The Impact of the Kobe Earthquake Damage and Reconstruction Projects on the Regional Population: A Panel Data Analysis on Disaster Reconstruction using Grid-Square Statistics

Keiichi SATO, Associate Professor, Senshu University (corresponding author)
satok@isc.senshu-u.ac.jp
+81(44) 911 – 0514
2-1-1, Higashi-mita,Tama-ku, Kawasaki-shi
Kanagawa, Japan 214-8580

Norio MAKI, Professor, Kyoto University

Abstract

The 1995 Kobe Earthquake was an urban epicentral earthquake of magnitude 7.3, and it caused approximately six thousand deaths. Additionally, over one hundred thousand dwellings collapsed completely, and many reconstruction projects, including city redevelopment projects, were implemented. In the twenty years since the earthquake, social economic data have accumulated, and quantitative analytical methods have been developed. Data maintenance of grid-square statistics has also progressed, and provision for research has begun. As government statistics are usually compiled at the city level, there can be data quality problems, such as those caused by the merger of cities and by city size differences. With grid-square statistics, these reliability problems can be circumvented, and the empirical analysis of social issues can progress. Therefore, many accurate policy analyses are conducted using scientific methods, such as by using panel data or through quasi experiments.

For this research, we obtained the grid-square census data of the wider Kobe area at five-year intervals from data gathered from 1985 to 2005, and from this we developed panel data. Using previous research, the information on housing damage and reconstruction projects was allocated to each grid-square. Using the constructed panel data, a time-series analysis of the regional population following the Kobe earthquake was then conducted. This data analysis enables a visualization of the effects of disaster damage and reconstruction projects on local populations.

1. Data Preparation

We obtained grid-square census data of the wider Kobe area from the Statistical Information Institute for Consulting and Analysis[1]. The purchased data were the population census and the economic census, which were recounted using a grid-square of approximately one square kilometer that divided Japan by latitude and longitude. The information on housing damage and reconstruction projects was allocated to each grid-square from previous related research (Chen, 2010). The variables used in this paper are illustrated in Table 1.

The geographical distribution of the collected grid-square data is shown in Figure 1. The figure illustrates the population changes from 1985 to 2005; there are 949 grid-squares. Data on redevelopment projects, land adjustment projects, and public housing for disaster victims are also combined in the figure. Likewise, each grid in Table 1 has data pertaining to five periods.

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[1] http://www.sinfonica.or.jp/eng/outline.html (accessed 30 July 2018).

Table 1. List of collected grid-square data

Variable	Description	Source
meshid	ID of each grid-square	Statistics Bureau
year	Year of the survey	Population Census
pop	Population	Population Census
under14ratio	0-14-year-old population / total population	Population Census
ib_rate	Self-employed number / number of employed people	Population Census
ps_rate	Number of primary industrial workers / number of employed people	Population Census
ss_rate	Number of secondary industrial workers / number of employed people	Population Census
single_rate	Number of single households / number of all households	Population Census
apart_rate	Number of households living in apartment housing / number of households living in housing	Population Census
facility	Number of business establishmens	Economic Census
landadjustment	Dummy variable of land adjustment project	Chen, 2010
redevelopment	Dummy variable of redevelopment project	Chen, 2010
number_ph	Number of public housing for disaster victims	Chen, 2010
damage_rate	Damage rate of housing	Chen, 2010

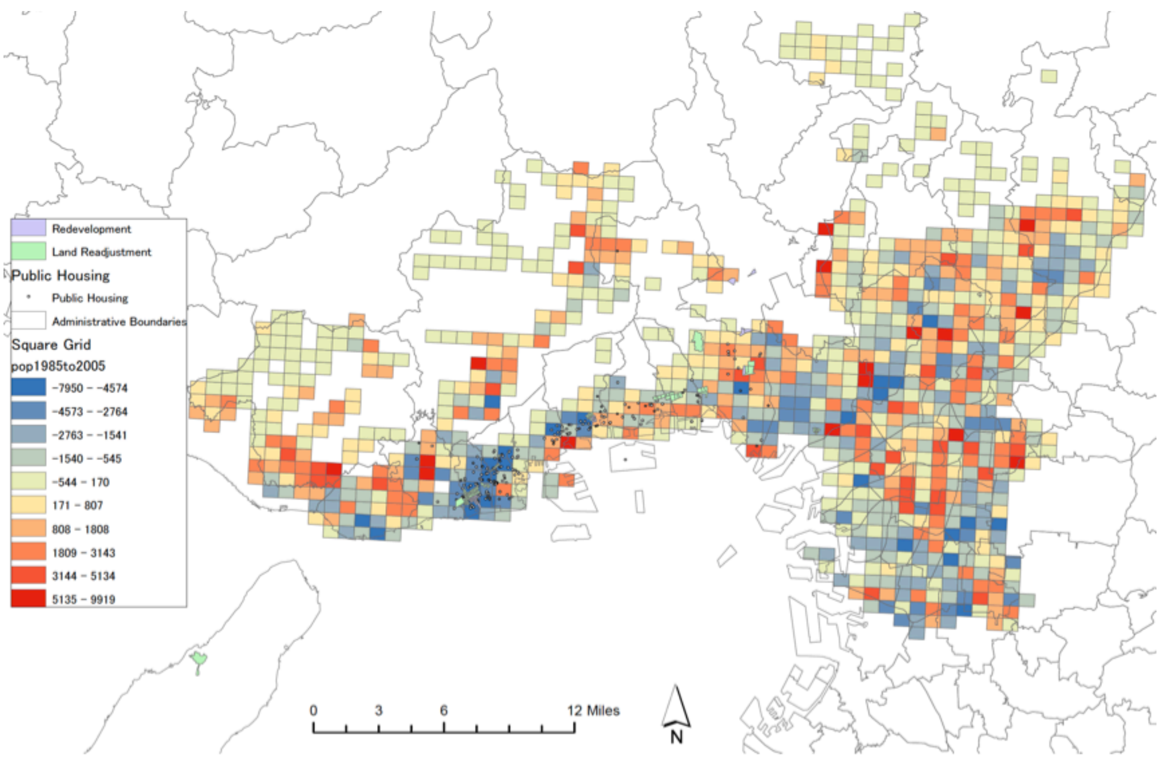

Figure 1. Sample figure of collected grid-square statistics

The collected data were organized as illustrated in Table 2 for panel data analysis. The damage rate was provided for 1995, and the same value was provided for 2000 and 2005. To analyze the impact of the progress of the reconstruction projects, redevelopment and land adjustment were set as dummy variables (as 0 in 1995, 1 in 2000, and 2 in 2005). As public housing was completed in approximately five years, the number of houses supplied was provided for 2000, and the same value was provided for 2005.

Table 2. Part of the prepared panel data

meshid	year	pop	…	redevopment	number_ph	damage_rate	…
51357170	1985	14707	…	0	0	0	…
51357170	1990	14877	…	0	0	0	…
51357170	1995	11083	…	0	0	57.67	…
51357170	2000	12102	…	1	46	57.67	…
51357170	2005	12309	…	2	46	57.67	…
51357171	1985	17583	…	0	0	0	…
51357171	1990	13989	…	0	0	0	…
51357171	1995	9760	…	0	0	47.52	…
51357171	2000	11249	…	1	160	47.52	…
51357171	2005	11168	…	2	160	47.52	…
…	…	…	…	…	…	…	…

Table 3. Basic statistics of the prepared data

Variable	Min.	1st Qu.	Median	Mean	3rdQu.	Max.
year	1985	1990	1995	1995	2000	2005
pop	22	1357	6289	7514	12383	31368
under14rate	0.00	12.46	15.17	15.82	18.68	74.07
ib_rate	0.00	8.77	11.11	12.10	14.45	66.67
ps_rate	0.00	0.08	0.27	3.57	1.53	72.06
single_rate	0.00	13.22	23.44	24.25	33.16	88.89
apart_rate	0.00	17.60	47.06	42.65	63.61	100.00
facility	1	34	179	474	558	12977
landadjustment	0.00	0.00	0.00	0.01	0.00	1.00
redevelopment	0.00	0.00	0.00	0.01	0.00	1.00
publichousing	0.00	0.00	0.00	0.05	0.00	1.00
number_ph	0.00	0.00	0.00	6.93	0.00	1220
damage_rate	0.00	0.00	0.00	1.75	0.00	68.32

2. Panel Data Analysis

Panel data (also known as time-series data) constitute a dataset in which the behavior of entitiesis observed across time. By using panel data, the impact of disaster damage and reconstruction projects on regional populations can be analyzed by omitting heterogeneity for each grid-square.

In this paper, we estimated the pooled OLS and the fixed effect model using data obtained by measuring the 949 grid-squares for five periods. Pooled OLS is a model in which the constant term does not depend on time or subject, and it is the same as OLS analysis of cross-section data. The equation for the Pooled OLS model is as follows:

$$\begin{aligned} pop_{it} = \alpha &+ \beta_1 under14rate_{it} + \beta_2 ib\_rate_{it} + \beta_3 ps\_rate_{it} + \beta_4 single\_rate_{it} \\ &+ \beta_5 apart\_rate_{it} + \beta_6 facility_{it} + \beta_7 landadjustment_{it} \\ &+ \beta_8 redevelopment_{it} + \beta_9 number\_ph_{it} + \beta_{10} damage\_rate_{it} + u_{it}, \end{aligned}$$

where pop is the dependent variable, α is the constant term, β values are coefficients of independent variables, and i and t are indices for entities and time.

The fixed effect model is a model in which the constant term depends on the entity. In the fixed effect model, there is no assumption of the correlation between the fixed effect and the independent variable; however, it is not possible to directly use static variables as independent variables. The estimation used the least squares dummy variable (LSDV) estimation[2]. The equation for the fixed effect model becomes:

$$pop_{it} = \alpha_i + \beta_1 under14rate_{it} + \cdots + \beta_{10} damage\_rate_{it} + u_{it},$$

where α_i is the constant term, and other variables are the same as the pooled OLS.

The estimated results are given in Table 4. An F test was conducted to determine whether the coefficients of the fixed effect model were all equal. As the result of the analysis, the p-value was very small, and we rejected the null hypothesis that the pooled OLS model is a true model with a significance level of 0.1%. In other words, the fixed effect model was appropriate to analyze this data.

From the fixed effect model, ib_rate, apart_rate, facility, damage_rate, landadjustment, and number_ph had a statistically significant impact on population changes. The influence of plus 35 people to a square-grid was estimated when the proportion of households living in apartment housing increased by 1%. When the number of business establishments increased, the influence of plus 1.6 people to a square-grid was estimated. The influence of minus 77 people per 1% housing damage rate was calculated and the five-year progress of the land adjustment project was calculated as the influence of plus 1017 people. The impact of plus 4.5 people per every disaster reconstruction public housing development was calculated.

3. Consideration

In this paper, the impact of the damage and reconstruction projects and changes in socioeconomic indicators on regional populations after the Kobe earthquake were estimated using arranged grid-square panel data. The influence of the progress of the land adjustment project on population increases was estimated as being extremely large, but the effect of the progress of redevelopment projects on population growth was not statistically significant. Population trends from disaster reconstruction projects are shown in Figure 2. The grid-squares where disaster reconstruction projects were conducted had higher damage rates and larger population changes compared with other grid-squares. There were no differences in the trends between the redevelopment and land adjustment projects. Given the quantity of data, there is a possibility that it is difficult to evaluate the redevelopment projects statistically.

There is room to improve the panel data by constructing more reliable models, and it is possible to add more detailed information about the reconstruction projects. Additionally, we attempted to clarify the relationship between prior regional trends and disaster reconstruction situations. A population ratio under the age of fourteen may be insufficient to develop regional population structures, and it is conceivable that clustering indexes of the regional population structure, as suggested by Sato et.al (2014), could be used. It could also be possible to add regional indicators such as social capital to improve the data panel.

Furthermore, this empirical research method could be applied to the Great East Japan Earthquake and Tsunami Disaster of 2011. It could lead to the evaluation of

[2] For details of the estimation method, see Davidson and MacKinnon (2004, Section 7.10).

reconstruction projects in the Tohoku region, and it will provide useful information for reconstruction planning after future massive disasters such as the anticipated Nankai Trough Earthquake.

Table 4. The estimated results of the two models

Outline	Variable or index	Pooled OLS		Fixed Effects Model	
		Estimate	Pr(>|t|)	Estimate	Pr(>|t|)
population census	under14rate	56.647	0.001 ***	3.669	0.336
	work_rate	-9.018	0.416	2.378	0.424
	ib_rate	215.364	0.000 ***	-12.535	0.034 *
	ps_rate	-220.783	0.000 ***	-1.004	0.818
	single_rate	34.559	0.000 ***	-4.597	0.152
	apart_rate	83.106	0.000 ***	35.543	0.000 ***
economic census	facility	1.485	0.000 ***	1.609	0.000 ***
disaster damage	damage_rate	-16.139	0.166	-77.575	0.000 ***
reconstruction projects	landadjustment	2517.481	0.000 ***	1016.789	0.000 ***
	redevelopment	-844.074	0.299	53.458	0.774
	number_ph	1.631	0.344	4.560	0.000 ***
fit index	Adj. R-Squared	0.420		0.047	
	F-statistic	313.711		108.416	
	p-value	< 2.22e-16		< 2.22e-16	
model comparison	F test for individual effects	F = 144.47, df1 = 948, df2 = 3785, p-value < 2.2e-16			

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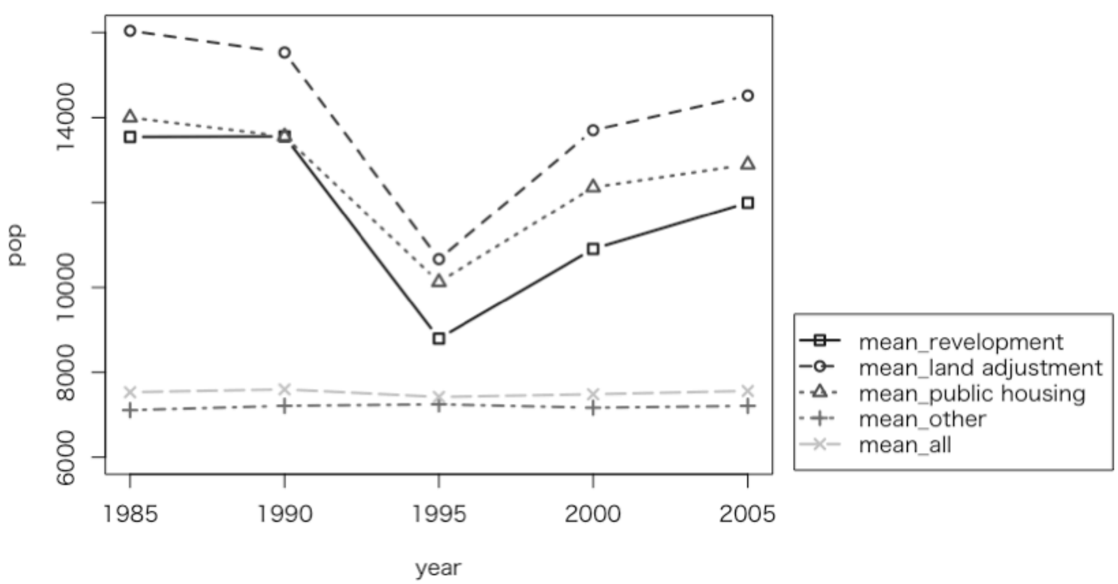

Figure 2. Population trends from reconstruction projects

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