Long-term Effects of the Hyogo Nanbu Earthquake on Economic Activities at the Port of Kobe : Time Series Analysis

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1 Introduction

The January 17, 1995 Hyogo Nanbu Earthquake caused great damage to facilities at the Port of Kobe, leaving 179 of the 188 public berths inoperational. Moreover, damage was not limited to the physical facilities, but also brought about indirect effects. For example, cargo traffic at the port of Kobe, Japan's largest port, has not yet returned to pre-earthquake levels. In order to understand or estimate the total impact of the disaster, it is necessary to investigate whether this loss of cargo traffic is a temporary phenomenon or will continue permanently and lead to long-term losses.

There are many good impact assessments with respect to the port of Kobe and useful results are obtained [Chang (2000) and Fujimoto (1999)]. However, most of the impact assessments depend on mainly plotting time series data. Using only this approach , it is difficult to determine from visual inspection if the subtle deviations from the trend are significant. With this background in mind, the objective of the current research is to develop a scientific methodology to objectively determine if the loss will persist permanently, by conducting an empirical analysis of the Hyogo Nanbu Earthquake Disaster.

2 Methodology

2.1 Long-term influence of the earthquake disaster and structural change

One of the main reasons why loss from an earthquake disaster can remain for a long period is that some structural change in port activities can occur. This structural change can be brought about, for example, by changes in cargo traffic routes, or changes in the economic activities in the hinterland of the damaged port. This structural change is reflected also in economic indicators, such as the amount of cargo traffic. The approach taken in this research is to test for change in the model structure and its parameters, as reflected in a time series model of an economic indicator, rather than to analyze directly the concrete phenomena in real economic activities. From the viewpoint of statistics, the structural change is defined as when a model's structure and its parameters are not the same before and after some dividing point. For example, in AR (1) model (autoregressive model of order one), a structural change is expressed as follows.

$$X_t = C + \alpha X_{t-1} + \beta t + \epsilon_t \quad \epsilon_t \sim N(0, \sigma) \tag{1}$$

$$X_t = C + \Delta C + (\alpha + \Delta\alpha) X_{t-1} + (\beta + \Delta\beta) t + \epsilon'_t \quad \epsilon'_t \sim N(0, \sigma + \Delta\sigma) \tag{2}$$

Here, equations (1) and (2) represent the time series model before and after the earthquake event. C denotes a constant term and t denotes time trend. The terms ϵ_t and ϵ'_t express the error term before and after the earthquake event, where ϵ_t and ϵ'_t are distributed normally with mean 0 and standard deviation σ and $\sigma + \Delta\sigma$ respectively. And when either ΔC, $\Delta\alpha$, $\Delta\beta$, or $\Delta\sigma$ is statistically significant, the structural change is defined as having occured. However, in this research, the data sets are defined so as to exclude the structural change point, and therefore the time series are stable before and after the earthquake. A time series in a stable period is classified as either a stationary or non-stationary process.

Fig.1 shows a typical time series with influence from an earthquake. It changes from a stable period to a transition period, where parameters of the model continue to change, and then it returns to a stable period. The methodology for classifying this transition period and stable period will be discussed below. From the viewpoint of long-term impact, the types of structural change can be classified and defined as shown in Table 1. Here, long-term impact of an earthquake is defined as when the difference of parameters of time series models between the pre- and post-earthquake stable periods is statistically significant.

- Cases 1, 2 and 3 : The time series is stationary before and after the earthquake. The difference in the parameters of both models can be thought to last for a long time. However, there might be a case that the transition period is also stationary and there is no ending point of this transition period.

- Case 4 : The time series is stationary before the earthquake and non-stationary after the earthquake. This indicates that the time series is still in the transition period.

- Cases 5, 6 and 7 : The time series is non-stationary before and after the earthquake. The same kind of analysis as that of the stationary variable is employed, but it is more

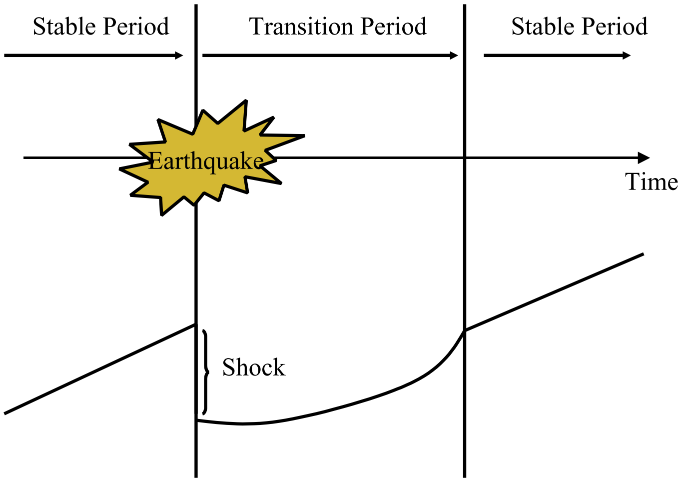

Fig.1: Typical time series with influence from an earthquake

Table 1: Patterns of effects of earthquake disasters

	Stable Period (Pre-Earthquake)	Transition Period	Stable Period (Post-Earthquake)	Change of Parameters	Structural Change	Impact
1	Stationary	No	Stationary	No	No	No
2	Stationary	Yes	Stationary	No	No	Short-Term
3	Stationary	Yes	Stationary	Yes	Yes	Long-Term
4	Stationary	Yes	Non-stationary	Yes	Yes	–
5	Non-stationary	No	Non-stationary	No	No	No
6	Non-stationary	Yes	Non-stationary	No	No	Short-Term
7	Non-stationary	Yes	Non-stationary	Yes	Yes	Long-Term

difficult to determine the end of the transition period. To identify it, careful diagnostic tests for the model are required

2.2 Statistical tests for the analysis of long-term effects

In order to classify the patterns of effects of earthquake disasters such as in Table 1, it is required to combine several statistical tests. In general, the process of statistical testing shown in Fig.2 should be adopted in terms of investigating long-term effects of earthquake disasters. Step 1 is a test for the stationarity of the model, such as a unit root test. Details about this test are given in the next section. In step 2, any kinds of tests for structural change such as the test developed by Chow (1960) can be used. This step is useful when we are not sure about the influence of the earthquake by merely looking at the time series. If it is found that the transition period exists as a result of this step, we will determine the end of this transition period and stationarity of the stable period after the earthquake in the next step. However, if there is no significant change, the following steps can be omitted. Basically we need to conduct careful diagnostic checks whether established model for the estimated stable period is right or not. Transition period is determined by choosing two stable periods before and after the earthquake.

Step 4 is a test for parameter changes between the models obtained for each stable period. Change of the parameters can be thought to last for a long time.

Step 5 is an estimation of loss, which can be conducted by setting the time to when estimation is required.

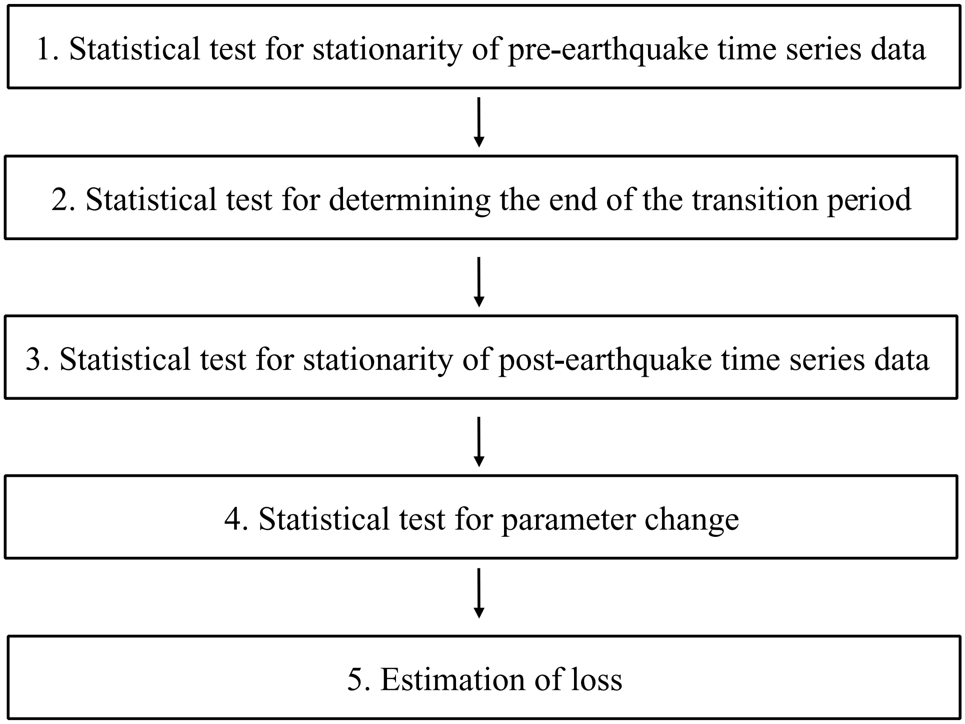

Fig.2 : The process of statistical testing

2.3 Time series modeling

2.3.1 Unit root test

One of the ways to determine stationarity of time series, which looks having a time trend, is to conduct a unit root test. This test determines if the stochastic part of time series is statonary or nonstationary. Many unit root tests such as the Dickey-Fuller test are to determine the stationarity of time series and can be expressed as follows,

$$
\begin{aligned}
X_t &= C + \alpha X_{t-1} + \beta t + \epsilon_t \qquad (3)\\
H_0 &: \alpha = 1\\
H_1 &: \mid \alpha \mid < 1
\end{aligned}
$$

where X_t, C and ϵ_t indicate a time series variable, a constant term, and an error term, respectively. The null hypothesis is that the process is non-stationary and the alternative hypothesis is that it is stationary.

2.3.2 Cointegration Analysis

Cointegration theory was developed by Engle and Granger (1987) to test the long-term stable relationship between more than two variables. We leave the details to Engle and Granger (1987), but apply this theory to see the effects of an earthquake disaster on the relationships between major ports. Johansen (1995) provides statistics to determine the number of cointegration relationships among multiple variables.

3 Analysis of the Impact on Cargo Traffic

3.1 Monthly cargo traffic at the Port of Kobe

First, prototype-analysis of earthquake disaster impact on Kobe Port using monthly data is performed. However, step 2 of Fig.2 was omitted here because sufficient period is selected to avoid a transition period. All the data was divided into two periods. One is from January, 1990 to December, 1994 and the other is from January, 1996 to June, 1999. The model is set to AR(1) after looking at a correlogram and partial correlogram of the first half time series . A unit root test (Dickey-Fuller test) is applied to these two periods. The result is shown in Table 2. Because data for the second half was arbitrarily set to begin from one year after the earthquake disaster, in order to determine the convergence point, it is required to change the data division point step by step.

Table 2 shows that all the pre-earthquake data sets are stationary, and the time series for export and import cargo traffic converge to stationarity one year after the earthquake. On the other hand, transshipped cargo, for which Kobe is in competition with foreign ports, and domestic cargo, which appears to be influenced by completion of the Akashi strait bridge in 1998, do not converge to stationary one year after the earthquake because unit root

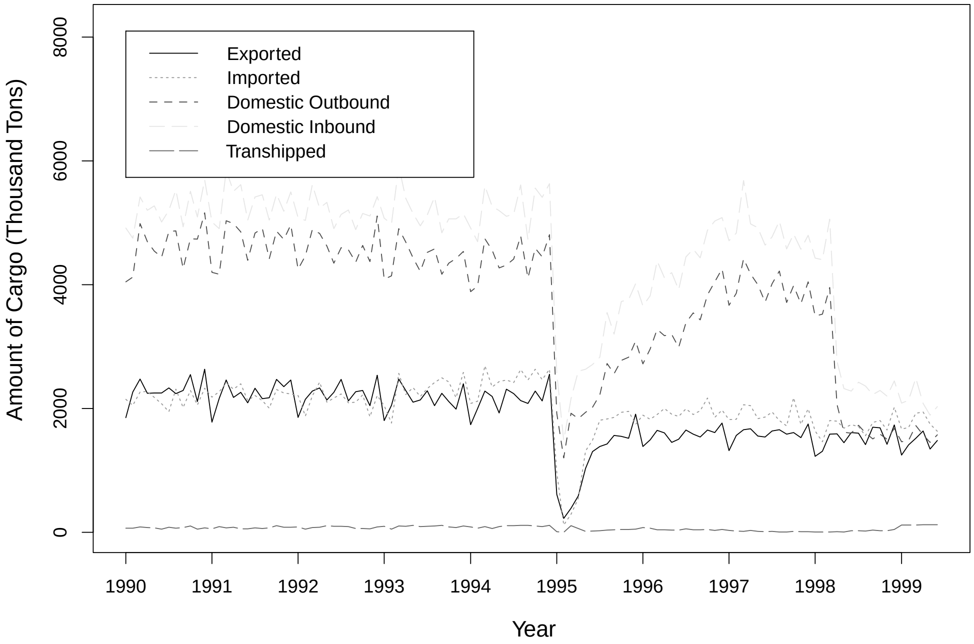

Fig.3: Monthly Cargo Traffic from Jan, 1990 to June,1999.

Table 2: Results of unit root tests for various types of cargo (t-statistics)

	Deterministic Trend	Export	Import	Tranship	Domestic Outbound	Domestic Inbound
Pre-earthquake	C	-10.2*	-7.3*	-7.86^*	-6.78^*	-8.21^*
	$C + \beta t$	-9.62^*	-6.37^*	-7.81^*	-7.46^*	-8.05^*
Post-earthquake	C	-7.12^*	-6.21^*	-1.46	-2.17	-2.316
	$C + \beta t$	-6.82^*	-4.96^*	-0.4945	-0.63	-0.589

$*$ denotes rejecting the null hypothesis that the process includes a unit root at the 5 % level of significance.

Table 3: Statistical test for change of parameter

	Estimated Parameter Change	F Statistics	P-Value
ΔC	-996359	2376^*	0
$\Delta \alpha$	0.178	1.22	0.276
$\Delta \beta$	569	0.106	0.746

$*$ denotes rejecting the null hypothsis $\Delta C = 0$

Hypothesises are not rejected. Therefore, it seems that transshipped cargo and domestic cargo were still in an unstable change process one year after the earthquake disaster. Next, a statistical test for change in parameters, which corresponds to step 4 of Fig.2, is performed with respect to the export cargo time series data. Equations (5) and (6) were obtained as a result of estimating the parameters for the pre-earthquake time series in the case of first including a time trend. The numbers in brackets indicate $F_{1,56}$ value for the hypothesis that the value of the parameter is 0.

$$
\begin{aligned}
X_t = 3003877 \quad - & \quad 0.308X_{t-1} - 3290t + \epsilon_t && (4) \\
& \quad (3.88) \qquad\quad (5.40) && \\
& \quad \epsilon_t \sim N(0, 180567) && (5)
\end{aligned}
$$

Table 3 shows that only change in the constant term is statistically significant. Removing the time trend term and calculating again, the change in the constant term is -667569, and reduction of this constant term will remain in the long run. This section showed the prototype analysis to examine the long-term effects of damage according to Fig.2, and estimating the loss as mentioned above.

3.2 Yearly cargo traffic of Japanese major ports

This section examines whether a long-term stable relationship exists among Japanese major ports using Johansen type of cointegration analysis$^{3)}$. Results of unit root tests and cointegration tests are given by Kajitani (2000). As a result of applying the Johansen procedure, the existence of cointegration relationships is shown in Fig. 4 in total amount of cargo. After conducting Chow's test for parameter change, the existence of structural change was found to be significant at the level of 1 % significance level.

Fig.4:Cointegration relationship of Japanese major ports (Total amount of Cargo)

4 Conclusion

In this research, the process of statistical testing required in order to examine long-term effects of damage of disaster was first proposed. Then, this process was applied to monthly data sets of the port of Kobe and to Japanese five major domestic ports. Analysis showed that the earthquake affected not only the port of Kobe but also the stable relationships among the Japanese five major ports. Including the influence of the regional economy in the model, and analyzing causal relationships are subjects for further research.

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