The impact of natural disasters: how the 2009 earthquake transformed the economy of L'Aquila's labour market area

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Abstract

We investigate the economic impact of the 2009 earthquake in L'Aquila labour market area (Italy) through a synthetic difference-in-differences method over the period 2004-2013. The shock immediately disrupted local economy with a 27.3% and 38.2% reduction in employment and firms number. However, these effects are not statistically significant as measured 5 years after the earthquake suggesting a rebound process in terms of employment and number of firms. Such findings are the result of heterogeneous dynamics across the manufacturing and services sectors: the former exhibited a permanent contraction in the number of employees and firms, whereas the latter experienced a strong recovery after a short-term negative effect. Such dynamics induced an increase of sector dissimilarity of L'Aquila with respect to other labour market areas in Abruzzo.

Keywords: earthquake; L'Aquila; resilience; employment; firms; synthetic difference-in-differences.

1. Introduction

In recent years, debate in territorial studies has hosted a growing number of contributions regarding how regions adapt and react to shocks (Tan et al., 2020; Silva et al., 2021; Pierri et al., 2023; Zhang and Wang, 2023), i.e. how they prove to be resilient to unforeseen events. Among the various aspects under scrutiny, the effects of natural and environmental events play a significant role (Cavallo and Noy, 2010), specifically in studies aimed at understanding regional economies' reactions to earthquakes, tsunamis, floods, hurricanes and climate change. This strand seeks to measure how quickly local populations and their activities recover from such shocks and emergencies (Martin, 2012). Although a shared definition on what a resilient region is, as well as on how to measure such capacity, is still missing, attempts to identify patterns so far usually relied on bringing evidence from case studies, in most cases referring to events occurred in Asian and American countries. Considering the "geographical diversity, variety and unevenness of resilience" (Pike et al., 2010, 71), though, conclusion drawn from single areas cannot be adopted straight away to make inferences.

This paper aims to add a European case study to the debate on regional resilience focusing on an area interested by a 6.3 Mw magnitude, 8.8 kms deep earthquake that hit the Italian town of L'Aquila (capital of Abruzzo region) and surrounding municipalities on April 6, 2009. In doing so, not only we aim to bring more evidence on the debate to support emerging theoretical trends, but also we seek to deepen the analysis on the most tremendous earthquake (in terms of physical damage and community displacement) occurred in Italy after 1980. Besides such event, we reckon the area is of interest also because its economic performances had already been negatively influenced by the end of public policies support after the 1990s (Barone et al., 2016; Iapadre and Mariani, 2020), so much so that it was recently identified as being 'trapped' (Iammarino et al., 2020).

Other contributions provide evidence on how the economy of the area has changed after the event, even though some specifications are needed. Regarding the geographical scale of analysis, Di Pietro and Mora (2015) and Mendoza, Breglia and Jara (2020) respectively use data at provincial (NUTS 3) and regional (NUTS 2) level, both of which include areas that were not hit by the earthquake. Researchers adopting L'Aquila's labour market area (LMA)[1] as spatial unit of analysis, need to consider that in 2011 the Italian National Statistics Institute (ISTAT) made some relevant changes in the list of municipalities that compose each Italian LMA; this makes accurate comparisons spanning from before the earthquake to most recent years more difficult, even though L'Aquila's LMA varied only marginally. In a report dedicated to the economy of the area ten years after the event, Banca d'Italia (2019) statedly reports a marginal statistical discontinuity in calculating percentage variations on employment in economic sectors between 2008 and 2016; for the same reason, authors also deliberately did not report comparisons with other LMAs in Abruzzo due to major changes they underwent across the 2011 revision.

In our paper, we concentrate on the L'Aquila's area with the aim to go further in depth on analysing changes using a time span of 10 years (2004-2013). In particular, we study the short term impact of the earthquake by measuring its effects 1 year after the event when policy

[1] Labour market areas (LMAs, "sistemi locali del lavoro - SLL" in Italian) are sub-regional geographical areas where the bulk of the labour force lives and works, and where firms can find the main part of the labour force necessary to occupy the jobs they can offer. LMAs are defined on a functional basis, the key criterion being the proportion of commuters who cross the LMA boundary on their way to work. The Italian National Statistics Institute (ISTAT) counts 611 LMAs across the country; each one of them is composed by a list of municipalities, whose main last modification dates to 2011, when the 15th Population Census took place (for further details, see: www.istat.it/en/labour-market-areas).

packages of support were not implemented, yet. Moreover, we study the dynamic of the recovery process until 5 years after the disaster, to avoid that a too long time frame may confound our results due to other relevant events that may have affected the development patterns of L'Aquila. In this way, we bring about evidence on variations in the number of firms and employees for 15 economic sectors (as identified by ISTAT) and show results for 12 sub-sectors related to the manufacturing sector.[2] Furthermore, we add results on per capita income level, and sector diversification of the area with respect to other LMAs in Abruzzo. Then, we interpret them in relation to policy prescriptions that three governmental organizations elaborated on the specific case of L'Aquila soon after the event took place, i.e. the then called Italian Ministry for Territorial Cohesion, the Organisation for Economic Co-operation and Development (OECD), and the Centre for services, assistance, studies and training for the modernisation of public administrations (Formez PA).

We chose LMAs as spatial unit of analysis, since we consider they better identify the area hit by the earthquake, netting out other areas that were less or not affected but still form part of the province of L'Aquila (NUTS3 level) or Abruzzo region (NUTS 2 level). Eventually, we use a dataset freshly elaborated by ISTAT[3] that allows for comparisons within and across LMAs netting out the changes in their composition that occurred in 2011; this dataset, that, to the best of our knowledge, was not used so far in analysing the area we selected, considers LMAs as they were made up in 2001 and reports data until 2020 over this consistent set of administrative units. Analysing L'Aquila's LMA with recent data is furthermore useful to inform policy making, since the long reconstruction process is still ongoing, as are interventions to help the socio-economic, territorial and cultural fabric recover from the shock; as of 2022, indeed, around 10.9 billion euros were allocated for the physical reconstruction of the area[4] and 319 million euros were earmarked for its economic development.[5] Considering more public funds will be spent for the reconstruction (only 56% of it is considered to having been completed as of 2022) and for local development projects (the Italian National Recovery and Resilience Plan, PNRR, allocated 1.78 billion euros for this purpose in the bordering areas hit by the 2009 and 2016 earthquakes), a measurement of how the economy of the region has reacted so far can be useful to orientate near-future policy plans.

We find that the 2009 earthquake significantly disrupted L'Aquila's LMA in terms of employment and number of firms with long lasting effects. Indeed, both variables show an immediate significant reduction compared to the counterfactual, with an average treatment effect respectively equal to -27.3% and -38.2% in the same year when the disaster occurred. However, such an impact is not statistically significant five years after the event, due to a sharp recovery in the number of employees and firms.

We highlight how such result is the combined effect of heterogeneous dynamics involving the manufacturing and service sectors. The former is subject to permanent effects both in terms

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[2] We perform our analysis on all 16 NACE rev.2 one-digit sectors on which ISTAT disclosed data at LMA level in terms of number of employees and firms. Similarly, we conduct an analysis for the whole set of manufacturing sub-sectors (12, as identified according to NACE two-digit sectors) where the national statistical office provides data in terms of number of employees.

[3] This dataset is not yet publicly available, and was kindly shared by ISTAT with our research team to support this study. The ISTAT file discloses information related to the number of firms and employees by sector with reference to 2001 LMAs for our period of analysis (2004-2018). This dataset is particularly useful, as it provides information on a stable set of LMAs, thus avoiding inconsistencies of other publicly available dataset including heterogenous sets of LMAs over different years, due to major changes in LMAs structure occurred in 2011.

[4] Source: www.opendataricostruzione.gssi.it/home.

[5] Source: www.opendatalaquila.it/appsmaps/sviluppo-economico/.

of employees (-10.4%) and number of firms (-14.7%) that are still significant at 5 years from the earthquake. The latter experiences a strong economic recovery suggesting a not significant effect in terms of employees and firms' reduction with respect to the counterfactual, as measured 5 years after the event.

We further disaggregate results in terms of manufacturing and service sub-sectors. In particular, we highlight that the earthquake generates a strong negative impact in terms of employment in the "electrical components" (-36.9%), "other manufacturing" (-29.4%), "food" (-27.5%), and "wood-paper" (-13.9%) manufacturing sub-sectors. Some exceptions are represented by the "Chemicals" (30.8%), "Metallurgy" (21.1%), "Electronics" (19.1%), and "Transport" (8.3%) sub-sectors, obtaining an increase in employment with respect to the counterfactual. However, notice how these sub-sectors account for a small weight of L'Aquila LMA employment in the Manufacturing industry as reported in Table B2 (all below 5% with the exception of Metallurgy).

Conversely, across service sub-sectors we find a strong recovery mainly driven by industries associated with reconstruction activities such as the "construction" (+48.9%) and "real estate" sectors (+12.2%).

Finally, we provide evidence that such structural changes in the local economic structure of L'Aquila's LMA contribute to a significant growth of the local sector diversification, suggesting a stronger local competitive advantage in peculiar sectors with respect to the pre-treatment period. Such pattern is mainly the result of a growth in the relevance of the "construction", and "support services" sectors. We do not rather observe a significant impact of the earthquake in terms of income per capita respectively 1 and 5 years after the disaster. Such finding may be justified by the relevant financial support the area received after the event.

Overall, this paper provides an original contribution with respect to previous studies discussing the impact of L'Aquila earthquake under different facets. First, our study presents higher accuracy and granularity in terms of analysed spatial units, enabling a more precise identification of the impact of the disaster. Second, we rely on a wider sectoral disaggregation allowing to disentangle the earthquake effect across a large group of activities that has not been documented yet. By doing so, we aim to provide a precise understanding of which were the most disrupted sectors and which, conversely, may drive the economic recovery. Finally, our analysis is performed over a rich set of dependent variables, differentiating from extant literature that mainly focuses on employment and labour income, since we also estimate effects in terms of number of local firms and sector diversification, thus fuelling the debate on the resilience of L'Aquila's LMA.

The paper is organized as follows: section 2 reviews the literature production on regional economic resilience, with a focus on natural disasters, and frames our case study; section 3 reports data and the empirical methodology we adopted; in section 4, we show and discuss results; section 5, eventually, draws conclusions and highlights the main contributions of this research.

2. Theoretical Background and Research Framework

2.1 The notion of "resilience" and its relation to our case study

The appearance of the term "resilience" in scientific texts ascribes to at least three interpretations or uses of the term, known as 'engineering', 'ecological', and 'adaptive' resilience

(Pendall et al., 2010; Martin, 2012; Davoudi and Porter, 2012; Martin and Sunley, 2015; Modica and Reggiani, 2015; Wilson, 2017).

'Engineering' resilience, initially applied to materials and buildings, refers to the capacity of a system to return to its previous equilibrium state after a turbulence. 'Ecological' resilience not only considers how quick a system finds a new 'normality' after a turbulence, but also how much stress it can absorb before needing to find an alternative stability. Finally, 'adaptive' resilience, focuses on the capacity of a system to reorganize its form and/or function in prevision of, or after, the shock, so as to minimize its impact.

Along with a growing strand of literature, it is under this third conceptualization of resilience that we analyse the capacity of the L'Aquila area to adapt to the shock. By studying the short and the medium term effects of the earthquake, we contribute to the debate on the economic resilience to natural disasters through an analysis on how territories reconfigure their socio-economic structure and develop new growth trajectories. Such approach considers resilience not much as a capacity to 'bounce back' to a pre-defined state (as in the engineering view), but rather as the ability to 'bounce forward' towards new scenarios, paths or organizational forms (Pike, 2010; Manyena et al., 2011). This paradigm is thus particularly consistent with our framework of analysis aiming to assess the capacity of a regional economy to adapt its structure (firms, workers, technologies, institutions) to go over the shock (Reggiani et al., 2002; Simmie and Martin, 2010; Boschma, 2015). The 'adaptive' conceptualization of resilience also allows to scrutinize the socio-political processes that underpin territorial resilience, therefore allowing us to discuss our results in relation to the policy agendas that were designed to help L'Aquila's LMA better cope with the shock (Weichselgartner and Kelman, 2015).

In most cases, studies on the economic resilience of territories to natural events analyse and compare single or multiple cases, and then try to inductively draw general conclusions. A crowded debate aims to analyse macroeconomic output effects after natural shocks. No general consensus has emerged so far: some authors argue that such events are unlikely to affect economic growth (see, for example, Cavallo et al., 2013), some others find negative effects (see, for example, Raddatz, 2009), and other authors find the activation of "schumpeterian" destruction dynamics even in the short run (like Skidmore and Toya, 2002).

A growing number of contributions also now highlights that national and local governments play a crucial role in the territories' capacity to positively react to shocks both in developed and developing countries (Noy, 2009; Barone, 2014; Mendoza et al., 2020). How disasters caused by natural events affect labour markets at a local scale is a research area that needs further analysis. Some general trends that are emerging in relation to earthquakes show that public intervention to finance reconstruction activities usually boosts economic activity in the short run, offsetting the destruction of physical capital generated by the quake and that a shift in employment towards non-tradeable sectors, mostly construction, is usually observed (Trezzi and Porcelli, 2014; Kirchberger, 2017).

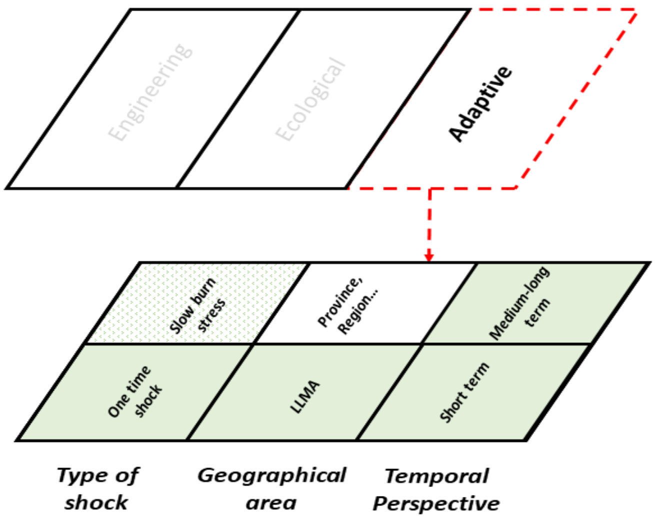
A few studies were also specifically dedicated to analysing the L'Aquila case, either as a standalone one, or in comparative terms. The first of the two previously mentioned trends was found in the area by Trezzi and Porcelli (2014), who concentrated on local fiscal multipliers, concluding that public funds allocated for reconstruction prevented a fall in the economic activity of the area. The second trend was highlighted by Basile et al. (2023) in an analysis comparing the 2009 earthquake with two other seismic events that recently occurred in Italy (known as Emilia-Romagna in 2012 and Central Italy in 2016). In their results, the L'Aquila earthquake appears to show the most negative impact compared to the other two events, both on aggregate employment rate and in terms of a stronger persistence of the effect of the shock over time. Eventually, they found that increased employment rate in the construction sector only partially offset job reductions in other sectors (especially in manufacturing).

In one of the first econometric analyses after the seismic event, Di Pietro and Mora (2015) gathered data from the 15 months following the earthquake and found that the employment likelihood fell in the quarter immediately after the event and then increased in the next four quarters. Regarding output and employment following seismic events, Porcelli and Trezzi (2019), comparing data from 22 earthquakes occurred in Italy between 1986 and 2011 (therefore including L'Aquila), found that following an earthquake, the observed contraction of output and employment is generally small or even negligible; eventually, Mendoza, Breglia and Jara (2020) compared the case with earthquakes occurred in Ecuador and Chile, concluding that Abruzzo seemed to experiment short run effects in working hours for women, but not in workers' salaries.

2.2 Research framework

We further define our case study following a classification proposed by Faggian et al. (2018), who suggest identifying three dimensions when analysing territorial shocks: the kind of shock, its geographical area and the temporal framework of analysis (see Figure 1).

Figure 1: The plot summarises our framework of analysis. The upper layer clarifies which conceptualization of resilience we refer to; the lower layer highlights how we position in terms of type of shock, geographical area and time perspective when we analyse the earthquake according to a framework proposed by Faggian et al. (2017). In terms of type of shocks we analyse L'Aquila 2009 earthquake, constituting a one-time shock. However, due to the contemporary financial recession and sovereign debt crisis, we consider L'Aquila LMA as also subject to slow-burn sources of distress.



Regarding the first point, a distinction has been proposed to divide what have been referred to as "one-time shocks" (Pendall et al., 2010, 78) or "'out-of-the-ordinary' events" (Martin and Sunley, 2015, 14), and what the same authors respectively call "slow-burn stresses" or "pressures". The first group includes sudden events that are usually exogenous in nature, such as an earthquake is. The latter encompasses crises that develop slowly and gradually over time, as could be de-industrialization processes or climate change effects. While experiencing the effects of the earthquake, the area we investigate was also subject to at least two "slow-burn" pressures that developed at a larger scales. One regards the 2008 global financial and economic crises and the 2010 European sovereign debt crisis, that strongly affected Italy. Both in the first (see Faggian et al., 2018) and in the second case (see Accetturo et al., 2022), Italian southern regions (that, according to ISTAT, include Abruzzo) proved to be vulnerable, increasing their divide with respect to northern and central administrative regions. The area we identified includes municipalities (20 out of 29) that are considered to be "inner areas" by the Italian National Strategy for Inner Areas (SNAI); this is relevant since peripheral areas seem to have suffered the consequences of the financial and economic crisis more than urban areas (Dijkstra et al., 2013; Urso et al., 2019). Even before recent crisis, the Abruzzo region had already reduced its economic growth, despite possessing a territorial capital and heritage of exceptional value, that in many cases is underutilized. After experiencing a fast growth of its economic structure between the 1960s and the early 1990s, the region entered a period of declining economic growth, ageing population and depopulation (OECD, 2013, 13); that was when both extraordinary public policies in Southern Italy came to an end, and when the region became no longer eligible for the Objective 1 EU structural funds programmes, therefore showing the weaknesses of its development bases (Barone et al., 2016; Iapadre and Mariani, 2020). In a European Commission report edited by Iammarino et al. (2020), Abruzzo was identified as an example of a European region that has fallen into a 'regional development trap', a concept that refers to regions that "face significant structural challenges in retrieving past dynamism or improving prosperity for their residents" (Diemer et al., 2022, 487). For all these reasons, policy agendas elaborated after the earthquake (later discussed) suggested considering the reconstruction as an opportunity to also enhance those territorial resources that were identified to better suit emerging local scenarios and re-think the development paths of the areas.

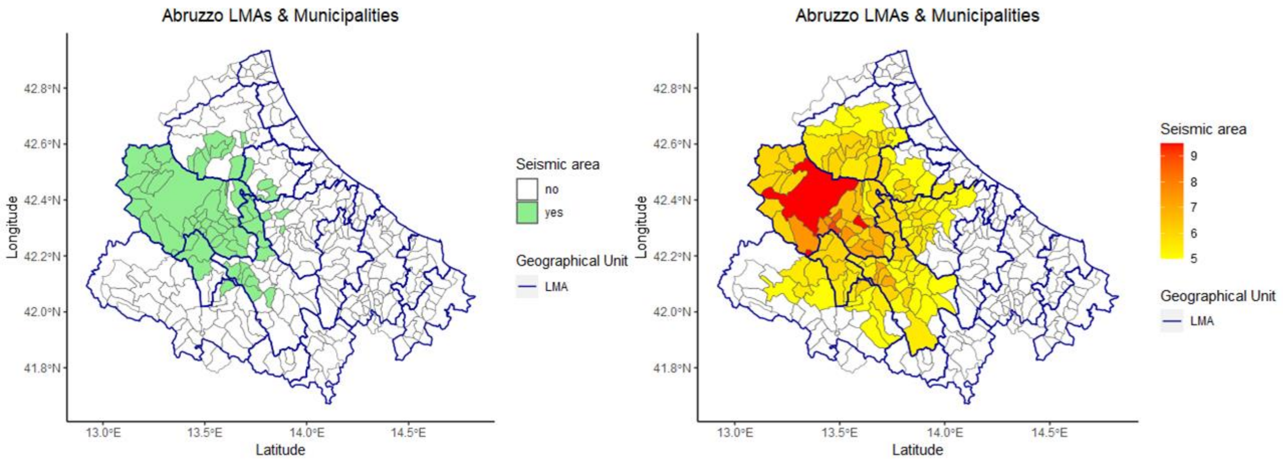
Regarding the geographical dimension, we decided to use data on L'Aquila's LMA for two main reasons: identifying the affected territories as the set of municipalities falling within the seismic area according to a related governmental decree[6] (in green in Figure 2, left panel), L'Aquila's LMA results to be the statistical unit of analysis encapsulating most of the affected municipalities.[7] Data at provincial level (NUTS 3) would include 79 more municipalities that were not considered to be affected by the quake. Secondly, measuring the damage intensity through the Mercalli scale, the municipalities included in the selected LMA also proved to be the most 'physically' affected by the earthquake. Figure 2 (right panel) shows that the highest intensity was observed in the municipalities of L'Aquila, San Pio delle Camere, Sant'Eusanio Forconese and Villa Sant'Angelo, representing the only administrative units with a Mercalli intensity equal or larger than 9.0. A lower earthquake magnitude was observed in the other LMAs of Abruzzo, as the average Mercalli scale for municipalities in our treated LMA is 6.8, whereas the same figure ranges between 5.0 (Chieti) and 5.9 (Popoli) when considering our control units. Notice also that the Mercalli scale was not disclosed for other municipalities in the region that were located far from the epicentre (left blank in Figure 2, right panel), since they did not experience any significant damage.

Figure 2: The left panel shows the LMAs in Abruzzo region through the blue line. Black lines border municipalities. In green, we colour those municipalities that were included in the seismic area. The right panel shows the 2009 earthquake intensity expressed through the Mercalli Scale. Input data are sourced from the National Institute for Geophysics and Volcanology (INGV) as disclosed by Galli and Camassi (2009). We colour each administrative unit with

[6] President of the Council of Ministers, Decree No. 3, April 16, 2009, supplemented by Decree No. 11, July 17, 2009, issued by the Commissioner designated for this purpose.

[7] Figure 2, left panel, highlights that only 3 municipalities out of 32 were not considered to be part of the seismic area in the L'Aquila's LMA.

the maximum value of the Mercalli scale associated by the mentioned study with each municipality of Abruzzo. We report in white those municipalities for which the Mercalli scale related to the 2009 earthquake was not provided.



Lastly, the temporal framework we identified conceives two intervals: considering the earthquake happened on April 6, 2009, we analyse short-run effects using the timeframe 2009-2013, and we discuss medium-term results through the timeframe 2009-2013.

3. Data and Methods

3.1 Empirical approach

We adopt a synthetic difference-in-differences (SDID) method recently introduced by Arkhangelsky et al. (2021) to unveil the impact of the 2009 earthquake on the L'Aquila's LMA over the time frame 2004-2013. This enables us to observe how the effects of the disaster unfold over a 5 years' time horizon after the event. We rely on this approach given its suitability for examining a setting in which a single unit is subject to a treatment and where other causal inference methods such as a traditional DID cannot be applied to an insufficient number of treated entities.

SDID aims to assess the effect of a treatment by comparing the outcome variable of the treated entity to a counterfactual scenario (synthetic control). This synthetic control is constructed by combining the outcome variables of various elements in the control group (referred to as the donor pool) with weights calculated based on the similarity of observable characteristics between the treated entity and the control group in the period preceding the treatment.

In this method, the Average Treatment Effect on the Treated (ATT) is computed as the difference between the outcome variable of the treated entity and that of the synthetic control during the post-treatment period. In particular, the ATT ($\hat{\tau}^{sdid}$) is estimated based on a two-ways fixed effects regression:

$$\left(\hat{\tau}^{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}\right) = \underset{\tau, \mu, \alpha, \beta}{argmin} \left\{ \sum_{i=1}^{N} \sum_{t=1}^{T} (Y_{i,t} - \mu - \alpha_i - \beta_t - W_{i,t}\tau)^2 \hat{w}_i^{sdid} \hat{\lambda}_t^{sdid} \right\} \quad (1)$$

where $Y_{i,t}$, is our dependent variable (see section 3.3 for further details), μ is a constant, α_i and β_t are LMAs and years fixed effects. Index *i* refers to LMAs, while subscript *t* denotes years. We provide a short and medium term estimates of the ATT. The former measures the impact of the earthquake at 1 year distance from the event thus focusing on the period 2004-2009. In this way, we expect to isolate the effect of the disaster without confounding factors related to reconstruction policies. The latter compares the development dynamics of L'Aquila and the counterfactual until 5 years after the event thus providing an insight on the recovery process focusing on the time frame 2004-2013.

Furthermore, $W_{i,t}$ is a dummy variable equal to 1 for treated units during the post-treatment period and 0 otherwise. Finally, $\widehat{w}_i^{sdid}$ represents the unit parameter allowing to give more weight to LMAs that tend to exhibit more similar characteristics in the pre-treatment period to our treated unit. In particular, weights are assigned to the donor pool in order to match pre-exposure trends of the treated unit and the synthetic control, to weaken the reliance on parallel trend assumptions.

Similarly, $\hat{\lambda}_t^{sdid}$ constitutes the time coefficient enabling to weight more pre-treatment years that are on average more similar to the post-treatment period.

Based on an algorithm elaborated by Arkhangelsky et al. (2021), we use the following formula to compute units' weights $\widehat{w}_i^{sdid}$, pointing to minimize the difference between the outcome variable of control elements and of the treated unit before the start of the treatment:

$$\left(\widehat{w}_0, \widehat{w}^{sdid}\right) = \underset{w_0 \in R,\, w^{sdid} \in \Omega}{argmin} \left\{ \sum_{t=1}^{T_{pre}} \left(w_0 + \sum_{i=1}^{N_{co}} w_i Y_{i,t} - \frac{1}{N_{tr}} \sum_{i=N_{co}+1}^{N} Y_{i,t} \right)^2 + \zeta^2 T_{pre} \|w\|_2^2 \right\} \quad (2)$$

$$\Omega = \left\{ w \in R_+^N : \sum_{i=1}^{N_{co}} w_i = 1, \qquad w_i = \frac{1}{N_{tr}} \; for\ all\ i = N_{co}+1, \dots, N \right\} \quad (3)$$

where N_{co} and N_{tr} represent the number of control and treated units, respectively, with $N = N_{co} + N_{tr}$. In our setting, N_{tr} is equal to 1, as our only treated unit is the LMA of L'Aquila. On the other hand, in order to optimize the identification of the most appropriate synthetic control, the donor pool is constituted by all the other Italian LMAs that did not experience a seismic event during the analysed period. In particular, we removed from the control group 12 LMAs located between Emilia-Romagna and Lombardy that in 2012 were subject to the earthquake occurred in May 2012 (Basile et al., 2023). Therefore, N_{co} is equal to 672.[8] Furthermore, T_{pre} refers to the years included in the pre-treatment period, corresponding to 2004-2008 in our framework of analysis. ζ is a regularization parameter, that is computed through the following formula:

$$\zeta = \left(N_{tr} T_{post}\right)^{\frac{1}{4}} \hat{\sigma} \quad (4)$$

where T_{post} denotes those years in the post-treatment period, corresponding to 2009-2018[9] and $\hat{\sigma}$ is computed as follows:

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[8] Here we report the list of the 12 LMAs removed from the donor pool since they were subject to the Emilia-Romagna earthquake occurred in May 2012: Bologna, Carpi, Correggio, Cremona, Ferrara, Guastalla, Lugo, Mirandola, Modena, Parma, Reggio nell'Emilia, Viadana. We also checked our list of LMAs included in our donor pool with the international disaster database which is available at the following link: https://climate-adapt.eea.europa.eu/it/metadata/portals/em-dat-the-international-disaster-database-year-of-launch.

[9] The earthquake occurred on April 6, 2009. Year 2009 is thus considered to be our year 0, i.e. when we begin to measure the event's impact.

$$\hat{\sigma} = \frac{1}{N_{co}(T_{pre}-1)} \sum_{i=1}^{N_{co}} \sum_{t=1}^{T_{pre}-1} (\Delta_{it} - \bar{\Delta}) \quad (5)$$

with

$$\Delta_{it} = Y_{i(t+1)} - Y_{it} \quad (6)$$

$$\bar{\Delta} = \frac{1}{N_{co}(T_{pre}-1)} \sum_{i=1}^{N_{co}} \sum_{t=1}^{T_{pre}-1} (\Delta_{it}) \quad (7)$$

The weight w_0 allows the SDID to differentiate from the seminal synthetic control method (SCM) introduced by Abadie and Gardeazabal (2003) and Abadie et al. (2010). Indeed, by the means of this coefficient, Equation (2) points to obtain parallel trends in the outcome variable of treated and control units in the pre-treatment period, thus adding more flexibility with respect to the traditional SCM approach, aiming to perfectly match the dependent variable of treated entity and synthetic control before the start of the treatment. The possibility to rely on this extra flexibility in the estimation of unit weights is related to the introduction of fixed effects in Equation (1) that allow to absorb the presence of constant differences between alternative units.

In addition, we rely on the following formula to compute time weights ($\hat{\lambda}_t^{sdid}$) having the goal to reduce bias and increase the precision of our estimates taking into account the similarity between years in the pre- and post-treatment periods:

$$\left(\hat{\lambda}_0, \hat{\lambda}^{sdid}\right) = \underset{\lambda_0 \in R, \lambda^{sdid} \in \Lambda}{argimin} \left\{ \sum_{i=1}^{N_{co}} \left(\lambda_0 + \sum_{t=1}^{T_{pre}} \lambda_t Y_{i,t} - \frac{1}{T_{post}} \sum_{t=T_{pre}+1}^{T} Y_{i,t} \right)^2 \right\} \quad (8)$$

$$\Lambda = \left\{ \lambda \in R_+^T : \sum_{t=1}^{T_{pre}} \lambda_t = 1, \qquad \lambda_t = \frac{1}{T_{post}} \; for\ all\ t = T_{pre}+1, \dots, T \right\} \quad (9)$$

where $T = T_{pre} + T_{post}$ and T_{post} is the total number of years of exposure to the treatment.

We rely on the algorithm version including time-varying exogenous covariates $X_{i,t}$ (see section 3.3 for further details) to better assess the similarity in observable characteristics between treated and control units. In particular, adjustments for such regressors are incorporated by estimating the SDID on the residuals of the following equation:

$$Y_{it}^{res} = Y_{it} - X_{it}\hat{\beta} \quad (10)$$

3.2 Variables description

This section contains a description of the set of variables we use in the empirical analysis as our dependent ($Y_{i,t}$) and control variables ($X_{i,t}$).

In terms of outcome variable $Y_{i,t}$, we consider alternative dimensions to assess the earthquake impact. In line with previous works focusing on effects of the L'Aquila's earthquake (Di Pietro and Mora, 2015; Porcelli and Trezzi, 2019; Basile et al., 2023), we consider the employment index with reference to year 2006 as our first dependent variable. In order to avoid size factors affecting our results, we measure the employment index as the ratio between the number of employees in LMA i in year t ($Employees_{it}$) and the number of employees in year 2006 in the underlying LMA. In formula:

$$Employment\ index_{it} = \frac{Employees_{it}}{Employees_{i,2006}}\ (11)$$

We use this definition of our variable of interest since we are interested in the detection of patterns of disruption and recovery of local employment, and the index well represents differences in growth, as it allows to identify percentages variations of employment with respect to the year of reference. Similar definitions of the dependent variable have been applied in the regional science literature also by Barone et al. (2016) and Scotti et al. (2023) to study the impact of public policies of financial support on alternative economic variables of treated units.

In addition, we distinguish from previous studies by analysing economic dynamics after the earthquake also in terms of number of firms in the underlying LMA. Consistently with our previous approach for the employment dimension, we define our dependent variable as the firm index with reference to year 2006, computed as the ratio between the number of firms in the underlying year ($Firm_{it}$) and the number of firms in year 2006:

$$Firm\ index_{it} = \frac{Firm_{it}}{Firm_{i,2006}}\ (12)$$

This measure provides a complementary perspective with respect to the employment variable since it allows assessing the attractiveness of L'Aquila's LMA after the earthquake as a place to start new business activities.

Data related to the yearly number of employees and firms at LMA level over the period 2004-2018 are disaggregated across sectors, based on the Nomenclature of Economic Activities (NACE) rev.2. Table 1 summarizes variables used in our analysis and specifies sources of information.

To enrich our analysis, we consider two additional indicators as our dependent variable. One is income per capita, enabling to evaluate the earthquake impact on the local level of wealth. Such variable is more in line with what Kirchberger (2017) and Mendoza et al. (2020) adopted to analyse the earthquake impact on labour income, and with Barone and Mocetti (2014), who focused on the Gross Domestic Product (GDP) per capita.

Also in this case, we define our dependent variable as the income per capita index with reference to year 2006, computed as the ratio between the income per capita in the underlying year ($Income\ per\ capita_{it}$) and income per capita in year 2006:

$$Income\ per\ capita\ index_{it} = \frac{Income\ per\ capita_{it}}{Income\ per\ capita_{i,2006}}\ (13)$$

The second is the Finger-Kreinin (FK) index, providing an insight into the sector diversification level of L'Aquila with respect to other LMAs in Abruzzo (Finger and Kreinin, 1979). Since a strong degree of dissimilarity with respect to the rest of the region may expose the area to a stronger risk of an idiosyncratic shock targeting the specific sectors where L'Aquila concentrates its competitive advantage, we use this indicator to assess the extent to which the earthquake affected the vulnerability of the local economic structure.

In particular, we compute the FK variable as follows:

$$FK_{it} = 0.5 * \sum_{k} \left| \frac{Employees_{ikt}}{Employees_{it}} - \left[\frac{Employees_{A,k,t} - Employees_{ikt}}{Employees_{A,t} - Employees_{i,t}} \right] \right| \quad (14)$$

where $Employees_{ikt}$ is the number of employees in LMA i in sector k in year t, $Employees_{it}$ is the total number of employees in LMA i in year t, $Employees_{A,k,t}$ is the number of employees in Abruzzo in sector k in year t and $Employees_{A,t}$ is the total number of employees in Abruzzo in year t. A larger value of such indicator (ranging between 0 and 1) thus means a higher sector dissimilarity of LMA i with respect to other Abruzzo's areas. Also in this case, we assess differences of sector diversification over time computing the FK index with reference to year 2006 as follows:

$$FK\ index_{it} = \frac{FK_{it}}{FK_{i,2006}} \quad (15)$$

On the other hand, in terms of covariates $X_{i,t}$, we consider the number of residents (*population*) in each LMA to control for the size of units. Moreover, we include the population density as an additional demographic variable. We consider the percentage of foreign people to account for heterogeneity in the local demographic structure from a social perspective (*foreign people*). We also plug in our model the portion of active population (*active population*), defined as the percentage of population aged between 15 and 64. By doing so, we control for potential differences in the local economic structure due to the presence of cohorts with diverse age classes. In line with Dube et al. (2010) and Gabillon and Magnac (2016), we have also considered the income per capita and the employment rate to account for other relevant economic variables and labour market factors. We encompass the number of vehicles (*Vehicles*) as a proxy of the availability of transportation infrastructures. Finally, we include the percentage of municipalities within the LMAs that are classified as coastal areas and as inner areas to account for potential alternative development patterns.[10] All control variables are made publicly available by ISTAT.[11]

Table 1: Definition and Sources of variables employed in our empirical analysis.

Variable class	Variable Name	Source of Data
Dependent Variable	Employment Index	Authors elaboration based on ISTAT, dataset disclosed for research purposes
	Firms Index	Authors elaboration based on ISTAT, dataset disclosed for research purposes
	Income per capita	ISTAT
	FK Index	Authors elaboration based on ISTAT, dataset disclosed for research purposes
Control Covariates	Population	ISTAT
	Population density	ISTAT
	Foreign Population	ISTAT

[10] The adopted methodology exploits also the historical values of the outcome of interest, as proposed by Abadie et al. (2015) to build the synthetic control.
[11] The ISTAT dataset is publicly available at the following link: http://dati.istat.it/?lang=en.

	Active Population	ISTAT
	Percentage of municipalities that are coastal areas	ISTAT
	Percentage of municipalities that are classified as inner areas	ISTAT
	Employment rate	ISTAT
	Vehicles	ISTAT

Table 2 shows descriptive statistics for our dependent and control variables. Table 3 highlights average values of such variables for our treated unit and the donor pool.

Table 2: We show descriptive statistics for our dependent and control variables. Data refer to the entire analysed period (2004-2018).

Variable	Q1	Median	Mean	Q3	Std.dev
Employment Index	0.967	1.00	1.01	1.034	0.058
Firm Index	0.953	0.983	0.974	1.000	0.067
Income pc	1.304	1.436	1.481	1.641	0.301
FK index	0.955	1.000	1.010	1.050	0.106
Population	21,498	46,938	107,602	94,854	282,391
Population density	68.350	138.169	263.438	304.086	385.65
Foreign Population	0.014	0.033	0.040	0.061	0.301
Active Population	0.664	0.650	0.648	0.633	0.023
Percentage of municipalities that are coastal areas	0.000	0.183	0.201	0.354	0.208
Percentage of municipalities that are classified as inner areas	0.067	0.215	0.226	0.615	0.395
Employment rate	0.362	0.437	0.426	0.486	0.075
Vehicles	16,570	36,858	87,327	78,523	235,139

Table 3: We show average values of our dependent and control variables for the treated unit (L'Aquila LMA) and control units observed during the pre-treatment period (2004-2008).

Variable	L'Aquila LMA [mean]	Other Abruzzo LMAs [mean]
Employment Index	0.983	0.974
Firm Index	0.887	1.001
Income pc	1.322	1.481
FK index	1.244	1.010

Population	98,016	107,622
Population density	61.805	264.003
Foreign Population	0.041	0.040
Active Population	0.337	0.352
Percentage of municipalities that are coastal areas	0.000	0.156
Percentage of municipalities that are classified as inner areas	1.000	0.412
Employment rate	44.038	42.610
Vehicles	85,753	87,330

4. Empirical Evidence

In this section, we discuss the results of the empirical analysis described in section 3.2. In particular, section 4.1 analyses the impact of the 2009 earthquake at the aggregate sectoral level in terms of firms, employment, income per capita and sector dissimilarity. Then, section 4.2 further investigates such results by disaggregating previous evidence between the manufacturing and service sectors. Finally, sub-sections 4.2.1 and 4.2.2 show how such evidence is driven at a high granular level by manufacturing and service sub-sectors. This progressively increasing level of granularity of the analysis in terms of sectoral disaggregation may enable to distinguish the sectors that mostly suffered the impact of the event and those driving the economic recovery, thus allowing policymakers to improve strategies aimed at strengthening local resilience.

4.1 All aggregated sectors

In a first step, we analyse the impact of the 2009 earthquake on L'Aquila's LMA considering all aggregated economic sectors. In Table 4, we exhibit the ATT estimates at 1- and 5-years distance from the event to disentangle its short and medium term effects. We show our results in terms of number of firms, number of employees, income per capita and sector diversification.

Overall, we highlight that the earthquake significantly disrupted the L'Aquila's LMA in terms of number of firms and employees. One years after the earthquake, the number of firms was 38.2% lower than that observed in the counterfactual (see also Figure 3). Similarly, employment experienced a significant reduction compared to the synthetic control (-27.3%), even though showing a lower magnitude with respect to the number of firms (see also Figure 4). Notice that these estimates should isolate the impact of the earthquake since reconstruction policies were not implemented yet. Interestingly, we find that such effects are transitory and not persistent, since the penalization in terms of number of firms and employees is not significant 5 years after the earthquake.

We also perform a set of robustness check to assess the validity of our findings. First, we employ a time placebo test, where we consider the year 2010 as the start of the treatment (rather than 2008). Panel B in Figures 3 and 4 highlights that the discontinuity between the treated unit and the synthetic control starts in 2009 in correspondence with the earthquake, thus suggesting that the measured effect is not due to other events occurred in the following years. Second, we perform a leave-one-out placebo test, where we exclude, one at a time, by the donor pool the 5 units in the control group receiving the highest units' weights $\hat{w}_i^{sdid}$. Also in this case, Panel C in Figures 3 and 4 shows that the measured ATT is not due to the specific set of control units included in the synthetic control. Indeed, the results are stable even when considering alternative combinations of units included in the donor pool to build the counterfactual. Finally, we do a space placebo test, where we virtually consider as treated all the other LMAs in Abruzzo. In this way, we also estimate a synthetic control for each LMA in Abruzzo that did not directly experienced the earthquake. Panel D in Figures 3 and 4 displays the difference between the outcome variable for the treated unit and the synthetic control for L'Aquila and the other LMAs of Abruzzo. In this way, we offer a further evidence of the economic penalization faced by L'Aquila since, especially in the years 2009 and 2010, it experiences a significantly larger gap with respect to other LMAs in Abruzzo, due to the earthquake. We also confirm how such effects in terms of both number of employees and firms are not anymore significant in a medium term perspective.

Conversely, we do not identify neither a short nor a medium term contraction of income per capita as shown in Panel A of Figure 5. Such evidence is corroborated by our time, "leave one out" and space placebo tests (see Panels B, C and D in Figure 5). Indeed, all these further analyses confirm the absence of significant results in terms of income per capita variation in L'Aquila with respect to alternative counterfactuals and other LMAs in Abruzzo. This result suggests that the local level of wealth did not apparently diminish, possibly due to the strong level of financial support received by territory after the natural disaster, as also suggested by Trezzi and Porcelli (2014) in the short run. Such results are consistent with previous evidence highlighting how earthquakes may lead to a growth of labour income (Kirchberger, 2017; Mendoza et al., 2020) and to negligible short-term impacts in terms of GDP per capita and potential positive long-term effects in case of effective packages of financial aid (Barone and Mocetti, 2014).

Finally, we observe significant coefficients when we account for sector diversification both in a short and medium term perspective. Indeed, the ATT of FK is positive and significant ($\hat{\tau} = 0.16$ and 0.19, respectively), thus meaning that the earthquake induced a pattern of sector dissimilarity that structurally changed the local economic structure of L'Aquila with respect to other LMAs in Abruzzo considering that the effects are still tangible 5 years after the earthquake (see Panel A in Figure 6). Panel B in Figure 6 highlights that the pattern of economic diversification of L'Aquila economy started in 2008 in correspondence with the earthquake and was not due to other events. Panel C in Figure 6 shows that the growth in the FK index is robust to the selection of alternative control units for the construction of the synthetic control. Finally, Panel D in Figure 6 suggests that the economy diversification observed in L'Aquila is stronger than that experienced by other LMAs in Abruzzo during the analysed period.

Table 4: We show the results of the SDID analysis described in section 3.2. The table reports the ATT estimates over the periods 2004-2013 and 2004-2018, thus disentangling the earthquake impact at 1- and 5- years distance from the event in order to highlight short and medium term effects. We show the impact in terms of number of firms, employment, income per capita and sector diversification when we consider all sectors aggregated.

Variable	**1 year**	**5 years**
Firms	-0.382*** (0.014)	0.023 (0.025)
Employees	-0.273*** (0.035)	0.045 (0.042)

Income pc	-0.043 (0.039)	0.030 (0.054)
FK	0.162** (0.069)	0.187** (0.080)

Note: *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.10

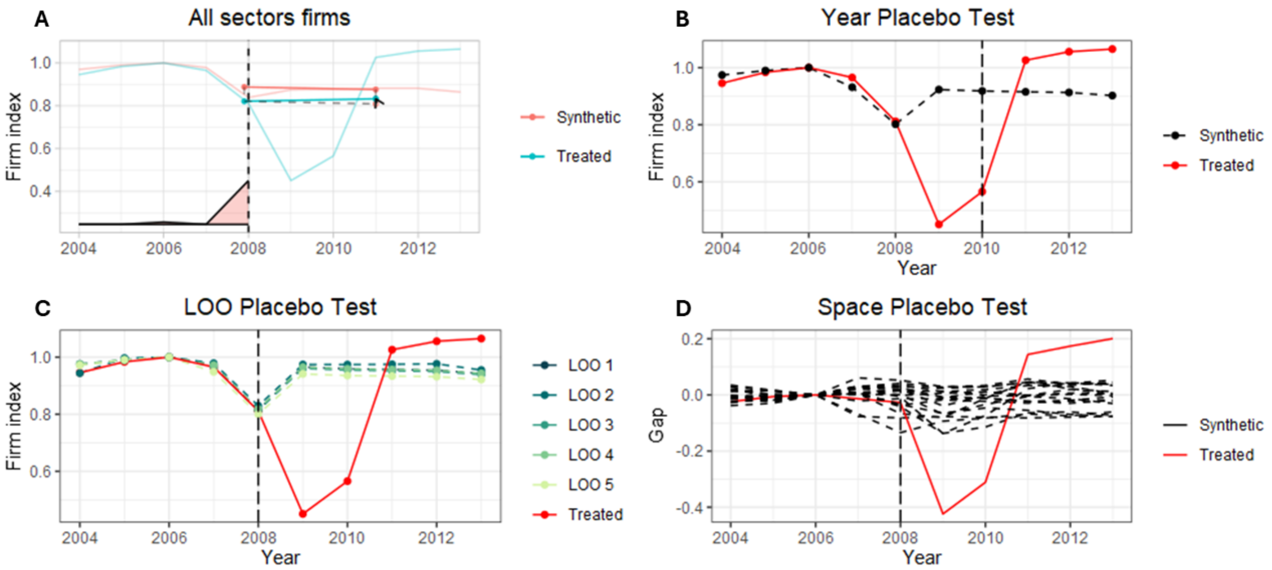

Figure 3: Panel A shows the trend of the firm index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of number of firms. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

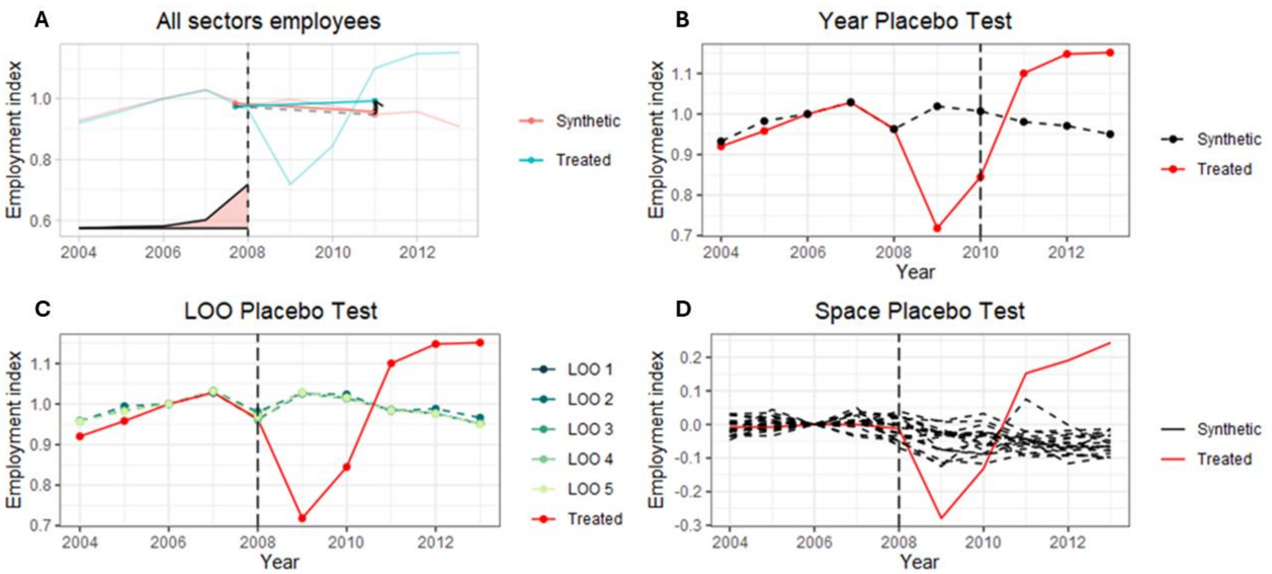

Figure 4: Panel A shows the trend of the employment index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of number of employees. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

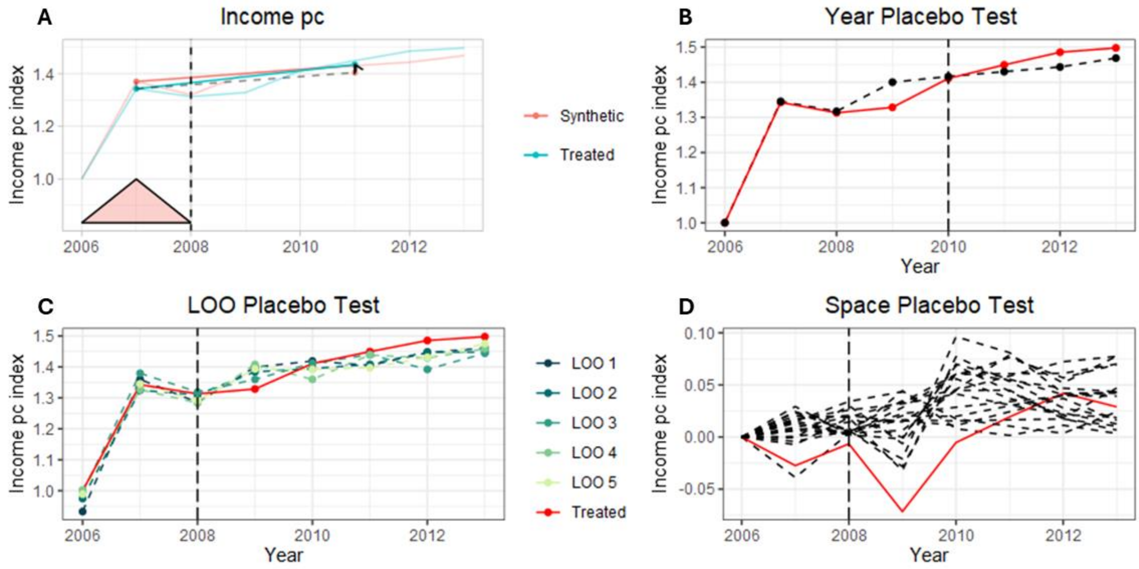

Figure 5: Panel A shows the trend of the income per capita index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of income per capita. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

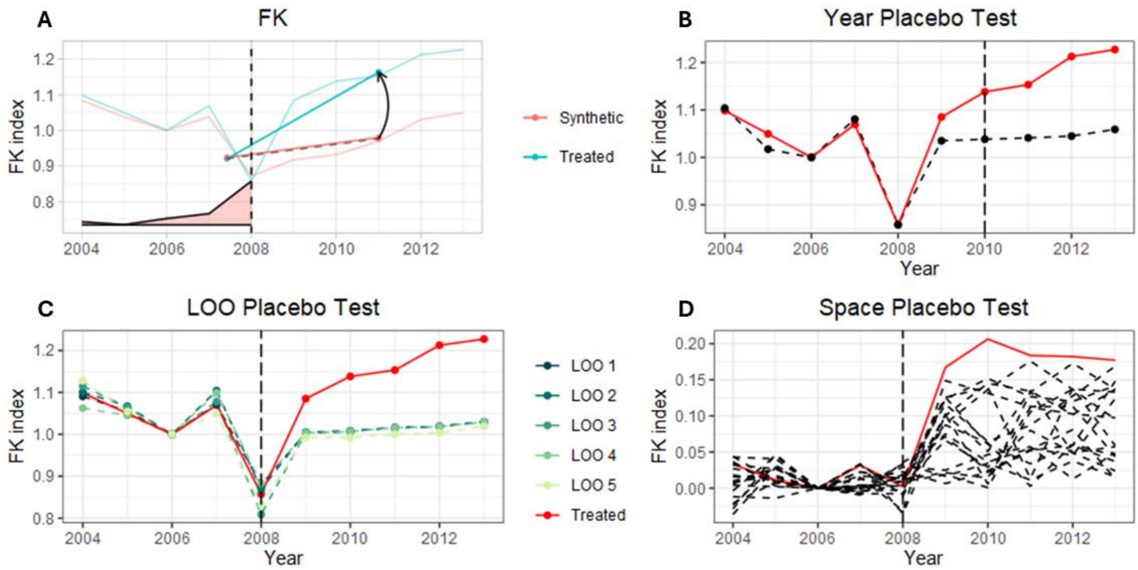

Figure 6: Panel A shows the trend of the FK index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of FK index. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

4.2 Manufacturing and service sectors

This section is dedicated to discussing the heterogeneity of the earthquake impact across the manufacturing and service sectors. The former refers to an analysis restricted to business activities that are classified in the NACE rev.2 sector "C", denoting manufacturing activities. The latter refers to an analysis focusing on all sectors that are not included in the primary or secondary sectors,[12] thus encompassing all business activities with a NACE sector code between D and S, with the exclusion of code O (denoting public administration sector, due to data unavailability).

Table 5 focuses on the manufacturing sector, displaying evidence of a strong reduction of activities as a consequence of the earthquake. Indeed, L'Aquila's LMA experienced an immediate reduction in the number of firms 1 years after the disaster that is 35.6% larger than that observed in the synthetic control. Similar evidence holds in terms of number of employees (-19.9%). Contrarily with the case where we consider all aggregate sectors, we find that the disruption of the local business environment was permanent with significant effects even 5 years after the event ($\hat{\tau} = -14.7\%$ and -10.4%, see also Panel A in Figures 7 and 8).

These impacts are robust to a set of alternative placebo tests. The time placebo test shows that the discontinuity between L'Aquila and the synthetic control occurs in 2009 when the earthquake took place and not in correspondence of other events (see Panel B in Figures 7 and 8). Furthermore, the leave one out placebo test highlights that the contraction of the manufacturing sector is not due to the specific control units included in the synthetic control since the result is stable even slightly changing the counterfactual (see Panel C in Figures 7 and 8). Moreover, the reduction of employment and number of firms in the manufacturing sector in L'Aquila is significantly larger than that observed in other LMAs in Abruzzo non subject to the earthquake (see Panel D in Figures 7 and 8).

The earthquake favourited a dynamic of manufacturing sub-sectors diversification, meaning that L'Aquila increased its competitive advantage in specific sub-sectors contributing to raise the dissimilarity of the local economic structure with respect to other LMAs in Abruzzo. Such pattern did not vanish in a medium-term horizon, since the ATT at 5-years distance ($\hat{\tau} = 0.09$) is even larger in magnitude if compared to the 1-year ATT ($\hat{\tau} = 0.06$, see also Panel A in Figure 9). Time, leave one out and space placebo tests corroborate these findings (see Panels B, C and D in Figure 9).

Table 6 allows to detect that the earthquake impact at aggregate level was the result of heterogeneous dynamics between the manufacturing and service sectors. Also the latter, indeed, showed a negative short term effect in terms of both number of firms and employment ($\hat{\tau} = -39.0\%$ and -26.1%, see also Panel A in Figures 10 and 11). Nonetheless, the 5-years ATT is positive and not significant in terms of number of firms ($\hat{\tau} = 2.2\%$) and employees ($\hat{\tau} = 6.6\%$) , thus meaning that the service sector experienced a relevant rebound after the event allowing to achieve levels of activities that are comparable with the pre-treatment period and that are not significantly different from those observed for the counterfactual. These patterns are confirmed also by our placebo tests. Indeed, we observe that the strong contraction of the services sectors started in 2009 in correspondence with the earthquake and not in following years (see Panel B in Figures 10 and 11). The leave one out placebo test confirm that the immediate reduction in the number of firms and employees, as well as the recovery in the medium term, were not due to the specific control units included in the synthetic control (see Panel C in Figures 10 and 11). Finally, the space placebo test demonstrates that such patterns are stronger in L'Aquila than in other LMAs in Abruzzo (see Panel D in Figures 10 and 11.

[12] By "primary sector" we refer to NACE sector codes A ("agriculture, forestry and fishing") and B ("mining and quarrying"). With the term Secondary sector, we refer to NACE sector code C ("manufacturing").

Table 5: We show the results of the SDID analysis described in section 3.2. The table reports the ATT estimates over the periods 2004-2013 and 2004-2018, thus disentangling the earthquake impact 1- and 5-years after it took place, in order to highlight short and medium term effects. We show the impact in terms of number of firms, employment, and sector diversification focusing on the manufacturing sector.

Variable	**1 year**	**5 years**
Firms	-0.356*** (0.021)	-0.147*** (0.034)
Employees	-0.199*** (0.021)	-0.104*** (0.024)
FK	0.059* (0.032)	0.085*** (0.032)

Also in this case, Panel A in Figure 12 exhibits that L'Aquila increased its sector diversification across service activities, with a medium-term transformation of the local economic structure, as demonstrated by the significant ATT 5 years after the quake ($\hat{\tau} = 0.12$). These results are confirmed by the time, leave one out and space placebo tests (see Panels B, C and D in Figure 12).

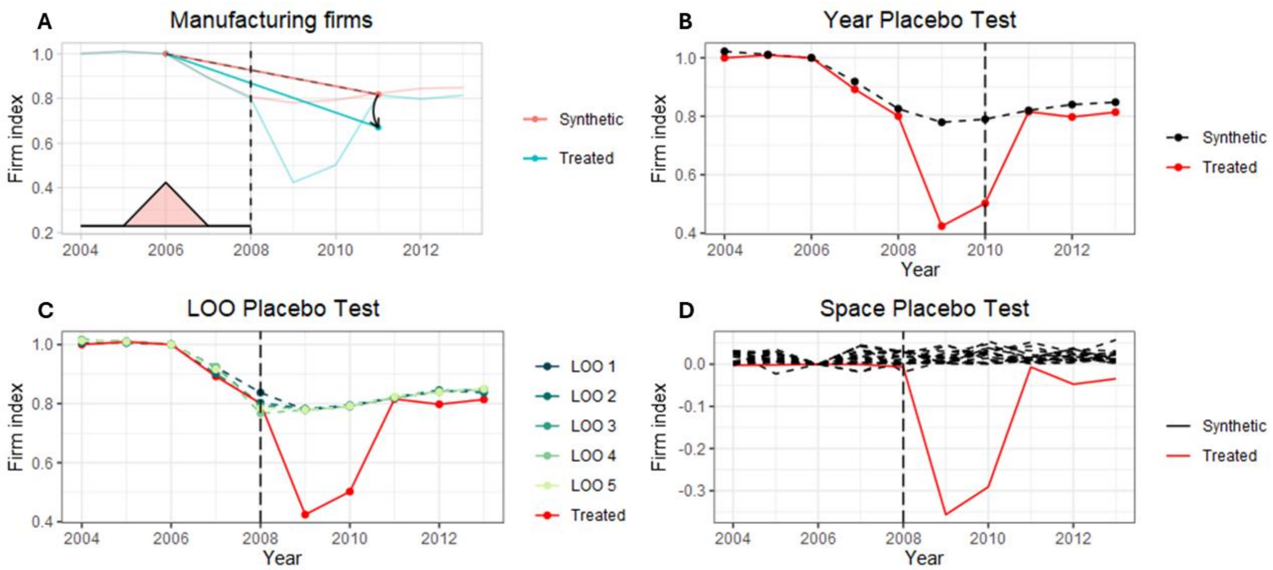

Figure 7: Panel A shows the trend of the firm index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of the number of firms in the manufacturing sector. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

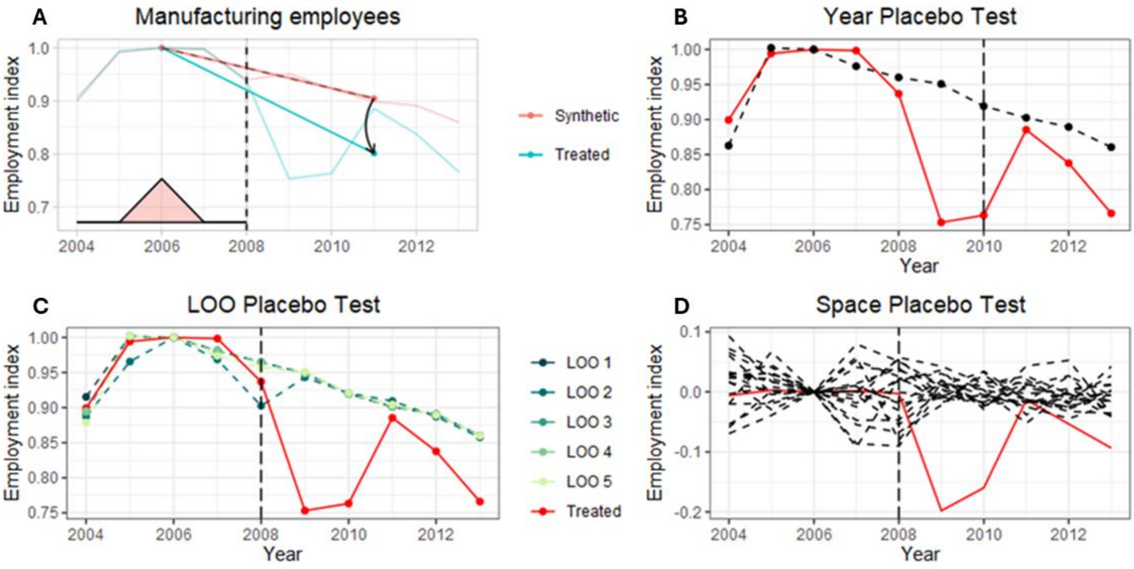

Figure 8: Panel A shows the trend of the employment index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of the number of employees in the manufacturing sector. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

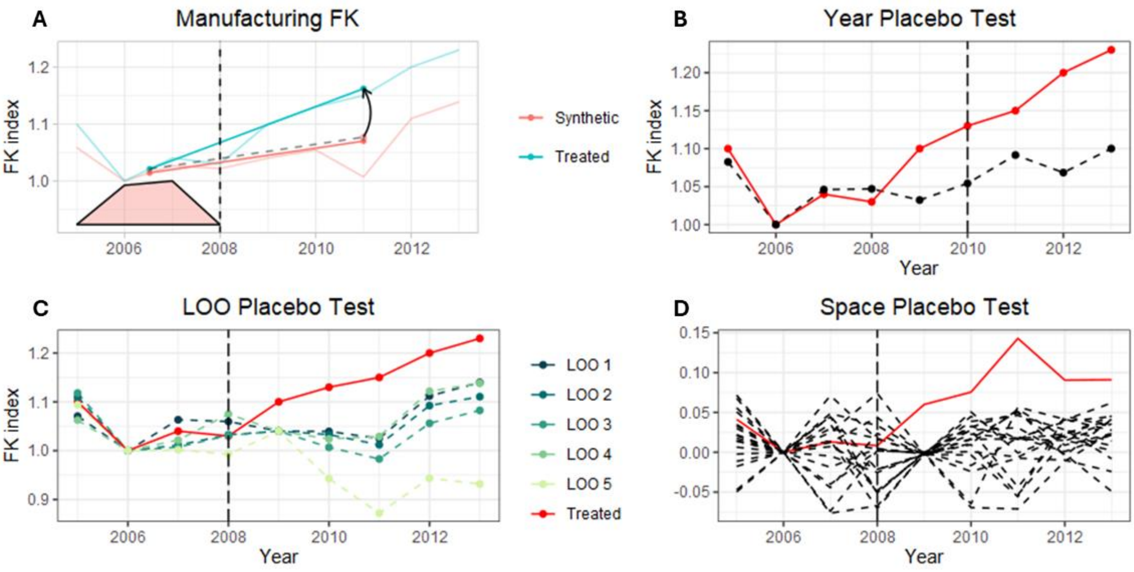

Figure 9: Panel A shows the trend of the FK index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of the FK index in the manufacturing sector. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

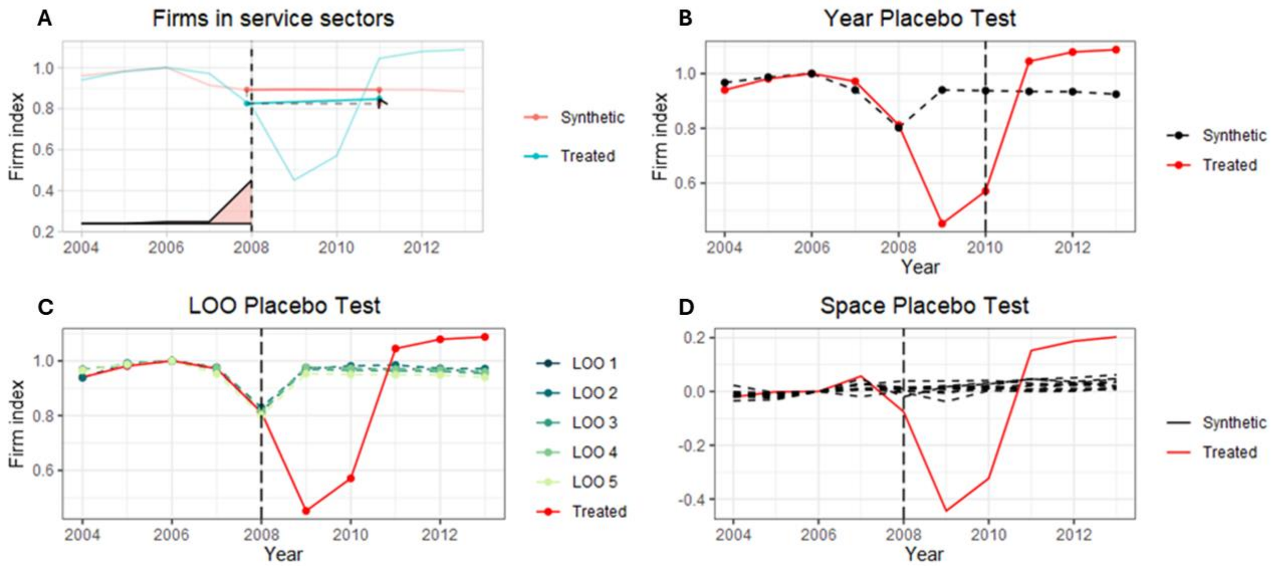

Figure 10: Panel A shows the trend of the firm index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of the number of firms in service sectors. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

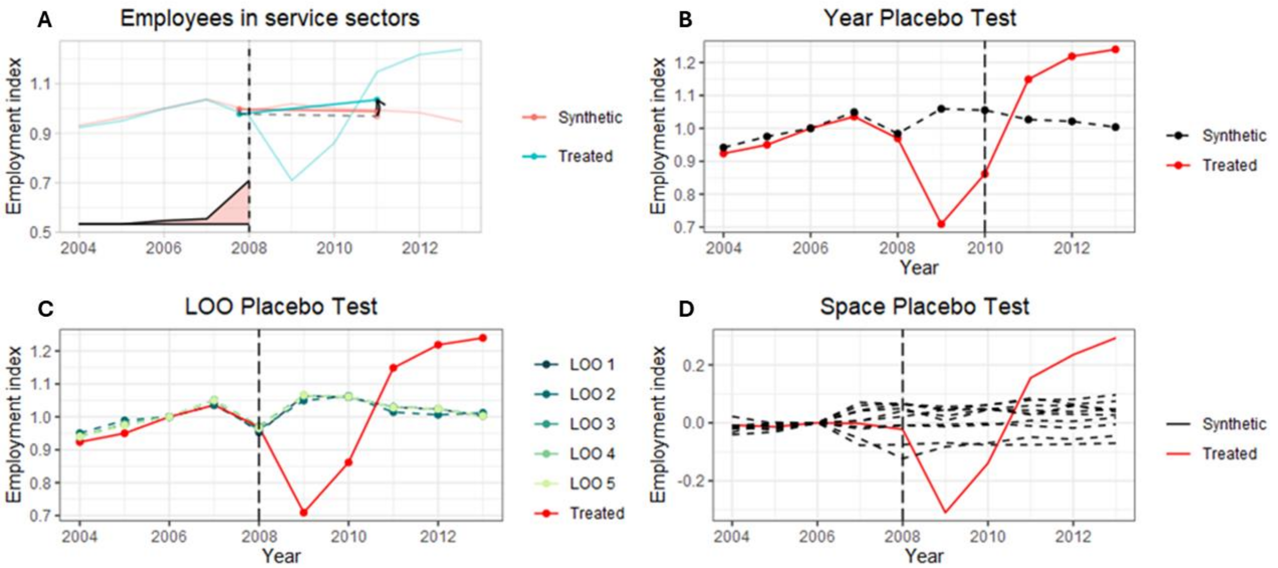

Figure 11: Panel A shows the trend of the employment index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of the number of employees in service sectors. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

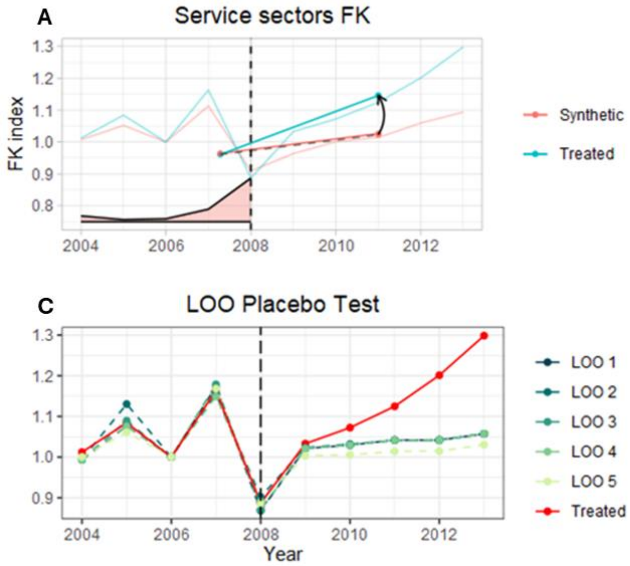

Figure 12: Panel A shows the trend of the FK index for the treated LMA of L'Aquila and the synthetic control over the time frame 2004-2013. The arrow highlights the ATT estimated through the SDID introduced by Arkhangelsky et al. (2021) as described in section 3.2. Estimates refer to the impact of the earthquake in terms of the FK index in service sectors. Panels B, C and D shows the results of a time, leave-one-out and space placebo tests.

Table 6: We show the results of the SDID analysis described in section 3.2. The table reports the ATT estimates over the periods 2004-2013 and 2004-2018, thus disentangling the earthquake impact 1- and 5-years after it took place, in order to highlight short and medium term effects. We show the impact in terms of number of firms, employment, and sector diversification focusing on the service sectors.

Variable	1 year	5 years
Firms	-0.390*** (0.015)	0.022 (0.028)
Employees	-0.261*** (0.037)	0.066 (0.046)
FK	0.082 (0.063)	0.123* (0.071)

4.2.1 Manufacturing sub-sectors

In this section, we analyse the impact of the earthquake across 12 manufacturing sub-sectors in terms of employment.

Table 7: We show the results of the SDID analysis described in section 3.2. The table reports the ATT estimates over the periods 2004-2009 and 2004-2013, thus disentangling the earthquake impact 1- and 5-years after it took place, in order to highlight short and medium term effects. We show the impact in terms of employment focusing on 12 manufacturing sub-sectors.

Sub-sector	1 year	5 years
Chemicals	0.209 (0.178)	0.308** (0.124)
Electrical components	-0.412*** (0.109)	-0.369*** (0.126)
Electronics	-0.143*	0.191***

	(0.079)	(0.062)
Food	-0.433*** (0.045)	-0.275*** (0.055)
Machineries	0.076 (0.115)	0.127 (0.093)
Metallurgy	0.011 (0.151)	0.211** (0.102)
Other manufacturing	-0.332** (0.121)	-0.294*** (0.105)
Pharmaceuticals	0.051* (0.027)	0.020 (0.046)
Rubber and other plastics	-0.054 (0.037)	0.091 (0.114)
Textile	-0.062* (0.036)	-0.018 (0.122)
Transport	0.032 (0.035)	0.083*** (0.031)
Wood-paper	-0.376*** (0.088)	-0.139* (0.068)

Table 7 provides consistent results with respect to those displayed in section 4.2, highlighting that also the majority of manufacturing sub-sectors experienced a significant immediate downturn at employment level. The most hardly penalized sub-sector in the short term is the "food" industry with a reduction of number of employees compared to the synthetic control equal to -43.3%. Other sectors displaying a negative 5-years ATT larger than 10% (in absolute values) are "electrical components" (-36.9%), "other manufacturing" (-29.4%), and "wood-paper" (-13.9%). Notice how such disruption affects sectors accounting for more than 55% in terms of total employees across manufacturing sub-sectors, during the pre-treatment period as shown in Table B2 in Appendix B.

Nonetheless, we also find manufacturing sub-sectors showing a positive ATT. Some examples are represented by the "chemicals" (30.8%), "electronics" (19.1%), "metallurgy" (21.1%), and "transport" (8.3%). However, these sub-sectors only represent slightly more than 25% of total employment in the manufacturing sector. Finally, "machineries", "pharmaceuticals", "rubber and plastics", as well as "textile" do not show statistically significant variations of employment.

These results, combined with the previous evidence of a positive FK, allow us to explain the main dynamics behind the sector diversification of L'Aquila's manufacturing sector with respect to other LMAs in Abruzzo. This finding is indeed the effect of a strong employment reduction in specific sectors such as "food" and "other manufacturing", and an increase in the relevance of other activities such as the metallurgy sector (long-term $\tau = 7.1\%$).

4.2.2 Service sub-sectors

In this section, we disaggregate our analysis on the service sectors, disentangling the impact of the earthquake across relevant sub-sectors.

Table 8 highlights that some activities in the service sectors actually experience a positive and significant medium term ATT. Such evidence holds for the "construction" and the "real estate” sectors in terms number of employees (+48.9% and +12.2%, respectively). This pattern coincides with the start of the reconstruction activities, that boosted such sectors. We also observe how the Construction sector significantly increased its relevance within the economy of the L'Aquila's LMA (see Table B3 in Appendix B), raising its weight by 6.1% (from 18.3% over the period 2004-2008 to 24.4% over the period 2009-2013).

Consistently with the results presented in section 4.2 for the service sectors, we find a large number of activities characterized by a negative and statistically significant 1-year ATT. Notable examples are the “ICT” (-51.9%), “Restaurants and Accommodation” (-50.4%), “other services” (-50.3%), “real estate” (-45.1%), “education” (-43.9%), “healthcare” (-42.6%), “entertainment” (-34.6%), “wholesale trade” (-33.2%), “professional activities” (-24.0%), and “finance” (-16.2%), sub-sectors.

However, we find that these activities tended to experience a significant rebound in terms of number of employees with most sub-sectors reducing the intensity of the ATT in a long-term perspective; some of them loose the statistical significance or even show a positive coefficient (like “construction”, “restaurants and accommodation”, “real estate”, “ICT”, “professional activities”, “education”, “healthcare”, “support services”, and “entertainment”).

The combined evidence of such dynamics at service sub-sectors level with the positive ATT for the FK variable highlighted in section 4.2 suggests that L'Aquila's LMA was subject to a strong diversification across service activities with respect to other LMAs in Abruzzo. This is due to the development of a strong competitive advantage in the “construction”, and “support services” activities (raising their weight in terms of percentage employees after the earthquake). Such pattern was also determined by the contemporary loss of relevance for the “wholesale and trade” sub-sectors, characterized by a negative ATT equal to -8.5% at 5 years from the earthquake.

Table 8: We show the results of the SDID analysis described in section 3.2. The table reports the ATT estimates over the periods 2004-2009 and 2004-2013, thus disentangling the earthquake impact 1- and 5-years after it took place, to highlight short and medium term effects. We show the impact in terms of employment focusing on 15 service sub-sectors.

Sub-sector	1 year	5 years
Construction	-0.086 (0.076)	0.489*** (0.112)
Restaurants and accommodation	-0.504*** (0.088)	-0.057 (0.087)
Real estate	-0.451** (0.221)	0.122* (0.067)
Utilities	-0.070 (0.093)	-0.167** (0.152)
Water supply	-0.032 (0.065)	-0.176 (0.139)
Wholesale & trade	-0.332*** (0.057)	-0.085* (0.046)
Transportation	-0.216 (0.164)	-0.150 (0.147)
ICT	-0.519*** (0.173)	-0.021 (0.196)
Finance	-0.162*	-0.136***

	(0.084)	(0.049)
Professional activities	-0.240*** (0.091)	0.063 (0.111)
Support services	-0.295 (0.211)	0.125* (0.069)
Education	-0.439* (0.221)	-0.435 (0.359)
Healthcare	-0.426** (0.176)	0.039 (0.098)
Entertainment	-0.346*** (0.138)	-0.098 (0.119)
Other services	-0.503*** (0.086)	-0.276** (0.126)

5. Conclusions

In this paper, we analysed the impact of the 2009 earthquake on the L'Aquila's LMA in terms of number of employees and firms, income per capita and sector diversification. Furthermore, we investigated how such effects can be declined across different economic sectors.

The empirical evidence suggests that the natural event immediately disrupted the local economy both in terms of employment and number of firms, with effects equal to -27.3% and -38.2% 1 years after the earthquake. We also showed how these results are transient, since they do not hold 5 years after the earthquake. Moreover, we found that the area did not experience a significant reduction in terms of income per capita; we also highlighted a strong pattern of sector diversification of L'Aquila with respect to other LMAs in Abruzzo over the time analysed.

In addition, we disentangled how such findings are the combined evidence resulting from heterogenous dynamics characterizing the manufacturing and service sectors. Although both experienced a significant contraction in terms of number of employees and firms in the short term, the former was subject to persistent effects (5-years ATT equal to -10.4% and -14.7%), and the latter showed a strong recovery of underlying activities leading to not significant 5-years ATT coefficients. Interestingly, we obtain a stronger penalization in terms of number of firms rather than employees both when we consider all sectors aggregated and when we focus either on the manufacturing or service sectors. Such findings highlight the importance to study the impact of the natural event across different outcome variables, suggesting that L'Aquila's LMA was more resilient in terms of capacity to attract labour force, and less attractive for opening new firms.

In a study elaborated soon after the earthquake, the OECD (2013) already highlighted that an observed decrease in the manufacturing sector was representing a threat for the economy of the Abruzzo region (*idem*, 62-64), suggesting that a regional innovation strategy to strengthen the manufacturing sector was urgently needed (*idem*, 109-147). Our results suggest that policymaking should still concentrate on this. A shift of employment from tradeable to non-tradeable sectors as observed in L'Aquila also represents a threat according to a recent study by the OECD (2018) on productivity and jobs, where authors recognize that European regions whose economies were more successful over the last years were those whose tradeable sectors increased their volumes.

Finally, we documented a strong pattern of sector diversification, characterizing both manufacturing and service activities. In the former case, such dynamic can be justified by a strong reduction of the relevance of "food", and "other manufacturing" sub-sectors, combined with a relevant growth in "metallurgy" activities. Apart from these few exceptions, the manufacturing sector, in aggregate terms, has not proven to be resilient so far in terms of adapting to new conditions; even though negative trends are found in our counterfactuals too, its decrease in L'Aquila is evidently more pronounced.

The service sector, instead, shows some form of resilience as compared to our counterfactuals, since the employees' curve significantly grew in the medium term; such area of economic activity seems to have found a new equilibrium, with the slope regarding employees being even more marked than it was before the event. This rebound in the service sector is due in particular to those activities associated with the reconstruction phase, such as "construction", "real estate" and "support services",[13] that significantly rose their relevance within the local economic structure. On a report on L'Aquila elaborated soon after the event, the Ministry for Territorial Cohesion (Ministero per la Coesione Territoriale, 2012, 7-8) already warned that an increased employment in these sub-sectors would probably only last until reconstruction activities are needed. Afterwards, employment in sub-sectors directly and indirectly linked to reconstruction activities will probably experience a decrease in its weight, therefore urging to find alternative long-lasting economic areas where to foster development, unless firms related to these activities specialize in tradeable goods and services and export know-how, a possibility highlighted by Formez PA (2011, 77). This equilibrium risks to be precarious, and therefore needs to be kept under attention.

Eventually, in aggregate terms, analysing how the number of firms and employees evolved throughout the considered span of time, we can say that L'Aquila's LMA experienced a rather quick rebound after the event, coinciding with the beginning of the reconstruction activities, and then entered a new optimal equilibrium in the medium run; indeed, the two curves reached larger values than those describing number of firms and employees in our counterfactuals. However, the basis of such equilibrium may not be strong enough to withstand the end of extraordinary public financing for reconstruction, with the risk that a situation similar to that mentioned regarding the 1990s will arise.

Overall, our work sheds light on the effects generated by the 2009 earthquake on the L'Aquila's LMA providing a comprehensive overview of the impact across alternative variables of interest and different economic sectors. The high granularity of our analysis may provide a detailed comprehension of the dynamics that lay behind more aggregate evidence of previous studies, thus supporting policy makers in further refining recovery strategies to increase the resilience of the territory, since the reconstruction process is still ongoing.

[13] According to ISTAT, "professional activities" include engineering, architectural, geological and cartographic studios.

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Appendix A

Figure A1 reports the geographical distribution of the treated unit (L'Aquila, in red) and the donor pool (in green). We also highlight (in grey) the LMAs excluded from the control units as they were subject to the Emilia-Romagna earthquake in May 2012.

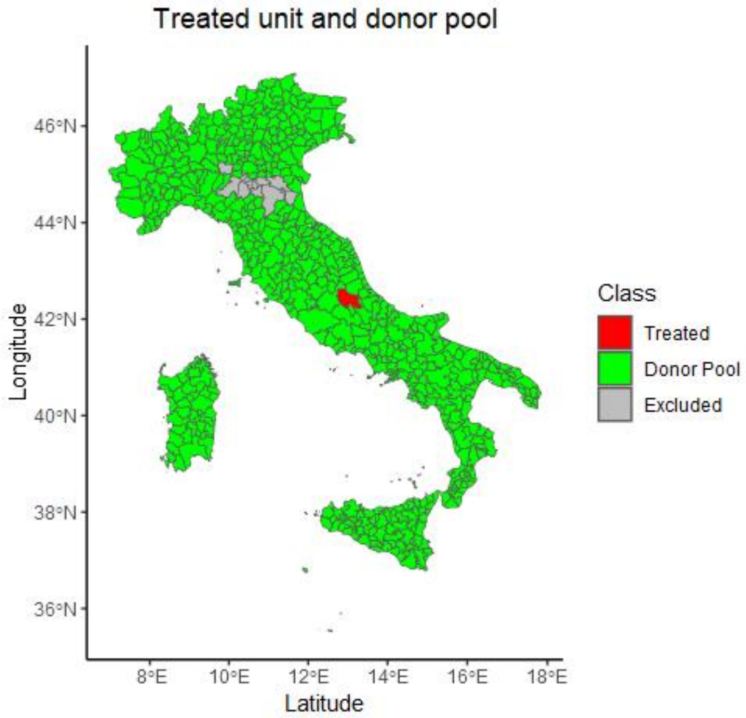

Figure A1: The geographical distribution of the treated unit (L'Aquila, in red) and the donor pool (in green). We also highlight the LMAs excluded from the control units as they were subject to the Emilia-Romagna earthquake in May 2012.

Appendix B

In this section, we report the number of employees' weight of alternative sectors combinations in L'Aquila's LMA at different time horizons. In particular, Table B1 focuses on the manufacturing and service sectors. Table B2 considers the weights of manufacturing sub-sectors, whereas Table B3 shows the relevance of service sub-sectors.

Table B1: Sector weights in terms of number of employees with respect to total employees in the analysed sectors in L'Aquila's LMA. We focus on manufacturing and service sectors, excluding those economic activities on which no data were available (e.g. agriculture). The table reports average values over the considered time periods.

	2004-2008	**2009-2013**
Manufacturing	0.185	0.151
Service sectors	0.815	0.849

Table B2: Sector weights in terms of number of employees with respect to total employees in manufacturing sub-sectors in L'Aquila's LMA. The table reports average values over the considered time periods.

	2007-2008	**2009-2013**
Chemicals	1.24%	1.52%
Electrical components	1.33%	1.60%
Electronics	3.81%	3.34%
Food	21.95%	20.59%
Machineries	0.88%	1.56%
Metallurgy	19.65%	20.72%
Other manufacturing	16.37%	16.62%
Pharmaceuticals	0.80%	0.80%
Rubber and other plastics	11.59%	12.57%
Textile	6.02%	5.35%
Transport	0.62%	0.67%
Wood-paper	15.58%	14.44%

Table B3: Sector weights in terms of number of employees with respect to total employees in service sectors in L'Aquila's LMA. The table reports average values over the considered time periods.

	2004-2008	2009-2013
Utilities	0.95%	1.09%
Water supply	1.35%	1.83%
Construction	18.31%	24.41%
Wholesale & trade	23.44%	20.07%
Transportation	6.25%	5.80%
Restaurants and accommodation	10.33%	9.80%
ICT	2.34%	1.98%
Finance	4.15%	3.73%
Real estate	0.88%	0.72%
Professional activities	9.97%	9.56%
Support services	10.75%	11.58%
Education	0.77%	0.59%
Healthcare	5.38%	5.35%
Entertainment	1.38%	0.93%
Other services	3.75%	2.56%