Italian Economic Journal (2024) 10:269–291
https://doi.org/10.1007/s40797-023-00226-6

RESEARCH PAPER

Migration Responses to Earthquakes: Evidence from Italy

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Received: 11 June 2022 / Accepted: 1 April 2023 / Published online: 27 April 2023

Abstract

In this paper, we analyze the migration responses to natural disasters by focusing on the three most devastating earthquakes in Italy in recent decades: L'Aquila 2009, Emilia Romagna 2012, and Central Italy 2016. Using municipality-level data for 2002–2019 and adopting a new difference-in-difference approach with multiple periods and multiple groups, we evaluate the causal effect of these events on internal and international inbound and outbound migration of both Italian and foreign citizens. The results suggest that, despite the massive destruction, there is no evidence that these earthquakes significantly impacted the migration of Italian citizens. We only found evidence of the effect of the earthquake in L'Aquila on the short-distance migration of foreign citizens.

Keywords Natural disasters · Migration · Counterfactual analysis · Difference-in-difference

JEL Classification F22 · J61 · R23 · C14 · C21

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1 Introduction

Natural disasters always affect human life, suddenly changing its social and economic environment and forcing it to react promptly to the emergency that arises. The changes in the populations affected by these events may depend on the nature and intensity of the phenomenon and many other economic and cultural factors. Generally, however, the affected territories lose population due to both natural and migratory dynamics (e.g. Gráda 2019; Mahajan and Yang 2020). Both internal and international emigrations can represent valid adjustment mechanisms to cope with the negative economic impact of any natural disaster. However, natural disasters can also hinder emigration by tightening the liquidity constraints of potential migrants (Cattaneo and Peri 2016), generating remittances or other financial inflows to affected areas (Yang 2008), raising risk aversion of the local population (Beine et al. 2021), or creating new job opportunities in the area hit by the disaster and thus generating immigration flows (Halliday 2006). Indeed, the final effect on net migration flows can be ambiguous.

In this study, wholly natural and unpredictable phenomena are considered: earthquakes. In particular, the reference events are the earthquakes that hit: (i) L'Aquila and surrounding municipalities in 2009, (ii) Emilia Romagna in 2012, and (iii) Central Italy in 2016. A comprehensive understanding of the effects of natural disasters on internal and international migration in Italy over the last 20 years, based on a counterfactual analysis (such as difference-in-difference or synthetic control), is still lacking. Most studies focus on international or internal migration, while both can be possible adjustment mechanisms (Bekaert et al. 2021). Furthermore, some are based on a simple descriptive rather than an adequate counterfactual analysis. Finally, they all focus on the effect of a single event due to the difficulties of a multi-treatment analysis.

Adopting a new difference-in-difference (DID) approach with multiple periods and multiple groups (Callaway and Sant'Anna 2021), this study aims to evaluate the causal effect of the three recent major earthquakes in Italy on internal and international inbound and outbound migration. The municipalities affected by the three events represent our groups of treated. The other municipalities in the same regions of the affected areas make up the control group. Compared to case-study analyses, this approach allows us to consider the effect of more than one event and evaluate the heterogeneity of the treatment effect.

More specifically, we try to answer the following research questions: Does migration serve as an adjustment mechanism and provide relief in the face of negative economic shocks in the aftermath of earthquakes, in line with Mahajan and Yang (2020) and Gráda (2019)? (RQ-1) Do new economic opportunities or exigencies linked to the reconstruction process stimulate new immigration flows, in line with Halliday (2006)? (RQ-2) Lastly, are these effects heterogeneous by the time of earthquake occurrence? (RQ-3)

Section 2 provides a brief review of the literature. Section 3 describes the three earthquakes and their consequences. Section 4 presents the migration data. Section 5 describes the methodology used. Section 6 discusses the results of the DID analysis. Section 7 concludes.

2 Literature Review

There is a growing body of literature on the effect of natural disasters on migration, but it is still primarily based on case studies. Beine and Parsons (2015) do not find a significant relationship between natural disasters in origin countries and international migration. However, they do provide evidence of an indirect effect of natural disasters on international migration flows, observing the widening wage gap between origin and destination countries. In a related study, Cattaneo and Peri (2016) find no evidence that natural disasters such as droughts, floods, and storms affect emigration rates in poor and middle-income countries. Looking at Italy, Spitzer et al. (2022) analyze whether emigration trends of severely damaged municipalities in Sicily and Calabria differed from those of other municipalities in the same regions due to the Messina-Reggio Calabria earthquake. The lack of a significant positive impact on international migration, despite the absence of legal restrictions on migration, adds to recent evidence in the literature that international emigration is not affected by natural disasters (e.g. Beine et al. 2019; Nawrotzki and DeWaard 2018).

Less evidence exists on the effect of natural disasters on internal migration. For the case of Italy, Ambrosetti and Petrillo (2016) analyze post-seismic population movements after the L'Aquila earthquake. The increased out-flows from L'Aquila to other provinces of Abruzzo seem to be based on an existing regular pattern of exchanges between the localities of the province of L'Aquila, suggesting that the management of the post-seismic reconstruction and recovery process had a role in exacerbating population displacement and social fragmentation.

Meta-analyses of contributions to the literature on the relationship between environmental disasters and migration have recently been conducted, collecting studies at micro and macro-level (e.g. Beine and Jeusette 2021; Cipollina et al. 2021). In particular, Cipollina et al. (2021) provide a systematic review of the literature on the impact of both slow-onset and fast-onset events on internal and international migration flows. According to the authors, this literature does not offer elements for identifying a clear and homogeneous causal link between environmental disasters and migration. Among the studies which find a significant impact of natural disasters, the analysis carried out by Drabo and Mbaye (2015) is worth mentioning. Disaggregating the population by educational level, they find evidence of brain drain effects in countries frequently affected by fast-onset disastrous events.

More generally, the evidence on the relationship between natural disasters and migration is quite mixed. While some studies have shown an increase in migration flows following natural disasters, others have found a negative or zero impact of these events on normal demographic dynamics (Mbaye and Zimmermann 2015). Furthermore, the effects may also differ depending on the type of natural disaster and the socioeconomic characteristics of the population or pre-existing criticalities in the affected area.

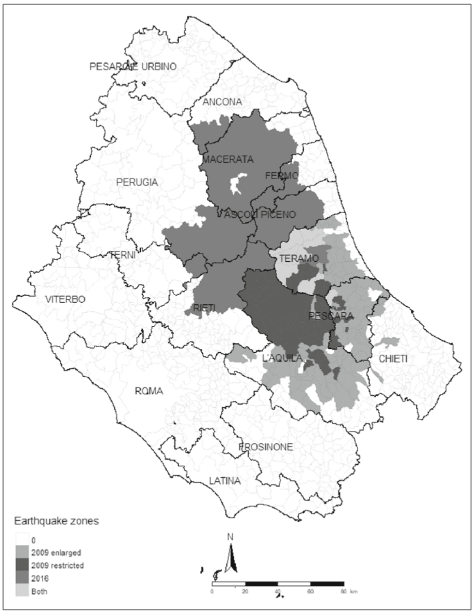
This study focuses on wholly natural and unpredictable phenomena: earthquakes. An earthquake can have different effects on demographic dynamics, linked to the degree of intensity of the phenomenon and the social and environmental characteristics of the affected population and territory, especially if demographic vulnerabilities are already present (Reynaud et al. 2020). The already-established migration patterns can also be essential to understanding the earthquake's migration response. For example, it is well known that migration in Italy is characterized by a relatively large share of repeat and temporary migrants (e.g. Spitzer and Zimran 2018), and this may be important in the case of responding to a natural disaster. Indeed, there is reason to believe that a temporary migration might be more responsive to a natural disaster than a permanent one (Bohra-Mishra et al. 2014). Moreover, Italian migration patterns follow a spatial diffusion process through immigrants' social networks (Zimran 2022). Finally, Lamonica and Zagaglia (2013) underline some differences in the determinants of migration among Italian and foreign citizens: while Italians mainly move towards highly-populated regions, foreign citizens make more varied choices, but both of them seem to be equally discouraged from migrating over long distances. This evidence may also be relevant to understand the response of migration to natural disasters in Italy.

Many studies provide descriptive demographic analysis comparing the situation before and after one of the most recent destructive earthquakes in Italy (L'Aquila, 2009). Among these, Pesaresi (2012) point out that the foreign component of immigration flows played a fundamental role in the demographic increase in the Abruzzo region after the quake. In a more recent study, Mannella et al. (2017) discuss the trend of the population returning home after the reconstruction process of the L'Aquila earthquake. The number of people returning home was 21,960 (41% of displaced people) after 1 year and 8 months from the earthquake, 42,408 (79%) after 6 years and 8 months from the earthquake, and 43,134 (80%) after about 8 years from the earthquake. As for the effect of the L'Aquila's earthquake on labor market outcomes, Di Pietro and Mora (2015) provide evidence that, while the quake had no significant impact on the short-term employment-population ratio, it led to a modest but significant reduction in the short-term labor force participation. There is also evidence of substantial heterogeneous effects by gender and level of education.

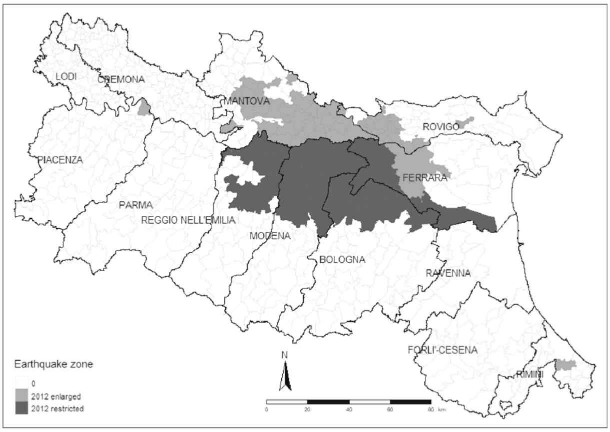
As our focus is on the migration impact of the earthquake in L'Aquila in 2009, in Emilia Romagna in 2012, and in Center Italy in 2016, in the next section, we will describe these events focusing on the degree of intensity of the phenomena themselves and on the social and environmental characteristics of the affected population and territories.

3 The Latest Major Earthquakes in Italy and Their Aftermath

On 6 April 2009, a shock of 6.3 on the Richter scale with the epicenter in L'Aquila caused 309 deaths and over 1500 injuries, becoming one of the most catastrophic recent events in Central Italy. The destructive effects were estimated with a value between 8 and 9 on the Mercalli scale: for private buildings alone, the damaged area amounts to approximately 2.5 million m^2 and 48% of the total housing. The decree of the Delegated Commissioner n. 3 of 16 April 2009 and the subsequent decree n. 11 of 17 July 2009 identified 57 municipalities affected by an intensity equal to or greater than the sixth degree of the Richter scale (see the *restricted earthquake zone* in Fig. 1a). The decree n. 39 of 28 April 2009 and subsequent legislative interventions extended this status to 105 other municipalities which reported damages having a causal link with the earthquake (see the *enlarged earthquake zone* in Fig. 1a). More than 65,000 people



(a) L'Aquila 2009 and Center Italy 2016



(b) Emilia 2012

Fig. 1 Municipalities of the earthquake zones and intensity of the earthquakes . Source: our elaboration on INGV data (Rovida et al. 2021, see http://emidius.mi.ingv.it/CPTI15-DBMI15)

were left homeless and, of these, about 90% resided in the city of L'Aquila alone; the population was displaced to durable dwellings or temporary lightweight structures. Mainly located in peripheral areas, these buildings have inevitably contributed to the phenomenon of social fragmentation (Contreras et al. 2017), especially in rural areas, often already subject to a process of depopulation and aging. According to Reynaud

Table 1 Characteristics of the treated units

	Earthquake zone			
	2009	2012	2016	Italy
Urban Centers	**22.8**	**92.9**	**38.7**	**38.7**
Poles	1.8	8.9	4.4	2.7
Inter-municipal poles	0.0	10.7	3.6	1.5
Belt	21.1	73.2	30.7	44.1
Inner areas	**77.2**	**7.1**	**61.3**	**61.3**
Intermediate areas	43.9	7.1	37.2	29.2
Peripheral areas	33.3	0.0	24.1	18.8
Ultra-peripheral areas	0.0	0.0	0.0	3.7
Cities	0.0	3.6	0.0	3.4
Towns and suburbs	3.5	44.6	8.8	28.9
Rural areas	96.5	51.8	91.2	67.7
Inner hill	5.3	0.0	41.6	32.0
Coastal hill	0.0	0.0	5.8	9.9
Inner mountain	94.7	0.0	52.6	30.1
Coastal mountain	0.0	0.0	0.0	1.5
Flat land	0.0	100.0	0.0	26.5
Population density	53	229	77	164
Number of munic.	57	56	137	

Percentage values

et al. (2020), in 2009, the population of the affected municipalities recorded higher levels of aging than the other municipalities in the same region and compared to the national average.

Most of the municipalities in the *restricted zone* (44 out 57) are classified as "inner areas" (Table 1), while the others are "urban centers", and only 1 (the municipality of L'Aquila) is a "urban pole".[1] Most of the municipalities in the earthquake zone are also classified as "inner mountain" and "rural" areas (i.e. as sparsely populated areas, according to the Eurostat classification based on the degree of urbanization; see https://ec.europa.eu/eurostat/ramon/miscellaneous/index.cfm?TargetUrl=DSP_DEGURBA).

Managing the post-earthquake phase required almost 17.5 billion euros, of which 90% was dedicated to real estate assets and the recovery and development of the production activities. To date, the state of the reconstruction works is quite different between the city of L'Aquila and the other municipalities in the earthquake zone (the ratio between the disbursed funds and those financed is 71% in the town of L'Aquila and 36% elsewhere). Financial aid to reconstruct private buildings was mainly provided to permanent homeowners in the municipalities affected by the earthquake. The

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[1] "Urban poles" are those municipalities capable of simultaneously offering essential services, such as upper secondary schools, hospitals of a certain level, and railway stations classified at least as "Silver" (see https://www.agenziacoesione.gov.it/strategia-nazionale-aree-interne/la-selezione-delle-aree/). Inner areas are those municipalities with a travel-time distance from the nearest pole of at least 20 min. Inner areas are qualified as "intermediate" (if the distance from the nearest pole is between 20 and 40 min), "peripheral" (between 40 and 75 min), or "ultra-peripheral" areas (more than 75 min). Urban centers less than 20 min from the nearest pole are "inter-municipal poles" or "belts". The inter-municipal poles are networks of contiguous municipalities able to offer essential services.

ownership requirement had to be accompanied by the permanent residence for the first home (in this case, the funding covered the entire cost). Financial aid was also provided for the second home, but to a lesser extent.[2] Residents in these municipalities have also been granted tax breaks. Due to the 2009 L'Aquila earthquake, social security and welfare contributions were suspended until 15 December 2010.

The 2012 earthquake, with the two main events of May 20 (magnitude 5.9 Richter scale, with epicenter in the municipality of Finale Emilia) and May 29 (magnitude 5.8 Richter scale, with epicenter in the municipalities of Cavezzo and Medolla), hit an area of Emilia-Romagna between the provinces of Modena, Ferrara, Reggio Emilia, and Bologna and, marginally, the regions of Veneto and Lombardia. The earthquake caused 29 victims, nearly 390 were injured, and about 41,000 people were forced to abandon their homes. Overall, Decree no. 74 of 6 June 2012 identified 56 municipalities involved in these seismic events (see the *restricted earthquake zone* in Fig. 1b). Subsequent decrees and legislative interventions have enlarged the definition of the earthquake zone, adding another 48 municipalities as involved in the seismic event (see the *enlarged earthquake zone* in Fig. 1b). The damage to productive activities exceeds that to homes and infrastructures, as a high density of industrial activities characterizes the area. Indeed, the characteristics of these municipalities are pretty different from those affected by the L'Aquila earthquake. Most of them are urban centers (9% poles, 11% inter-municipal poles, and 73% belts,) and only 7% are (intermediate) inner areas (Table 1). They are mainly small towns and rural lowland areas.

The contributions granted by Decree-Law 74/2012 and subsequent ones for the reconstruction process and for overcoming the emergency in the affected municipalities amount to a total of about 8 billion euros, of which 93% exclusively dedicated to the reconstruction of private buildings and productive activities. The rebuilding is 90% complete, especially for the private buildings. Similarly to the L'Aquila earthquake, financial aid for the reconstruction of private buildings was mainly provided to permanent homeowners. The payments of taxes, social security, and welfare contributions were suspended until 30 November 2012.

The 2016 earthquake was divided into several events, defined by the INGV (National Institute of Geophysics and Volcanology) as "Amatrice-Norcia-Visso seismic sequence": the first strong shock occurred on 24 August 2016 and had a magnitude of 6.0 on the Richter scale, with its epicenter located along the Valle del Tronto, between the municipalities of Accumoli (RI) and Arquata del Tronto (AP), causing 299 victims and 388 injured; the subsequent earthquakes of 26 and 30 October had the municipalities of Castelsantangelo sul Nera (magnitude 5.9 on the Richter scale) and Norcia (magnitude 6.5 on the Richter scale) as epicenters. These last two events did not cause victims, mainly for two reasons. First, the involved area, having a strong agricultural and tourist vocation, was characterized by a low population and production density. Second, being adjacent territories to the epicenters of the August shock, this area was already severely affected and almost 17 thousand people had already been displaced. The surface of the overall affected area extends for a total of approximately 8000 km^2, with four regions involved (Abruzzo, Umbria, Marche, and Lazio)

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[2] See, for example, the Legislative Decree 39/2009 and the numerous subsequent ordinances, including the DPCM 04/02/2013 relating to the requirements for requesting contributions for reconstruction.

(Fig. 1). The earthquake zone is much less densely populated than the regional average and with a higher average age of the inhabitants. Furthermore, of the 190,000 homes in the Marche region earthquake zone (at the 2011 census), a share equal to 26% was empty or occupied by non-residents, three points more than the national average (Banca 2017). The characteristics of the 137 municipalities involved are similar to those of the affected area by the L'Aquila earthquake. However, the average altitude is lower (Table 1) and 12 of them have been hit by both events (see Fig. 1).

Decree-Law 189/2016 and subsequent ones provided about 13 billion euros to finance the reconstruction in the affected area, of which 85% for private buildings alone. Here the reconstruction has just begun: updated reports show that the number of requests for contributions presented for the reconstruction of private buildings amounts to 22,700, of which 14,234 have been approved, with 4.3 billion euros in funded grants. Also, for the 2016 Central Italy earthquake, financial aid for the reconstruction of private buildings was mainly provided to permanent homeowners. The terms of obligations and payments for social security and welfare contributions have been suspended until 30 September 2017.

4 Migration Data

The source of migration and population data is Istat (Population Register Database). The spatial unit of analysis is the municipality. In particular, data on internal and international migration flows were collected for the period 2002–2019 for all the municipalities affected by an earthquake (the treated units) and for all the other municipalities in the country.

The following aggregates are calculated for each territorial unit: (i) internal inflows and outflows of Italian and foreign citizens within the same province (NUTS-3 level), outside the province but within the same region (NUTS-2 level), and outside the region; (ii) international inflows and outflows of Italian and foreign citizens; (iii) Italian and foreign population of the municipality in the period 2002–2019.

Based on this information, the following groups of outcome variables were constructed for each year and municipality: (a) internal outflows (per Thousand of inhabitants) of Italian and foreign citizens in the same province, outside the province but within the same region, and outside the region; (b) internal inflows (per Thousand of inhabitants) of Italian and foreign citizens from the same province, from outside the province but within the same region, and from outside the region; and (c) international immigration and emigration flows (per Thousand of inhabitants) of Italian and foreign citizens. The population of Italians was used in calculating the migration rate of Italian citizens, and the population of foreigners in calculating the migration rate of foreign citizens.[3]

A descriptive analysis of the dynamics of these migration rates is reported in the online *Appendix A*. In a nutshell, it seems that only the recovery period after the L'Aquila earthquake (i.e. the years 2010–2012) was characterized by short-term and

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[3] The Italian population by citizenship (Italian/foreign), used in the calculation of migration rates, is taken from the Intercensal Estimates of the Population from 1 January 2002 to 1 January 2019 elaborated by the Italian National Institute of Statistics (Istat).

short-distance emigration of Italian citizens from L'Aquila's quake zone in line with Ambrosetti and Petrillo (2016). These internal emigration rates appear much higher than the national average, while the trend of emigration rates of Italian citizens abroad is similar to the national average. On the other hand, there are no increases beyond the national average in the emigration rates of Italian citizens from the two earthquake zones (Emilia 2012 and Central Italy 2016) following the respective shocks. The dynamics of emigration rates of foreign citizens from the three areas do not show any substantial deviation from the national average, except for the sudden increase in 2011 in the average emigration rate abroad from L'Aquila's quake zone.

As immigration rates are concerned, there is an increase, beyond the national average, in inflows to L'Aquila's quake zone in the aftermath of the event, especially of foreign citizens from other regions. At the same time, no specific pattern emerges for the other two areas. In particular, we find evidence of a significant increase in internal immigration towards the areas hit by the 2009 earthquake of Romanians, Albanians, and North Macedonia citizens (this evidence is available upon request). It is well known that these ethnic communities are intensively employed in the construction sector. Therefore, their arrival from other Italian territories can be primarily associated with the process of post-earthquake reconstruction. However, we cannot deduce a causal relationship between environmental disasters and population migration from these descriptive evidence. Only a counterfactual analysis, such as the one described below, can determine whether the events have a causal effect.

5 Methodology

To evaluate the impact of the three earthquakes on the various outcomes mentioned above (i.e. the short, medium, and long-distance migration rates), we use difference-in-differences (DID) techniques. In the canonical DID setup, there are two time periods (say $t-1$ and t) and two groups: no one is treated in $t-1$, while in period t some units are treated, and some units are not (the *control group*). If, in the absence of treatment, the average outcomes for treated and control groups would have followed parallel paths over time (*parallel trends assumption*), one can estimate the average treatment effect for the treated subpopulation (ATT) by comparing the average change in outcomes experienced by the treated group with the average change in outcomes experienced by the control group. In this standard approach, the ATT can be estimated by using a two-way fixed effects (TWFE) estimator (Imbens and Wooldridge 2009):

$$Y_{it} = \alpha_t + \alpha_i + \beta D_{it} + v_{it}$$

where D_{it} is a treatment dummy variable equal to one if unit i is treated in period t and zero otherwise, and β is the treatment parameter, i.e. the effect of the earthquake on migration.

Our analysis considers different groups of treated units, corresponding to the three areas involved in the earthquakes that occurred in 2009, 2012, and 2016, respectively. With multiple groups, β is a weighted average of individual two-group/two-period DID estimators with the weights proportional to the group size. However, when different groups are treated in different periods, as in our case, some of the 2 × 2 estimates enter the average with negative weights. The reason is that already-treated units (i.e. municipalities already affected by an earthquake) act as controls, and changes in a portion of their treatment effect over time are subtracted from the DID estimates. In these cases, the TWFE can generate biased estimates of the ATT.

A natural way to solve this problem with multiple periods and multiple groups is to compute the group-time average treatment effect, i.e. the effect of each of the three earthquakes for each year after the shock. Following Callaway and Sant'Anna (2021), we define G as the period of the first treatment of each municipality (2009, 2012, and 2016 in our case), which also identifies the group to which it belongs. So, the average effect of an earthquake for municipalities in group g at time t is given by:

$$ATT(g,t) = \mathbb{E}[Y_t(g) - Y_t(0)|G_g = 1] \tag{1}$$

where G_g is a binary variable equal to 1 if a municipality is first treated (i.e. was hit by an earthquake) in period g, $Y_t(g)$ denotes the potential outcome of municipalities at time t if they were affected by an earthquake in period g, and $Y_t(0)$ denotes municipalities' untreated potential outcome at time t if they were not affected by an earthquake across all available periods. Callaway and Sant'Anna (2021) propose a methodology to identify, estimate, and make inference about $ATT(g,t)$ when the parallel trends assumption holds potentially only after conditioning on observed pre-treatment covariates (X). Specifically, the group-time ATT for group g in period t is nonparametrically identified and given by

$$ATT(g,t) = \mathbb{E}\left[\left(\frac{G_g}{\mathbb{E}[G_g]} - \frac{\frac{p_g(X)C}{1-p_g(X)}}{\mathbb{E}\left[\frac{p_g(X)C}{1-p_g(X)}\right]}\right)\left(Y_t - Y_{g-1} - m_{g,t}(X)\right)\right] \tag{2}$$

where $p_g(X)$ is the generalized propensity score (GPS), with $C = 1$ for municipalities never affected by an earthquake, Y_t is the potential outcome at time t, Y_{g-1} is the potential outcome in the period $g-1$, and $m_{g,t}(X) = \mathbb{E}\left[Y_t - Y_{g-1}|X, C = 1\right]$ is the population outcome regression for the "never-treated" group. This is a weighted average of the "long difference" of the outcome variable, with the weights depending on the propensity score. Therefore, the algorithm uses observations from the control group and group g, omitting other groups, and assigns more weight to observations from the control group with characteristics similar to those frequently found in group g.

The estimate of $ATT(g,t)$ is obtained using a two-step strategy. In the first step, one estimates the nuisance functions for each group g and time t, $p_{g,t}(X)$ and $m_{g,t}(X)$. In the second step, one plugs the fitted values of these estimated functions into the sample analog of $ATT(g,t)$ in (2) to obtain estimates of the group-time average treatment effect. To conduct asymptotically valid inference, Callaway and Sant'Anna (2021) also propose to use a computationally convenient multiplier-type bootstrap procedure to obtain simultaneous confidence bands for the group-time average treatment effects.

Estimated $ATT(g,t)$ values can be directly used for learning about treatment effects heterogeneity (i.e. they allow us to consider how the effect of earthquakes varies by group and time) and to construct aggregate causal effect parameters. The simplest way of combining $ATT(g,t)$ across g and t is the weighted average of $ATT(g,t)$ putting more weight on $ATT(g,t)$ with larger group sizes:

$$\theta_W^O = \frac{1}{k} \sum_{g \in \mathbb{G}} \sum_{t=2}^{T} 1\{g \leq t\} ATT(g,t) P(G = g | G \leq T) \tag{3}$$

with $k = \sum_{g \in \mathbb{G}} \sum_{t=2}^{T} 1\{g \leq t\} P(G = g|G \leq T)$. Unlike β in the TWFE regression specification (1), this simple combination of the $ATT(g,t)$'s immediately rules out troubling issues due to negative weights.

Another aggregate measure that may be of interest in our analysis is the average group-specific treatment effect:

$$\theta_{sel}(g) = \frac{1}{T - g + 1} \sum_{t=g}^{T} \sum ATT(g,t) \tag{4}$$

Note that $\theta_{sel}(g)$ is the average effect of being affected by an earthquake among municipalities in group g, across all their post-treatment periods. We can also consider an average across groups of $\theta_{sel}(g)$ as an overall measure of treatment effect in place of θ_W^O:

$$\theta_{sel}^O = \sum_{g \in \mathbb{G}} \theta_{sel}(g) P(G = g|G \leq T) \tag{5}$$

This alternative measure has the advantage of not putting more weight on groups that participate in the treatment for longer.

6 Results and Discussion

We use the estimated $ATT(g,t)$ described above to answer our research questions.[4] The analysis was performed using a selected sample of municipalities. Specifically, only the municipalities belonging to one of the five regions (Emilia Romagna, Umbria, Marche, Lazio, and Abruzzo) affected by an earthquake in the sample period were selected, plus the municipalities belonging to three Lombard provinces (Mantova, Cremona, and Lodi), and those belonging to the province of Rovigo in Veneto, since these four provinces are spatially contiguous to some municipalities of Emilia hit by the earthquake in 2012: some of them have never been affected by an earthquake in the period 2002–2019, 57 belong to the "2009" group (*restricted* definition of the affected area) and are all in the Abruzzo region, 56 belong to the "2012" group (*restricted* definition of the affected area) and are located in Emilia Romagna, and 137 belong

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[4] The estimates are computed using the open-source software `R` (library `did`). All estimates are performed using the doubly-robust approach developed by Sant'Anna and Zhao (2020) and available in the `R` package `DRDID`.

to the "2016" group and are located in Umbria, Marche, Lazio, and Abruzzo. The decision to restrict the sample of control units to the contiguous municipalities was based on the consideration of using a spatially homogeneous sample within which the main difference is represented by the treatment, as in a spatial regression discontinuity design.

We have selected a set of variables capturing several municipalities' characteristics to estimate the Generalized Propensity Scores through a logit model. Summary statistics for these variables are provided in Table 2, with the t-tests for equal means between each treated group and the control group. As expected, spatial units hit by the quakes in 2009 and in 2016 have, on average, a higher probability of being above the 90th percentile of the seismic risk index distribution with respect to never treated units. This is not the case for municipalities hit by the quakes in 2012 and located in Emilia Romagna: surprisingly, they have statistically the same seismic risk. The three groups of treated units also differ in terms of several other features, such as demographic characteristics, degree of urbanization, distance from urban poles, altimetric position, and economic structure.

6.1 The Impact of the Earthquakes on Out-Migration

The effect of earthquakes on the emigration rate is first estimated to assess whether short, medium, or long-distance migration serves as an adjustment mechanism and provides relief in the face of negative shocks. Table 3 shows the aggregate average treatment effects for various outcomes. In particular, the table shows (i) a simple weighted average of all group-time average treatment effects (ATT) with weights proportional to group size, (ii) group-specific effects, and (iii) the weighted average of group-specific effects. The table also reports the *P value* of a Wald test of the parallel trends assumption. Here, this assumption would not be rejected at conventional significance levels.

The upper side of Table 3 displays the aggregate ATT on the outgoing flows of Italian citizens. The lack of significant effects indicates that earthquakes have no impact on Italian citizens' short, medium, or long-distance emigration. None of the estimated group-specific ATT for each group are statistically significant.

Surprisingly, the results do not corroborate the narrative that in the aftermath of the 2009 earthquake in the province of L'Aquila a large portion of Italian citizens left the earthquake zone in reaction to the shock and moved to other Abruzzo provinces or to other regions (Ambrosetti and Petrillo 2016). The upsurge of the internal out-migration rate of Italian citizens from the affected area in the aftermath of the earthquake displayed by our descriptive analysis (online *Appendix A*) also seems to odds with the evidence of a negative, albeit not significant, ATT for the group "2009" in the case of internal out-migration to the same province, to other provinces within the same region and to other regions. This contrasting evidence might depend on the computation of the average municipality rate. While our counterfactual analysis measures the ("*unweighted*") average treatment effect of the earthquake on the treated, the descriptive evidence shows the "*weighted*" average of the out-migration rates of all municipalities within the affected area.

Table 2 Summary statistics on municipalities' characteristics for treated and never treated units

	2009	2012	2016
Seismic risk[a]	73.815	− 4.819	41.558
	(0.000)	(0.365)	(0.000)
Demographic characteristics			
ln Population density in 2002	− 1.178	0.702	− 0.848
	(0.000)	(0.000)	(0.000)
Share of popul. aged >65	7.195	− 2.121	4.006
	(0.000)	(0.000)	(0.000)
Urbanization degree			
Cities	− 1.095	2.477	− 1.095
	(0.000)	(0.330)	(0.000)
Towns and suburbans	− 16.491	24.643	− 11.241
	(0.000)	(0.000)	(0.000)
Rural areas	17.586	− 27.119	12.336
	(0.000)	(0.000)	(0.000)
Urban centers			
Poles	− 1.584	5.689	0.140
	(0.417)	(0.148)	(0.531)
Inter-municipal poles	− 1.268	9.447	2.382
	(0.000)	(0.028)	(0.147)
Belts	− 19.652	32.510	− 10.047
	(0.000)	(0.000)	(0.017)
Inner areas			
Intermediate areas	6.817	− 29.899	0.184
	(0.317)	(0.000)	(0.966)
Peripheral areas	18.333	− 15.000	9.088
	(0.005)	(0.000)	(0.018)
Altimetric position			
Inner hill	− 29.481	− 34.745	− 6.861
	(0.000)	(0.000)	(0.122)
Coastal hill	− 14.453	− 15.453	− 8.613
	(0.000)	(0.000)	(0.000)
Inner mountain	72.985	− 27.752	30.803
	(0.000)	(0.000)	(0.000)
Flat land	− 29.051	70.494	− 29.051
	(0.000)	(0.000)	(0.000)
Economic structure			
Share of manufacturing employment	− 0.120	0.176	0.010

Table 2 continued

	2009	2012	2016
	(0.000)	(0.000)	(0.627)
Share of agriculture employment	0.042	− 0.100	0.043
	(0.054)	(0.000)	(0.005)

Difference in mean values and two-sample t test for equal means. Our elaborations on Istat data

[a] Seismic risk: probability of being above the 90th percentile of the seismic risk index distribution

Table 3 Earthquakes treatment effects on out-migration

	To same province	To other provinces within same region	To other regions	Abroad
	Italian citizens			
Simple weighted average	− 0.262	− 0.373	− 0.829	− 0.087
	(0.366)	(0.259)	(0.476)	(0.164)
Weighted avg. of group-specific effects	− 0.360	− 0.358	− 0.809	− 0.141
	(0.313)	(0.289)	(0.535)	(0.203)
Group specific effect: 2009	− 0.075	− 0.986	− 1.422	0.133
	(1.060)	(0.643)	(1.176)	(0.185)
Group specific effect: 2012	− 0.101	0.189	− 0.165	− 0.101
	(0.155)	(0.214)	(0.219)	(0.248)
Group specific effect: 2016	− 0.577	− 0.455	− 0.904	− 0.245
	(0.533)	(0.506)	(0.775)	(0.352)
P value Wald test DID ass.	0.126	0.270	0.303	0.371
	Foreign citizens			
Simple weighted average	**6.586**	0.569	0.928	− 0.028
	(3.349)	(1.014)	(1.736)	(1.798)
Weighted avg. of group-specific effects	3.211	− 0.160	− 0.078	0.601
	(2.889)	(1.325)	(1.646)	(2.175)
Group specific effect: 2009	**23.338**	0.295	3.838	− 2.924
	(8.365)	(2.962)	(5.133)	(5.548)
Group specific effect: 2012	1.181	2.243	1.837	− 0.210
	(4.719)	(1.218)	(1.444)	(1.456)
Group specific effect: 2016	− 1.885	− 2.418	− 2.321	1.919
	(4.323)	(2.417)	(2.992)	(3.741)
P value Wald test DID ass.	0.399	0.101	0.234	0.130

Restricted earthquake zones with contiguous municipalities as control units sample. Dependent variable: emigration rate. The table reports aggregated treatment effect parameters under the conditional parallel trends assumption and with clustering at the municipality level. The row 'Simple Weighted Average' reports the weighted average (by group size) of all available group-time average treatment effects (ATT_W^O). The row 'Weighted Average of group-specific effects' reports the weighted average of the three group-specific average treatment effects (ATT_W^{Sel}). The row 'Group-specific Effects' summarizes average treatment effects by the timing of the earthquake. Standard errors in parenthesis. ATT in bold means that the confidence band at 95% significance level does not cover the zero

These considerations prompted us to repeat the DID analysis using weighted observations, with weights proportional to the population of the sample units (see online *Appendix B*). The aggregate group-specific ATT for each group is still statistically not significant. This evidence confirms the lack of empirical support for the hypothesis that earthquakes substantially increase the short or long-distance out-flows of Italian citizens.

Another important issue that merits being more deeply investigated concerns the composition of the "trapped population". In the literature on environmental migration, the problem of involuntary immobility (e.g. Lubkemann 2008) and inability to escape environmentally risky and vulnerable locations (e.g. Thiede and Brown 2013) has been increasingly addressed. Here, we look at the population of Italian citizens most exposed to the three analyzed shocks that decided to stay within the earthquake zone or were less able to migrate away from its consequences. Do they mostly include young or old people, high or low-educated people? In particular, as well known in the migration literature, young and high-skilled individuals account for most of the internal migration in developed countries (Greenwood 1997), and thus they are also more likely to move away from the affected area. Therefore, we have carried out a DID analysis using emigration rates of Italian citizens aged 24–55 and distinguished by the level of education. Specifically, we distinguish individuals with (a) no formal education or a primary school education, (b) a lower-secondary school education, (c) an upper-secondary school education, and (d) a tertiary school or higher education level. Overall, the results (reported in the online *Appendix C*) confirm the lack of short, medium,and long-distance emigration of Italian citizens in response to the quakes, regardless of their level of education and age.

The lack of evidence of a positive effect of earthquakes on the emigration of Italian citizens can mainly attributed to post-quake financial and fiscal aid. Public action to restore the initial conditions plays a fundamental role after traumatic environmental events (Cipollina et al. 2021). In particular, the large amount of public funds disbursed for the reconstruction of private buildings and the suspension of tax payments in all three affected areas (see Sect. 3) may have represented a vital incentive to stay.

Moreover, the attachment to the place, in the form of social contacts, and the sense of belonging to the local community may also have played an important role in explaining the "immobility paradox", as migration costs can be considerably high, especially for international migration. Nor can alternative adjustment mechanisms be ruled out. In some cases (for example, in the large municipality of L'Aquila), "voicing" was probably one of the few responses to the earthquake. Hirschman (1970) distinguished between alternative ways of reacting to deterioration of the socio-economic context, indicating "voice" as the tool for members of the community to agitate and exert influence for change "from within". Noy (2017) discussed how people affected by a natural disaster could use their voice to ask for novel policies and compensations. In this case, voicing becomes a substitute for emigration, since it mitigates adverse natural shocks on income. Some elements favor the hypothesis that the preferred response to the earthquake of residents and local authorities was to voice to be compensated for their losses by the national government. Following Beine et al. (2019), this kind of voicing can be defined as "domestic" or "internal" voicing. There are also many

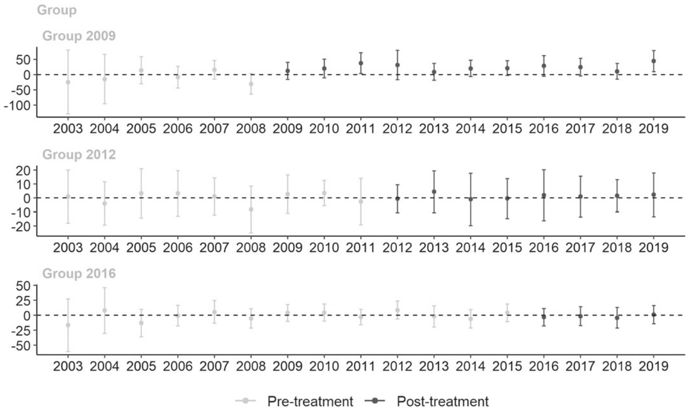

Fig. 2 The effect of earthquakes on outflows of foreign citizens to other municipalities, within the same province . Source: our elaboration on Istat data

examples of voicing from the central government or academic sources to the rest of the world (“international” voicing).[5]

Risk aversion can also help explain the trapped population phenomenon. Risk aversion acts indeed as a negative self-selection factor of emigration. By raising risk aversion, earthquakes could have made local people more risk averse, lowering their intentions to leave their current location (Beine et al. 2021).

Although the estimates do not provide strong support for the view that short, medium or long-distance migration act as an adjustment mechanism against the quake for Italian citizens, there is some evidence that the quake in L’Aquila caused an increase in emigration of foreign citizens to other municipalities of the same province (Table 3). The aggregate group-specific effect for “2009” shows that this shock caused an increase in emigration to the same province of about 23 foreigners per 1000 foreign people (Fig. 2).[6]

The weighted estimates confirm this evidence for “2009” and also show a slightly positive impact (about five foreign emigrants per 1000 foreign people) of the 2012 earthquake on the emigration of foreigners to the same province. However, all the effects disappear once we consider as treated units all the municipalities included in an enlarged version of the earthquake zone (see online *Appendix E*), suggesting that these events had an impact only on very short-distance movements towards areas near the narrow earthquake zone and less affected by the quakes. In other words, since only

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[5] An example of international voicing is the OECD report written by several Academic people in the aftermath of the L’Aquila 2009 earthquake; see https://www.oecd.org/regional/regional-policy/laquilaearthquakere-launchingtheeconomy.htm.

[6] The figure contains separate plots of $ATT(g, t)$ for each group (the first group is labeled “2009”, the second “2012”, and the third “2016”) in all periods from 2002 to 2019, along with a uniform 90% confidence band. The light-grey dots in the plots are pre-treatment pseudo-group-time average treatment effects and are useful for testing the parallel trends assumption. Dark grey dots are post-treatment group-time average treatment effects. The confidence bands always include zero, thus confirming the result of the Wald test of the parallel trends assumption. All inference procedures use clustered bootstrap standard errors at the municipality level. The whole set of $ATT(g, t)$ plots is reported in the online *Appendix D*.

Table 4 Earthquakes treatment effect on in-migration

	From same province	From other provinces within same region	From other regions	From abroad
	Italian citizens			
Simple weighted average	− 0.296	− 0.136	− 0.587	− 0.119
	(0.528)	(0.467)	(0.649)	(0.196)
Weighted Avg. of group-specific effects	− 0.164	0.043	− 0.506	− 0.245
	(0.508)	(0.562)	(0.435)	(0.212)
Group specific effect: 2009	− 0.596	− 0.898	− 1.815	0.299
	(1.270)	(1.073)	(1.781)	(0.440)
Group specific effect: 2012	− 0.437	− 0.003	0.609	− 0.132
	(0.684)	(0.230)	(0.355)	(0.075)
Group specific effect: 2016	0.094	0.378	− 0.607	− 0.535
	(0.748)	(1.066)	(0.471)	(0.331)
P value Wald test DID ass.	0.145	0.351	0.428	0.136
	Foreign citizens			
Simple weighted average	**5.898**	1.754	1.529	1.100
	(2.362)	(1.109)	(1.666)	(9.726)
Weighted avg. of group-specific effects	3.061	1.375	0.255	− 4.278
	(2.333)	(1.453)	(1.438)	(7.854)
Group specific effect: 2009	**22.139**	**8.065**	10.439	17.463
	(6.694)	**(2.238)**	(6.215)	(23.279)
Group specific effect: 2012	1.818	1.129	− 0.218	4.136
	(2.979)	(1.145)	(1.431)	(19.125)
Group specific effect: 2016	− 1.102	0.754	− 1.671	− 14.515
	(3.690)	(2.623)	(1.924)	(9.165)
P value Wald test DID ass.	0.137	0.480	0.115	0.260

ATT in bold means that the confidence band at 95% significance level does not cover the zero. Restricted earthquake zones with contiguous municipalities as control units sample. Dependent variable: immigration rate. See Table 3

short-distance migration flows are significantly involved, the larger the geographical area of the treated group, the lower the average impact detected.

6.2 The Impact of the Earthquakes on In-Migration

The results of the aggregate effect of earthquakes on immigration rates are reported in Table 4. Firstly, there is no evidence of a significant impact for all groups under analysis on the immigration of Italian citizens. At the same time, there is evidence in favor of the hypothesis that new economic opportunities or exigencies linked to the reconstruction process stimulate new migratory flows of foreign workers in the affected area of L'Aquila. However, these inflows do not come from abroad. Still, they are

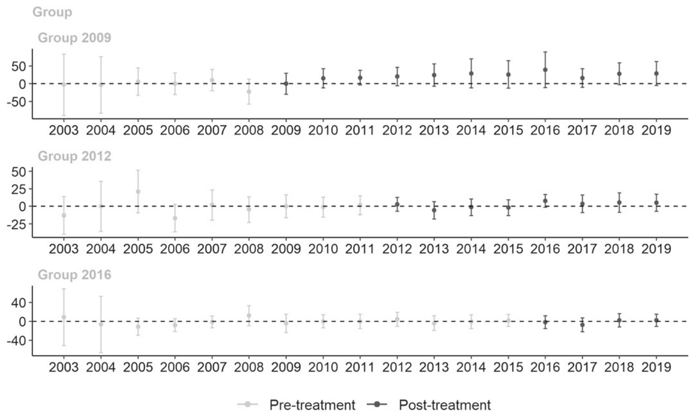

Fig. 3 The effect of earthquakes on inflows of foreign citizens from other municipalities, within the same province . Source: our elaboration on Istat data

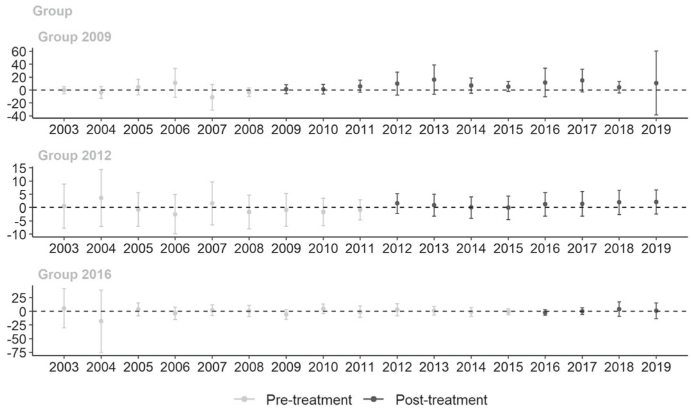

Fig. 4 The effect of earthquakes on inflows of foreign citizens from other provinces, within the same region . Source: our elaboration on Istat data

mainly short-distance inflows: the group-specific effect indicates that this shock caused an increase in immigration from the same province of about 22 foreign immigrants per 1000 foreign people and from the other provinces of the same region of about 8 per 1000. The effect on the inflow of foreigners from other municipalities of the same province began soon after the shock and reached its maximum level in 2016 (Fig. 3). The effect on the inflow of foreigners from other Abruzzo provinces was delayed compared to the previous one, but it reached its maximum level earlier in 2013 (Fig. 4). In both cases, a cyclical trend is observed, probably due to the trend in demand for reconstruction labor. A similar path emerges for the effect of the L'Aquila earthquake on the immigration rate of foreigners from other regions. The aggregate group effect (an increase of about ten immigrants per 1000 foreigners) is not statistically significant at 10%, but this ATT value becomes significant once we compute weighted observations (Figs. 5, 6).

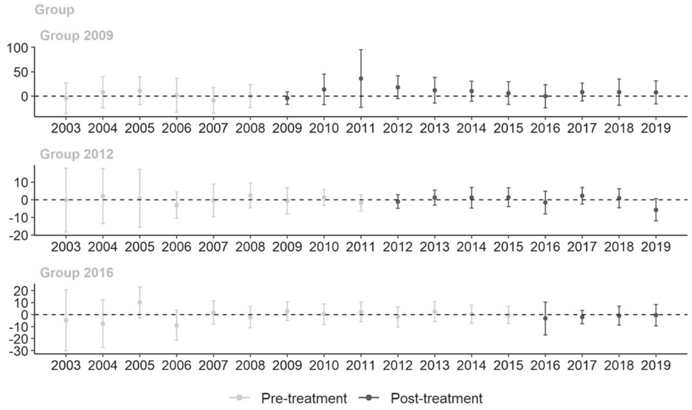

Fig. 5 The effect of earthquakes on inflows of foreign citizens from other regions . Source: our elaboration on Istat data

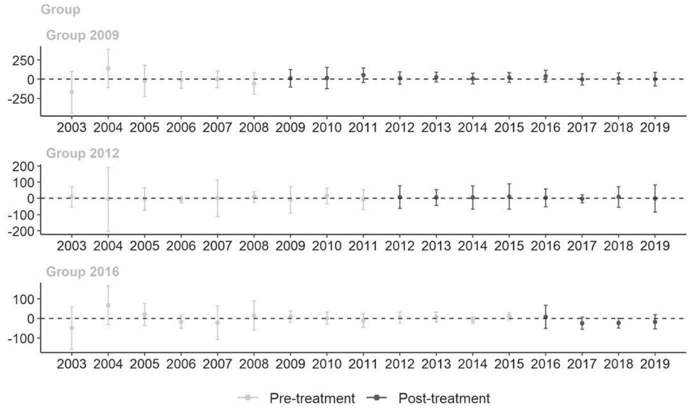

Fig. 6 The effect of earthquakes on inflows of foreign citizens from abroad . Source: our elaboration on Istat data

The movements of foreigners within the host country could be influenced by factors closely related to the *dynamics of local labor markets*. When an earthquake occurs, the *construction sector* takes on greater importance in the local economy due to its remarkable role in reconstruction. Other sectors, especially *tradable sectors* (most of which are probably hit by the shock, such as manufacturing industries), see their relevance reduced (Kirchberger 2017). These shifts in labor demand represent a new economic opportunity for low-skilled workers employed in the construction sector. At the same time, they stimulate the outflow of workers with precarious economic and social conditions and, now, with reduced job opportunities in tradable sectors. In this context, foreign citizens are considered more vulnerable due to the less protected conditions where they generally work and live than natives. In particular, the economic base of the area hit by the earthquake in 2009 includes numerous wholesale and retail trade activities, mainly concentrated in the city center of L'Aquila and many small firms linked to the construction sector. However, it is also still characterized by a limited number of crucial high-tech manufacturing plants in the pharmaceutical and ICT sectors. Porcelli and Trezzi (2016) note that the destruction of physical capital produced by the quake tends to hurt economic activity, but this impact could be offset by reconstruction activities (typically financed by public subsidies).

Overall, the L'Aquila earthquake in 2009 had a negative impact on the local labor market, but significant effects on sectoral shifts in employment also occurred. Using a DID approach, Basile et al. (2023) show that the earthquake in L'Aquila caused a decrease in the overall employment rate and an increase (decrease) in labor demand in the construction sector (in manufacturing) within the local labor market areas affected by the quake. Instead, thanks to their more extensive production base, local labor markets hit by the Emilia-Romagna earthquake have proven much more resilient.

Overall, the internal movements of foreigners observed in this study (increase in short distance in-migration and out-migration of foreigners) could be related to the concept of "replacement migration" (King and Skeldon 2010), which may occur within countries when a large emigration creates a vacuum that migrants from other parts of the country can fill. Several studies have highlighted the role played by community networks in the distribution of immigrants from the same countries of origin across space in host countries (Bartel 1989). Networks are based on kinship, common origin, and sharing of the same culture and relationship. Migrants in contact with other migrants have access to resources through the network (e.g. connections for work and accommodation and information on residence permits, entry fees, and health care). These resources are essential for dealing with the new situations migrants find in the host country: networks can be considered a means to generate and reproduce social capital. Alongside the "adaptive function", networks also perform a "selective function": the network selects the most suitable people to migrate. Usually, people do not move randomly but follow partial information based on advice and stories from relatives or neighbors (Sandu et al. 2018). These recommendations probably do not always lead to the best allocation of resources regarding migrants' skills. Still, they play a crucial role in the distribution of foreigners in the host country. In the case of L'Aquila, it is possible that the networks acted as "mediators", identifying job opportunities (related to the reconstruction process) and helping foreigners who worked in the most affected sectors move outside the earthquake zone. The observed "replacement" of migrants fits into this network dynamics. It suggests that, following a shock, foreigners could remain linked to the host territory if migrants from the same community are already settled in nearby areas and can support them in adapting their specific skills to the dynamics of the labor market.

7 Conclusions

In this paper, we have tried to answer three research questions related to migration response to the three latest earthquakes in Italy. The first question concerns the possibility that migration acts as an adjustment mechanism in the face of these adverse shocks (*RQ-1*). A second one regards the stimulus to new immigration flows generated by the new economic opportunities linked to the reconstruction process (*RQ-2*). The last question relates to the possible heterogeneity of these responses by the time of earthquake occurrence (*RQ-3*). According to our empirical results, the answers to these questions depend on the nature of the migrants.

As for Italian citizens, we do not find any significant effect of the three earthquakes on either immigration or outmigration outcomes. In particular, in line with several studies that fail to uncover any response from emigration to natural disasters (Berlemann and Steinhardt 2017), our results fail to provide compelling evidence of a clear-cut connection between the three events and the internal or international displacement of Italian citizens. These results also suggest that the reconstruction process would not be able to refrain from the demographic decline characterizing inner areas in Abruzzo and Central Italy. More strategic policy actions aimed to improve access to essential services, such as those described in Barca et al. (2014), are crucial to guarantee an adequate level of citizenship among inner areas' inhabitants and thus to reduce the depopulation dynamics.

Some significant results, instead, are obtained when the outcome variables are computed using migration flows of foreign citizens. However, these results are heterogeneous across the considered events. First, our results show that only the earthquakes in L'Aquila caused an increase in the internal emigration of foreign citizens. The latter is less likely to be homeowners and are less rooted in the territory. The internal migration of foreigners in Italy is more than double that of Italian citizens (Casacchia et al. 2019). Furthermore, the share of earned income on total income is higher for foreign citizens than Italians. Once their (primarily temporary) jobs were lost due to quakes, foreign citizens were more likely to move away from the affected areas than Italian citizens. Finally, there is evidence in favor of the hypothesis that new economic opportunities or exigencies linked to the reconstruction process stimulate new migratory flows of foreign workers in the affected area of L'Aquila. However, these inflows do not come from abroad but are mainly short-distance inflows. In other words, the earthquakes did not stimulate more immigration from abroad. Still, they did have a particular impact on the redistribution of foreign workers within the country, causing both short-distance immigration and outmigration flows of these workers. Some evidence about short-distance outflows and inflows of foreign citizens also emerged after the Emilia earthquake, but only if we give more weight to the most populated municipalities (see online *Appendix B*). We do not observe significant evidence for the Central Italy earthquake, but we cannot exclude that some effects will arise in the future, since in the case of the other two earthquakes the effects showed up between three and five years after the shock, probably due to the delay in the rebuilding process. All in all, the evidence of an increase in the migration of foreign citizens as the effect of an earthquake deserves particular attention, also considering the cultural differences that could result in a different approach of foreigners to the labor market or to social habits.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40797-023-00226-6.

Funding Open access funding provided by Università degli Studi dell'Aquila within the CRUI-CARE Agreement.

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