical significance in only one specification (column 5, based on the official emigration statistics). Moreover, these negative estimates could simply be the product of a negative correlation between employment in construction and in agriculture. In Panel B, we "horse race"

[93] Importantly, this finding is not inconsistent with Mahajan and Yang's (2020) finding of a positive interaction between the *level* of migration and the stock of past migrants because we have specified the outcome variable in logarithmic terms, which makes the estimated effect proportional to the base rate of migration.

[94] There is evidence of an increase in construction wages in the region after previous earthquakes (Caputo 1908). Such a mechanism is also discussed by Yang (2008b) as explanations for a decline in migration after earthquakes in El Salvador.

[95] Indeed, the refugees returning to these cities, especially Messina, were likely out of work and could have absorbed a considerable portion of the new demand for reconstruction labor.

[96] Arcari (1936) provides province-level information on wages of various classes of agricultural workers, including agricultural day laborers beginning in 1905 (see also the provincial annual real wage measures provided by Federico, Nuvolari, and Vasta 2019). There is a general upward trend in wages in Messina, with no discernible deviation after the earthquake. However, the lack of more geographically detailed data prevents any stronger conclusion.

the two interaction terms, finding that our agricultural day labor result is qualitatively robust whereas the construction labor interaction becomes zero or slightly positive and statistically insignificant, inconsistent with the suspected mechanism of construction labor absorbing would-be migrants.[97]

Another possible explanation for the lack of a migration response is that the earthquake had only a short-term effect on the attractiveness of a location, but that migration decisions were driven by long-run incentives, which might have been unaffected by the temporary shock. Such a view contradicts the history of slow recovery from the earthquake, as described above.[98] Additionally, Bohra-Mishra, Oppenheimer, and Hsiang (2014) suggest that temporary migration may be more responsive than permanent migration to shocks; but the largely temporary nature of the Italian migration means that this potential explanation is likely not applicable in this case. Finally, Bettin and Zazzaro (2018), David (2011), Mohapatra, Joseph, and Ratha (2009), Paul (2005), and Yang (2008a) attribute a non-positive migration response to remittances and other financial inflows to the affected area. We have not been able to locate data on remittances that would enable us to test this mechanism, though our results for heterogeneity by the size of the migrant network do point against it. Moreover, it appears that governmental financial aid to the affected area, though initially present, was limited. For instance, only 866 of 30,000 businesses that applied were granted subsidies in the first four months after the earthquake (Di Paola and Savasta 2005), and the head of the relief committee forbade the allocation of funds to individuals (Bosworth 1981). Indeed, it appears that the primary channel through which government aid flowed into the area was through reconstruction spending (Farinella and Saitta 2019), which as we have argued above, had a limited role in shaping migration responses.

[97] Another way to assess the claim that reconstruction efforts were severely limited is to examine the effects of the earthquake on communes' long-run development. This analysis builds on results associating disasters with creative destruction (Barone and Mocetti 2014; Gignoux and Menéndez 2016; Hornbeck and Keniston 2017). In particular, if reconstruction efforts were important, we expect future benefits to severely damaged communes due to creative destruction; conversely failing to find such future benefits would be consistent with the lack of important reconstruction efforts. We perform such an analysis in Online Appendix Figure B.8, focusing on what we believe to be the only commune-level measure that can be observed at a high enough frequency to perform such an analysis—population (ISTAT 2018b). This Figure presents event studies of the form of equation (2). We find that there is no systematic evidence of differential pre-trends prior to 1901 (the last census prior to the earthquake). We then find a population decline in 1911 and 1921, the duration of which is consistent with our qualitative evidence regarding the delays in reconstruction. We then see severely damaged communes returning to being indistinguishable from non-severely damaged communes, with negative point estimates after World War II. The lack of a future gain in severely damaged communes supports our evidence of a lack of organized reconstruction efforts.

[98] To further test this theory, we take advantage of a 7.2-magnitude earthquake striking Calabria in 1905, with severity details in Online Appendix Figure B.9. If indeed a single earthquake, despite its magnitude and long reconstruction period, were insufficient to cause individuals to update their views on the long-run incentive to remain at home, then perhaps two severe earthquakes in three years might be sufficient. To test this, Online Appendix Table B.10 shows the results of estimating equation (3) with x_i taking a value of one for communes experiencing severe damage in the 1905 earthquake. We find that communes unaffected by the 1905 earthquake had a somewhat smaller (but still imprecisely estimated) response to the 1908 earthquake (the severe × post coefficient) at a decline of 6 log points. We also find a negative coefficient on severe × post × severe 1905, indicating a more negative response to the 1908 earthquake among communes that also experienced the 1905 earthquake severely. Communes experiencing both earthquakes had an estimated decline in migration in response to the 1908 earthquake of 22 percent—a meaningfully larger estimate than in Table 4. But these results are not statistically significant and are very imprecisely estimated, likely due to the fact that there were only 21 communes experiencing severe damage in both earthquakes.

Finally, returning to the role of tenancy status, were unattached workers more positively reactive because they were not fettered by contractual obligations, or because they were not attracted by the greater exigencies, characteristic of workers who had stakes in the capital with which they were working? To tackle this question, Table 8 estimates equation (3) and analogs of it with the share of building owners, the share of land owners, both shares, and both shares alongside the share of agricultural day laborers as the interaction characteristics. The greater exigencies theory suggests that owners of buildings, which were the main capital damaged by the earthquake, would be incentivized to dedicate their own labor to rebuilding or repairing their own property, and thus a greater share of building owners would be associated with a lesser migration response to the shock. Land, on the other hand, was less likely to be damaged and in need of repair. Thus, although both variables indicate the presence of wealth, the greater exigencies explanation predicts that the interaction coefficient with ownership of buildings would be more negative than that of ownership of land. In fact, the results of Table 8 appear to show the opposite. When included as the sole interaction characteristic, ownership of buildings has a strongly positive and often statistically significant coefficient, as is the case when the sole interaction characteristic is land ownership. When both measures are included together, however, the coefficient on building ownership is made more positive and approaches statistical significance more closely, whereas the coefficient for land ownership is negative. Even when the share of agricultural day laborers is added as an additional interaction variable, the interaction coefficients of buildings remains highly positive in the Ellis Island specifications and zero in the official statistics, while that for land ownership remains negative in the Ellis Island specifications, lending further support to the notion that attachment to the land hindered an emigration response to the earthquake.[99]

Instead the only consistent finding that helps to explain variation in the reaction of migration to the earthquake is the share of agricultural day laborers. This does not appear to be attributable to the possibility that the owners of real property, particularly buildings, had greater exigencies caused by the earthquake, to the share of construction workers who would have been attracted by the reconstruction, or to the overall share of agricultural workers of all types. Instead, the most plausible explanation is that this feature of the labor market was important because, unattached by contracts and economic commitments, agricultural laborers could react more quickly to the shock.

[99] Similarly, the more positive emigration response in areas with more building owners points against an argument attributing the greater responsiveness of areas with more agricultural day laborers to the lower standards of living of this group.

5.6 Robustness

The online appendix contains the details of a variety of robustness checks that we perform on our results. Online Appendix G.1 repeats the main results without controlling for the differential trends according to distance from the nearest emigration epicenter. Online Appendix G.2 tests the sensitivity of the results to dropping the main cities of Messina and Reggio Calabria from our analysis to exclude their potentially unique conditions and large death tolls, tests the sensitivity to sequentially dropping communes in order of the share of deaths to further ensure that potentially inaccurate death counts do not drive our results, and tests the sensitivity of the results to re-assigning internal migrants in the main cities to other communes to address potential internal migration. Online Appendix G.3 tests robustness to including the interaction of time with various controls to address concerns over differential trends driven by level differences in these measures across groups.[100] In all cases, our main results are robust to these checks.

We also include two other checks of our results. Online Appendix Table B.11 "horse races" the interaction of severe × post with the agricultural labor share against analogous interactions with various characteristics studied above. In all cases, the interaction of the agricultural labor share remains positive and statistically significant. This is true also in Online Appendix Table B.12, which tests for heterogeneous responses to the earthquake on a variety of additional commune characteristics not discussed above and "horse races" them with the agricultural labor share.

6 Conclusion

How does a large shock to an area already experiencing mass migration affect migration? Does migration provide relief? Or does the shock inhibit movement overseas? This paper answers these questions in the context of the most devastating earthquake to strike modern Europe, and arguably the most destructive natural disaster in modern European history, which occurred in the midst of the Age of Mass Migration in one of the areas most affected by this phenomenon. Our answer is that, on average, there was no large positive response of migration, and indeed that there is no clear evidence of any aggregate effect, though our point estimates do indicate a short-lived and mild negative average effect. However, this does not mean that the earthquake had no effect at all on emigration. Instead, we find that a greater share of agricultural day laborers was associated with increased migration, which we interpret as evidence that attachment to the land acted as a barrier to responding to shocks through migration. Explanations that have been cited for

[100] In particular, our difference-in-differences regressions include each control interacted with the "post" indicator and our event study regressions include each control interacted with time.

non-positive migration responses in other contexts, such as tightening liquidity constraints, labor demand generated by reconstruction efforts, and an inflow of funds to the affected regions, do not seem to have played a role in this case.

The results of this paper advance our knowledge of the Messina-Reggio Calabria earthquake itself, add to the large recent literature on the Age of Mass Migration, and contribute to the debate over the impact of push and pull factors on migration in this context (Gould 1979; Hatton and Williamson 1998), pointing to a weak role for temporary push factors relative to pull factors. More importantly for current international migration, we shed light on the question of how migration is affected by natural and man-made disasters. As a changing climate has increased the likelihood of natural disasters (Intergovernmental Panel on Climate Change 2012), particularly in the developing world, concern has grown over the degree to which individuals will be displaced in the aftermath of such events (World Bank 2018). It remains an open question whether and under what circumstances individuals in the affected region can find relief through migration, and specifically, whether such shocks will lead to an influx of refugees to developed countries. The case that we study demonstrates that even when borders are open and the magnitude of the disaster is enormous, the reaction can be a complex outcome of both positive and negative effects that aggregate to a seemingly unremarkable total. Altogether, the effects of such events are far more nuanced than simple intuition would suggest.

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Tables

Table 1: Population of the cities of Messina and Reggio Calabria by birthplace, 1901 and 1911

	Messina		Reggio Calabria	
Birthplace	1901	1911	1901	1911
Same commune	127,017	106,025	37,175	32,530
	(0.848)	(0.838)	(0.837)	(0.754)
Other commune in same province	9,888	7,838	3,927	4,872
	(0.066)	(0.062)	(0.088)	(0.113)
Elsewhere in Sicily	4,244	6,167	824	1,826
	(0.028)	(0.049)	(0.019)	(0.042)
Elsewhere in Calabria	3,833	2,386	668	755
	(0.026)	(0.019)	(0.015)	(0.017)
Total	149,778	126,557	44,415	43,162

Notes: The "Total" row includes births elsewhere in Italy and abroad; for this reason, the first four rows of each column do not sum to the figure in the "Total" row. Fractions of total population in parentheses.

Sources: For 1901, the data are from the 1901 Italian census of population, Volume II, Table V.A, pages 357–8. For 1911, the data are from the 1911 Italian census of population, Volume VI, Table IX.A, pages 78 and 85.

Table 2: Summary statistics for earthquake exposure and emigration

	Sicily and Calabria		Calabria		Sicily		Italy
	Severe	Not	Severe	Not	Severe	Not	All
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Earthquake exposure							
Distance to epicenter (km)	39.148	138.634	39.484	128.431	38.209	148.335	701.232
	(20.557)	(57.250)	(21.917)	(46.338)	(16.474)	(64.566)	(312.131)
Mercalli intensity	8.364	5.868	8.395	6.198	8.276	5.554	1.248
	(0.704)	(1.185)	(0.732)	(0.747)	(0.621)	(1.417)	(2.209)
Deaths per thousand	17.473	0.012	18.087	0.014	15.759	0.011	0.277
	(57.465)	(0.124)	(45.970)	(0.122)	(82.543)	(0.127)	(7.509)
Emigrants per thousand							
Ellis Island, 1905–1908	13.177	14.035	11.816	13.282	16.978	14.756	5.893
	(16.242)	(14.625)	(16.278)	(12.585)	(15.588)	(16.312)	(11.001)
Ellis Island, 1909–1912	11.665	13.378	9.925	12.663	16.526	14.062	5.338
	(12.871)	(11.732)	(12.392)	(10.931)	(12.989)	(12.416)	(8.828)
Ellis Island, prime, 1905–1908	9.717	8.504	9.212	8.702	11.124	8.314	3.762
	(11.776)	(8.923)	(12.250)	(8.674)	(10.260)	(9.154)	(7.098)
Ellis Island, prime, 1909–1912	7.997	7.698	7.249	8.242	10.086	7.178	3.268
	(8.347)	(7.064)	(8.452)	(7.384)	(7.705)	(6.705)	(5.599)
Official, 1905–1908	34.146	36.296	35.196	38.948	31.030	33.710	27.614
	(19.560)	(21.662)	(19.579)	(19.194)	(19.242)	(23.545)	(26.933)
Official, 1909–1912	31.899	34.195	30.740	37.742	35.340	30.735	26.343
	(18.184)	(19.185)	(17.328)	(17.778)	(20.200)	(19.871)	(26.674)
Migrant Characteristics, 1905–1908							
Age	26.572	25.262	27.227	25.735	24.969	24.818	25.667
	(3.989)	(3.806)	(4.280)	(3.965)	(2.549)	(3.596)	(5.541)
Male	0.873	0.773	0.896	0.808	0.818	0.741	0.797
	(0.136)	(0.172)	(0.135)	(0.172)	(0.122)	(0.167)	(0.228)
Prime-aged male	0.750	0.635	0.786	0.674	0.664	0.599	0.677
	(0.183)	(0.215)	(0.173)	(0.211)	(0.179)	(0.213)	(0.277)
Child	0.117	0.181	0.100	0.156	0.158	0.205	0.140
	(0.109)	(0.139)	(0.106)	(0.133)	(0.103)	(0.141)	(0.170)
Observations	879	5,056	647	2,472	232	2,584	55,743
Communes	110	632	81	309	29	323	6,971

Notes: Standard deviations in parentheses. Observations are at the commune-year level. Mercalli measures are imputed where missing. Observation numbers are the minimum with observations for migration, distance from earthquake epicenter, deaths, and population in the Ellis Island-based dataset. Commune numbers are the number of distinct communes among these observations. Emigration rates are expressed per thousand population for clarity, but we use the (logarithm of the) decimal rate (i.e., migrants per capita) for analysis. Prime-aged defined as ages 18–65.

Table 3: Summary statistics for commune and district characteristics

	Sicily and Calabria		Calabria		Sicily		Italy
	Severe	Not	Severe	Not	Severe	Not	All
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Commune characteristics							
Population (1901, 1,000)	5.861	6.684	4.545	3.219	9.538	9.979	4.460
	(15.954)	(15.171)	(8.543)	(3.169)	(27.627)	(20.441)	(15.275)
Distance to emigration epicenter (km)	210.730	126.660	223.090	157.615	176.205	97.224	152.175
	(25.821)	(60.018)	(15.647)	(47.628)	(14.815)	(55.661)	(93.997)
District characteristics (1901)							
Agricultural day laborer share	0.303	0.308	0.315	0.320	0.267	0.297	0.166
	(0.055)	(0.078)	(0.037)	(0.075)	(0.078)	(0.079)	(0.098)
Agricultural employment share	0.622	0.645	0.653	0.698	0.535	0.595	0.625
	(0.115)	(0.109)	(0.082)	(0.045)	(0.145)	(0.127)	(0.140)
Finance employment share	0.006	0.006	0.004	0.003	0.010	0.008	0.007
	(0.004)	(0.004)	(0.002)	(0.001)	(0.005)	(0.004)	(0.005)
Construction employment share	0.055	0.038	0.044	0.029	0.086	0.047	0.052
	(0.040)	(0.016)	(0.035)	(0.007)	(0.037)	(0.018)	(0.043)
Building owners per cap.	0.183	0.196	0.180	0.184	0.191	0.208	0.198
	(0.041)	(0.055)	(0.027)	(0.038)	(0.067)	(0.064)	(0.089)
Land owners per cap.	0.157	0.174	0.149	0.163	0.180	0.184	0.216
	(0.048)	(0.056)	(0.034)	(0.042)	(0.070)	(0.065)	(0.114)
Commune financial development							
Bank credit (l./cap., 1905)	5.955	4.659	7.853	4.501	0.654	4.810	0.516
	(31.940)	(35.392)	(37.037)	(46.639)	(3.525)	(19.338)	(11.472)
Bank credit (l./cap., 1905, 25km)	0.463	0.680	0.543	0.886	0.241	0.485	
	(0.328)	(0.912)	(0.332)	(1.104)	(0.182)	(0.624)	
Bank assets (l./cap., 1905)	4.347	4.646	5.561	5.142	0.957	4.172	0.490
	(23.732)	(44.082)	(27.430)	(60.432)	(5.151)	(17.725)	(13.665)
Bank assets (l./cap., 1905, 25km)	0.380	0.785	0.406	1.035	0.305	0.547	
	(0.284)	(1.203)	(0.299)	(1.419)	(0.223)	(0.893)	
Postal credit (l./cap., 1887)	1.698	3.233	1.221	2.163	3.029	4.256	
	(3.276)	(5.267)	(2.762)	(4.496)	(4.183)	(5.735)	
Postal credit (l./cap., 1887, 25km)	0.135	0.140	0.106	0.108	0.216	0.171	
	(0.092)	(0.079)	(0.077)	(0.051)	(0.081)	(0.087)	
Mutual aid membership per cap. (1904)	0.004	0.009	0.005	0.006	0.003	0.011	
	(0.011)	(0.019)	(0.012)	(0.017)	(0.007)	(0.021)	
Mutual aid assets (l./cap., 1904)	0.137	0.149	0.175	0.134	0.032	0.163	
	(0.397)	(0.538)	(0.453)	(0.563)	(0.119)	(0.515)	
Observations	110	632	81	309	29	323	6,968

Notes: Standard deviations in parentheses. Observations are at the commune level. Observation numbers are the minimum with observations for all variables in the Ellis Island-based dataset. Financial measures are expressed in levels for clarity but we use logs for analysis, adding one to each measure before dividing by population to address zeroes. The abbreviation l./cap. in the commune financial development measures denotes lire per capita.

Table 4: Difference-in-differences results

	Ellis Island				Official Data	
			Prime-Age Only			
	(1) All	(2) Deaths	(3) All	(4) Deaths	(5) All	(6) Deaths
Panel A: Sicily and Calabria	−0.071	−0.054	−0.086	−0.070	−0.085	−0.053
District-Clustered b.s. p	(0.577)	(0.640)	(0.527)	(0.570)	(0.456)	(0.665)
Randomization Inference tail mass	{0.266}	{0.314}	{0.228}	{0.278}	{0.224}	{0.310}
District-Clustered b.s. 95% CI	[-0.446 0.393]	[-0.415 0.382]	[-0.463 0.367]	[-0.422 0.382]	[-0.305 0.129]	[-0.292 0.125]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.751	0.751	0.741	0.741	0.618	0.617
Districts	35	35	35	35	35	35
Panel B: Italy	−0.057	−0.040	−0.076	−0.060	−0.068	−0.037
District-Clustered p	(0.662)	(0.746)	(0.553)	(0.627)	(0.393)	(0.645)
Randomization Inference tail mass	{0.212}	{0.274}	{0.120}	{0.166}	{0.200}	{0.320}
District-Clustered 95% CI	[-0.311 0.198]	[-0.285 0.204]	[-0.326 0.175]	[-0.300 0.181]	[-0.223 0.088]	[-0.194 0.121]
Observations	39,525	39,525	37,333	37,333	61,160	61,160
R-squared	0.799	0.799	0.795	0.795	0.788	0.788
Districts	284	284	284	284	284	284
Panel C: Sicily	−0.123	−0.105	−0.124	−0.106	−0.069	−0.037
District-Clustered b.s. p	(0.577)	(0.610)	(0.608)	(0.601)	(0.641)	(0.778)
Randomization Inference tail mass	{0.158}	{0.188}	{0.152}	{0.180}	{0.282}	{0.352}
District-Clustered b.s. 95% CI	[-1.165 0.562]	[-0.761 0.561]	[-0.719 0.546]	[-0.728 0.544]	[-0.519 0.223]	[-0.444 0.226]
Observations	2,708	2,708	2,678	2,678	2,815	2,815
R-squared	0.767	0.767	0.752	0.752	0.672	0.672
Districts	24	24	24	24	24	24
Panel D: Calabria	−0.035	−0.022	−0.065	−0.052	−0.145	−0.117
District-Clustered b.s. p	(0.674)	(0.797)	(0.475)	(0.631)	(0.506)	(0.697)
Randomization Inference tail mass	{0.252}	{0.296}	{0.190}	{0.224}	{0.068}	{0.106}
District-Clustered b.s. 95% CI	[-0.217 0.175]	[-0.184 0.140]	[-0.249 0.127]	[-0.219 0.249]	[-0.624 0.630]	[-0.675 0.759]
Observations	2,896	2,896	2,865	2,865	3,294	3,294
R-squared	0.733	0.733	0.728	0.728	0.516	0.512
Districts	11	11	11	11	11	11

Significance levels, district clustered b.s.: [a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$

Notes: This table presents difference-in-differences coefficients for severe-times-post. P-values from a wild bootstrap clustering at the district level are in parentheses. Tail mass values from a randomization inference test are in curly braces. Ninety-five percent confidence intervals from the wild bootstrap clustered at the district level are in square braces. In panel B, the district-clustered p-values and confidence intervals are based on large-sample approximations, not the bootstrap. Columns (1), (3), and (5) use unadjusted base populations to compute migration rates; columns (2), (4), and (6) use populations adjusted for earthquake deaths. All regressions include commune fixed effects, province-year indicators, and distance from the nearest emigration epicenter-times-post. Observations limited to 1905–1912.

Table 5: Heterogeneous responses with respect to agricultural day labor

	Ellis Island				Official			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Severe x Post	−0.071	0.003	−0.001	0.007	−0.085	−0.041	−0.100	−0.079
District-Clustered b.s. p	(0.569)	(0.977)	(0.996)	(0.959)	(0.430)	(0.443)	(0.400)	(0.294)
Randomization Inference tail mass	{0.266}	{0.488}	{0.436}	{0.436}	{0.224}	{0.392}	{0.294}	{0.262}
District-Clustered b.s. 95% CI	[-0.452 0.393]	[-0.184 0.311]	[-0.161 0.328]	[-0.221 0.305]	[-0.307 0.127]	[-0.188 0.074]	[-0.323 0.124]	[-0.194 0.095]
Severe x Post x Ag Lab Share		0.351^a		0.339^b		0.143^a		0.155
District-Clustered b.s. p		(0.004)		(0.045)		(0.007)		(0.574)
Randomization Inference tail mass		{0.004}		{0.012}		{0.102}		{0.156}
District-Clustered b.s. 95% CI		[0.095 0.599]		[0.014 0.831]		[0.042 0.381]		[-0.265 0.555]
Severe x Post x Ag Share			0.195	0.002			0.154^c	0.064
District-Clustered b.s. p			(0.144)	(0.985)			(0.053)	(0.642)
Randomization Inference tail mass			{0.108}	{0.338}			{0.138}	{0.178}
District-Clustered b.s. 95% CI			[-0.030 0.464]	[-0.331 0.392]			[-0.003 0.282]	[-0.432 0.308]
Observations	5,604	5,604	5,604	5,604	6,109	6,109	6,109	6,109
R-squared	0.751	0.752	0.752	0.752	0.618	0.619	0.621	0.623
Districts	35	35	35	35	35	35	35	35

Significance levels, district-clustered b.s.: [a] p<0.01, [b] p<0.05, [c] p<0.1

Notes: Sample includes all communes in the regions of Sicily and Calabria. Dependent variable is unadjusted emigration rate relative to 1901 population from the source listed in the column header. P-values from a wild bootstrap clustering at the district level are in parentheses. Tail mass values from a randomization inference test are in curly braces. Ninety-five percent confidence intervals from the wild bootstrap clustered at the district level are in square braces. Ag Share is defined as the fraction of the 1901 male labor force in agriculture at the district level, and is standardized to have mean zero and standard deviation one. Ag Lab Share is the share of the 1901 male labor force in agricultural day labor (*giornalieri di campagna*) at the district level and is standardized to have mean zero and standard deviation one in the sample. All regressions include commune fixed effects, province-year indicators, and distance from the nearest emigration epicenter-times-post. Observations limited to 1905–1912.

Table 6: Heterogeneous responses with respect to liquidity

	Ellis Island				Official Data	
			Prime-Age Only			
	(1) All	(2) Deaths	(3) All	(4) Deaths	(5) All	(6) Deaths
a. Severe x Post x District Credit Employment Share	−0.182	−0.168	−0.181	−0.167	−0.138[c]	−0.110[c]
District-Clustered b.s. p	(0.166)	(0.225)	(0.220)	(0.243)	(0.068)	(0.097)
Randomization Inference tail mass	{0.034}	{0.044}	{0.046}	{0.052}	{0.112}	{0.126}
District-Clustered b.s. 95% CI	[-0.472 0.049]	[-0.395 0.064]	[-0.418 0.054]	[-0.448 0.064]	[-0.377 0.018]	[-0.329 0.034]
b. Severe x Post x Credit per capita	−0.111[b]	−0.089	−0.111[b]	−0.089	−0.072[b]	−0.057
District-Clustered b.s. p	(0.014)	(0.154)	(0.045)	(0.268)	(0.036)	(0.160)
Randomization Inference tail mass	{0.050}	{0.084}	{0.056}	{0.106}	{0.034}	{0.076}
District-Clustered b.s. 95% CI	[-0.199 -0.045]	[-0.162 0.068]	[-0.190 -0.006]	[-0.188 0.093]	[-0.124 -0.021]	[-0.091 0.045]
c. Severe x Post x Credit per capita (25km)	−0.273	−0.262	−0.234	−0.223	−0.135	−0.115
District-Clustered b.s. p	(0.468)	(0.480)	(0.474)	(0.531)	(0.766)	(0.896)
Randomization Inference tail mass	{0.004}	{0.006}	{0.022}	{0.024}	{0.012}	{0.016}
District-Clustered b.s. 95% CI	[-1.408 0.640]	[-1.293 0.590]	[-1.160 0.545]	[-1.088 0.540]	[-0.636 0.676]	[-0.888 0.757]
d. Severe x Post x Assets per capita	−0.108[b]	−0.085	−0.105[c]	−0.082	−0.072[b]	−0.057
District-Clustered b.s. p	(0.014)	(0.169)	(0.066)	(0.309)	(0.036)	(0.161)
Randomization Inference tail mass	{0.052}	{0.092}	{0.062}	{0.116}	{0.028}	{0.070}
District-Clustered b.s. 95% CI	[-0.194 -0.040]	[-0.161 0.065]	[-0.185 0.007]	[-0.182 0.088]	[-0.126 -0.021]	[-0.091 0.043]
e. Severe x Post x Assets per capita (25km)	−0.291	−0.278	−0.253	−0.240	−0.138	−0.114
District-Clustered b.s. p	(0.442)	(0.449)	(0.412)	(0.455)	(0.631)	(0.852)
Randomization Inference tail mass	{0.002}	{0.004}	{0.018}	{0.020}	{0.008}	{0.016}
District-Clustered b.s. 95% CI	[-1.253 0.749]	[-1.169 0.651]	[-1.058 0.594]	[-1.020 0.610]	[-0.443 0.599]	[-0.749 0.766]
f. Severe x Post x Postal Credit per capita	−0.028	−0.015	−0.048	−0.034	0.005	0.010
District-Clustered b.s. p	(0.587)	(0.759)	(0.392)	(0.571)	(0.927)	(0.816)
Randomization Inference tail mass	{0.414}	{0.480}	{0.310}	{0.368}	{0.388}	{0.364}
District-Clustered b.s. 95% CI	[-0.128 0.085]	[-0.121 0.095]	[-0.168 0.056]	[-0.162 0.083]	[-0.077 0.154]	[-0.073 0.150]
g. Severe x Post x Postal Credit per capita (25km)	−0.094	−0.077	−0.077	−0.060	−0.048	−0.015
District-Clustered b.s. p	(0.438)	(0.516)	(0.492)	(0.611)	(0.230)	(0.648)
Randomization Inference tail mass	{0.410}	{0.444}	{0.466}	{0.488}	{0.384}	{0.436}
District-Clustered b.s. 95% CI	[-0.476 0.347]	[-0.438 0.254]	[-0.456 0.364]	[-0.412 0.257]	[-0.103 0.068]	[-0.084 0.132]
h. Severe x Post x MA Members per capita	0.139	0.152	0.130	0.144	−0.082	−0.073
District-Clustered b.s. p	(0.121)	(0.136)	(0.201)	(0.198)	(0.118)	(0.124)
Randomization Inference tail mass	{0.022}	{0.014}	{0.012}	{0.010}	{0.026}	{0.046}
District-Clustered b.s. 95% CI	[-0.044 0.439]	[-0.044 0.445]	[-0.066 0.458]	[-0.077 0.564]	[-0.254 0.110]	[-0.234 0.126]
i. Severe x Post x MA Assets per capita	−0.028	−0.007	−0.024	−0.003	−0.055	−0.039
District-Clustered b.s. p	(0.573)	(0.914)	(0.759)	(0.960)	(0.169)	(0.246)
Randomization Inference tail mass	{0.334}	{0.474}	{0.382}	{0.482}	{0.056}	{0.116}
District-Clustered b.s. 95% CI	[-0.129 0.113]	[-0.129 0.176]	[-0.176 0.156]	[-0.169 0.257]	[-0.117 0.075]	[-0.094 0.106]
j. Severe x Post x Network	0.059	0.061	0.017	0.019	−0.009	−0.014
District-Clustered b.s. p	(0.753)	(0.737)	(0.817)	(0.811)	(0.880)	(0.858)
Randomization Inference tail mass	{0.346}	{0.340}	{0.356}	{0.356}	{0.486}	{0.498}
District-Clustered b.s. 95% CI	[-0.209 0.217]	[-0.205 0.210]	[-0.265 0.172]	[-0.286 0.176]	[-0.156 0.137]	[-0.184 0.102]

Significance levels, district-clustered b.s.: [a] p<0.01, [b] p<0.05, [c] p<0.1

This table presents the coefficient on the interaction listed in each row from estimating equation (3) with the listed dimension of heterogeneity as x_i, standardizing it to have mean zero and standard deviation one. Sample includes all communes in Sicily and Calabria. P-values from a wild bootstrap clustered at the district level in parentheses. Tail mass values from the randomization inference test are in curly braces. Ninety-five percent confidence intervals from the wild bootstrap clustered at the district level are in square braces. All regressions include commune fixed effects, province-year indicators, and distance from the nearest emigration epicenter-times-post. Observations limited to 1905–1912.

Table 7: Additional difference-in-differences results with share of district employment in construction and agricultural day labor

	Ellis Island				Official Data	
			Prime-Age Only			
	(1) All	(2) Deaths	(3) All	(4) Deaths	(5) All	(6) Deaths
Panel A						
Severe x Post	0.018	0.025	−0.004	0.002	−0.082	−0.072
District-Clustered b.s. p	(0.957)	(0.930)	(0.981)	(0.993)	(0.643)	(0.701)
Randomization Inference tail mass	{0.428}	{0.448}	{0.382}	{0.394}	{0.250}	{0.278}
District-Clustered b.s. 95% CI	[-0.196 0.460]	[-0.194 0.447]	[-0.225 0.467]	[-0.218 0.415]	[-0.393 0.237]	[-0.381 0.237]
Severe x Post x Constr Share	−0.068	−0.059	−0.081	−0.073	-0.129^{c}	−0.110
District-Clustered b.s. p	(0.276)	(0.356)	(0.232)	(0.241)	(0.079)	(0.148)
Randomization Inference tail mass	{0.186}	{0.200}	{0.142}	{0.158}	{0.030}	{0.032}
District-Clustered b.s. 95% CI	[-0.165 0.111]	[-0.150 0.131]	[-0.186 0.079]	[-0.190 0.084]	[-0.509 0.311]	[-0.493 0.340]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.751	0.751	0.742	0.742	0.620	0.619
Districts	35	35	35	35	35	35
Panel B						
Severe x Post	0.010	0.016	−0.016	−0.009	−0.069	−0.059
District-Clustered b.s. p	(0.933)	(0.854)	(0.888)	(0.940)	(0.555)	(0.610)
Randomization Inference tail mass	{0.444}	{0.452}	{0.406}	{0.434}	{0.246}	{0.268}
District-Clustered b.s. 95% CI	[-0.233 0.295]	[-0.205 0.275]	[-0.201 0.283]	[-0.216 0.294]	[-0.286 0.369]	[-0.271 0.319]
Severe x Post x Constr Share	0.041	0.051	0.021	0.030	−0.089	−0.069
District-Clustered b.s. p	(0.583)	(0.507)	(0.733)	(0.625)	(0.400)	(0.540)
Randomization Inference tail mass	{0.378}	{0.406}	{0.352}	{0.374}	{0.058}	{0.072}
District-Clustered b.s. 95% CI	[-0.151 0.265]	[-0.137 0.267]	[-0.161 0.202]	[-0.139 0.224]	[-0.478 0.121]	[-0.494 0.136]
Severe x Post x Ag Lab Share	0.360^{b}	0.362^{b}	0.337^{b}	0.339^{b}	0.148	0.156
District-Clustered b.s. p	(0.026)	(0.034)	(0.034)	(0.022)	(0.444)	(0.413)
Randomization Inference tail mass	{0.008}	{0.008}	{0.012}	{0.010}	{0.138}	{0.128}
District-Clustered b.s. 95% CI	[0.063 0.922]	[0.047 0.926]	[0.050 0.817]	[0.057 0.837]	[-0.269 0.434]	[-0.248 0.429]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.752	0.752	0.743	0.743	0.621	0.620
Districts	35	35	35	35	35	35

Significance levels, district-clustered b.s.: ^{a} p<0.01, ^{b} p<0.05, ^{c} p<0.1

Notes: Sample includes all communes in the regions of Sicily and Calabria. The construction labor share and the agricultural labor share are both at the district level and are both standardized to have mean zero and standard deviation one. P-values from a wild bootstrap clustered at the district level in parentheses. Tail mass values from the randomization inference test are in curly braces. Ninety-five percent confidence intervals from the wild bootstrap clustered at the district level are in square braces. All regressions include commune fixed effects, province-year indicators, and distance from the nearest emigration epicenter-times-post. Observations limited to 1905–1912.

Table 8: Additional difference-in-differences results with district property owners per capita and share of district employment in agricultural day labor

	Ellis Island				Official Data	
			Prime-Age Only			
	(1) All	(2) Deaths	(3) All	(4) Deaths	(5) All	(6) Deaths
Severe x Post	−0.031	−0.018	−0.046	−0.033	−0.080	−0.057
District-Clustered b.s. p	(0.528)	(0.719)	(0.371)	(0.531)	(0.415)	(0.711)
Randomization Inference tail mass	{0.366}	{0.398}	{0.304}	{0.350}	{0.106}	{0.178}
District-Clustered b.s. 95% CI	[-0.155 0.106]	[-0.141 0.138]	[-0.175 0.086]	[-0.160 0.110]	[-0.276 0.083]	[-0.283 0.087]
Severe x Post x Building Owners per capita	0.336	0.316	0.321[c]	0.301	0.196[b]	0.156[c]
District-Clustered b.s. p	(0.138)	(0.243)	(0.067)	(0.120)	(0.017)	(0.054)
Randomization Inference tail mass	{0.002}	{0.002}	{0.002}	{0.004}	{0.146}	{0.194}
District-Clustered b.s. 95% CI	[-0.051 0.666]	[-0.069 0.658]	[-0.012 0.636]	[-0.031 0.554]	[0.074 0.331]	[-0.006 0.281]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.752	0.752	0.743	0.743	0.621	0.620
Districts	35	35	35	35	35	35
Severe x Post	−0.042	−0.028	−0.055	−0.042	−0.084	−0.058
District-Clustered b.s. p	(0.612)	(0.741)	(0.543)	(0.617)	(0.299)	(0.583)
Randomization Inference tail mass	{0.310}	{0.350}	{0.284}	{0.340}	{0.104}	{0.176}
District-Clustered b.s. 95% CI	[-0.264 0.151]	[-0.254 0.166]	[-0.275 0.152]	[-0.240 0.166]	[-0.247 0.073]	[-0.246 0.087]
Severe x Post x Land Owners Per Capita	0.252	0.239	0.243	0.229	0.177[b]	0.151[b]
District-Clustered b.s. p	(0.250)	(0.348)	(0.235)	(0.290)	(0.044)	(0.033)
Randomization Inference tail mass	{0.008}	{0.008}	{0.004}	{0.008}	{0.162}	{0.192}
District-Clustered b.s. 95% CI	[-0.107 0.616]	[-0.106 0.619]	[-0.087 0.556]	[-0.088 0.531]	[0.008 0.321]	[0.016 0.266]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.752	0.752	0.742	0.742	0.621	0.619
Districts	35	35	35	35	35	35
Severe x Post	−0.027	−0.014	−0.038	−0.026	−0.074	−0.050
District-Clustered b.s. p	(0.615)	(0.809)	(0.490)	(0.663)	(0.537)	(0.711)
Randomization Inference tail mass	{0.396}	{0.422}	{0.348}	{0.378}	{0.136}	{0.222}
District-Clustered b.s. 95% CI	[-0.150 0.088]	[-0.141 0.100]	[-0.165 0.079]	[-0.162 0.106]	[-0.257 0.094]	[-0.241 0.110]
Severe x Post x Building Owners per capita	0.748	0.694	0.703	0.651	0.220	0.101
District-Clustered b.s. p	(0.228)	(0.273)	(0.206)	(0.254)	(0.612)	(0.738)
Randomization Inference tail mass	{0.016}	{0.018}	{0.016}	{0.016}	{0.154}	{0.272}
District-Clustered b.s. 95% CI	[-0.994 2.287]	[-1.098 1.633]	[-0.831 1.423]	[-0.848 1.323]	[-0.951 0.600]	[-1.020 0.481]
Severe x Post x Land Owners per capita	−0.410	−0.376	−0.382	−0.350	−0.028	0.051
District-Clustered b.s. p	(0.294)	(0.301)	(0.315)	(0.359)	(0.918)	(0.808)
Randomization Inference tail mass	{0.058}	{0.062}	{0.072}	{0.082}	{0.442}	{0.408}
District-Clustered b.s. 95% CI	[-1.322 0.570]	[-1.512 0.706]	[-1.205 0.571]	[-1.194 0.628]	[-0.378 0.884]	[-0.291 0.944]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.752	0.752	0.743	0.743	0.621	0.620
Districts	35	35	35	35	35	35
Severe x Post	−0.005	0.008	−0.020	−0.008	−0.048	−0.024
District-Clustered b.s. p	(0.936)	(0.897)	(0.705)	(0.910)	(0.304)	(0.634)
Randomization Inference tail mass	{0.448}	{0.494}	{0.414}	{0.450}	{0.218}	{0.298}
District-Clustered b.s. 95% CI	[-0.156 0.141]	[-0.160 0.164]	[-0.147 0.115]	[-0.162 0.139]	[-0.177 0.068]	[-0.163 0.080]
Severe x Post x Building Owners per capita	0.506	0.453	0.473	0.423	0.044	−0.076
District-Clustered b.s. p	(0.144)	(0.180)	(0.103)	(0.148)	(0.880)	(0.828)
Randomization Inference tail mass	{0.064}	{0.078}	{0.094}	{0.116}	{0.352}	{0.394}
District-Clustered b.s. 95% CI	[-0.383 2.161]	[-0.414 2.215]	[-0.175 1.895]	[-0.289 2.111]	[-1.223 1.298]	[-1.119 1.269]
Severe x Post x Land Owners per capita	−0.281	−0.249	−0.259	−0.228	0.067	0.146
District-Clustered b.s. p	(0.227)	(0.289)	(0.252)	(0.298)	(0.804)	(0.641)
Randomization Inference tail mass	{0.152}	{0.174}	{0.212}	{0.238}	{0.356}	{0.264}
District-Clustered b.s. 95% CI	[-1.585 0.564]	[-1.596 0.708]	[-1.557 0.447]	[-1.650 0.437]	[-1.101 0.920]	[-1.246 0.876]
Severe x Post x Ag Lab Share	0.184[b]	0.183[b]	0.173[c]	0.172[c]	0.119	0.121
District-Clustered b.s. p	(0.038)	(0.030)	(0.066)	(0.069)	(0.391)	(0.456)
Randomization Inference tail mass	{0.084}	{0.088}	{0.212}	{0.124}	{0.106}	{0.106}
District-Clustered b.s. 95% CI	[0.034 0.330]	[0.040 0.337]	[-0.051 0.321]	[-0.037 0.331]	[-0.094 0.367]	[-0.105 0.375]
Observations	5,604	5,604	5,543	5,543	6,109	6,109
R-squared	0.753	0.752	0.743	0.743	0.622	0.621
Districts	35	35	35	35	35	35

Significance levels, district-clustered b.s.: [a] p<0.01, [b] p<0.05, [c] p<0.1

Notes: Sample includes all communes in the regions of Sicily and Calabria. The interaction variables are all at the district level and are all standardized to have mean zero and standard deviation one. P-values from a wild bootstrap clustered at the district level in parentheses. Tail mass values from the randomization inference test are in curly braces. Ninety-five percent confidence intervals from the wild bootstrap clustered at the district level are in square braces. All regressions include commune fixed effects, province-year indicators, and distance from the nearest emigration epicenter-times-post. Observations limited to 1905–1912.

Figures

Figure 1: Map of districts in the affected area

Note: Districts in the provinces of Messina and Reggio Calabria are labeled. The earthquake epicenter is indicated by the large dot.

(a) Mercalli scores

(b) Severity indicator

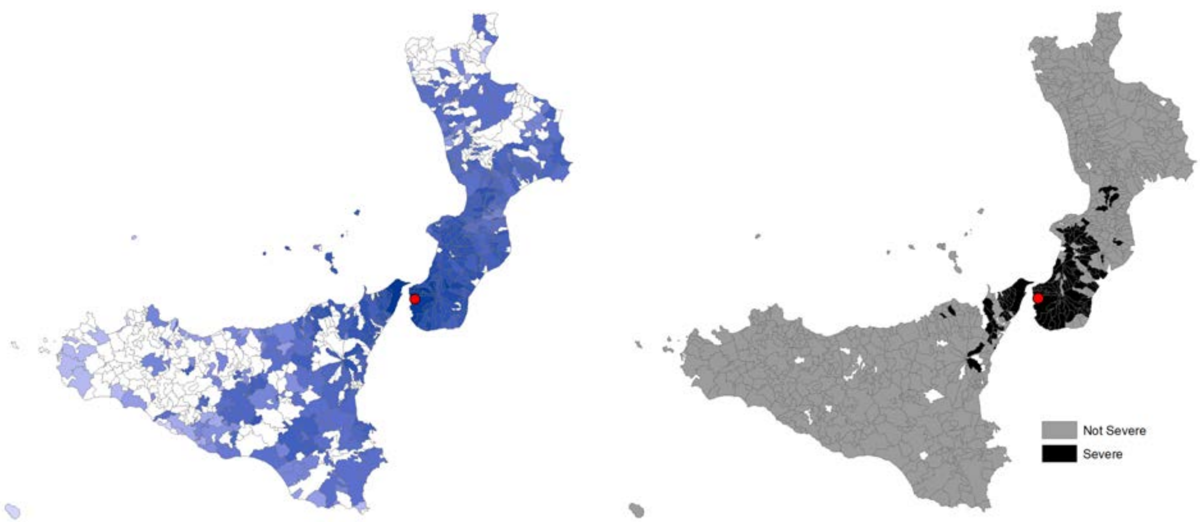

Figure 2: Earthquake damage

Note: The large dot indicates the earthquake epicenter. Panel (a) presents the Mercalli scores derived from Guidoboni et al. (2007), as described in text. Darker colors indicate higher Mercalli severity; white communes have no data. Panel (b) presents the severity indicator, which takes a value of one for communes with Mercalli severity of VIII or greater. White communes in panel (b) are those that were created in the 1920s or later. In some cases, there are migrants assigned to these communes (based on geographic location), but they are reassigned to the original commune, which is necessary due to the absence of population data for these new communes.

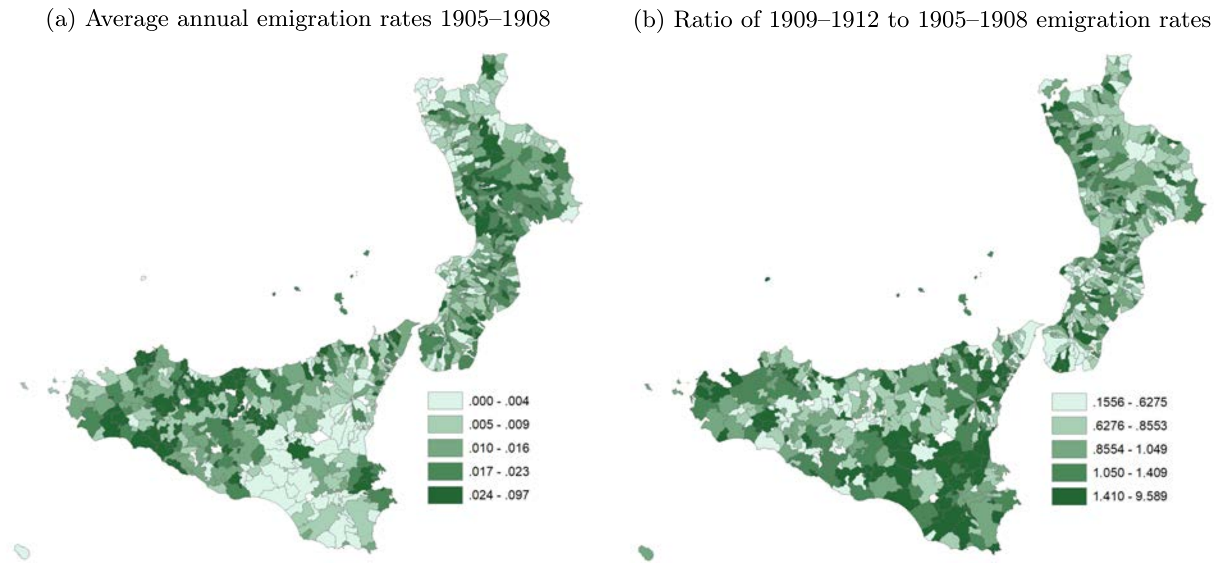

Figure 3: Commune-level emigration rates

Note: Data are from Ellis Island. Panel (a) shows average annual emigration rates for 1905–1908. Panel (b) shows the ratio of the average annual emigration rate for 1909–1912 to that for 1905–1908. Both map scales are based on quantiles of the distribution.

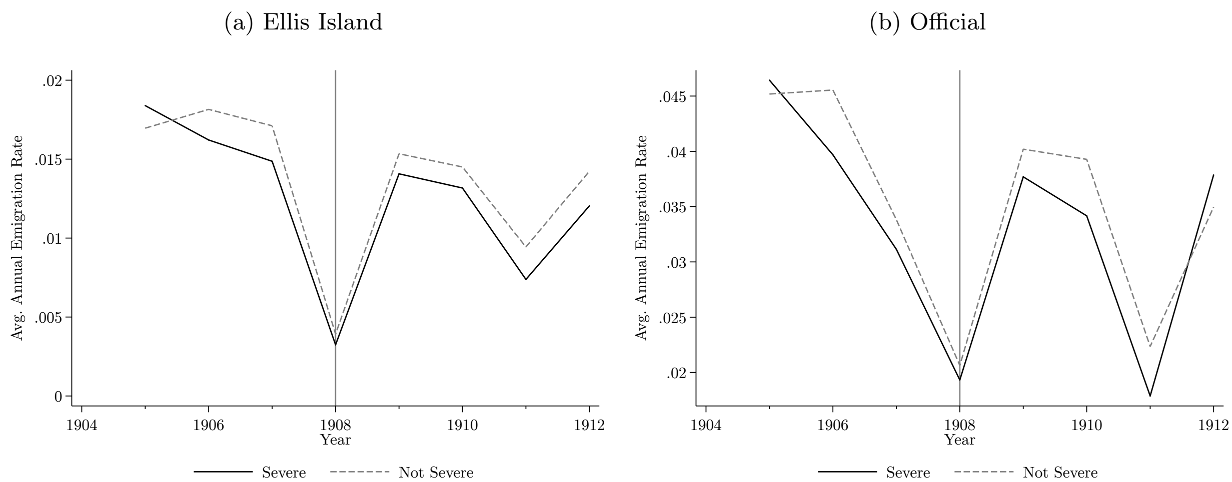

Figure 4: Emigration trends for Sicily and Calabria

Note: "Severe" indicates communes experiencing severe damage from the earthquake. "Not Severe" indicates all communes in Sicily and Calabria not experiencing severe damage from the earthquake. These are average annual emigration rates across communes (i.e., they are not weighted by commune population).

(a) Ellis Island (b) Official

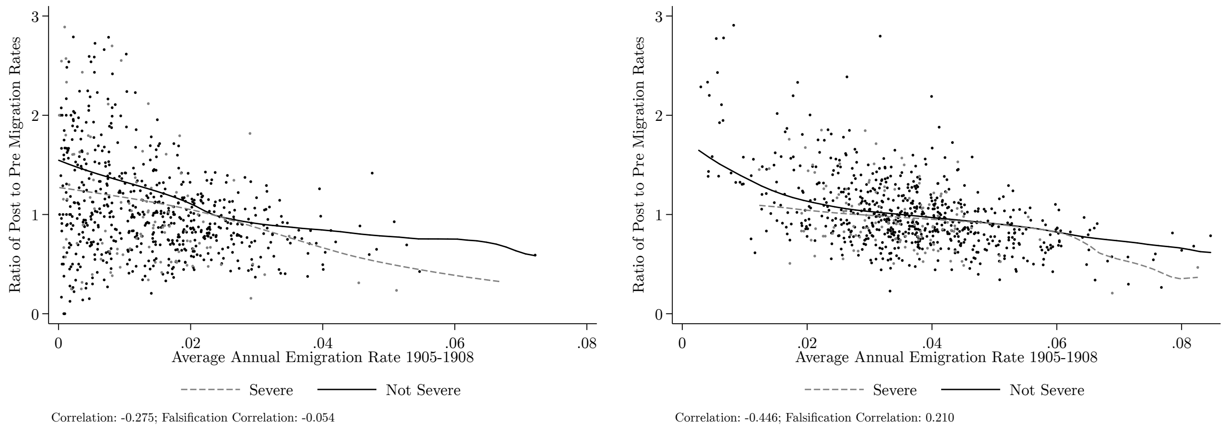

Figure 5: β-convergence in emigration rates

Note: "Severe" indicates communes experiencing severe damage from the earthquake. "Not Severe" indicates all communes in Sicily and Calabria not experiencing severe damage from the earthquake. This figure plots the change in emigration rates over the period 1905–1908 to 1909–1912 (i.e., the ratio of the latter to the former) against the average annual emigration rate for 1905–1908 at the commune level using data from Ellis Island. Communes that more than tripled their migration (27 in panel a and 2 in panel b) are omitted from the scatterplots (but not the non-parametric regressions) for clarity. One commune in panel (a) with a 1905–1908 migration rate over 0.08 is also omitted from the scatter plot for clarity.

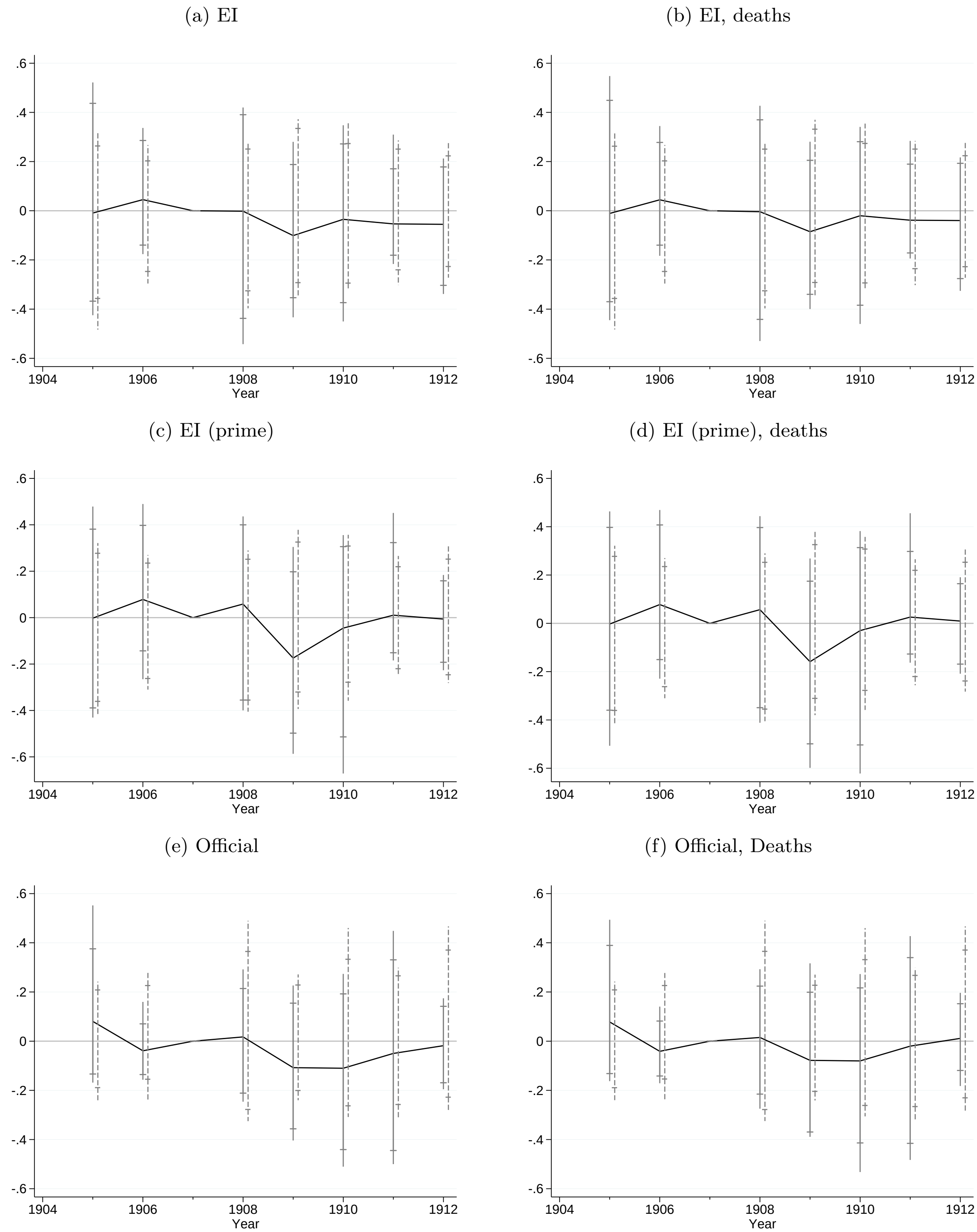

Figure 6: Event studies for the effect of the earthquake on migration

Note: Sample includes all communes in the regions of Sicily and Calabria. All event studies control for a year-specific function of distance from the nearest emigration epicenter and have 1907 as the base year. Solid bars are 90- and 95-percent confidence intervals from a wild bootstrap clustered on the district level. dashed bars are the middle 90 and 95 percent of randomization inference replications. The measure on the y-axis is the effect in logs.

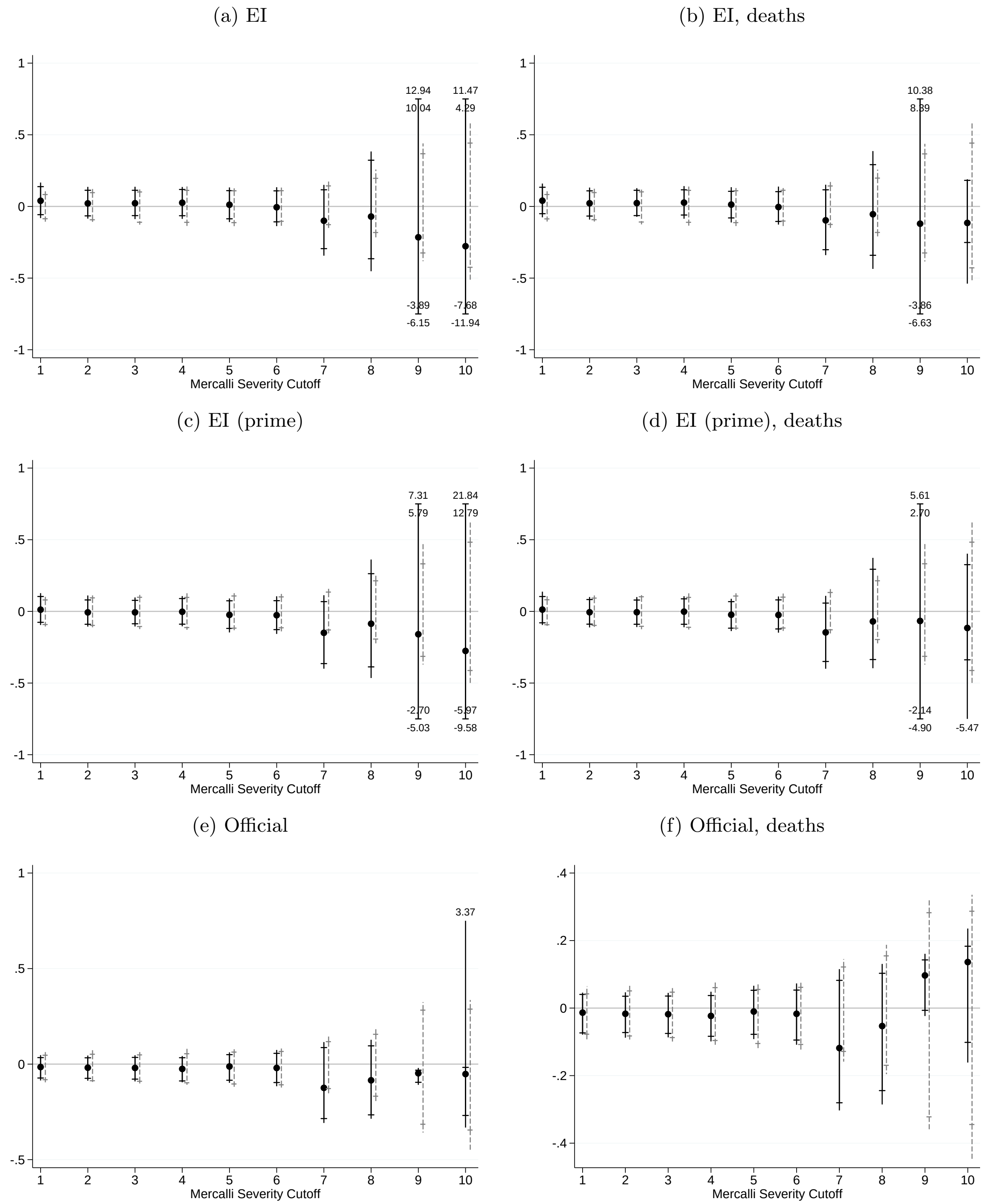

Figure 7: Difference-in-differences results varying Mercalli cutoffs for severity

Note: These figures present the estimated difference-in-differences coefficient from estimating equation (1) with the value listed on the x-axis as the Mercalli score cutoff for defining severe damage. Sample includes all communes in the regions of Sicily and Calabria. Solid bars are 90- and 95-percent confidence intervals from the wild bootstrap, clustered on the district level. Dashed bars are the middle 90- and 95-percent of results from the randomization inference permutations. When the absolute value of the extreme of a confidence interval exceeds 0.75, the interval is truncated and the true value listed either outside the interval (95-percent) or inside the interval (90-percent).

Figure 8: Event studies at the district level

Note: Sample includes all districts in Italy. Bars represent 90- and 95-percent ranges of estimates from the randomization inference exercise. The measure on the y-axis is the year-specific effect in terms of log migration rates.

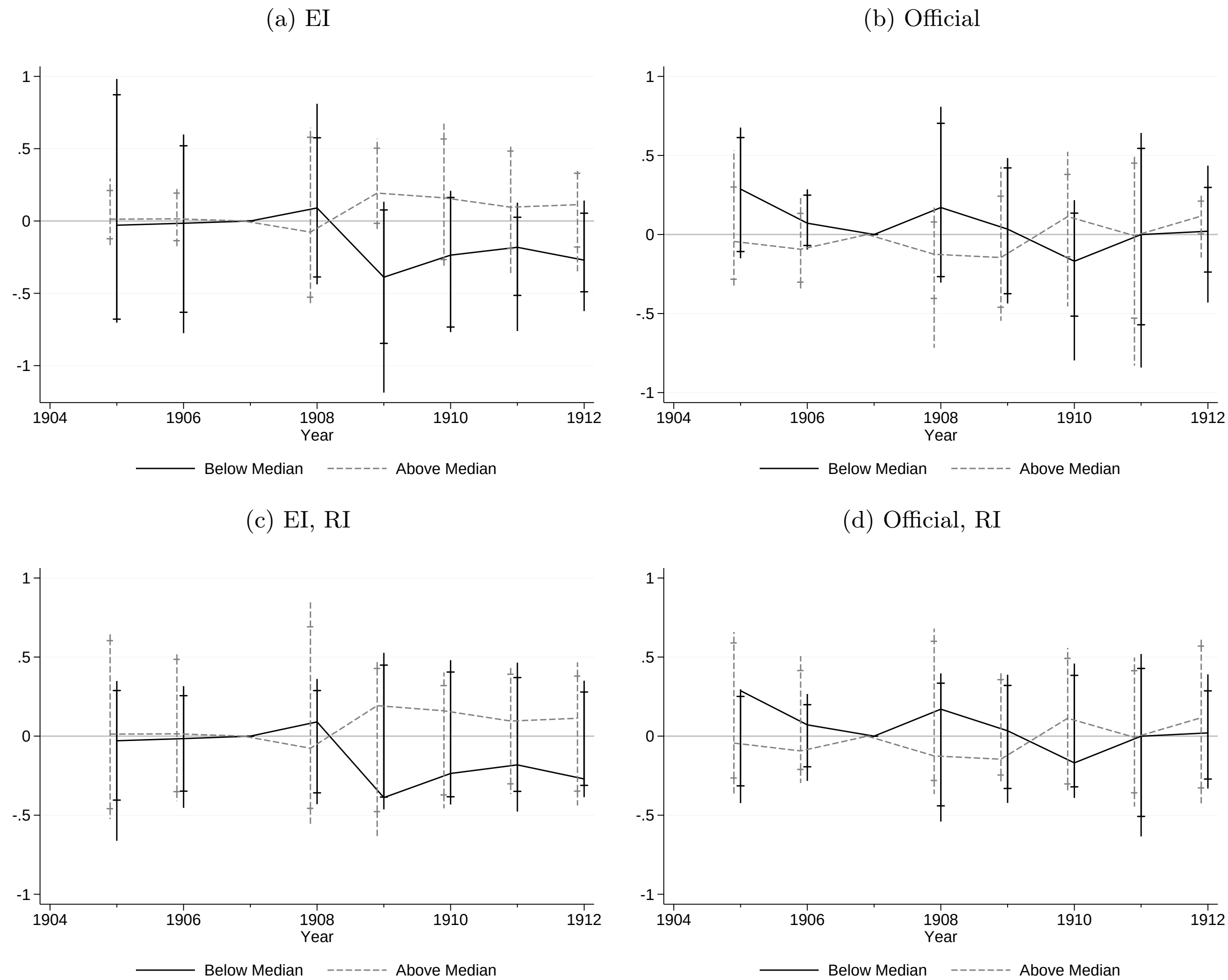

Figure 9: Event studies divided by share of district employment in agricultural day labor

Note: Sample includes all communes in the regions of Sicily and Calabria. All event studies control for a year-specific function of distance from the nearest emigration epicenter and have 1907 as the base year. In panels (a) and (b), bars indicate 90- and 95-percent confidence intervals clustered on the district level, computed by a wild bootstrap. In panels (c) and (d), bars indicate the middle 90 and 95 percent of estimates from the randomization inference exercise. The division into "below median" and "above median" is based on the distribution of the share of employment in agricultural day labor in the sample. The measure on the y-axis is the effect in logs.

A Demographic Accounting for Messina and Reggio Calabria

In this section, we use data on births, deaths, and emigration from the communes of Messina and Reggio Calabria to compute a plausible upper bound for the possible internal migration to Messina and Reggio Calabria following the earthquake. This analysis has the additional benefit of providing new estimates of death tolls from the earthquake for these two communes.

We begin by observing that the 1911 local-born population of a commune can be written as

$$n^{\ell}_{1911} = n^{\ell}_{1901} + b^{\ell} - d^{\ell}_{ne} - e^{\ell} + r^{\ell} + i^{\ell} - d^{\ell}_{e}, \tag{A.1}$$

where n^{ℓ}_{1911} is the local-born population in 1911, n^{ℓ}_{1901} is the local-born population in 1901, b^{ℓ} represents total births in the commune in 1901–1911, d^{ℓ}_{ne} represents total non-earthquake deaths of local-born individuals in 1901–1911, e^{ℓ} is the total international emigration of local-born individuals in 1901–1911, r^{ℓ} is the total return international migration of local-born individuals over 1901–1911, i^{ℓ} represents net in-migration of Messina-born individuals from domestic sources, and d^{ℓ}_{e} is the death toll of local-born individuals from the earthquake. The local-born population in 1901 and 1911, n^{ℓ}_{1901} and n^{ℓ}_{1911} is known from the census. Total births are known from the *Movimento dello Stato Civile* for years 1911–1911, which also provides information on total non-earthquake deaths, which we assign to the local-born and non-local-born groups according to their shares of 1901 population. Emigration data are from the *Statistica della Emigrazione Italiana per l'Estero* and are assigned to local-born and non-local-born groups in the same manner as deaths. Data on return migration are available from the *Annuario Statistico della Emigrazione Italiana dal 1876 al 1925*, but are only at the province-level and only for the period 1905-1911; we estimate the number of return migrants by using the province-level ratio of return migrants to emigrants over this period.

Table A.1 presents these figures. The remaining missing pieces in equation (A.1) are the domestic in-migrants i^{ℓ} and the earthquake deaths d^{ℓ}_{e}. In Table A.1, we impose the assumption that $i^{\ell} = 0$; that is, that there was no net in-migration or out-migration of local-born individuals.[101] We view this as an upper bound on the true in-migration flow. In reality, we expect that this figure was negative, reflecting a net movement of individuals out of their birth communes. Indeed, this must be the case unless there were a substantial flow of, for instance, Messina-born individuals living outside Messina back to their hometown after the earthquake, and similarly for Reggio Calabria. This upper bound on i^{ℓ} implies an upper bound on earthquake deaths d^{ℓ}_{e}, which we estimate as 29,845 for Messina-born individuals living in Messina and 7,782

[101] To be concrete, this means that there was no net movement of Messina-born individuals to Messina from elsewhere in Italy and similarly for Reggio Calabria.

for Reggio Calabria-born individuals living in Reggio Calabria.

We observe next that the non-local-born population of a commune can be written in a manner similar to equation (A.1), but omitting births. This yields a demographic law of motion of the form

$$n^f_{1911} = n^f_{1901} - d^f_{ne} - e^f + r^f + i^f - d^f_e, \tag{A.2}$$

where all terms are defined and computed analogously to those in equation (A.1). Our goal in equation (A.2) is to determine an upper bound for i^f, the net inflow of individuals born in other communes. To do this, we use the estimated death toll from Table A.1 and the assumption that deaths were randomly distributed between local-born and non-local born individuals according to their 1901 population shares to produce estimates of 5,348 deaths in Messina and 1,516 deaths in Reggio Calabria. These figures yield estimates of total deaths from the earthquake—35,193 in Messina, well short of the official count, and 9,298 in Reggio Calabria, above the official count. Note that, since these are upper bounds, they show that the official Messina death count, as suspected, is dramatically overstated, while that for Reggio Calabria is plausible.

We compute our estimates of i^f in Table A.2, arriving at 10,581 for Messina and 7,623 for Reggio Calabria. Note that these are also upper bounds. Moreover, it is important to realize that these are estimates of the total rate of in-migration over the entire period 1901–1911. Nonetheless, these figures are small relative to the 1901 province populations of 543,809 in Messina and 428,714 in Reggio Calabria, corresponding to average annual rates of about 2 per thousand (relative to average international emigration rates of over 25 per thousand).

Not all of these in-migrants, however, would have come in response to the shock of the earthquake. Indeed, there was likely some base level of population movement that would have occurred in the absence of the shock. Table A.2 also includes rough estimates of how many of these internal migrants were excess internal migrants driven by the earthquake. One reasonable approximation of the population inflow that would have occurred in the absence of the earthquake is that in-migration would have occurred to replace (non-earthquake) deaths and net international emigration of foreign-born individuals. The estimate $\hat{i^f}'$ in Table A.2 provides an estimate of in-migration after removing such replacements. This estimate is considerably smaller than the previous one, yielding a total in-migration of only 3,119 for Messina and 4,908 for Reggio Calabria.

Even these, however, are likely over-estimates of excess internal migration arising from the earthquake. Even if there were an internal migrant to replace each non-local-born resident of a city that died or emigrated, natural growth of the local population would have led to a reduction in the share of the non-local-born population. Another reasonable assumption is to assume that, in the absence of the earthquake, the share of non-local-born individuals in total population would have remained constant. Under this assumption we produce the estimate $\hat{i^f}''$ in Table A.2, which indicates a *negative* inflow of individuals from outside of Messina into it—that is, a small net out-migration of 562 individuals—and an inflow to Reggio Calabria of only 3,492 individuals, again small as compared to the province population of over 400,000.

Table A.1: Demographic accounting for Messina and Reggio Calabria, 1901–1911, locally born

		(1) Messina	(2) Reggio Calabria
n^ℓ_{1901}	Population 1901	127,017	37,175
b^ℓ	Total births 1901–1911	50,495	17,074
d^ℓ_{ne}	Non-earthquake deaths 1901–1911*	29,954	9,805
e^ℓ	Total emigrants, 1901–1911**	18,399	6,554
r^ℓ	Return migration based on provincial rates 1905–1911†	6,711	2,422
i^ℓ	Assumed net domestic in-migration	0	0
$\hat{n}^\ell_{1911}$	Implied population absent earthquake 1911‡	135,870	40,312
n^ℓ_{1911}	Actual population 1911	106,025	32,530
$\hat{d}^\ell_e$	Estimated earthquake deaths§	29,845	7,782

*: computed as $d_{ne} \times \frac{n^\ell_{1901}}{n^\ell_{1901}+n^f_{1901}}$, where d_{ne} represents total deaths regardless of birthplace

**: computed as $e \times \frac{n^\ell_{1901}}{n^\ell_{1901}+n^f_{1901}}$, where e represents total emigrants from the commune regardless of birthplace

†: return migrants are the product of e^ℓ and the province-level ratio of return migration to emigration for 1905–1911

‡: computed as $\hat{n}^\ell_{1911} = n^\ell_{1901} + b^\ell - d^\ell_{ne} - e^\ell + r^\ell$

§: computed as $\hat{d}^\ell_e = \hat{n}^\ell_{1911} - n^\ell_{1911}$

Sources: The total population by birthplace data are from Table 1. The birth and death figures are from the *Movimento dello Stato Civile* for 1901–1911. The emigration data are from the *Statistica della Emigrazione Italiana per l'Estero* for the commune level and from the *Annnuario Statistico della Emigrazione Italiana dal 1876 al 1925* for the province level. The return migration data, which are available only beginning in 1905, are from the *Annnuario Statistico della Emigrazione Italiana dal 1876 al 1925.*

Table A.2: Demographic accounting for Messina and Reggio Calabria, 1901–1911, non-locally born

		(1) Messina	(2) Reggio Calabria
n^f_{1901}	Population 1901	22,761	7,240
d^f_{ne}	Non-earthquake deaths 1901–1911*	5,368	1,910
e^f	Total emigrants, 1901–1911**	3,297	1,277
r^f	Return migration based on provincial rates 1905–1911†	1,203	472
$\hat{d}^f_e$	Estimated earthquake deaths‡	5,348	1,516
$\hat{n}^f_{1911}$	Implied population absent in-migration, 1911§	9,951	3,009
n^f_{1911}	Actual population 1911	20,532	10,632
$\hat{i}^f$	Estimated domestic in-migration, 1901–1911$^{\|\|}$	10,581	7,623
$\hat{i^f}'$	Net of replacement¶	3,119	4,908
$\hat{i^f}''$	Net of replacement and population growth#	-562	3,492

*: computed as $d_{ne} \times \frac{n^f_{1901}}{n^\ell_{1901}+n^f_{1901}}$, where d_{ne} represents total deaths regardless of birthplace

**: computed as $e \times \frac{n^f_{1901}}{n^\ell_{1901}+n^f_{1901}}$, where e represents total emigrants from the commune regardless of birthplace

†: return migrants are the product of e^f and the province-level ratio of return migration to emigration for 1905–1911

‡: computed as $\hat{d}^f_e = \hat{d}^\ell_e \times \frac{n^f_{1901}}{n^\ell_{1901}}$

§: computed as $\hat{n}^f_{1911} = n^f_{1901} - d^f_{ne} - e^f + r^f - \hat{d}^f_e$

||: computed as $\hat{i}^f = n^f_{1911} - \hat{n}^f_{1911}$

¶: computed as $\hat{i}^f - d^f_{ne} - e^f + r^f$

#: computed as $\hat{i^f}'' = \hat{i^f}' - \frac{b^\ell - d^\ell_{ne}}{n^\ell_{1901}} n^f_{1901}$

Sources: The total population by birthplace data are from Table 1. The birth and death figures are from the *Movimento dello Stato Civile* for 1901–1911. The emigration data are from the *Statistica della Emigrazione Italiana per l'Estero* for the commune level and from the *Annnuario Statistico della Emigrazione Italiana dal 1876 al 1925* for the province level. The return migration data, which are available only beginning in 1905, are from the *Annnuario Statistico della Emigrazione Italiana dal 1876 al 1925*.