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Measuring economic resilience of natural disasters: an analysis of major earthquakes in Japan

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Abstract

In recent years, the study of resilience of regional and local systems has become a popular topic in relation to the increasing of economic, social and environmental shocks. Despite the theoretical framework has been enriched through definitions and empirical investigations, accordance in measurement is still missing. In addition, economic repercussions and capacity to resiliently respond to natural disasters have been not enough debated.

This paper aims to enlarge the discussion of regional economic resilience proposing a measurement of the capacity to respond to natural disasters toward the construction of the indices of resistance and recovery for Japanese prefectures stricken by major earthquakes. These indices have been developed for measuring the capacity of regions to overcome economic shocks and they have not yet been applied to the case of natural disasters.

According to data provided by the Centre for Research on the Epidemiology of Disasters (CRED), Japan suffered of a total amount of 59 significant earthquakes in the years between 1900 and 2015. These impressive numbers have made the country one of the most proactive not only in the aspects related to aseismic technology but also in the process of prevention, recovery and hazard mitigation. In relation to the frequency of disasters and its proactivity in responding to natural shocks, Japan appears as an interesting unit of analysis to investigate economic resilience in face of catastrophes.

1. Introduction

Since the early research in ecology in the 1970s, definitions and analyses of resilience proliferated in order to contribute to define a theory of resilience and to understand capacity of regions and cities to cope with external disturbances. Several studies in *Regional Science* started to study economic resilience of systems in relation to periods of economic crisis trying to explain why some regions can better cope with shocks, showing a positive response to crisis with a specific attention to the interacting and multiple causes of this response (Fingleton *et al.*, 2012; Martin *et al.*, 2015; Di Caro, 2017; van Bergeijk *et al.*, 2017).

Despite the measurement is an issue still widely debated, a first methodology proposed and, subsequently, largely applied to study economic resilience of regions has been the recovery and the resistance indices theorized by Martin (2012). The author, in defining regional economic resilience, identifies four interrelated dimensions that contribute to understand how regional economies respond to shocks: resistance, recovery, reorientation and renewal. He proposed indices of resistance and recovery to evaluate the sensitivity of regions to shocks and their ability to react restoring an acceptable level of growth.

A first analysis of definitions and measurements of resilience in *Regional Science* – including empirical applications relative to indices of resistance and recovery of Martin (2012) - shows that while studying economic shocks is common, there is less interest in studying relationships between resilience, natural disasters and economic change. Literature suggests that researches based on the economic impact of natural disasters is a recent field (Lazzaroni and van Bergeijk, 2014) and these studies are even less when the unit of analysis narrows to region and city levels. This is an important lack in order to build a strong theory of resilience.

According to these reflections, the paper aims to enlarge the debate of regional economic resilience proposing a measurement of the resilience in response to natural disasters toward the construction of the indices of resistance and recovery. Particularly, the paper tries to apply the framework and the tools belonging to the study of regional economic resilience to test the ability of Japanese prefectures to cope with earthquakes. Building an index to measure the economic resilience of regions stricken by a natural disaster can help to identify, in relative terms, the system that has better reacted to the shock.

Starting from the data on employment of the OECD for the Japanese prefectures in which major earthquakes occurred, indices of resistance and recovery are calculated to identify which regions can be defined the most resilient. The aim of this analysis is to describe the economic effect of these disasters and identify changes in employment to understand the ability of the different areas to cope with earthquakes.

The first part of the paper is devoted to discussing the most relevant measurement methods proposed to analyse economic resilience. This analysis concerns the main contributions identified in literature looking at the authors, the type of shock and the methodology applied. The review focuses on the contributions of *Regional Science* in measuring resilience, mainly concerning the evaluation of recovery from economic shocks, and on the measure proposed to estimate the impact of natural disasters.

The second part, clarifies the origins of data and methodology applied to analyse the resilience of Japanese prefectures in face of earthquakes and a detailed discussion regards the construction of the indices.

In the final part, results and conclusions are presented in order to offer some insights to the study of economic resilience and natural shocks. A specific focus on each single event is proposed through an analysis of the long-run employment growth in order to understand the interaction between the economic and environmental shocks in affecting employment recovery. Results show that changes in employment not always are a clear consequence of natural shocks but often they intercept and overlap the cyclical periods of growth and decline of national and local economy.

2. Measuring economic resilience in the face of natural disaster

2.1 How to measure economic resilience in response to disasters?

Arguments considering both economic resilience to shocks and economic consequences of natural disasters are topics widely discussed. On the one hand, methods to measure resilience are several and they depend on the field of study, on the nature of the shock and on the aspects which the researcher wants to capture. Although the concept of resilience has increased its importance in several disciplines, including studies in regional and local economies, there is still no agreement on methodology for its measurement. This ambiguity might likely come from the presence of a high number of definitions and uses of resilience. Application of the concept in fields as far apart as science, psychology or economics and several measures of resilience proposed within the same discipline can increase difficulties in evaluating resilience (Modica and Reggiani, 2015). On the other hand, the study of the impacts of the natural disasters within the economy is a relative emerging theme in accordance with the increasing occurrence of catastrophes and natural calamities (Noy, 2009; Lazzaroni and van Bergeijk, 2014). Even in this growing literature what is still missing concerns not only the measure of effects on economy but also on the positive or negative impact of disasters on the short and long-run economic growth (Cavallo *et al.*, 2013; Skidmore and Toya, 2002).

In the economic field, several studies analysed different typologies of resilience through a number of methodologies going from environmental studies (Rose, 2004; Resilience Alliance, 2007) to research to support policies and decision-makers (ARUP, 2016; OECD, 2016).

Within such discipline, a field in which the literature of resilience has been very fruitful has been the study of regional resilience. Scholars in *Regional Science* have mainly focused on recovery from economic shocks following cyclical periods of growth and recession. The main idea was to understand the performance of local and regional economics during periods of crisis. Investigations have concerned long-term analysis on a single country (Cellini and Torrisi, 2014; Bell and Eiser, 2016) or comparison between different regions of Europe (Cuadrado-Roura *et al.*, 2016; Sensier *et al.*, 2016). The objects of the measurements have often been comparable macroeconomic variables such as GDP, output and employment. In other cases, they have tried to explain resilience to economic shock through difference in the innovation system of regions (Simmie, 2014).

Another part of scholars concentrated efforts in evaluating the resilience of systems in response to other types of disturbances. In the field of innovation, some studies have focused on technological aspects and patents to understand consequences of technological shocks in regions (Balland *et al.*, 2015). Fritsch *et al.* (2016), analysing the entrepreneurship, tried to recompose the evolution of regional economies in a very long-term period to highlight how regions coped with the Second World War and the slow establishment of a market economy.

Even methodologies of measurement have been several. going from description of case studies to highlight trajectories of change and identify the response of regions in the long-term (Simmie and Martin, 2010; Hu and Hassink, 2015), to more or less sophisticated quantitative analysis (Diodato and Weterings, 2015; Giannakis and Bruggeman, 2015)

Concerning the side of natural disasters, in studying economic aspects of shocks, a part of literature has paid attention to the capacity of regions to cope with natural shocks, as massive natural disasters or climate change. Generally, it is assumed that the economic damage of disasters has two different natures. On the one hand, there are direct costs, linked to the moment in which the event occurred and given by damage to physical assets. Some of these can be evaluated through a measure corresponding to a market price – as damage to infrastructures – while another part coincides with non-market damage for which price is not easy evaluable – these are damage to the natural ecosystem or to cultural and historical heritage (Hallegatte and Przyluski, 2010; Lazzaroni, and van Bergeijk, 2014). On the other hand, indirect damages are recorded in relation to flow of good and service that will be impossible to provide because of the occurrence of the disaster. These costs have consequences on macro-economic variables such as employment in relation to reductions in consumptions or investments (Pelling *et al.*, 2002).

According to Neumayer *et al.* (2014) three distinct factors concur to determine the damage of a disaster: the dimension of the disaster, the richness of the area, strategies of hazard mitigations. Concerning the first point, generally, an event with a higher magnitude would likely cause a major damage compared to the one that is barely perceptible. The problem related to the entity of economic damage and the richness of a country is an argument widely debated. The Intergovernmental Panel on Climate Change (IPCC) asses that economic losses caused by weather, climate and geophysical events are higher in developed countries while rate of deaths and economic losses as a proportion of gross domestic product (GDP) are higher in developing countries (IPCC, 2012). A part of literature considers poor countries as the most affected by the damage of natural disasters due to the vulnerability of their spatially concentrated productive assets compared to developed countries with insured assets, social services and diversified production (Pelling *et al.*, 2002). Finally, strategy of hazard mitigation and ex-ante measures to prevent effects of disasters has become one of most relevant topic in studying disasters, to the probably detriment of research on post-shock effects (Noy, 2009).

In studying the relationship between natural disasters and economic change different analyses have been proposed. An example is the work of Skidmore and Toya (2002) focused on the positive association between disaster frequency and long-run GDP growth. According to the authors, the growing of GDP depends on the push in developing new technologies given by the occurrence of the disaster.

Through the wide field of natural disasters, some scholars focused attention on impacts and responses of regions and cities to earthquakes. Ferreira and Karali (2015) propose an analysis to understand if major earthquakes have effects within the global market. duPont IV *et al.* (2015) use the synthetic control method to study the socio-economic impact of earthquake in Kobe in 1995 estimating a counterfactual based on data of town and cities not damaged by the quake. Variables used for measurement are among others demographic, environmental, economic, institutional and spatial-economic. Oliva and Lazzeretti (2017), reconstructing the recovery process of the city of Kobe try to identify new sectors emerged as a consequence of the earthquake. Through a counterfactual analysis, Pagliacci and Russo (2016) estimate the macroeconomic effects of the 2012 earthquake in Emilia-Romagna using municipality level data. Chang (2010) builds a theoretical framework to develop indicators to evaluate recovery for earthquakes based on recovery in population, number of business, gross regional product (GRP) and traffic port. Resilience is measured as the amount of time needed to reach a new normality after the occurrence of the disturbance.

Other studies of resilience in face of earthquakes try to link effects of natural disasters to changes in the labour market and employment. Fabling *et al.* (2016) measured the response of Christchurch region, in New Zealand, to Canterbury earthquake, in 2011, through an analysis of jobs and accumulated earnings for workers. Porcelli and Trezzi (2016) compare provincial data for 22 earthquakes occurred in Italy between 1986 and 2011 through an empirical investigation considering two alternative dependent variables, the rate of change of provincial output and the employment rate. Mehregan *et al.*, (2012) use a shift-share analysis to estimate long-term impacts of disasters on employment and to find changes in the structure of employment due to the earthquake.

Although the number of approaches in measuring resilience, some criticisms still exist and they increase when the object analysed is a natural disaster. In analysing resilience, natural disasters and economic changes, poor attention is often paid to the long-term economic effects of natural disasters and short-term analysis are preferred because of difficulties on identifying and isolating the long-term economic effects of natural shocks (Benson and Clay, 2004).

A large part of analyses is focused on evaluating the impact of the shock through a measure of the decrease in physical capital and the amount of financial damage. In order to evaluate response and evolution in the economic scenario as a consequence of natural disasters, indeed, a number of scholars used macroeconomic indicators to understand economic performance of systems in relation to shocks. A general indicator can be found in the gross domestic product (GDP) and its annual growth. In general, measuring effects of natural disasters using as a proxy GDP can distort perceptions of the impacts because of the amount of the capital invested in the reconstruction and debris removing activities (Horwich, 2000). In some case a growing trend occurs in the aftermath of a disasters due especially to the amount of investment in the construction sector (Alabala-Bertrand, 1993).

2.2 The resistance and the recovery indices

In discussing economic resilience of regions, the seminal work of Martin (2012) describes four dimensions that concur to the economic resilience of regions, resistance, recovery, reorientation and renewal. Resistance is the degree of sensitivity of the system to the shock while recovery gives an idea of the ability of the system to overcome the shock and can be measured by the speed or the degree of recovery process. The reorientation's phase occurs when a shock accelerates existing paths or favours transformations in the economic structure and, finally, the renewal can involve a restoration of the pre-shock growth path or a moving on new growth trends. These two final phases may be linked to the concepts of adaptation and the adaptability (Grabher, 1993) and may be useful to explain changes related to resilience and creation of new trajectories.

In measuring regional economic resilience, the author proposes two simple indices in order to evaluate the ability of the regions to resist to recessionary shocks and recovery in a post-recession period. The resistance index, or sensitivity index, is calculated as the change in employment in the region compared to the change at national level in the shock period. It helps to understand the ability of a region to cope with a shock and to demonstrate the recovery capacity of a region through a growth in employment in the period following the shock. The recovery index is measured as the change in employment in the region in the post-crisis period and shows the ability of the region to grow after a shock.

The resistance and recovery indices will be namely β_{res} and $\beta_{rec.}$ Indices are formalized as follow:

$$\beta_{res} = (\Delta E_r/E_r)/(\Delta E_n/E_n)$$

If β_{res} is greater than 1, the region has a low relative resistance to the shock. On the contrary, if β_{res} is lower than 1, the region has a high relative resistance to the shock.

$$\beta_{rec} = (\Delta E_r/E_r)$$

The sensitivity index of Martin (2012) has been applied to several studies, mainly to evaluate the capacity of regions and systems to cope with recessionary shocks (Table 1).

Table 1 Articles applying Martin (2012)'s indices

Contribution	Journal	Country	Period	Unit of analysis
Breathnach *et al.*, 2015	Regional Studies, Regional Science	Ireland	2001-2006, 2006-2011	10 functional regions
Di Caro, 2015	Camb J Reg Econ Soc	Italy	1993-1995, 2008-2010, 2012-2013	20 regions (NUTS 2)
Lagravinese, 2015	Camb J Reg Econ Soc	Italy	1970–1972, 1992–1995, 2008–2010	20 regions (NUTS 2)
Faggian *et al.*, 2017	The Annals of Regional Science	Italy	2007-2010	686 Italian Local Labor Systems (LLS)

Source: Authors' elaboration

In their work on Ireland, Breathnach *et al.* (2015) want to understand the trend of employment in the Irish regions after the 2007-08 recession period classifying regions on the basis of the growth ore the decline of employment pre-recessionary and post-recessionary period. They evaluate a sensitivity index that measures the regional employment change divided by the national employment change and two distinct resistance and resilience indices. The first divides the employment in region which shows a long-term growth in both pre- and post-recession period and those which have a long-term decline. The resilience index represents the rate between the regions with a long-term growth and a high sensitivity to the recession and regions showing a long-term decline.

Di Caro (2015), in his research of effects of crises on Italian regions evaluate the sensitivity index *à la* Martin as the regional percentage decline in employment relative to the national decline within three main periods. The first period (1993 to 1995) coincides with the devaluation of the Italian *Lira*;

the second period (2008-2010) overlaps the financial global crisis of 2008 and, finally, in the third period (2012-2013), a loss of the 6% of employment occurs as a consequence of previous economic crisis.

Lagravinese (2015) used a modified version of the index to measure the different effects of the economic crisis occurred in Italy between 1970 and 2011. Within such period, he identifies three main shock that affected Italian regions: the oil crisis of 1970-1973; the devaluation of the Italian *Lira* of 1992-1995; the recent recession of 2008-2010. According to the author, resistance index is $\beta res= [(\Delta Er/Er)-(\Delta EN/EN)] / |\Delta EN/EN|$. A positive value of βres is an indication of the major resistance of the region to the shock. A negative value of βres indicates a worst performance of the region compared to the national level.

In a recent work, Faggian *et al.* (2017) use a revised version of the sensitivity index. that is calculated as $SI= (E_{r,t}/E_{r,t-1})/(E_{n,t}/E_{n,t-1})$ where E_r is the total employment in the region and E_n is the total employment in the nation. The period (t) represents the recessionary period and the period (t-1) represents the pre-recessionary period. The recessionary period goes from 2009 to 2010, while the pre-recessionary period is from 2007 to 2008.The authors applied resistance and recovery indices to the Italian local labour system (LLS) to measure regional economic resilience to recessionary shock.

In this paper, we try to combine the methodologies applied in the evolutionary economic field to study regional economic resilience analysing dimensions of recovery and resistance in response to the most significant earthquakes occurred in Japan through the indices of resistance and recovery developed by Martin (2012). The aim of this analysis is to evaluate the economic impact of such disasters and identify changes in employment to understand the ability of the different areas to cope with earthquakes.

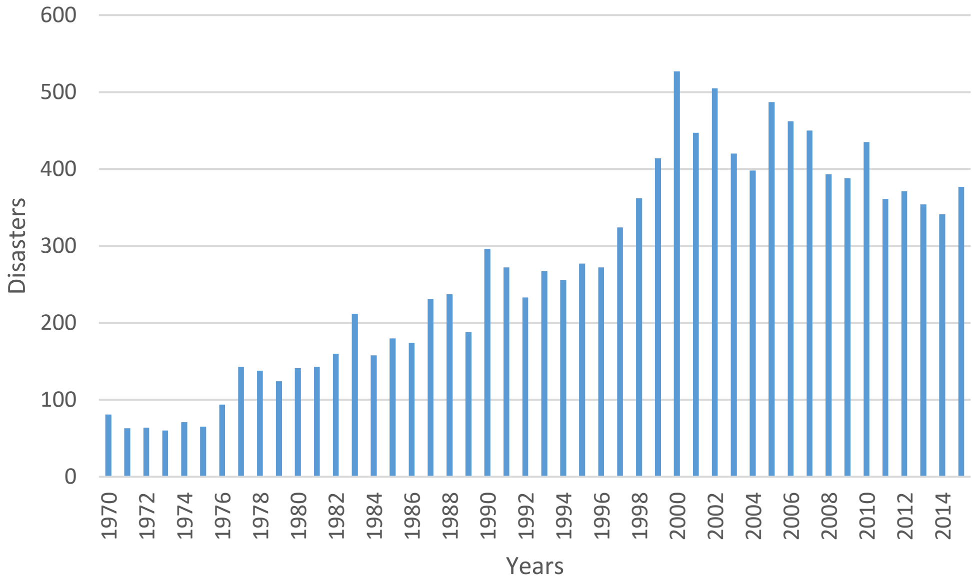
3. Data and methodology

3.1 Data

As underlined above, understanding consequences of natural disasters on the economic sphere of social system is a relative new field and few researches have paid attention to economic impact of disaster phenomena (Noy, 2009). This appears really surprising if we look at data on natural disasters occurred around the world. The amount of disasters between 1970 and 2000 shows indeed an increasing trend (Figure 1) in accordance with changes in population, urbanization, deforestation and desertification (ADRC, 2002)

The Centre for Research on the Epidemiology of Disasters (CRED) define a natural disaster as an unforeseen and sudden event that influences local capacity causing high damage, destruction and human suffering and requires assistance from national or international levels. It includes within this definition both natural disasters and disasters caused by human actions.

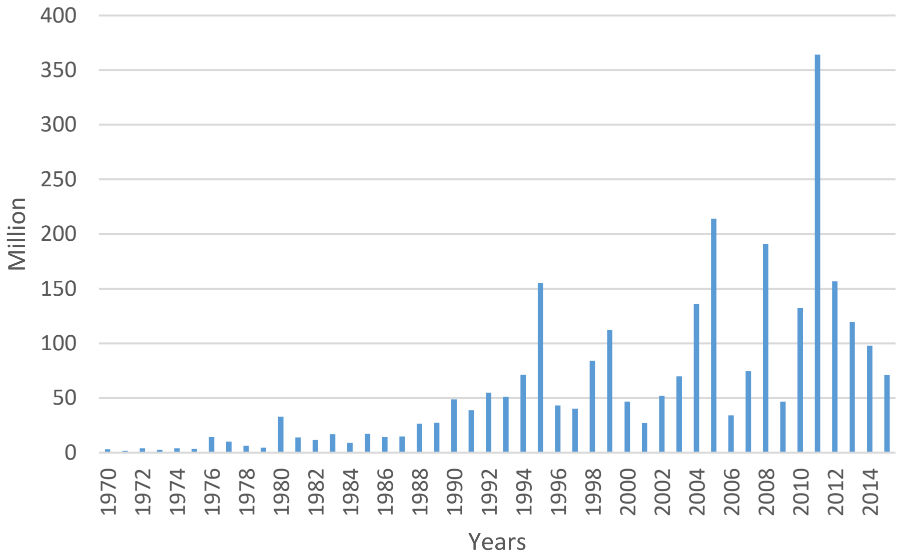
Figure 1 Number of disasters occurred in the world (1970-2015)



Source: CRED, EM-DAT database, 1970-2015

Figure 2 show the trend of the amount of economic damage caused by natural disasters between 1970 and 2015. According to CRED, estimated damage is related to losses in property, crops and livestock and its value is recorded at the moment of the event. It corresponds to the direct damage in accordance with the classification offered in literature.

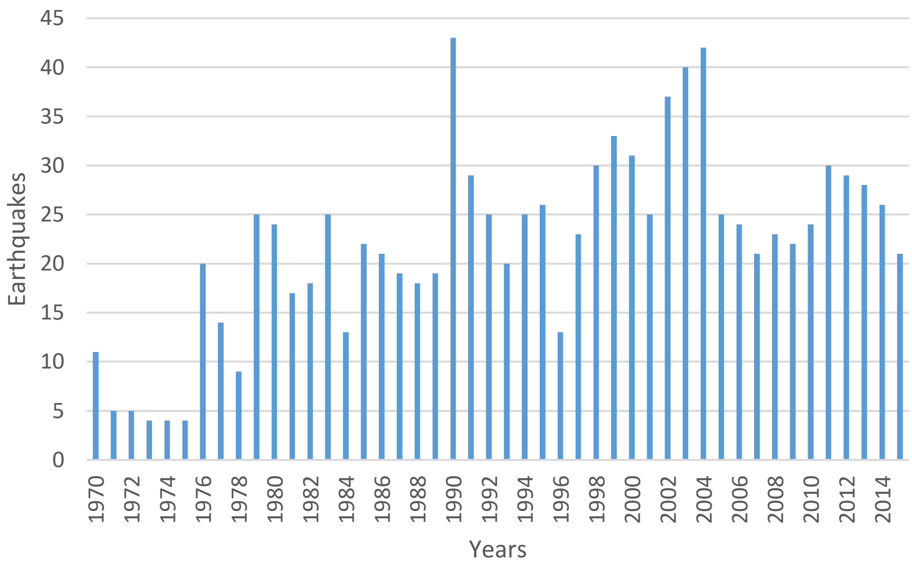
Figure 2 Total economic damage caused by natural disasters in the world, 1970-2015



Source: CRED, EM-DAT database, 1970-2015

A special focus on earthquakes shows a general increasing trend in number of earthquakes occurred around the world (Figure 3) and a concentration of such disasters in Asian regions (Figure 4).

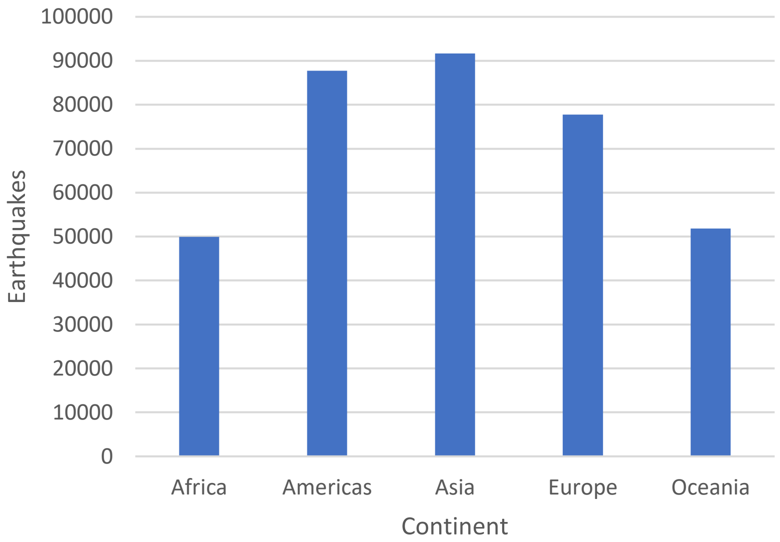
Figure 3 Number of earthquakes reported in the world, 1970-2015



Source: CRED, EM-DAT database, 1970-2015

Particularly, Japan suffered of a total amount of 59 significant earthquakes in the years between 1900 and 2015 due to its peculiar geographical in the Pacific Ocean on the Ring of Fire, one of the areas most affected by seismic activity.

Figure 4 Number of earthquakes occurred by country (1970-2015)



Source: CRED, EM-DAT database, 1970-2015

On the basis of the data of Government of Japan, about the 21 per cent of the earthquakes with a magnitude of 6 or greater have occurred in Japan (Yamamura, 2014). On the side of the economic damage, according to the database of CRED earthquakes are the third classified after floods and storms in respect of the total estimated damage. As a consequence, Japan is one of the most proactive in earthquakes prevention through investments in aseismic technology and an advanced planning in operations of recovery.

On the basis of these considerations, the study of the capacity of economies to overcome natural shocks, particularly earthquakes, restoring a pre-disaster level of growth or promoting a higher level, seems a relevant topic in studying the resilience of regions. Moreover, the case of Japanese prefectures may be an interesting unit of analysis to investigate economic resilience in face of natural shocks and to test ability to resist to and recovery from earthquakes.

Data used for selecting earthquakes come from the "Global Significant Earthquake Database" of the National Oceanic and Atmospheric Administration (NOAA) distributed by the National Centre for Environmental Information (NCEI). The database collects historical information of earthquakes related to date, time, location, focal depth, magnitude, intensity and socio-economic data, such as the total number of fatalities, injuries, houses damaged and destroyed and US dollar damage estimates when available.

These data have been compared to the data of the International Disasters Database released by the Centre for Research on the Epidemiology of Disasters (CRED) of the Université Catholique de Louvain (UCL) in Brussel. The database collects information of natural disasters providing data of the human impact of disasters, the disaster-related economic damage estimated and disaster-specific international aid contributions. For each earthquake, we analysed latitude and longitude to identify the epicentre of the quake and the area involved by the damage.

First, historical data on Japanese earthquakes have been preliminary selected and they have been listed according to the significance of the seism in order to select only the major earthquakes. According to NOAA database, significant earthquakes are those which have a magnitude greater than or equal to 7 on Moment Magnitude Scale (Mw) and/or an amount of deaths greater than or equal to 10 people and/or a damage greater than or equal to 1 million of dollar.

A second selection occurred to skim earthquakes in relation to availability of data and proximity of the epicentre to an urban area. In relation to the former, the recovery time of four years imposes to evaluate only earthquakes for which the data was available. In relation to the latter, we analyse data of earthquakes occurred close to urban centres. Indeed, some of the major earthquakes in Japan have their epicentre in the ocean and often no damage to people or buildings have been recorded. In the end, the analysis conducts to the selection of 5 major earthquakes occurred between 2003 and 2011 with a direct impact on 10 Japanese prefectures (Table 2).

Table 2 Selection of major earthquakes* occurred in Japanese Prefectures between 1995 and 2011

Year	Prefecture	Mag.	Deaths	Injuries	Damage**
2003	Iwate Miyagi Yamagata Akita	7	-	143	233
2003	Hokkaido	8.3	-	755	90
2004	Kyoto Wakayama Osaka	7.4	-	40	-
2007	Niigata	6.6	9	1,088	12,500
2008	Tokyo	6.9	13	357	-

*(Mag. ≥ 7 or Num. Deaths ≥ 10 or Damage ≥ 1 million $)
**Damage is evaluated in Million US $
Source: Authors' elaboration on data from NOAA database, 2016

The earthquake of 2003 occurred in the north of Japan, in the Tohoku region, struck the prefectures of Iwate, Miyagi, Yamagata and Akita. The earthquake caused about 143 injured people, 720

destroyed buildings and damage to many roads and water line in the entire district of Tohoku. It caused a series of fires and landslides and an economic damage of about 233 million US dollars.
The second earthquakes occurred in 2003 in the Hokkaido prefecture causing 755 injuries, landslides and damages to power outages and roads. The estimated damage was 90 million US dollars.
The earthquake of 2004 occurred in the Kansai region affected the prefectures of Kyoto, Wakayama and Osaka. The earthquake caused about 40 injuries, fires and damage to electricity lines and generated a tsunami with waves of almost one meter high.
The earthquake occurred in Chubu region in 2007 affected the prefecture of Niigata. It caused about 9 deaths, at least 1,088 wounded, damages to 875 houses, roads and bridges and created landslides. The economic damage was about 12.5 billion US dollars.
Finally, the earthquake of 2008 occurred in the Tokyo prefecture in the Kanto region. The earthquake caused 13 deaths, 357 injured and 614 damaged buildings. The epicentre was in north of Tokyo.

3.2 Methodology

In order to estimate the resilience of Japanese prefectures to earthquake, we calculate two different indices starting from resistance and recovery indices theorized by Martin (2012).
Such indices have been mainly applied to test the ability of regions to cope with economic shocks but the main idea here is to recombine the indices to apply them to the case of earthquakes in Japan. Starting from the data on employment of the OECD for the Japanese prefectures in which major earthquakes occurred, we used the indices of Martin (2012) as the basis to build two different indices to evaluate the ability of Japanese prefectures to resist and recover after the occurrence of the earthquakes.
To evaluate the resistance of the prefectures to the earthquake we used the revised version of the sensitivity index proposed by Faggian *et al.* (2017). This version overcomes the possibility of problems relative to the concordance or discordance of signs as suggested by the authors. Our new indices are formalized as follow:

$$\beta_{res} = (E_{p,t}/E_{p,t-1})/(E_{w,t}/E_{w,t-1})$$ [1]

with:
t as the year of the earthquake

[1] To improve the robustness of the index, resistance has been evaluated on the basis of the formula proposed by Lagravinese (2015). The results are shown in Appendix 1. The performances of the single prefectures confirm the value and it is possible to evidence small changes in the relative positions of the value inside each quadrant.

t_{-1} as the year before the earthquake;

p as the single prefecture stricken by the quake;

w as the whole of the prefectures stricken by major earthquakes.

Thus, $E_{p,t}/E_{p,t-1}$ represents the ratio of the employment of the prefecture in year of the earthquake and the year before the $E_{w,pt}/E_{w,t-1}$ is the ratio of change the employment for all the selected prefectures between the same periods.

If β_{res} is greater than 1, the region has a high relative resistance to the shock; on the contrary, if β_{res} is lower than 1, the region has a low relative resistance to the shock.

To evaluate the recovery after the earthquakes, we build the recovery index as follow:

$$\beta_{rec} = (\Delta E_p/E_{p,t})$$

with

t as the year of the earthquake;

p as the single prefecture stricken by the quake;

w as the whole of the prefectures stricken by major earthquakes.

Recovery index measures the ratio of variation in employment occurred in the prefecture between the fourth year after the earthquake and the year of the earthquake (t). The four-year period is chosen reflecting on the possible implication of investments in reconstruction occurred in the years immediately after the earthquake. As highlighted by Horwich (2000) a measure based on macro variables can distort perceptions of the disaster impact by the amount of the capital invested in the reconstruction and debris removing activities. Moreover, a period superior to four years can cause overlapping of earthquakes in the same prefecture, especially in countries frequently subject to seismic event as Japan is. Finally, in evaluating economic resilience Hill *et al.* (2011) suggests that a considerably short period of four year to return to pre-shock levels should pass in order to define a region as resilient.

4. Results

Using the model explicated in the previous sections, we calculated resistance and recovery indices for the major earthquakes that stricken the Japanese prefectures between 2003 and 2008. According to data described in section three, we evaluate such indices for 10 prefectures in which 5 major earthquakes occurred. The values of resistance and recovery are shown in Table 3.

Table 3 Resistance and recovery indices

Prefecture	Resistance	Recovery
Hokkaido	0.9942	-0.0071
Iwate	0.9589	0.0103
Miyagi	0.9878	-0.0008
Akita	0.9778	-0.0325
Yamagata	0.9861	-0.0225
Kyoto	0.9956	0.0047
Osaka	1.0030	-0.0012
Wakayama	1.0137	-0.0243
Niigata	0.9859	-0.0362
Tokyo	1.0119	0.0066

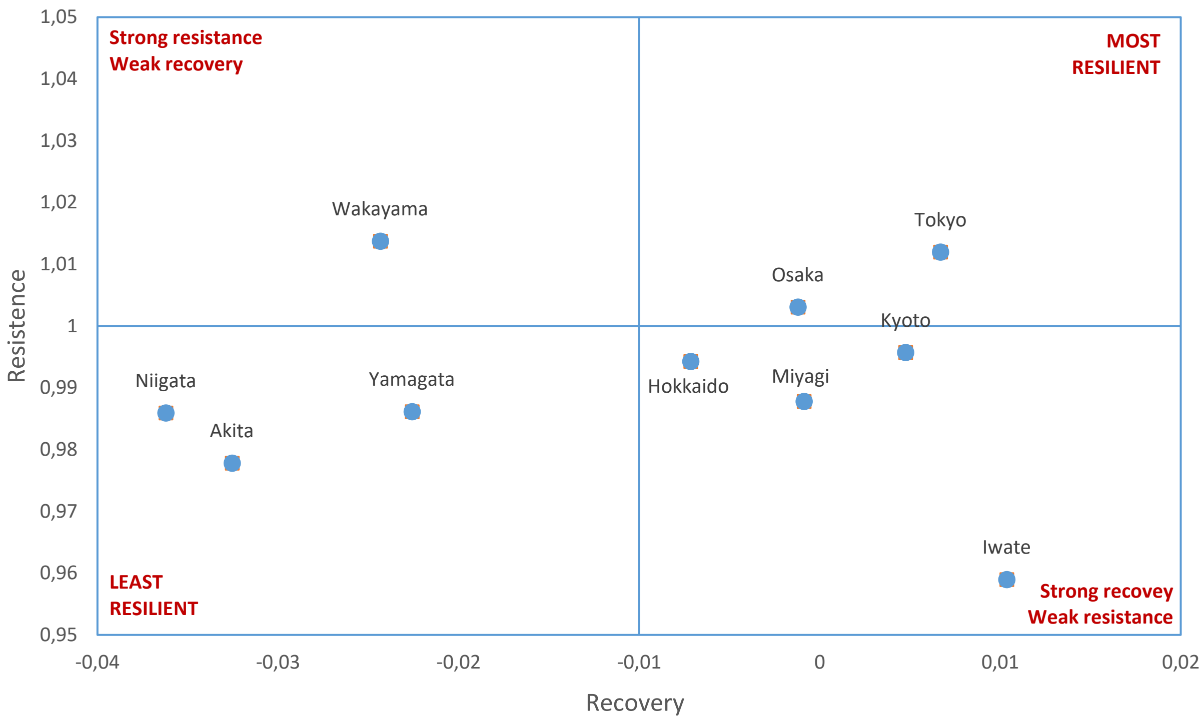
Source: Authors' elaboration

A preliminary analysis of the indices shows that the lowest value for Resistance Index belongs to Iwate prefecture (0.9589), while the highest belongs to Wakayama prefecture (1.0137). Moreover, the lowest value of Recovery Index is that of Niigata prefecture (-0.0362), while the highest value belongs to Iwate (0.0103). This analysis suggests that Iwate prefecture had a high sensitivity to the earthquake but it was the prefecture that best performed in the fourth year after the earthquake showing the major increase in employment. Wakayama was the prefecture that had the best resistance to the earthquake. Niigata prefecture had the worst performance in the recovery period.

An interesting analysis can be done looking at the responses of the prefectures involved in the same earthquake. This was the case of the 2003 earthquake in Iwate, Miyagi, Yamagata and Akita prefectures and the 2004 earthquake in Kyoto, Osaka and Wakayama. In relation to the first earthquake, Miyagi was the prefecture that best resisted to the shock. Iwate had the best recovery and it was the only prefecture in which employment showed a positive change in four years following the earthquake. In respect to the 2004 earthquake, the prefecture of Wakayama best resisted to the earthquake but Kyoto was the prefecture that had the higher recovery and the only prefecture which had a positive change.

Comparing indices of recovery and resistance, we can understand which prefectures were the most and the least resilient (Figure 5).

Figure 5 Resistance and recovery indices of Japanese prefectures calculated for the major earthquakes occurred between 2003 and 2008



Source: Authors' elaboration

According to the measurement of the indices, the prefectures that best resisted and recovered from the shock have been Osaka and Tokyo. We can define these prefectures as the most resilient; on the contrary, the prefectures of Akita, Yamagata and Niigata have the worst performance in resistance and recovery. Consequently, we can define them as the least resilient. Prefecture of Wakayama has a strong resistance but a weak recovery. Hokkaido, Kyoto, Iwate and Miyagi have a low resistance but a strong recovery.

However, a critical discussion of changes in the employment rate of Japanese prefectures in relation to earthquakes, cannot be indifferent to the macro-economic aspects that affected the Japanese economy in recent decades and to a description of the main characteristics of the employment system. A critical analysis of major economic trend compared to resistance and recovery ability in face of earthquakes allows to contextualize changes in employment of each prefecture to the change in the national employment and to demonstrate if changes in employment during or following the natural

shocks are a direct consequence of it. Finally, to best understand the analysis of the change in employment should consider some specific feature of the employment system in Japan.
Resistance and recovery indices, in fact, can be useful to evaluate performances of Japanese prefectures in relative terms giving a measurement of resilience in response to earthquakes but it can be interesting comparing such results with an analysis of the employment trends of each prefecture in the long-period to identify the role of economic shocks in resistance and recovery abilities of Japanese prefectures. This critical discussion offers a brief description of the main periods of crisis that affected Japanese economy in recent years and underline how the characteristics of the employment systems may influence response to shocks. What emerges is that in some cases, an overlapping between effects of natural and economic shocks may exist.
After the Second World War, the country had an economic boom, often remembered as the "Japanese economic miracle", performing a 3.9 percent average annual growth rate of its domestic product (Saxonhouse and Stern, 2003). This apparently unstoppable growth, however, crushed against the economic bubble of the early 90s, which led the country into the "lost decade" of the Japanese economy (Flath, 2005). This was a period characterized by a long-term stagnation of output and productivity. During the period between 1992 and 1999, GDP restarted to increase by 1% on average per year. The dimension of this growth, compared to the growth by 3.9% in the period between 1981 and 1991, assumed a low relative importance (Genda and Rebick, 2000). In the period between 2002 and 2007 an expansion of the output occurred and was mainly related to a growth in exports (OECD, 2009). Another interesting point in the analysis of the crises in Japan is the response of the system to the economic and financial 2008 crisis. During the global financial crisis, while a decrease of the aggregate demand occurred, the decline of the level of the unemployment was slower. Moreover, unemployment rate responded better to the decrease in GPD than other countries.
Specific features of the labor market in Japan can partially explain the response to economic crisis. Japanese employment system originated in the post-war period and is characterized by a specific structure defined as "lifetime employment" system (*shūshin koyō*) (Hijzen *et al.*, 2015). Despite it has been reformed and revised over years, it is considered as a peculiarity of the Japanese economic system and appears to be a key element for both economic miracle and for the long period of economic stagnation.
One of the characteristics of the lifetime employment system refers to a law that prohibited firms to offer fixed contracts for multiple years. Thus, the possible typologies of contract to hire employers were indefinitely-term contracts and short and fixed-term contracts of a maximum of one year. This law was abolished with a revision of the legal standards for the labour market in 1998 making the market job more flexible but, at the same time, more sensitive to the economic fluctuations

(Kambayashi and Kato, 2009). A second characteristic of the lifetime employment is the propensity of firms to avoid the layoff of employers preferring a reduction in the working hours. This involve a higher maintenance of jobs for Japanese workers during periods of economic crisis. Moreover, salary increases with the age of the employer boosting workers to keep their jobs.

The features of the lifetime employment system influenced the response of the country in front of the different economic crisis. On the one hand, the system has been criticized as characterized by a strong "rigidity" constituting an impediment for change and recovery of the Japanese economy in the period of continued stagnation of 1990s; on the other hand, it has been regarded as an incentive to the creation of firm-specific human capital and the knowledge generation.

The period of prolonged stagnation experienced by the country changed some aspects of its structure favouring an evolution of the employment system, leading to the reduction of the regular employee and fostering flexibility of the employment system. However, a negative impact is highlighted and it was major for specific categories of workers, such as women and less skilled workers.

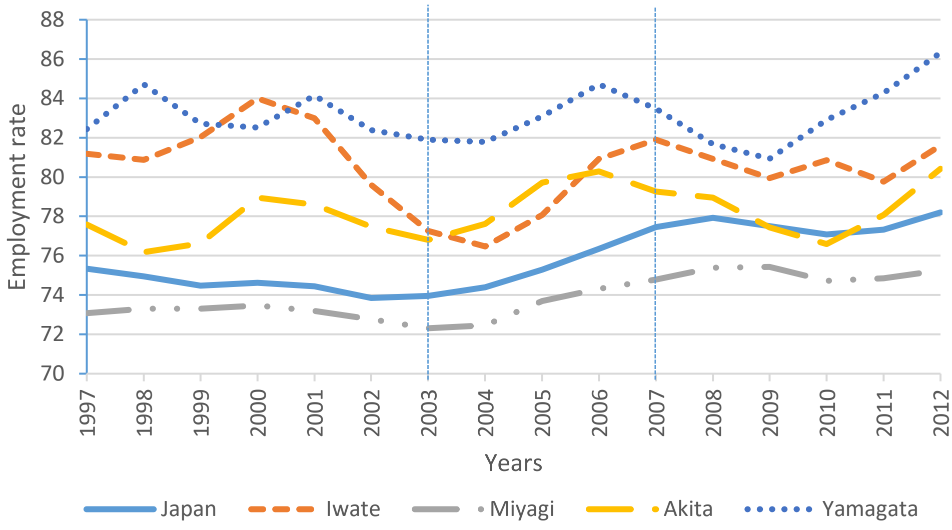
Despite the reform of employment system, some key elements remained unchanged as the propensity to long-term relationship between firms and employers. In the years of the recent economic crisis, a general good recoverability of Japanese labour market is observed. Such positive response is associated with the features of the Japanese labour market and, particularly, its lifetime peculiarity and the tendency of Japanese employees to maintain jobs in a period of economic crisis (Hijzen *et al.*, 2015).

The structure of the lifetime employment system, thus, led with different responses of the Japanese economy against crisis. On the one hand, it encouraged workers to keep their jobs even if system is under external pressures favouring the stability of the labour market; on the other hand, despite it can be considered a reason of rigidity, the reforms of the past years favoured an adaptation of the system to the changed circumstances and made it more flexible to perturbances. However, flexibility may also increase the sensitivity of the system to shocks.

Looking at employment trend in each single prefecture, it is possible to highlight cases in which an overlapping occurs between earthquakes and period of economic growth or decline. In other cases, a likely low correlation between the earthquake and the evolution of employment rate.

Concerning the earthquake of 2003, in Iwate, Miyagi, Akita and Yamagata, different behaviours characterize period of resistance and recovery (Figure 6).

Figure 6 Employment rate growth paths in the prefectures of Iwate, Miyagi, Yamagata, Akita and Japan



Source: OECD statistics

In the Iwate prefecture, employment rate decreased in the period between the occurrence of the earthquake and the fourth year after the shock, recording a trough around 2004 and a peak in 2007. The decrease already started before the earthquake.

In the Miyagi prefecture after the earthquake, one year of relative stability in employment rate occurred and an increase is recorded between 2004 and 2007. Again, a period of relative stability is observed until 2009. Before the earthquake, a low decrease of the employment rate started in 2000. The Miyagi prefecture showed the most similar trend to the national change in employment rate.

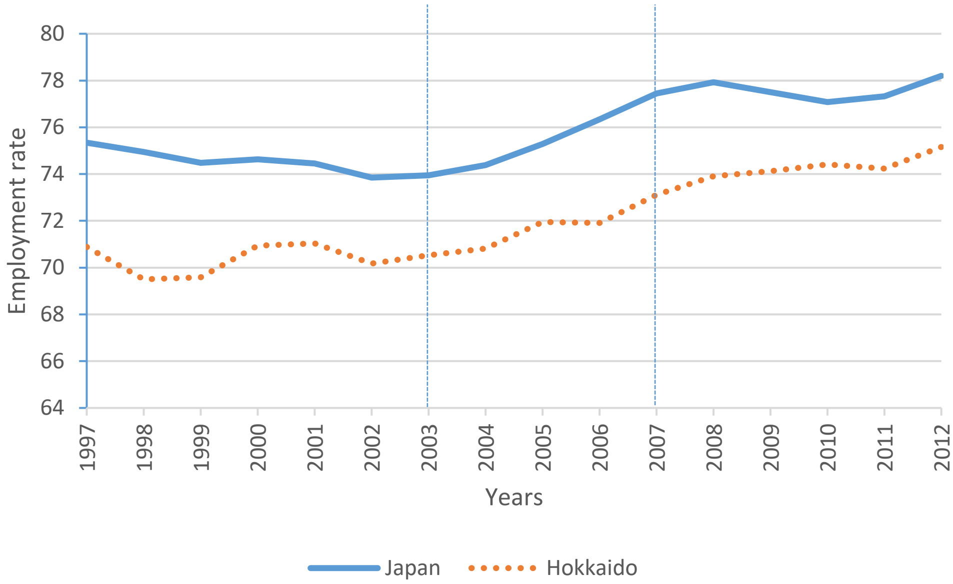
In the Akita prefecture, the year of earthquake corresponded to a trough in the decrease of the employment rate started in 2000. The growing trend is observed until 2006 and, then, again a period of decrease happened until 2010. Therefore, the recovery period is characterised by a former increase in the three years following the earthquake and a subsequent decrement of the employment rate.

Finally, in the Yamagata prefecture, the earthquake occurred in a period of a relative slow decrease of the employment rate started in 2001. During the recovery period, a peak was in 2006 followed by a decrease recorded until 2009.

Generally, prefecture of Iwate, Miyagi, Akita and Yamagata recorded a fluctuating trend in the period between 2002 and 2007, a period characterized by a growth of the national accounts. The economic recovery started around 2003-2004, with a delay in respect to the national trend. It is possible to speculate that the delayed recovery can likely be caused by the occurrence of the earthquake.

Figure 7 compares trends in employment rate for Hokkaido and Japan. The growth path of employment rate shows a similar trend with the national growth.

Figure 7 Employment rate growth path in the Hokkaido prefecture and in Japan

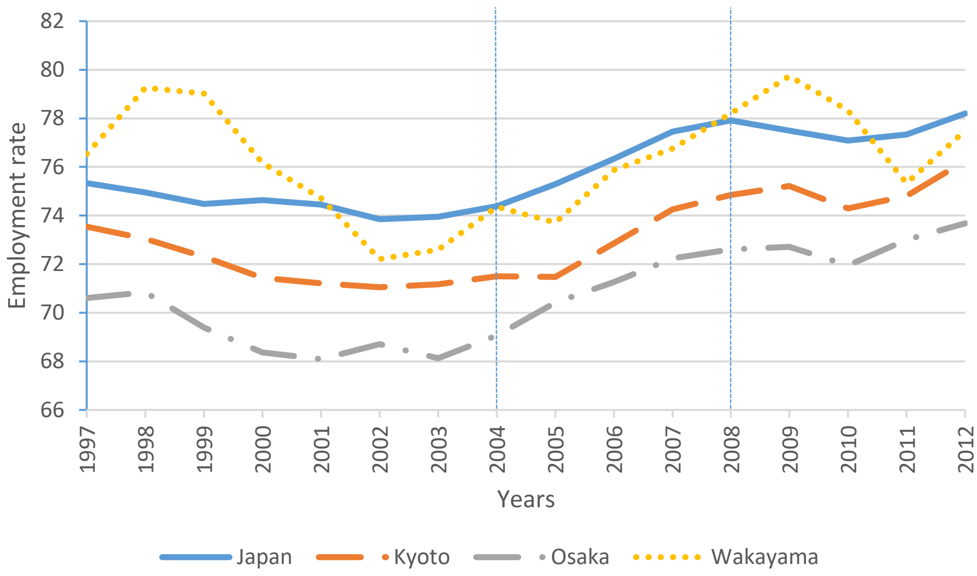


Source: OECD statistics

An increase of the employment rate occurred between the year of the earthquake and the next four years. This trend not only is the same as the employment rate of Japan but it started one year before the earthquake. This anlysis reflects the difficulty to associate the growth in employment as a direct consequence of the earthquake. The growth in employment coincides with the growth of output started in 2002, the year that signed the end of the lost decade so it is likely associated with the positive economic recovery which occurred between 2002 and 2007. An effect that can be associated with the earthquake is the slower increasing rate of employement recorded by the Hokkaido prefecture compared to the national trend.

In relation to earthquake of 2004, Figure 8 shows that the prefecture of Kyoto recorded a decrease in the employment rate started in 2000 and a following increase from 2005 to 2009. The trend of the prefecture is similar to the trend of the whole of Japan. In Osaka, it is possible to observe an increase of the employment rate started in 2003, the year before the earthquake. Such a positive trend is maintained until 2009. Wakayama prefecture had a peak in the year of the quake followed by a negative change in employment ending in 2005. A continued increase is observed until 2009.

Figure 8 Employment rate growth paths in the prefectures of Kyoto, Wakayama, Osaka and Japan



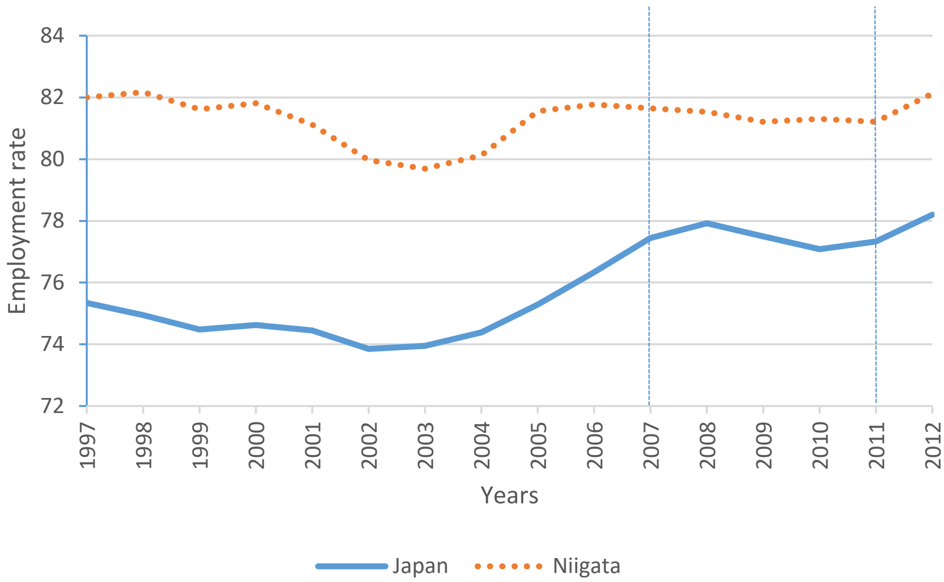
Source: OECD statistics

In general, all the prefectures were in a positive trend when the earthquake occurred based on the growth favoured by the economic recovery of 2002-2007. However, in the year of the quake, a fall of the employment rate can be observed for Wakayama and Kyoto prefectures. Such effect could probably be related to the earthquake.

In Niigata, the recovery period is characterized by a moderate and slow decrease in the rate of employment started in 2003. The changes in employment in the prefecture are similar to the trend observed for the whole Japan. It is interesting to highlight that the prefecture recorded a previous big earthquake in 2004. It caused about 40 deaths, 3,183 injured and 6,000 destroyed buildings. There were landslides, fires and damage to roads and the pipes of gas, electricity and water. The estimated economic damage amounts to approximately 28 billion dollars. The resistance and recovery indices for the Niigata's earthquake of 2004 has not been calculated because the recovery period of four year overlaps with the earthquake which occurred in 2007.

As showed in Figure 9, a slower growth of employment rate occurred in Niigata compared to national path.

Figure 9 Employment rate growth paths in the prefectures of Niigata and Japan



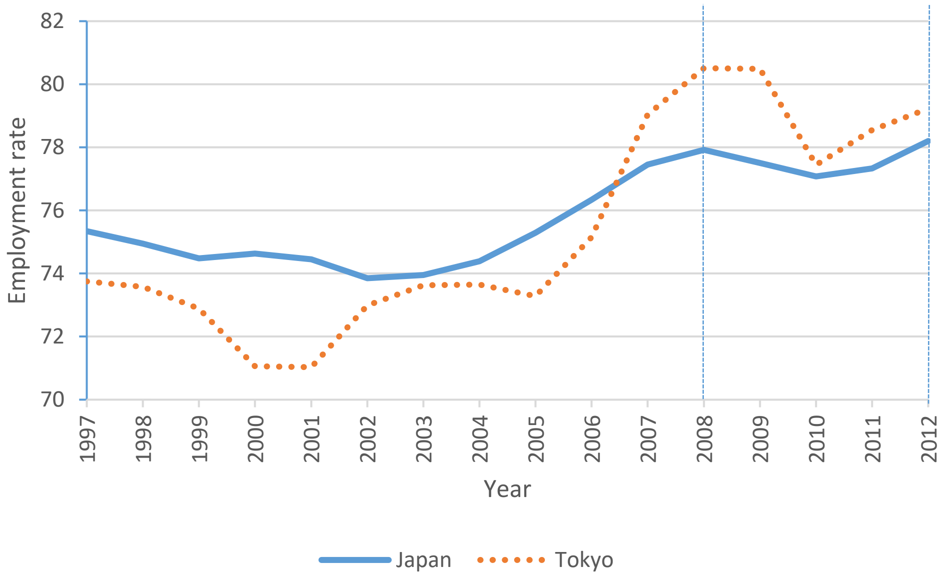
Source: OECD statistics

This trend is confirmed both for the years following the earthquake in 2004 and the earthquake in 2007. It is possible to assume that the earthquakes caused a consequent slowdown of the economic recovery.

Finally, the case of the Tokyo earthquake shows that changes in employment likely depend on the occurrence of the economic crisis of 2008, Figure 10.

In the year of the Tokyo earthquake, a peak in the employment rate of the prefecture is recorded. After one year of stability, between 2008 and 2009, it is possible to record a decrease in the observed variable. A trough is recorded in 2010 and a following increase is kept until 2012. The drop of employment rate is perceived more deeply in the economy of the city of Tokyo than in the national trend. The year of the earthquake is also the year of global economic and financial crisis.

Figure 10 Employment rate growth paths in the prefectures of Tokyo and Japan



Source: OECD statistics

5. Conclusions

The paper focuses on the analysis of resistance and recovery of Japanese prefectures in order to identify the resilience in response to major earthquakes occurred in the country between 2003 and 2008. We build two indices based on resistance and recovery indices proposed by Martin (2012), in the revised version of Faggian *et al.* (2017). After a critical analysis of the main measurement methods of resilience in relation to different types of shocks and in many fields of study, we discussed the construction of our indices. These were calculated through the OECD employment data of the Japanese prefectures, selecting those affected by significant earthquakes between 1997 and 2012. Results for indices were discussed highlighting the prefectures that recorded the best and worst performance, in order to identify the most and the least resilient. Finally, a contextual analysis was proposed to highlight the major changes in trends in the employment rate of the prefectures compare to national trend.

Building an index through the measure of change in employment in the regions hit by a shock can help to identify in relative terms the system that has better reacted to the shock. This kind of measurement is certainly useful to identify the impact of the shock and the consequent performance of the region in the recovery period. A measurement based on employment can represents both a measure of national and regional well-being an appropriate comparable indicator between regions, allowing easy confrontation of regional performances in response to the same event. Moreover, a comparison based on a pre-shock and post-shock state can give the idea of the evolution of the phenomenon and how resilience acts to support or contain it.

The discussion around economic trend of each single prefecture shows, on the one side, that impacts of the economic and environmental shocks are often parallel and, sometimes, they overlap. The economic effects of natural disasters can exacerbate some regional dynamics and slow down the growing paths. Proposing an analysis of long-term territorial dynamics caused by a natural disaster can help to understand the impact of the disaster but also the interaction between the economic and environmental aspects and to identify vulnerable aspects of regional economies. Recognizing these vulnerabilities could foster joint actions able to face with increasingly unstable systems where boundaries between economic, social and environmental spheres are more and more blurred.

On the other side, not always economic fluctuations of employment depend on the occurrence of earthquakes. In our view, this does not affect the validity of the analysis because it concerns of a simple comparison between the response of different economic systems to the single event. However, the analysis can be surely future improved going in deep in developed a model to identify variables that can foster economic resilience in face to earthquakes but this goes beyond the objective of the paper and it will be a further object of analysis.

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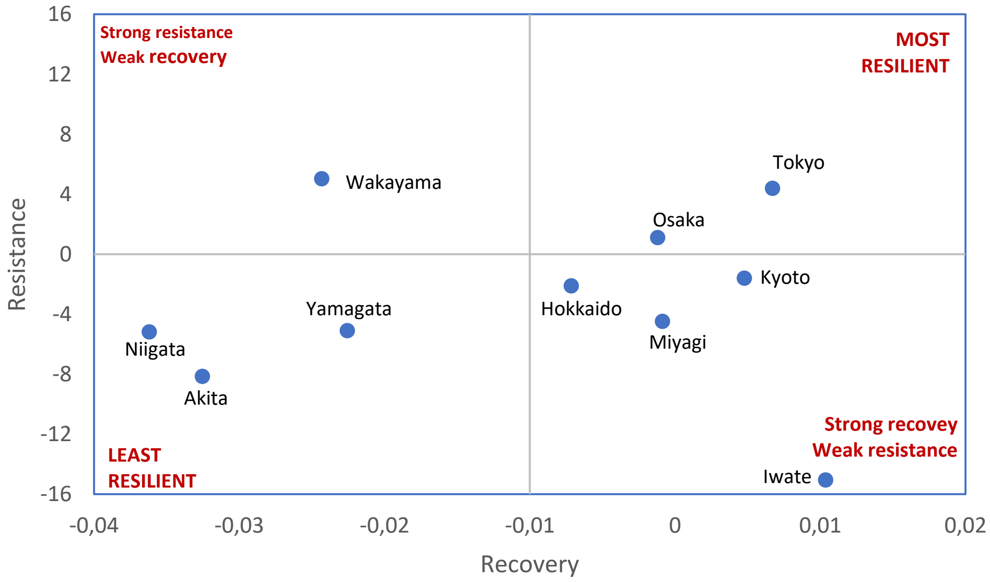
Appendix 1

Table A.1 Resistance Indices calculated following Lagravinese (2015)

Region	Recovery	Resistance
Hokkaido	-0,00715	-2,0982
Iwate	0,010355	-15,0512
Miyagi	-0,00087	-4,4692
Akita	-0,03255	-8,1354
Yamagata	-0,02258	-5,0844
Kyoto	0,004754	-1,5788
Osaka	-0,0012	1,1219
Wakayama	-0,02434	5,0346
Niigata	-0,03621	-5,1675
Tokyo	0,006692	4,3918

Source: Authors' elaboration

Figure A.1 Resistance and recovery indices of Japanese prefectures calculated for the major earthquakes occurred between 2003 and 2008



Source: Authors' elaboration