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Original paper

Damage Assessment in Tourism Caused by an Earthquake Disaster

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Abstract Natural disasters such as large-scale earthquakes can often reduce the number of tourists to a region, even in areas that suffered less damage. The belief is that this reduction in tourism is the result of psychological reasons such as people’s uncertainty about levels of service, and so, they prefer to avoid traveling to these regions. However, the reduction in tourism after an earthquake and the characteristics of this reduction have not been quantified or fully investigated. As a result, the extent of the reduction in tourism, how long an earthquake continues to affect tourism, and what areas are affected has yet to be clearly demonstrated. To better understand these losses, this study developed a framework by which we can estimate the periods of loss and the number of people who cancel their travel plans to affected areas. This framework is based on a time series analysis and is applied to five recent earthquake disasters. The results demonstrate that the disaster impacts both the disaster area and surrounding areas but that, in all cases, the numbers of tourists return to the original trends within at most a year.

Key words time series analysis, statistical test, natural disaster, tourism

1. INTRODUCTION

Japan has suffered many earthquake disasters in the past as a result of the high levels of seismic activity in the region. One of the problems caused by earthquakes that has not been fully investigated is the reduction in the number of tourists after a disaster. This phenomenon occurs in areas that suffered structural damage as well as surrounding areas that were not obviously affected. Countermeasures for this reduction in tourism have been proposed (Hiroi 2005; Sekiya 2004). However, it has proven difficult to establish which factors cause this reduction (Ministry of land, Infrastructure, Transport and Tourism 2005) because it is not only affected by service disruptions in damaged areas, but also by people’s impressions, the seasons, weather, and the economic situation. Sekiya (2003) pointed out that people’s hesitation in visiting a damaged area is a primary factor in the decline in tourism. Moreover, Sekiya also believed that events that generated more news caused a greater decline in tourism. Maeda (2005) suggests

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that if people assume that a larger area was damaged than was actually the case, this deters them from sightseeing in the region.

However, there is limited year-on-year data from hotels on which to base a report on the reduction in tourism demand. The loss of tourists after an earthquake disaster, as well as the characteristics of these losses, has not been quantified and investigated. As a result, it is not clear for how long the decrease continues or how many people cancel their travel plans in the wake of an earthquake. It is also necessary to analyze how large an area is affected by the decline in tourism.

To better understand the reduction in tourism, this study develops a framework by which we can estimate the periods of loss and the number of people who call off their travel plans. This framework is based on a time series analysis that tests structural changes and is applied to five recent Japanese earthquake disasters, namely the Great Hanshin-Awaji earthquake in 1995, the Noto Peninsula earthquake in 2007, the Niigata Chuetsuoki earthquake in 2007, and the Iwate-Miyagi Nairiku earthquake in 2008.

2. BASIC CONCEPT OF THIS STUDY

2.1 Reduction in Tourism Demand in Japan

Hyogo Prefecture (1994) reported that “the total number of tourists in Hyogo Prefecture in fiscal year 1996 was 18 million 870 thousand. It was 4 million less than the previous year because the Great Hanshin-Awaji Earthquake reduced the number of tourists in Kobe, Hanshin, and Awaji regions.” Niigata Prefecture (2007) reported that “the number of tourists is reduced by Niigata Chuetsuoki (Off-shore) earthquake in 2007.” The loss of tourism as a result of the Great East Japan Earthquake is also reported. According to the Japan Tourism Agency (2011), “people refrained from many kinds of activities, and it was one of the reasons for a reduction in tourism not only in the directly damaged area but also in areas that were not directly damaged. After the Great East Japan earthquake, 61% of tourists canceled their hotel reservations in the Tohoku region, 48% in the Kanto region, and 36% across Japan. Jiji press (2012) said that the sales of major private travel agencies in March also decreased by 31.5% (for the first time in recent 6 months).” The Great East Japan earthquake is different from the other earthquake disasters because it also involved the accident at the nuclear power plant. However, it is reasonable to assume that the effect of the earthquake disaster itself was significant.

2.2 Tourist Information for each Disaster

The tourist numbers are extracted from tourism reports issued by the Hyogo, Niigata, Ishikawa, Miyagi, and Iwate Prefectures. Table 1 presents the data used in this study. Each prefecture is divided into regions in the tourism reports. It should be noted that each prefecture uses its own method for calculating the number of tourists. Fig. 1 represents the data of tourists in the Chuetsu region in Niigata Prefecture as an example. As seen in Fig. 1, it is difficult to identify the decrease in the number of tourists from a visual observation because the data include seasonality and other trends. Thus, some scientific approaches are necessary.

2.3 Approach of This Study

Many studies analyze how long the economic influence of a natural disaster lasts. Worthington and Valadkhani (2004) estimated how long a natural disaster affects the capital market. Kajitani et al. (2001) assessed the influence of the Great Hanshin Awaji earthquake on Kobe port. Kim and Wong (2006) analyzed how the volatility in tourism demand changed as a result of an exogenous shock. However, no study estimates how the time series data of tourists changes structurally, how long the effect lasts, and how many tourists call off their travel plans. This study adopts time series analysis, as per previous works, in an attempt to answer these research questions, especially in small regions.

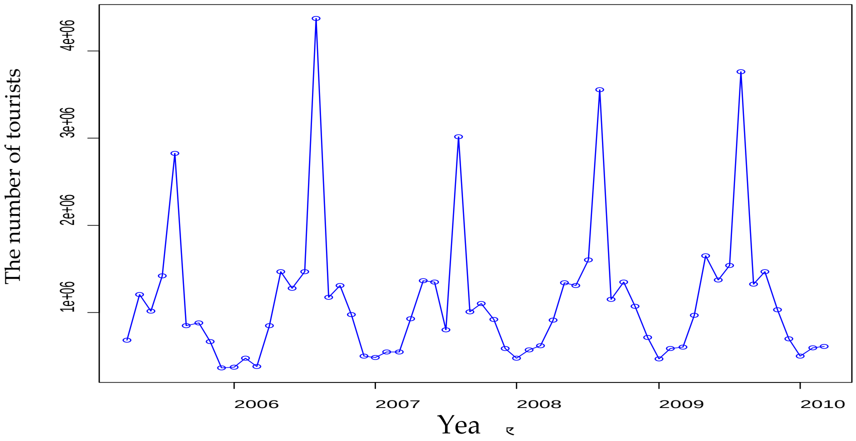

Fig. 1. Number of the tourists in Chuetsu region in Niigata Prefecture

As a basis for the analysis, this study employs an autoregressive moving average (ARMA) model that calculates a present value from past values and error terms. This model makes it possible to represent complicated time series, such as that shown in Fig. 1, using a few parameters. A shock resulting from a disaster is modeled by an intervention analysis. An intervention analysis adds some disturbance terms to a model (Box and Tiao 1975). If the ARMA model is used on its own, it is not possible to represent a shock, but by combining it with an intervention analysis, the shock can be modeled effectively. In this study, dummy variables are applied to the periods after an earthquake. If a dummy variable representing the shock of an earthquake can be assumed to be zero, the earthquake has no effect during the period. However, if the dummy variable cannot be assumed to be zero, the earthquake does have an effect during the period. This method is often applied in the field of finance. For example, it was used in a study that tested the stability of a stock return during the Asian currency crisis (Ho and Wan 2002). In recent years, this method has also been applied to natural disasters. For example, some studies investigate the influence of Hurricane Hugo on environmental projects (Fox 1996) and estimate the effect of a natural disaster on the price of Australian assets (Worthington and Valadkhani 2004).

3. PROCEDURES TO ESTIMATE MODELS AND THE EFFECTS OF AN EARTHQUAKE

Fig. 2 shows this study’s framework for estimating the effect of an earthquake. The framework consists of six procedures, as described below.

3.1 Procedure 1

An autoregressive integrated moving average (ARIMA) model is estimated based on tourists’ time series data “before” an earthquake. The ARIMA model can be described as follows. First, an ARMA model is given by the following formula:

$$\Phi(B)y_t = \mu + \Theta(B)\varepsilon_t \tag{1}$$

Here, *Φ* is a polynomial of the lag operator representing the AR model that calculates the present value from past values, and *Θ* represents the MA model that calculates the present value from past error terms. If the data have unit roots (the data become stationary by difference), the ARIMA model is obtained by applying the ARMA model to the data after differentiating. That is, the ARIMA model is given as follows:

$$\Phi(B)\Delta^d y_t = \Theta(B)\varepsilon_t \tag{2}$$

Here, *d* is a degree of difference. The ARIMA model is used to analyze time series data (Box and Jenkins 1970). In Procedure 1, the Box and Jenkins method is used for the data before an earthquake. Only the data before an earthquake is used because if a structure has changed as a result of the earthquake, it is not appropriate to apply the same model to the data both before and after the event.

The detail of the ARIMA model estimation is as follows. First, it is important to make the time series stationary because the ARIMA model is based on a stationary time series. Therefore, a seasonal adjustment is performed before further analysis. The data is divided into trend, seasonal, and random variation, and a moving average is used to remove the seasonal variation. Fig. 3 represents the time series data in the Chuetsu region both before and after the seasonal adjustment. Moreover, to obtain the stationary data, the time trend or unit root must be removed. The question of whether to detrend or to differentiate a time series prior to further analysis depends on whether the time series is trend-stationary or difference-stationary (Maddala and Kim 1998), which can be established using a unit root test (Dickey and Fuller 1979; Said and Dickey 1988). If the degree of difference is decided by the unit root test, then the parameters of the ARIMA model are estimated. Because the lag orders of the AR process and MA process should be small values (Worthington and Valadkhani 2004), 0~10 are selected as lag orders for the AR and MA processes; that is, 121 combinations of parameters are estimated. Next, two tests are performed on the 121 ARIMA models. First, a t-test is used to estimate whether the parameter can be assumed to be zero. Second, the residuals of a model must be a white noise. Therefore, a Ljung-Box test is used to test if the residual errors of a model can be assumed to be white noise. The Q statistics of the Ljung-Box test are as follows:

$$Q(j) = n(n+2)\sum_{l=1}^{j} \frac{1}{n-l} r_l^2 \tag{3}$$

Here, *j* is the maximum degree of correlation coefficient and $r_1 \cdots r_j$ are correlation coefficients. Q has an asymptotic chi-square distribution on the null hypothesis that all autocorrelations are zero. Finally, one model is chosen based on Akaike's information-theoretic criterion (AIC) from all models that passed these two tests. Through this process, a more appropriate model is chosen using Procedure 1.

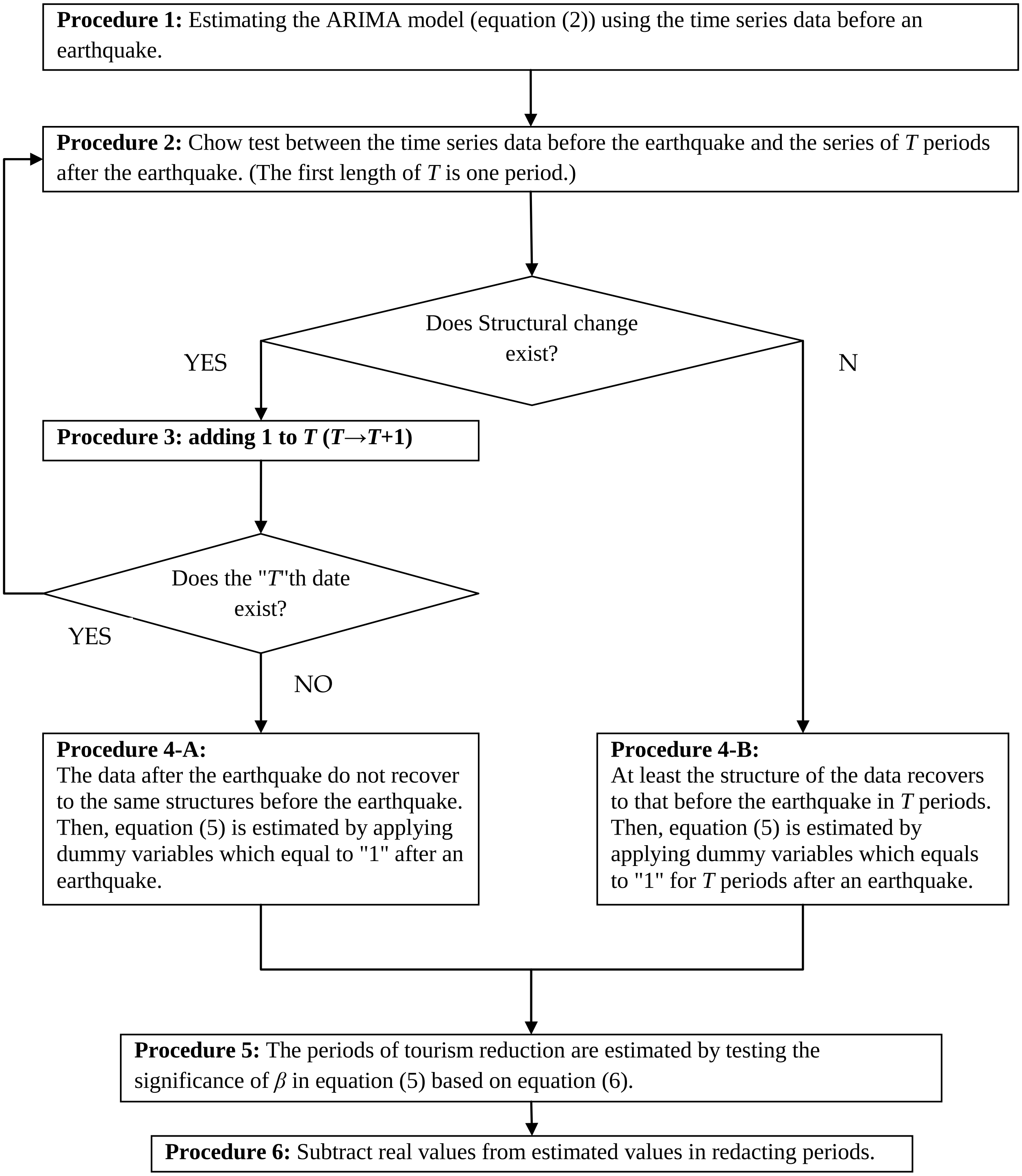

Fig. 2. Framework for estimating the decrease in tourism demand

Table 1 Data sets for this study

Prefecture	Hyogo	Ishikawa	Niigata	Miyagi	Iwate
Date period	Apr.1986～Mar.1997	Jun.2001～Dec.2009	Apr.2005～Mar.2010	Jun.2003～Dec.2009	Jun.2001～Dec.2009
Regional division	Kobe	Noto	Chuetsu	Kurihara	Kitakamigagwa
	Hanshin	Kanazawa	Uonuma・Higashikubiki	Tomai	Rikuchukaigan-nanbu・Tono
	Higashi-Harima	Hakusan	Niigata・Yahiko	Osaki	Morioka・Hatimandaira
	Awaji	Kaga	Aganogawa	Ishinomaki	Rikuchukaigan-tyubu
	Nishi-Harima		Jyoetsu	Kesennuma・Motoyoshi	Kenhoku・Rikuchukaigan-hokubu
	Tanba		Sado	Sendai	
	Tajima		Iwafune Tainai	Sennan	

3.2 Procedures 2 and 3

Procedure 2 and Procedure 3 test whether a structural change exists in the time series data. The definition of a structural change in this study is that parameters of a model have changed significantly since a certain shock occurred. If time series data have changed structurally after the shock, it is not appropriate to apply the same model before and after the structural change. The Chow test is used to decide whether a structural change has occurred (Chow 1960). The Chow test statistic is as follows:

$$F = \frac{(RSS_r - RSS_{u1} - RSS_{u2})/(1+p+q)}{(RSS_{u1} + RSS_{u2})/n - 2(1+p+q)} \tag{4}$$

Here, *RSS r* is a residual sum of squares, which is estimated from the models applied to all the data, *RSS u1* is a residual sum of squares estimated from the same model applied to the data before the earthquake, *RSS u2* is a residual sum of squares estimated from the data after the disaster, *p* and *q* are the number of parameters of the AR and MA processes, respectively, and *n* is the number of samples. The critical p-value is 5% in this study. The null hypothesis is that "there is no structural change in the time series data."

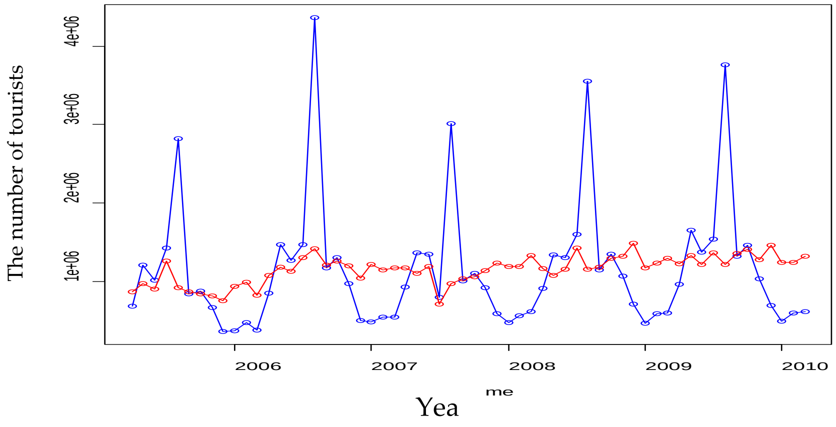

Fig. 3. Number of tourists in the Chuetsu region before and after seasonal adjustment

In Procedure 2, the Chow test is performed between the data before the earthquake and the data with length *T* after the earthquake. The length of *T* is initially set as 1. If the Chow tests detects a structural change, *T* is incremented by 1 (i.e., *T* + 1) in Procedure 3. Procedures 2 and 3 are repeated until no structural change is detected or the length of *T* becomes equal to the length of the data after the earthquake. The purpose of these procedures is to find the periods (of length *T*) in which the structural change is not found by continuously adding one to the period length. If an appropriate *T* is found, the model can be estimated using data after the earthquake and the accuracy of the model can be improved.

3.3 Procedure 4

Procedure 4 estimates a model that quantifies how long a reduction in tourism demand continued. This study uses an ARIMA model, including an intervention analysis, to describe the effect of an extraordinary event on the model. One of the intervention analysis methods is to employ dummy variables, as follows:

$$\Phi(B)\Delta^d y_t = \Theta(B)\varepsilon_t + \sum_{t=1}^{N} \beta_t D_t \tag{5}$$

where *Dt* is a dummy variable, *βt* is a parameter of the dummy variable and *N* is a total number of the time series data. When *a* is the number of data (corresponding to periods) before an earthquake, dummy variable *Dt*= 1 if *t* is bigger than *a* and less than *a* + *T*. That is, periods T indicate the duration of earthquake impacts. In other periods, *Dt* equals to zero. When a dummy variable is one, the dummy parameter becomes an appropriate value for representing the effects of a shock.

If a recovery from the structural change is found in Procedure 3, a model of equation (5) is estimated by applying dummy variables which equal to one from *t* = *a* + *1* to *a* + *T* in Procedure 4-B. However, if a recovery from the structural change is not detected, we cannot say that the effect of the earthquake has vanished. In this case, the dummy variables are applied which equal to one from *t* = *a* + 1 to *N* (*T* = *N* - *a*) to a model of equation (5). The model parameters are estimated in the same way as Procedure 1.

3.4 Procedure 5

Procedure 5 estimates how long tourism demand is reduced after an earthquake by using dummy parameters of the model estimated in Procedure 4. If a dummy parameter cannot be assumed to be zero, it is reasonable to believe that the earthquake had an effect. First, a null hypothesis that “all dummy parameters are zero” is tested. If the null hypothesis is rejected, it is reasonable to presume that the shock had an impact during at least the first period after the event, and if the null hypothesis is accepted, it can be said that there was no effect on tourism demand during the period. In the case of a rejection, a null hypothesis that “all dummy parameters other than the first are zero” is tested. If the null hypothesis is rejected, the hypothesis that “all dummy parameters other than the first and second are zero” is tested in the same way. These tests are repeated until the null hypothesis is not rejected. In general, for the null hypothesis,

H0: $\boldsymbol{\beta}_k = (\beta_{a+k}, \ldots, \beta_{a+T}) = \mathbf{0}$

(All dummy parameters from *k* to T periods after the earthquake are zero.)

H1: At least one of the parameters in the null hypothesis is non-zero.

where *a* is the number of data (time periods) before an earthquake. This null hypothesis is tested from *k* = 1 to *k* = *T*, and if the null hypothesis is not rejected for the first time for a certain value of *k*, this means the "*k*"th period after an earthquake is the first in which the event has no effect. In addition, the event did have an effect from its occurrence to the "*k* – *1*"th period. The F-test statistic is as follows:

$$F = \frac{(RSS(2) - RSS(1))/m}{RSS(1)/(n-K)} \tag{6}$$

where *RSS* (1) is the residual sum of squares of the model in Procedure 4 and *RSS* (2) is the residual sum of squares of the model estimated under the null hypothesis. In addition, *m* is the number of variables in the null hypothesis, *n* is the number of data items, and *K* is the number of variables in the model estimated in Procedure 4.

3.5 Procedure 6

Procedure 6 estimates the amount of tourism reduction. This estimation is done by comparing the hypothetical number of tourists without the disaster to the actual number of tourists. The hypothetical number of tourists after the disaster is interpolated by the time series model estimated in Procedure 1. Equation (2) is estimated based on the time series, which exclude the earthquake-affected periods detected by Procedure 5. Based on this time series model, the hypothetical number of tourists (without earthquake case) is estimated by one-step ahead forecasting (interpolation) for the earthquake-affected periods. Before and after the affected periods, the observed data is used for estimating the parameters of equation (2).

The real number of tourists is subtracted from the hypothetical number of tourists from equation (2) for the periods affected by an earthquake, and the result is the estimate of the reduction. All operations in the framework in Fig. 2 end after conducting Procedure 6.

4. ESTIMATION OF THE IMPACT OF PAST DISASTERS ON TOURISM DEMAND

4.1 Estimation Results

Using the framework in Fig. 2, reductions in tourism demand in the Hyogo, Niigata, Ishikawa, Iwate, and Miyagi Prefectures were estimated. For example, Table 2 shows the results of Procedure 1 as applied to the Chuetsu region in Niigata Prefecture (the Niigata Chuetsuoki earthquake occurred in 2007).

MA(1) in Table 2 represents a parameter of order 1 for the MA process. Similarly, AR(1) represents a parameter of degree 1 for the AR process, as follows. The results of Procedures 2 and 3 are represented in Fig. 4. The red line in Fig. 4 represents the p-values of the statistics and the blue line represents the 5% critical p-value. It can be seen that p-values are less than 5% in the first 7 periods after the earthquake but that structural changes are not detected after this period (one period means one month). With a critical p-value of 5%, the structure of Chuetsu region recovered during the 8th period after the earthquake. In this case, Procedure 4-B will be conducted as the next step in the framework.

Table 2 Results of Procedure 1 in the Chuetsu region

Degree of AR process	0			
Degree of MA process	1			
Parameter of MA process (t-value)	MA(1)	–0.432	(–2.52)	
p-value from Ljung-Box test	Lag	p-value	Lag	p-value
	1	0.77	11	0.92
	2	0.87	12	0.95
	3	0.81	13	0.96
	4	0.82	14	0.96
	5	0.76	15	0.96
	6	0.85	16	0.96
	7	0.91	17	0.92
	8	0.85	18	0.93
	9	0.89	19	0.94
	10	0.93	20	0.95
AIC	-18.49			
Adjusted R-square	0.56			
Unit root	exists			

Table 3 shows the results of Procedure 4-B. Here, β represents a dummy parameter in equation (5). Dummy variables are applied to seven periods in which the structural changes exist and the model of equation (5) is estimated. It is found that a shock exists in the period in which the earthquake occurred because $\beta 1$ has a larger value than the others. It is also found that the effect of the earthquake gradually diminishes because the t-value of the dummy parameters becomes smaller as time passes.

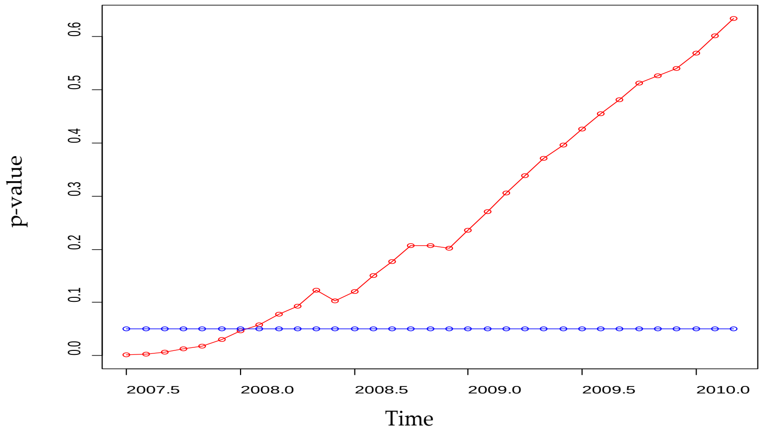

Fig. 4. Result of Procedures 2 and 3 in Chuetsu region (significance tests of dummy parameters)

(Blue: 5% significance level Red: p-values of t-test at each time period)

Table 4 shows the estimation results of the impact periods determined by Procedure 5. When *k* is set as one (one period after the earthquake), the null hypothesis that “all dummy parameters are zero” is rejected. However, when *k* is set as two, the null hypothesis that “all dummy parameters other than the first are zero” cannot be rejected. Therefore, the reduction in tourism demand continued for one month.

This is an acceptable result considering that the number of tourists in July 2007 (in which the earthquake occurred) is 45.7% down from the previous year. The number of tourists in August 2007 is 31.1% down from the previous year, so while it seems that a large effect exists, it is still 6.5% up from the number of tourists in August 2005. The reason a reduction in tourism demand is not detected by the statistical test in August 2007 is that the difference is not extraordinary in the overall time series data. In fact, Niigata Prefecture (2006) reported that the number of tourists in August 2005 was higher than normal as a result of good weather.

Table 3 Results of Procedure 4-B in the Chuetsu region

Degree of AR process	0			
Degree of MA process	1			
Parameter of MA process (t-value)	MA(1)	–0.534	(–4.61)	
The number of dummy variable	7			
Dummy parameters （t-value）	β_1	–0.512	(–5.152)	
	β_2	–0.198	(–1.861)	
	β_3	–0.151	(–1.346)	
	β_4	–0.130	(–1.119)	
	β_5	–0.066	(–0.558)	
	β_6	0.004	(0.032)	
	β_7	–0.040	(–0.031)	
p-value from Ljung-Box test	Lag	p-value	Lag	p-value
	1	0.71	11	0.24
	2	0.89	12	0.14
	3	0.66	13	0.17
	4	0.35	14	0.22
	5	0.40	15	0.25
	6	0.52	16	0.31
	7	0.59	17	0.37
	8	0.11	18	0.41
	9	0.16	19	0.40
	10	0.21	20	0.43
AIC	-75.2			
Adjusted R-square	0.81			

Finally, Procedure 6 estimates the extent of the reduction in the number of tourists. Procedure 5 shows that the earthquake has an effect during the first period after the event. Then, the first data after the earthquake (the data as of July 2007) is handled as a missing value, which is then estimated. The difference between the estimated value and the real value is the amount of the reduction in tourism demand. Table 5 shows the results of Procedure 6.

The observed value, hypothetical value, amount of reduction, and standard error in Table 5 are represented by a unit of a thousand. The framework shows that the reduction in tourism demand continued for one month, and the amount of the reduction was 665 thousand in the Chuetsu region. The model in Procedure 6 fitted the observed time series well, as shown by the correlation coefficient. Figs. 5 and 6 represent the observed values and the hypothetical values of the number of tourists in the Chuetsu region in Procedure 6, respectively. The black line shows the observed values, the red line shows the hypothetical values, and the two green dotted lines represent the 95% confidence interval in Fig. 5. The point in the blue circle is the data on July 2007 and lies outside the confidence interval. In Fig. 6, the horizontal axis and vertical axis represent the observed values and the estimated values, respectively. The angle of the black line is 45 degrees. Only one estimated point in July 2007 is far below the observed data. The other estimated points are relatively close to the observed data.

Table 4 Results of Procedure 5 in the Chuetsu region

	F-value	P-value
$k = 1$	2.250	0.024
$k = 2$	0.700	0.731

Table 5 Results of Procedure 6 in the Chuetsu region

Degree of AR process	0			
Degree of MA process	1			
Parameter of MA process	MA(1)	–0.537	(–4.52)	
p-value from Ljung-Box test	Lag	p-value	Lag	p-value
	1	0.81	11	0.53
	2	0.95	12	0.39
	3	0.69	13	0.46
	4	0.59	14	0.53
	5	0.54	15	0.59
	6	0.59	16	0.64
	7	0.59	17	0.65
	8	0.42	18	0.69
	9	0.45	19	0.71
	10	0.50	20	0.67
AIC	-72.4			
Adjusted R-square	0.68			
Real value at missing value	797			
hypothetical value at missing value	1462			
Amount of reduction	665			
95% confidence interval	1023～377			
Standard error	177.89			

4.2 Analysis of Reduction and Recovery of Tourism Demand

Table 6 shows the results of applying the framework to five earthquake disasters in Japan. The periods in which the earthquakes exhibited an effect and the amount of reduction in tourism demand are represented. The “Rate of reduction” is defined as “observed value”/“estimated value.” That is, the “Rate of reduction” is an index that represents how the real value is small when compared to the estimated value when there was no earthquake. “Distance from severe damaged region” is defined as the distance from the most directly damaged region of each prefecture (the Great Hanshin Awaji earthquake – Kobe region, Noto peninsula earthquake – Noto region, Niigata Chuetuoki earthquake – Chuetu region, Iwate-Miyagi Narikiku earthquake – Kurihara region). In case of the Hanshin-Awaji Earthquake, a decrease in the tourism demand is detected in the Hanshin, Kobe, Awaji, and Tajima regions in Hyogo Prefecture. In the same way, a reduction is detected in the Chuetsu region in Niigata Prefecture, the Noto region in Ishikawa Prefecture, Kitakamigawa in the Iwate region, and the Kurihara, Osaki, Sendai, and Tomai regions in Miyagi Prefecture. The decrease lasted the longest in the Kobe region (11 months), the second longest in the Awaji region (9 months), and the third longest in the Kurihara region (5 months). The effects lasted less than 5 months in the other regions.

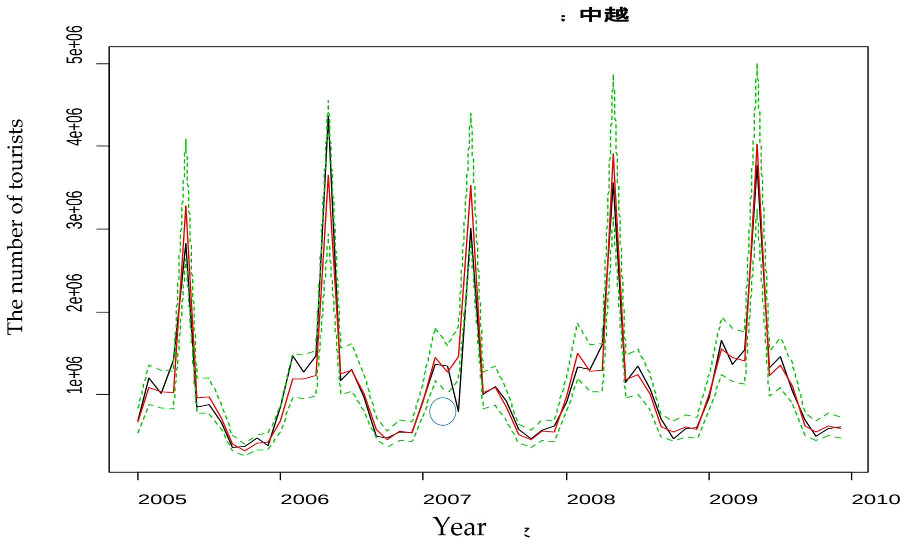

Fig. 5. Real value and hypothetical value in the Chuetsu region

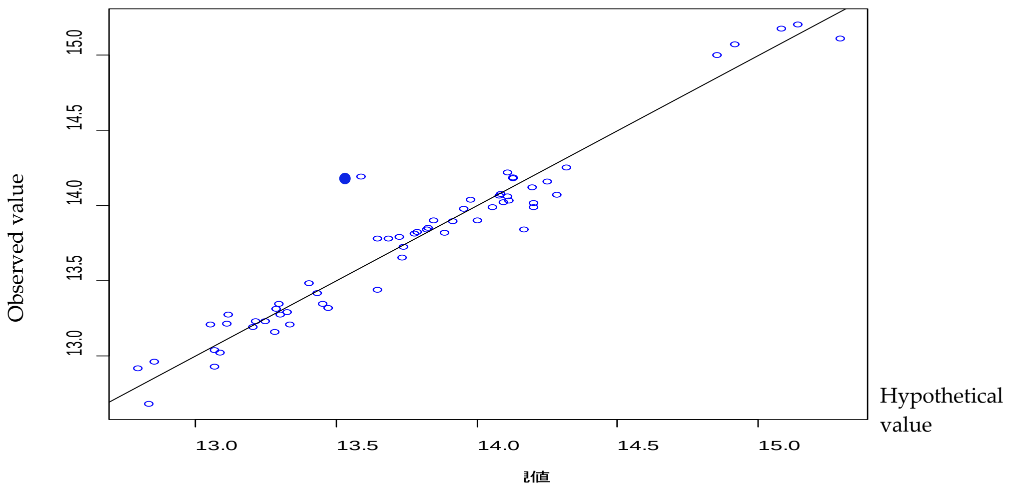

Fig. 6. Real value and hypothetical value in the Chuetsu region

The Fire and Disaster Management Agency (2006) in Japan reported that 6,434 people were killed and 104,906 structures were completely destroyed as a result of the Great Hanshin Awaji earthquake (Mw 7.3); one person was killed and 686 structures were completely destroyed after the Noto peninsula earthquake (Mw 6.9); 15 people were killed and 1,331 structures were completely destroyed after the Niigata Chuetsuoki earthquake (Mw 6.8); and 17 people were killed and 30 structures were completely destroyed after the Iwate-Miyagi Nairiku earthquake (Mw 7.2). These facts and the information in Table

6 show that the decrease in tourism after the Iwate-Miyagi Nairiku earthquake is relatively larger than that after the Niigata Chuetsuoki and Noto peninsula earthquakes, although the number of completely destroyed structures from these earthquakes is much higher than that from the Iwate-Miyagi Nairku earthquake. Therefore, it cannot simply be concluded that there is some correlation between a decrease in tourism demand and direct damages. The magnitude also seems not to be correlated with a decrease in tourism because the decrease in the number of tourists in Niigata Prefecture is more than that in Ishikawa Prefecture, even though the magnitude of the Niigata Chuetsuoki earthquake was smaller than that of the Noto peninsula earthquake.

In the Kobe region, it seems that the large scale of the direct damage is a major cause of the decrease in tourism demand. Here, tourism recovered within one year, during which time the social infrastructure was basically repaired. In contrast, in the Kurihara and Kitakamigawa regions, a choking dam in the river channel was created by the landslide around a hot spring area, and these regions were exposed to hazards for a relatively long time (two years before removing a control on being near to the dam). It seems that this also affected the reduction of tourism in these regions. The number of tourists in some regions, such as the Sendai and Tajima regions, that are relatively far from the main damaged regions suffered less direct damage. This may have been the result of rumors. However, if there is some complementarity between a large city and its surrounding area in terms of tourism, damage in a large city could affect tourism in the area around it. Here, the complementarity of the cities indicates that when a big city has many hotels and its surrounding area has few, the number of tourists could be reduced in both the city and its surrounding area because tourists who want to stay overnight may have few places to stay if they are concerned that the city might be damaged by the earthquake.

To more precisely analyze the reduction in tourism demand, a linear discriminant function is estimated that decides if a reduction exists as a distance from a severely damaged region. The estimated linear discriminant function is as follows:

$$DIndex = 0.02936091 \times DISTANCE - 1.49972 + \varepsilon \tag{7}$$

where *DISTANCE* is the distance from the severely damaged region and ε is the error term. If *Dindex* is smaller than zero, it means that an effect of earthquake exists, and if *Dindex* is bigger than zero, it means that an effect does not exist. It is found from equation (7) that if a region is more than 51.07 km from the severely damaged region, there is no reduction in tourism demand in the region. Table 7 shows the accuracy of the discriminant function.

Tajima and Sendai are expected to have little probability of a reduction in tourism, but they did in fact show such a reduction. However, some regions in which a reduction in tourism demand is expected to exist show no such reduction. Higashi-Harima, Nishi-Harima, and Ishinomaki fall into the latter group. The reason for this is not clear. In order to do a more precise analysis, a factor analysis is necessary concerning the economic structure of a city on factors such as the scale of the tourism industry, the complementarity with the surrounding area, and accessibility.

The simple geometric distance should be replaced by the actual travel time considering the transportation system. Economic relationships between the cities and regions, and the type of resources for sightseeing in each region are also significantly important. The positive and negative contents broadcasted by the media regarding the damages in the regions would also affect people’s decision to travel.

The analysis here is limited, summarizing only the geometric relationship, but has a potential to be enhanced to better explain the decrease of demand by considering these affecting factors more rigorously.

Table 6 Results of the framework in each region

Hyogo	Kobe*	Hanshin	Higashi-Harima	Awaji	Nishi-Harima	Tamba	Tajima
Affected periods (by the month)	11	3	0	8	0	0	2
Amount of reduction (thousands of units)	10,541	1080	0	1,926	0	0	187
Rate of reduction (%)	54.7	12.3	0	25.0	0	0	10.0
Distance from severely damaged region (km)	0	20.0	22.1	37.3	48.4	56.5	101.3
Destroyed houses	104,906						
Niigata	Chuetsu*	Uonuma Higashikubiki	Niigata Yahiko	Aganogawa	Jyoetsu	Sado	Iwahune Tainai
Affected periods (by the month)	1	0	0	0	0	0	0
Amount of reduction (thousands of units)	665	0	0	0	0	0	0
Rate of reduction (%)	45.5	0	0	0	0	0	0
Distance from severely damaged region (km)	0	56.0	56.2	60.8	62.3	76.9	104.2
Destroyed houses	1,331						
Ishikawa	Noto*	Kanazawa	Hakusan	Kaga			
Affected periods (by the month)	2	0	0	0			
Amount of reduction (thousands of units)	152	0	0	0			
Rate of reduction (%)	14.1	0	0	0			
Distance from severely damaged region (km)	0	60.4	68.9	101.0			
Destroyed houses	686						
Iwate	Kitakamigawa*	Rikutyukaigan-nanbu・Tono	Morioka・Hatimandaira	Rikutyukaigan-tyubu	Kenhoku・Rikutyukaigan-hokubu		
Affected periods (by the month)	4	0	0	0	0		
Amount of reduction (thousands of units)	728	0	0	0	0		
Rate of reduction (%)	13.7	0	0	0	0		
Distance from severely damaged region (km)	47.2	79.9	108.8	129.7	175.0		
Destroyed houses	2						
Miyagi	Kurihara*	Tomai	Osaki	Ishinomaki	Kesennuma Motoyoshi	Sendai	Semnan
Affected periods (by the month)	5	1	2	0	0	3	0
Amount of reduction (thousands of units)	543	9	151	0	0	1,510	0
Rate of reduction (%)	59.5	4.5	9.8	0	0	15.8	0
Distance from severely damaged region (km)	0	15.1	18.0	41.0	51.5	53.1	77.1
Destroyed houses	28						

Table 7 Results of estimated linear discriminant function applied to reduction in tourism demand

		Estimation by discriminant function	
		No decrease of tourists	Decrease of tourists
Estimation through framework	No decrease of tourists	17	2
	Decrease of tourists	3	8

5. CONCLUSIONS

Earthquake disasters can often reduce the number of tourists in a region, even in regions not seriously affected by the event. However, the decrease in the number of tourists after an earthquake disaster and its characteristics are neither quantified nor investigated. This study analyzes the duration and area in which tourist demand decreased after recent earthquake disasters. The framework in this study involves (1) estimating a time series model using stable data before an earthquake, (2) detecting the structural changes and periods affected by earthquake, and (3) estimating the amount of a reduction in tourism demand (estimated value – real value) based on the results of (2). A program is developed to carry out this framework automatically and is applied to actual time series data before and after earthquakes.

The estimations of the amount and periods of reduction in tourism shows that the structure of time series recovered from the shock of an earthquake within one year even in the case of large earthquakes such as the Great Hanshin Awaji earthquake. Natural damming of a river due to landslide occurred around the Kurihara and Kitakamigawa regions, and these regions experienced a reduction in tourism for a relatively longer period, even though direct damage was relatively small. Furthermore, the spatial effect of an earthquake is investigated based on a test of whether or not reduction in tourism demand exists in each region. Reduction in tourism demand is likely to occur in an area located within about 50 km from a severely damaged region. It is expected that reductions not caused by direct damage are likely to occur near the 50 km boundary. However, some regions located outside the boundary experienced a reduction in tourism. Examples of the latter group are the Tajima and Sendai regions.

One of the reasons for the reduction in tourism demand even in less seriously damaged areas could be the result of urban structure, which includes geographical location, an economic bloc, a traffic network, and the complementarity between a large city and its surrounding areas in the tourism industry. There could be some cases in which damaged areas are not that accessible, and people may view the city and its surrounding areas as one and the same in terms of tourism. The number of tourists could also be reduced when an area has many tourists who live in distant areas, because people who live in distant areas are strangers and may have concerns about safety.

In this study, analyses are made to quantify the reduction in tourism demand as a result of an earthquake by using tourist time series data from past disasters. Some characteristics of tourism reduction and its spatial effects are identified. Future studies should analyze the characteristics of regions with respect to the urban structure and investigate the relationship between the reduction in tourism demand and the amount of news generated about the earthquake from a psychological point of view. Furthermore, it should be considered that other events could affect the tourism demand such as weather conditions and size and timing of regional social events. In order to estimate only the effects of an earthquake disaster, the analysis should be enhanced by carefully checking these conditions. Intensive post-disaster survey is one of the necessary approaches as well as advancing the time-series modeling itself.

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APPENDIX

Table 8. Results of model estimation in Procedure 6

			Kobe		Hanshin		Awaji		Tajima		Noto	
Degree of AR process			0		1		2		6		1	
Parameter of AR process (t-value)	AR1				0.92 (14.3)		1.68(14.1)		0.69 (5.05)		0.92 (17.6)	
	AR2						-0.93(-9.10)		-0.53 (-4.49)			
	AR3								-0.29 (-2.48)			
	AR4								0.66 (6.12)			
	AR5								-0.52 (-4.88)			
	AR6								0.56 (5.87)			
Degree of MA process			2		3		8		7		1	
Parameter of MA process (t-value)	MA1		1.03 (18.1)		0.39 (2.80)		-1.72(-11.6)		0.31 (1.94)		-0.49 (-4.35)	
	MA2		1.00 (10.4)		0.47 (2.73)		0.97(4.80)		1.15 (6.65)			
	MA3				-1.02 (-6.74)		-0.38(-2.01)		0.81 (4.43)			
	MA4						0.63(3.09)		0.70 (3.68)			
	MA5						-0.36(-1.64)		0.73 (4.24)			
	MA6						-0.35(-1.56)		-0.02 (-0.13)			
	MA7						0.58(2.74)		0.59 (3.99)			
	MA8						-0.27(-2.14)					
p-value from Ljung-Box test	Lag		p-value		p-value		p-value		p-value		p-value	
	1	11	0.96	0.99	0.97	0.99	0.90	0.90	0.68	0.94	0.38	0.90
	2	12	0.99	0.51	0.99	0.51	0.99	0.63	0.59	0.95	0.68	0.56
	3	13	0.75	0.59	0.75	0.59	0.96	0.69	0.73	0.97	0.83	0.63
	4	14	0.87	0.67	0.87	0.67	0.97	0.76	0.71	0.99	0.90	0.66
	5	15	0.93	0.72	0.94	0.72	0.97	0.72	0.80	1.00	0.91	0.72
	6	16	0.92	0.78	0.92	0.78	0.9	0.76	0.88	1.00	0.72	0.49
	7	17	0.96	0.83	0.96	0.83	0.94	0.80	0.87	1.00	0.80	0.51
	8	18	0.98	0.85	0.98	0.85	0.97	0.85	0.92	1.00	0.87	0.58
	9	19	0.98	0.89	0.98	0.89	0.95	0.88	0.91	1.00	0.89	0.64
	10	20	0.99	0.92	0.99	0.92	0.92	0.91	0.94	1.00	0.91	0.69
AIC			-174.2		-358.9		-308.0		-313.2		-261.8	
Adjusted R-square			0.84		0.86		0.86		0.93		0.70	

			Kitakamigawa		Kurihara		Tomai		Osaki		Sendai	
Degree of AR process			2		2		0		0		1	
Parameter of AR process	AR1		1.44 (8.95)		0.41 (1.09)						0.95 (15.7)	
	AR2		-0.74 (-5.73)		0.37 (0.82)							
Degree of MA process			2		2		3		1		1	
Parameter of MA process	MA1		-1.22 (-8.87)		0.25 (0.30)		0.40 (4.03)		0.37 (3.58)		-0.81 (-7.67)	
	MA2		0.71 (4.68)		-0.12 (-1.16)		0.66 (7.04)					
	MA3						0.55 (4.07)					
p-value from Ljung-Box test	Lag		p-value		p-value		p-value		p-value		p-value	
	1	11	0.93	0.99	0.92	0.68	0.50	0.50	0.97	0.69	0.84	0.73
	2	12	0.92	0.97	0.98	0.49	0.77	0.52	0.75	0.71	0.91	0.80
	3	13	0.98	0.98	0.88	0.55	0.84	0.60	0.65	0.77	0.70	0.85
	4	14	1.00	0.97	0.84	0.59	0.93	0.63	0.62	0.73	0.65	0.88
	5	15	1.00	0.98	0.92	0.61	0.73	0.70	0.75	0.62	0.68	0.92
	6	16	1.00	0.99	0.90	0.68	0.29	0.71	0.54	0.61	0.73	0.93
	7	17	1.00	0.99	0.34	0.72	0.35	0.71	0.60	0.64	0.71	0.95
	8	18	0.98	0.98	0.44	0.68	0.38	0.74	0.61	0.66	0.59	0.96
	9	19	0.99	0.99	0.52	0.62	0.33	0.79	0.65	0.53	0.69	0.94
	10	20	0.98	0.99	0.60	0.62	0.41	0.84	0.73	0.34	0.77	0.96
AIC			-331.2		-196.0		-67.5		-243.5		-202.9	
Adjusted R-square			0.49		0.71		0.90		0.92		0.74	