# Long-term Impacts of the 1995 Hanshin–Awaji Earthquake on Wage Distribution†

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**Abstract**

The objectives of this paper are to explore how the 1995 Hanshin–Awaji Earthquake has affected the wages of people in the earthquake area over the 17 years since the earthquake and to examine which part of the wage distribution has been most negatively affected by comparing the wage distribution between disaster victims and non-victims. To do so, we used three decomposition methods, developed by (i) Oaxaca (1973) and Blinder (1973), (ii) DiNardo, Fortin, and Lemieux (1996) ("DFL"), and (iii) Machado and Mata (2005) and Melly (2006). Our findings are as follows. First, the Oaxaca and Blinder decomposition analysis shows that the negative impact of the earthquake is still affecting the mean wages of male workers. Second, the DFL decomposition analysis shows that middle-wage males would have earned more had the 1995 Hanshin–Awaji Earthquake not occurred. Finally, the Machado–Mata–Melly decomposition analysis shows that the earthquake had a large, adverse impact on the wages of middle-wage males, and that their wages have been lowered since the earthquake, by 5.0-8.6%. This result is similar to that from the DFL decomposition analysis. In the case of female workers, a long-term negative impact of the earthquake on wages was also observed, but only for high-wage females, by 8.3-13.8%.

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## 1. Introduction

An earthquake of unprecedented scale occurred at 14:46 on March 11, 2011, with its epicenter off the coast of the northern part of Japan (the Tohoku area in particular). Since then, many people have questioned how long it will take for Japan to recover from the effects of this Great East Japan Earthquake. Not only did the earthquake cause devastating damage to the Tohoku area, but the resulting tsunami also damaged infrastructure and facilities along the Pacific coastline of the northern part of Japan—and, in particular, the Fukushima No. 1 nuclear power plant.[1] It is well known that the tsunami triggered core meltdowns in three of that power plant's reactors.

Although some time has passed since the Great East Japan Earthquake, the disaster areas are still undergoing the processes of restoration and reconstruction. Although it appears that post-quake reconstruction is progressing in the Tohoku area, it will take a significant amount of time for the area to be fully restored to its pre-earthquake level: much infrastructure, such as the ports and roads, is still under reconstruction. There are many unemployed workers who lost their jobs because the disaster destroyed their workplaces. Additionally, many people lost their houses and properties and had to be evacuated to temporary housing until new houses are built. From a short-term perspective, the earthquake and subsequent events have left the disaster victims facing financial and physical hardships. It is thus important to investigate when this hardship is likely to end and how the disaster victims can be

[1] According to the Japanese National Police Agency, the death toll stood at 15,854 persons, and another 3,155 were still missing as of March 10, 2012. Approximately 344,000 evacuees still lived in temporary housing and accommodation as of February 29, 2012. The Japanese government estimated the cost of damage incurred as a result of the earthquake at JPY16.9 trillion.

assisted to return to their normal lives.

Because little time has elapsed since the Great East Japan Earthquake, we cannot yet evaluate its devastating impact from a long-term perspective. Instead, here, we examine the long-term impact of the Hanshin–Awaji Earthquake of 1995. Similar to the Great East Japan Earthquake, this earthquake inflicted devastating damage on the Hanshin area, between the major cities of Osaka and Kobe, which was densely populated and largely industrialized. By assessing the negative impacts of the 1995 Hanshin–Awaji Earthquake from a long-term perspective, this paper aims to investigate to what extent the negative impacts of the earthquake had continued unsolved or had been attenuated at the time of our survey in 2012. This may assist development of a long-term vision relevant to the reconstruction following the Great East Japan Earthquake.

Several studies have analyzed the effects of natural disasters on people’s lives, in economic and mental terms. Notably, Ohtake *et al*. (2012) estimated the long-term impact of the Hanshin–Awaji Earthquake, using online survey data that we also analyzed, on annual income and the amount of social capital related to interactions with neighbors and friends. Their results indicated how the earthquake adversely affected the current level of subjective well-being of disaster victims through a decrease in annual income and deterioration in social capital. More specifically, a disaster victim whose house collapsed, partially or completely, because of the earthquake or was destroyed by fire would have earned additional annual income of between JPY873,000 and JPY946,000 in 2011 had the earthquake not occurred. The earthquake also resulted in the deterioration of social capital related to social interactions. Moreover, these levels of social capital have not yet been fully restored—in particular, the loss of social capital measured by the degree of an individual's interaction with his/her neighbors. The decrease in annual income and the deterioration in social capital were found in that paper to have reduced the subjective well-being of the disaster victims.

Our paper differs from previous studies in that it focuses particularly on how large-scale natural disasters, such as the Hanshin–Awaji Earthquake, affect changes in the wage distribution of disaster victims versus non-victims, who were engaged in work from the time when the earthquake occurred in 1995 to the time the survey was conducted in 2012. We paid particular attention to which part of the wage distribution was most negatively affected by the 1995 Hanshin–Awaji Earthquake.

It can easily be predicted that low-wage workers would be most vulnerable to natural disasters, and thus the Hanshin–Awaji Earthquake most adversely affected workers categorized in the lowest percentiles of the wage distribution over the 17 years since the earthquake. This is only one possibility but high-wage or middle-wage workers might suffer most economically from the natural disasters. Assuming that the negative impact of the earthquake on wage distribution was persistent and prevalent during the 17 years following the earthquake, we examined how the 1995 Hanshin–Awaji Earthquake affected the wages of people in the earthquake areas over the 17 years and investigated which part of the wage distribution has been most negatively affected by comparing the wage distribution between disaster victims and non-victims.

In this paper, the case of the 1995 Hanshin–Awaji Earthquake is analyzed with the intention of being able to better forecast the long-term structural changes that may occur in areas destroyed by the Great East Japan Earthquake in 2011. There are some limitations to using the Hanshin–Awaji Earthquake case. First, the two earthquakes differed in terms of the subsequent disasters. While the Hanshin–Awaji Earthquake caused fires that destroyed many houses, the Great East Japan Earthquake created a 15-meter tsunami and the nuclear plant incident. Second, the disaster areas destroyed by the two earthquakes differed in their industrial characteristics. While the Hanshin–Awaji Earthquake damaged mainly a manufacturing and services industries region, the Great East Japan Earthquake devastated a region where the majority of workers were employed in the fisheries and agricultural industries. Finally, the disaster areas differ in terms of the population distribution by age. There was a relatively large, older population in the Tohoku area when the Great East Japan Earthquake struck, whereas there was a relatively large younger population in the Hanshin area in 1995.

However, analyzing the Hanshin–Awaji Earthquake case also has some advantages. One of the most important is that analyzing the Hanshin–Awaji Earthquake that occurred 17 years ago allowed us to examine the long-term impact of the earthquakes on people's lives. Moreover, in terms of the scale of the natural disaster, the Hanshin–Awaji Earthquake was similar to the Great East Japan Earthquake. This will enable us to better predict the long-term effects of the Great East Japan Earthquake on the wage structure and income inequalities in the disaster area. Our paper also contributes to the existing literature because this is the only study, to our knowledge, which empirically analyzes long-term impacts of a natural disaster on the wage distribution. Although many empirical studies have analyzed economic impacts of natural disasters, most of them focused on how natural disasters would affect economic growth or consumption behaviors. The impacts of natural disasters on the labor market using micro data have been little examined. In this regard, analyzing the relationship between the earthquake and wage distribution in this study may lay the foundation for future studies assessing the impact of natural disasters on accumulation of human and health capital.

We used an Internet survey to collect original data from victims and non-victims in the disaster area of the Hanshin–Awaji Earthquake and on persons living in several selected non-disaster areas at the time of the Hanshin–Awaji Earthquake. The survey was conducted in March 2012. Because natural disasters are usually considered to be unexpected exogenous shocks, we can conduct a unique natural experiment and then identify the exact impact of the natural disaster by comparing outcomes between a treatment group and a control group. We define here that the disaster victims belong to the treatment group, whereas the control group consists of both non-victims from the disaster area and persons from the selected non-disaster areas.

The objectives of this paper are to explore how the Hanshin–Awaji Earthquake has affected the wage distribution over the 17 years since its occurrence and to identify who has incurred the largest wage loss: low-wage, middle-wage, or high-wage victims, in comparison with non-victims. In this paper, we used three decomposition methods: those proposed by i) Oaxaca (1973) and Blinder (1973), ii) DiNardo, Fortin, and Lemieux (1996) ("DFL"), and iii) Machado and Mata (2005) and Melly (2006).

The main findings can be summarized as follows. First, according to the Oaxaca and Blinder decomposition analysis, the 1995 Hanshin–Awaji Earthquake still had a negative impact on the mean wages of male workers 17 years after the earthquake. However, its effect on the mean wages of female workers had disappeared. Second, the DFL decomposition analysis indicated that middle-wage male workers would have earned more had the 1995 Hanshin–Awaji Earthquake not occurred. That is, middle-wage male workers were the most severely affected by the earthquake. In contrast, this was not true for female workers. Finally, the Machado–Mata–Melly decomposition analysis also showed that the earthquake had a large, negative effect on the wages of middle-wage males, and that their wages have been lower since the earthquake, by 5.0-8.6%. This result is similar to that of the DFL decomposition analysis. In the case of female workers, the negative impact of the 1995 earthquake on wages remained for high-wage females in 2011, by 8.3-13.8%.

The remainder of the paper is organized as follows. We begin with a literature review in Section 2 and then provide a brief overview of the 1995 Hanshin–Awaji Earthquake in Section 3. We discuss the econometric specification in Section 4 and then describe our original data set in Section 5. Subsequently, we present the estimated results in Section 6 and discuss the interpretation of the results in Section 7. The final section provides some concluding remarks.

## 2. Literature Review

This section provides a literature review of research papers relevant to the analysis of the impacts of natural disasters.[2] We begin with a review of the literature on the short-term impacts of natural disasters. Raddatz (2007) and Noy (2009) first estimated the impacts of natural disasters from a short-term perspective, regressing per capita GDP on the scale of natural disasters. Both authors found the same result, indicating that natural disasters had a negative impact on the economy of the disaster areas in the short term. Noy (2009) added interaction terms with each country's economic and political characteristics and a natural disaster term as explanatory variables and then re-estimated the impact of the natural disasters on the economy. Noy's findings

[2] Cavallo and Noy (2011) summarized a wide range of previous studies in this field.

indicated that when a country is less economically developed or less mature, the impact of a natural disaster was more serious and more persistent.

Several studies have analyzed the long-term impact of natural disasters. Noy and Nualsri (2011) reported that a natural disaster has a negative economic impact in the long and short term. In contrast, Skidmore and Toya (2002) reported that a natural disaster has a positive economic impact in the long term. Skidmore and Toya (2002) pointed out a "creative destruction" effect to support their finding. They explained that a natural disaster eliminates old inefficient industries and encourages new, more efficient industries to arise, thereby contributing to economic growth in the long term. According to the theory, natural disaster-induced creative destruction (Cuaresma, Hlouskova, and Obersteiner, 2008) occurs in developed countries, but not in developing countries. This may be because it is difficult to introduce and disseminate new technologies in developing countries.

Cavallo et al. (2010) showed the difference between the actual economic growth path and the estimated counterfactual growth path that would have been accomplished without a natural disaster and then quantitatively calculated the long-term impact of a natural disaster on economic growth. They found that the long-term impact of natural disasters on economic growth was negligible. Using the same econometric method, DuPont and Noy (2012) estimated the long-term impact of the Hanshin–Awaji Earthquake on per capita GDP for Hyogo Prefecture, which includes the Hanshin and Awaji areas. They reported that the long-term effect was *not* negligible, finding that the per capita GDP of Hyogo Prefecture would have been higher, by JPY500,000, in 2007 had the 1995 Hanshin–Awaji Earthquake not occurred.

As explained above, the economic impacts of natural disasters have been analyzed by some previous studies. However, most of the studies examined economic growth or consumption behaviors in relation to natural disasters and little attention has been paid to the impacts of natural disasters on the labor market using micro data. Therefore, our study that empirically analyzes long-term impacts of a natural disaster on the wage distribution using micro data may contribute to a deeper understanding of the mechanism behind the impacts of natural disasters on the productivity of individual workers.

## 3. The Hanshin–Awaji Earthquake

In this section, we provide a brief overview of the scale of the Hanshin–Awaji Earthquake and the extent of damage inflicted by it. At 5:46 a.m. on January 17, 1995, an earthquake of magnitude 7.3 struck off the coast of the northern part of Awaji Island. The displacement of the fault line that extends from Awaji Island to Mt. Rokko, located beyond Kobe City, caused strong tremors in the areas located along the line.

The Japanese government officially declared the following 10 cities and 10 municipalities in Hyogo Prefecture to be the most severely damaged region. The 10 cities were Kobe City (damage was particularly severe in Suma, Hyogo, Nagata, Nada, and Higashi-Nada wards), Amagasaki City, Itami City, Nishinomiya City, Ashiya City, Takarazuka City, Kawanishi City, Akashi City, and Miki City in the Hanshin area, and Sumoto City on Awaji Island. The 10 municipalities were Tsuna Town, Awaji Town, Hokutan Town, Ichinomiya Town, Goshiki Town, Higashiura Town, Midori Town, Seitan Town, Mihara Town, and Nantan Town, all on Awaji Island. The orange-colored area of Figure 1 shows Hyogo Prefecture which includes these disaster areas.[3]

[3] Outside Hyogo Prefecture, a seismic intensity of 4 on the Japanese scale was recorded

Next, we briefly introduce the extent of the damage inflicted by the earthquake. The Fire and Disaster Management Agency (FDMA) finalized a report on the status of the damage on May 19, 2006. According to its report, 6,434 people were killed and 3 persons remained missing, while 104,906 houses (accommodating 186,175 households) were destroyed completely, 144,274 houses (accommodating 274,182 households) were destroyed partially, and 269 fires were recorded.[4] Additionally, much of the infrastructure of the region was destroyed. The FDMA reported that 1,579 public buildings, 7,245 sections of road, and 330 bridges were damaged. Broadcast footage of a toppled section of the Hanshin Expressway's Kobe line shocked many viewers. The Kobe lines of the railways operated by the West Japan Railway Company and private railway companies (Hanshin, Hankyu, and Sanyo), as well as the facilities of municipal subway and bus operators, were also severely damaged, bringing traffic in the region to a standstill. The lifeline infrastructure also sustained significant damage.

## 4. Econometric Method

To estimate the long-term impacts of the 1995 Hanshin–Awaji Earthquake on wage differentials, we investigate the causes of the differences in current wage distributions between disaster victims and non-victims. We use three decomposition methods: those proposed by (i) Oaxaca (1973) and Blinder (1973), (ii) DiNardo, Fortin, and Lemieux (1996) (DFL), and (iii) Machado and Mata (2005) and Melly (2006). Using these methods, we decompose the wage differentials into two components: one part explained by the differences in characteristics of the two groups and the other part capturing the

in Toyonaka City, Osaka Prefecture.

[4] See the Hyogo prefectural government Web site: http://web.pref.hyogo.jp/pa20/pa20_000000015.html

effect of the earthquake.

The wage equation for group V (victims) and group N (non-victims) is formulated as:

$$Y_g = X_g \beta_g + u_g\,, \;\; g = V, N, \qquad (1)$$

where Y denotes log hourly wages, X is a vector of individual characteristics affecting wages (annual income in 1995, years of schooling, age, and age squared), and β is a vector of returns to these characteristics.

Using the Blinder–Oaxaca decomposition, we investigate whether the difference in the mean wage between disaster victims and non-victims is derived from differences in the observed characteristics of the two groups or from the variations in unobserved factors, which we consider to be the long-term impacts of the earthquake. The difference in the mean wage between group V (victims) and group N (non-victims) can then be written as:

$$\overline{Y_V} - \overline{Y_N} = \overline{X_V}(\widehat{\beta_V} - \widehat{\beta_N}) + (\overline{X_V} - \overline{X_N})\widehat{\beta_{N,}} \qquad (2)$$

where the first term on the right-hand side of equation (2) represents the unexplained component and the second term indicates the explained component. The estimates of the effect of the earthquake may be biased if the differences in unobserved heterogeneity between V and N are not taken into consideration. To find the unbiased effect of the earthquake, we considered the difference in the 1994 annual income between V and N as one of the explained components, because the difference in annual income captures the difference in the possible unobserved characteristics between V and N before the earthquake.

The following four variables are included as explanatory variables: annual income in 1994, years of schooling, age, and age squared. The reason we do not include other characteristics that could possibly have changed after the earthquake (e.g., length of tenure, years of work experience, industry type) in our estimated equation is that we intended to see the variations of the omitted factors that could affect the wages as the results of the earthquake; for example, we did not control for a length of tenure in the estimation that might have been shortened after the earthquake in order to make it reflected to the coefficients. In other words, we estimated the differences of current prices for annual income in 1994, years of schooling, age and age-squared in the labor market, and these prices, which reflect the variation of the omitted characteristics, indicate the effect of the earthquake on wages in 2011.

Next, using the DFL decomposition method, we create the counterfactual wage distribution for victims, assuming that the labor environment faced by victims is the same as that faced by non-victims.

$$F_{Y_V^c}(y) = \int F_{Y_V|X_V}(y|X)\,\Psi(X)dF_{X_V}(X), \qquad (3)$$

where $\Psi(X) = dF_{X_N}(X)/dF_{X_V}(X)$ is a reweighting factor. The idea of the DFL decomposition method is to replace the distribution of X of group V ($F_{X_V}(\cdot)$) with the distribution of X of group N ($F_{X_N}(\cdot)$) using the reweighting factor $\Psi(\cdot)$. The reweighting factor can be estimated as:

$$\Psi(X) = \frac{\Pr(X|g=N)}{\Pr(X|g=V)} = \frac{\Pr(g=N|X)/\Pr(g=N)}{\Pr(g=V|X)/\Pr(g=V)}. \qquad (4)$$

To estimate $\text{Prob}(g = N \ |X)$, we pooled the two groups and then estimated the probability of an individual belonging to group N as a function of X, using a logistic regression model.

The Machado and Mata (2005) decomposition method allows decomposing wage differences at each quantile of the wage distribution to explained differences and unexplained differences, similar to the Blinder–Oaxaca approach that decomposes the difference in the mean wage.

The decomposition is undertaken based on a counterfactual distribution of $Y_V$. This is the distribution of wages for victims that would have prevailed if the labor environment of victims had been the same as that of non-victims. This counterfactual distribution is denoted by $F(\widetilde{Y_V}|X_V, \widehat{\beta_{N,\theta}})$, where $\widetilde{Y_V}$ are generated values of $Y_V$, and $\widehat{\beta_{N,\theta}}$ are the $\theta^{th}$ quantile regression coefficients estimated by quantile regression using the sample of non-victims.

The steps in the Machado and Mata (2005) algorithm to construct $F(\widetilde{Y_V}|X_V, \widehat{\beta_{N,\theta}})$ are as follows:

1. For each quantile θ = 0.01, 0.02,…, 0.99, we estimate the quantile regression vector of coefficients $\widehat{\beta_{N,\theta}}$ for the sample of non-victims.
2. We use the sample of victims to generate fitted values $\widetilde{Y_V} = \widehat{\beta_{N,\theta}}' X_V$. For each θ, this generates $N^V$ fitted values, where $N^V$ is the sample size of the victims. Next,

we randomly select s = 100 elements of $\widetilde{Y_V}(\theta)$ for each θ and stack these into a $99 \times 100$ element vector $\widetilde{Y_V}$. The c.d.f. of these values is the counterfactual distribution for victims.

3. We compare the counterfactual distribution with the actual wage distribution of victims and non-victims.

The wage difference at the $\theta^{th}$ quantile can be decomposed as follows:

$$Y_N(\theta) - Y_V(\theta) = \left[Y_N(\theta) - \widetilde{Y_V}(\theta)\right] + \left[\widetilde{Y_V}(\theta) - Y_V(\theta)\right]. \qquad (5)$$

The first term in brackets on the right-hand side of equation (5) represents the explained component at the $\theta^{th}$ quantile. The second term in brackets indicates the explained component, which presents the true effect of the earthquake, at the $\theta^{th}$ quantile.

Melly (2006) proposed another estimator that is numerically identical to that used by Machado and Mata (2005) if the simulations used in the latter procedure are repeated to infinity. Melly's estimator is faster to compute and can be used to bootstrap results to provide standard errors. Thus, we used the procedure proposed by Melly (2006).

**5. Data**

We conducted a unique online survey of individuals developed exclusively for our project, with assistance from Nikkei Research Co. First, we undertook a screening survey nationwide, followed by the main survey. The questionnaires for the main survey were delivered to targeted individuals, based on the population distribution revealed by the screening survey. Responses were collected between March 15, 2012 and March 23, 2012. Demographic and regional adjustments were made for the sample layout and allocation, such as prefectures, municipalities, gender, and age.

The survey targeted two types of individual, aged from 20 to 80 years, who lived in Japan as at March 15, 2012: (i) individuals who lived in any of the 10 cities or 10 municipalities in Hyogo Prefecture in January 1995 that were recognized officially as disaster areas by the government, and (ii) individuals who lived in Yokohama City in Kanagawa Prefecture or in Osaka City, Suita City, Takatsuki City, or Sakai City in Osaka Prefecture. The first group of individuals included both disaster victims and non-victims. We treated the second group as a control group because the individuals had similar characteristics to the individuals in the first group. More specifically, Yokohama city was chosen to be the control group because of industrial similarity. The other regions in the second group are selected as the control group because they are the geographically neighboring to the disaster regions so that workers in both regions belong to the same labor market. In total, we collected 10,387 valid responses: 6,650 from the 10 cities and 10 municipalities (the Hanshin and Awaji areas), 1,646 from Yokohama City, 1,316 from Osaka City, 203 from Suita City, 216 from Takatsuki City, and 356 from Sakai City. The blue-colored area of Figure 1 is Kanagawa Prefecture which includes Yokohama City and the green-colored area is Osaka Prefecture which includes Osaka City, Suita City, Takatsuki City, and Sakai City. The outline of the survey is provided in the Appendix.

We restricted our sample to those who worked at the time of the 1995 Hanshin–Awaji Earthquake because we needed data on annual income in both 1995 and 2011 to identify any difference in changes in wage distribution between victims and non-victims. Furthermore, we restricted our sample to those who worked more than 35 hours per week at the time the survey was conducted.

Table 1 presents basic statistics for the workers by gender. Hourly wages are calculated by dividing the annual income by working hours. We used the median values of the categorical choice to recode the annual income in 2011 and working hours are calculated by multiplying the weekly working hours reported to the survey by 52 weeks in a year. The left columns of Table 1 summarize the basic statistics for male workers. The mean hourly wage for victims is ¥2292.69, which is lower than the corresponding mean hourly wage for non-victims for the whole sample (¥2560.70). Similarly, the mean log hourly wage for victims is lower than that for non-victims living in the Hanshin and Awaji areas (¥2516.50). This indicates that victims earned less than non-victims, on average, even 17 years after the earthquake.

The right columns of Table 1 present basic statistics for the female workers. The mean wage for victims is lower than that for non-victims for the whole sample (¥1549.24 vs. ¥1654.49). Furthermore, the mean wage of victims is lower than that of non-victims in the Hanshin and Awaji areas (¥1661.98). Similar to the case of male workers, the earnings of victims remained lower than that of non-victims, on average, some 17 years later.

## 6. Estimation Results

We begin with results of the Blinder–Oaxaca decomposition of the wage difference for males. The upper panel of Table 2 shows the results using the whole sample and the lower panel shows the results using samples restricted to Hanshin-Awaji area. First, wage differences for male workers are summarized in the left columns. The mean wage of disaster victims is lower than that of non-victims by 0.129 log points. The composition explained by the differences in observed characteristics is -0.068 log points, and the unexplained component is -0.060 log points. This indicates that the 1995 Hanshin–Awaji Earthquake still had a negative impact on the wages of male workers 17 years after the earthquake. When we restricted our sample to those who resided in the Hanshin and Awaji areas, the results were unchanged, as shown in the lower panel of Table 2. The mean wage of victims was lower than that of non-victims by 0.111 log points. The explained component is -0.050 log points, while the unexplained component is -0.062 log points. These results are similar to those obtained from the analyses using the whole sample.

The right columns of Table 2 present the results of the Blinder–Oaxaca decomposition of the wage difference for females. The upper panel of Table 2 shows the results using the whole sample. The mean wage of disaster victims is lower than that of non-victims by 0.052 log points, but the difference is not statistically significant. This indicates that the earthquake had no long-term impact on the wages of female workers in 2011, which was collected in the survey year 2012. The results using the subsamples of those who resided in the Hanshin and Awaji areas are indicated in the lower panel of Table 2. The mean wage of victims is lower than that of non-victims, by 0.047 log points. This result is similar to the results obtained from the analyses based on the whole sample. Although the statistically insignificant results may reflect the small sample size for female workers, the difference in magnitude and the unexplained component are much smaller than those of male workers.

Figure 2 shows the results of the DFL decomposition of the wage distribution for males. The upper panel has two figures showing the wage distributions of whole male sample. The first figure in the upper left side has two lines: the dashed line represents the actual distribution for victims while the solid line indicates the counterfactual distribution for victims calculated by the DFL method. The counterfactual wage distribution thus captures what wage distributions would have been if the labor environment of the victims had been identical to that of the non-victims. The solid line lies to the right of the dashed line, in the middle of each distribution. This means that the victims in the middle quantile of the wage distribution would have earned more had the Hanshin–Awaji Earthquake not occurred. The figure in the upper right side has the dashed line representing the actual distribution for non-victims and the solid line indicating the counterfactual distribution for victims, which is identical to the solid line of the left panel. The solid line is very close to the dashed line, which suggests no significant difference in characteristics between victims and non-victims. Two figures in the lower panel present the results of the DFL decomposition of the wage distribution for the male subsample residing Hanshin-Awaji area. We obtain the same result using the whole sample, in the sense that disaster victims in the middle quantile of the wage distribution suffered the most severe damage from a long-term perspective.

Figure 3 shows the results of the DFL decomposition of the wage distribution for females, with the same structure of the figure 2. In the right side, the solid and dashed lines are very close, suggesting no significant difference in characteristics between victims and non-victims, as seen in the case of male workers. However, in contrast to the case with male workers, the figures in the left side show that there is not a significant difference between the solid and dashed lines. This indicates that for female workers from both whole sample and subsample of the Hanshin and Awaji areas, the negative impact of the earthquake on the wage distribution had been eliminated when the survey was conducted.

Table 3 presents the results of the Machado–Mata–Melly decomposition of the wage difference of males using the whole sample and restricted sample to Hanshin-Awaji area. First, left columns show the results of the whole sample. At all quantiles, the differences were statistically significant, indicating that the wages of non-victims were higher than those of victims in all quantiles. The differences were larger at lower quantiles. At the $10^{th}$ percentile, the wages of disaster victims were lower than those of non-victims by 0.166 log points. At the $90^{th}$ percentile, the wages of disaster victims were lower than those of non-victims by 0.067 log points. However, at the $10^{th}$, $20^{th}$, and $90^{th}$ percentiles, the unexplained components were not statistically significant. This indicates that the negative impact of the 1995 Hanshin–Awaji Earthquake on wages had already been eliminated for low- and high-wage workers. However, the unexplained component was significant for the middle quantile. The unexplained component at the median is 0.078 log points, which is larger than the unexplained component at the mean (0.060 log points), estimated by the Blinder–Oaxaca decomposition. This indicates that the earthquake had a considerable negative impact on the wages of middle-wage workers.

We then restricted the sample to those who resided in the Hanshin and Awaji areas. The right columns of Table 3 present the results using subsamples. Similar to the left columns, the wage differences were statistically significant in all quantiles, but the unexplained components were significant only in the middle quantiles. The unexplained component at the median (0.081 log points) was larger than that at the mean (0.062 log points).

Table 4 presents the results of the Machado–Mata–Melly decomposition of the wage difference for females. The left columns show the results using the whole sample. In contrast to the case for males, the differences were statistically significant at the 60th percentile and above. Furthermore, the unexplained components were significant at the 80th and 90th percentiles. This indicates that a negative impact of the 1995 earthquake on wages still existed for high-wage females. The right columns of Table 4 present the results using the subsample of Hanshin and Awaji residents. Similar to the left columns of the whole sample, the differences were statistically significant at the 60th percentile and above, while the unexplained components were significant only at the 80th and 90th percentiles. The unexplained component at the 90th percentile was 0.138 log points.

## 7. Discussion

As presented in the previous section, the earthquake had a large negative impact on middle-wage males and high-wage females. Male workers with mid-range wages suffered most from the earthquake, whereas only high-wage female workers were negatively affected. One possible reason for the difference in the wage levels affected by the earthquake between genders is that the wage distribution of females lies to the left of that of males. Table 5 shows the gender gap in hourly wages: indeed, the hourly wages of females in the top quantile are similar to the wages of males in the middle quantile. This indicates that male middle-wage workers and female top-wage workers may, in fact, work under similar labor environments; thus, these “homogeneous” people were negatively affected similarly by the earthquake.

Why did the earthquake result in a lowering of the current wages of people whose houses were damaged by the earthquake? It may seem more convincing that losing *offices* due to the earthquake would be more related to a reduction in wages? To evaluate the adequacy of our definition of victims as those with damaged houses, we conducted the same analysis to examine whether the earthquake affected wages of victims whose offices were damaged by the earthquake. However, we found no long-term negative impact on wages of those with damaged offices after the earthquake. A possible reason why only those who ended up with damaged houses after the earthquake are negatively affected in terms of their wages is that they might have changed their consumption behavior such that they invested more to reconstruct their houses, but less on health capital and human capital. Such a decrease in investment in the development of skills, and health may have led to the long-term negative effect on their wages. This interpretation is supported by Sawada and Shimizutani (2007) and Sawada and Shimizutani (2008), who reported that victims of the 1995 Hanshin–Awaji Earthquake decreased their consumption levels. Another possibility is that when victims moved to other regions after the earthquake, they had to change to a new career that did not match their abilities and skills and thus did not allow them to earn as much as they would have if the earthquake had not occurred.

We have explained the reason for the decrease in the wages of disaster victims from the labor-supply side. One may question whether the negative impact on wages may be related to the reduction in labor demand after the earthquake. However, it should be noted that the victims and non-victims belonged to the same labor market within and near earthquake-damaged areas—Hanshin-Awaji area and Osaka—and thus a negative change in labor demand should have affected both victims and non-victims. Even considering the possibility of labor demand change in both victims and non-victims, our findings suggest that the wages of victims have been more negatively affected than those of non-victims.

Finally, the negative effects on middle-wage male victims and high-wage female victims may be explained by their individual characteristics. Table 6 reports the descriptive statistics regarding educational status, the type of employment (employee of private company or organization, government employee, management position, self-employed, family employee in a self-employed business, and unknown/forgotten), and industry. This is summarized by wage level: low-wage ($25^{th}$ percentile and below), middle-wage (between $25^{th}$ and $75^{th}$ percentiles), and high-wage (above the $75^{th}$ percentile) workers.

One might think the reason that middle-wage males have suffered most economically is because most of them are self-employed, whose businesses are run from their houses, and thus they have lost their workplaces. However, the left columns of Table 6 indicate that 77.8% of the middle-wage males were employees of private companies or organizations. This proportion is indeed higher than those of low-wage males and high-wage males. In contrast, the self-employed accounted for only 6.1% of the total employment type of middle-wage males, and this proportion is lower than those of low- and high-wage males. That most middle-wage males were employees of private companies/organizations, not self-employed, shows that the reason for the negative effect on middle-wage males is *not* because they were self-employed and suffered due to losing both their houses and workplaces after the earthquake.

The right columns of Table 6 show educational status, the type of employment, and industry for female victims. Although the proportion of self-employed high-wage females was higher than those of low- and middle-wage females, the fact that the proportion was as low as 2.8% should not be overlooked. This suggests that self-employment and loss of the house/workplace is also not a likely explanation of the negative effect on the wages of high-wage females.

## 8. Concluding Remarks

Since the Great East Japan Earthquake struck the eastern part of Japan, some time has passed. It is important to examine the extent to which the earthquake has affected people's lives and its likely long-term impact on the economy. This paper examined a similar large-scale natural disaster in Japan, the 1995 Hanshin–Awaji Earthquake, and estimated its long-term impact on wage distribution. This exercise may facilitate anticipation of the long-term impact of the Great East Japan Earthquake.

We collected original data through an Internet survey, which included a range of variables indicating the extent of housing damage, individual characteristics, and annual income, both at the time of the earthquake and when the survey was conducted, for both victims and non-victims of the earthquake.

We summarize our findings as follows. We used three methods to examine how the 1995 Hanshin–Awaji Earthquake has affected the wage distribution: (i) the Blinder–Oaxaca decomposition, (ii) the DFL decomposition, and (iii) the Machado–Mata–Melly decomposition. First, the Blinder–Oaxaca decomposition analysis showed that the 1995 Hanshin–Awaji Earthquake still had a negative impact on the mean wages of male workers 17 years after the earthquake by 6.0-6.2%, but that its impact had disappeared for female workers. Second, our finding from the DFL decomposition analysis is that the wages of middle-wage workers would have been higher had the 1995 Hanshin–Awaji Earthquake not occurred. This analysis indicated that middle-wage workers were affected most adversely by the earthquake. This result did not hold true for female workers. Finally, similar to the result from the DFL decomposition analysis, the Machado–Mata–Melly decomposition analysis shows that the earthquake had a large negative impact on the wages of middle-wage male workers, and that they would have earned more had the earthquake not occurred, by 5.0-8.6%. Also, in the case of high-wage females, the negative impact of the 1995 earthquake on wages remained and they would have earned by 8.3-13.8%.

It is surprising that, although 17 years have passed since the earthquake, the wages of the disaster victims in the middle-income class had been most negatively affected by the earthquake. We conclude that the negative impacts of the earthquake on wages are long lasting for disaster victims belonging to the middle-income class. The estimated results obtained from the Hanshin-Awaji earthquake in this study can be interpreted in the policy context. It may easily be thought that low-waged workers are the victims who suffer most economically from the natural disaster and thus they need more supports to recover to the pre-disaster level. However, the results of this study give us an in-depth understanding of the mechanism underlying the impacts of natural disasters on the wage distribution: middle-wage workers were found most negatively affected by Hanshin-Awaji earthquake in this study. It should be noted that we need to formulate a long-term recovery plan for middle-wage workers to more efficiently assist recovering from natural disasters in particular the Great East Japan Earthquake.

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Table 1. Basic statistics for males

| | | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Victims / Non-victims | Variables | Obs. | mean | s.d. | min | max | Obs. | mean | s.d. | min | max |
| Victims | wage | 423 | 2292.69 | 1452.04 | 133.55 | 8413.46 | 139 | 1549.24 | 984.27 | 225.36 | 9615.38 |
| | income | 423 | 613.00 | 341.25 | 75.00 | 1750.00 | 139 | 369.78 | 203.11 | 75.00 | 1750.00 |
| | income in 1995 | 423 | 507.62 | 268.44 | 75.00 | 1750.00 | 139 | 307.91 | 162.16 | 75.00 | 1100.00 |
| | years of schooling | 423 | 14.84 | 2.17 | 9.00 | 21.00 | 139 | 13.76 | 1.93 | 10.50 | 21.00 |
| | age | 423 | 49.28 | 7.71 | 27.00 | 79.00 | 139 | 45.88 | 6.50 | 31.00 | 63.00 |
| | working hours | 423 | 55.09 | 16.04 | 35.00 | 108.00 | 139 | 47.99 | 12.92 | 35.00 | 108.00 |
| Non-victims (Whole sample) | wage | 2029 | 2560.70 | 1442.67 | 144.23 | 8856.28 | 544 | 1654.49 | 984.77 | 240.39 | 8413.46 |
| | income | 2029 | 665.16 | 346.10 | 75.00 | 1750.00 | 544 | 399.95 | 251.03 | 75.00 | 1750.00 |
| | income in 1995 | 2029 | 560.50 | 257.72 | 75.00 | 1750.00 | 544 | 327.07 | 185.79 | 75.00 | 1750.00 |
| | years of schooling | 2029 | 14.80 | 2.10 | 9.00 | 21.00 | 544 | 14.05 | 1.96 | 9.00 | 21.00 |
| | age | 2029 | 49.60 | 7.00 | 21.00 | 79.00 | 544 | 46.23 | 6.50 | 23.00 | 72.00 |
| | working hours | 2029 | 52.62 | 14.72 | 35.00 | 108.00 | 544 | 47.09 | 11.62 | 35.00 | 108.00 |
| Non-victims (Hanshin-Awaji area) | wage | 1101 | 2516.50 | 1404.84 | 144.23 | 8856.28 | 311 | 1661.98 | 1020.50 | 244.46 | 8413.46 |
| | income | 1101 | 651.66 | 337.19 | 75.00 | 1750.00 | 311 | 402.17 | 257.50 | 75.00 | 1750.00 |
| | income in 1995 | 1101 | 550.18 | 249.87 | 75.00 | 1750.00 | 311 | 317.68 | 203.13 | 75.00 | 1750.00 |
| | years of schooling | 1101 | 14.75 | 2.11 | 9.00 | 21.00 | 311 | 14.05 | 2.00 | 9.00 | 21.00 |
| | age | 1101 | 49.88 | 6.99 | 21.00 | 70.00 | 311 | 46.82 | 6.77 | 23.00 | 72.00 |
| | working hours | 1101 | 52.31 | 14.77 | 35.00 | 108.00 | 311 | 47.05 | 10.73 | 35.00 | 100.00 |

Note: Table 1 presents basic statistics for the workers by gender. Hourly wages are calculated by dividing the annual income by working hour and the unit is Japanese Yen. The income is measured in 10,000 Japanese Yen. The left columns of Table 1 summarize the basic statistics for male workers and the right columns for female workers.

Table 2. Blinder–Oaxaca decomposition of the wage difference

| Wage differences for Victims vs. Non-victims | | Males | | | Females | |
|---|---|---|---|---|---|---|
| Whole sample | Difference | -0.129 | *** | (0.034) | -0.052 | (0.056) |
| | Explained | -0.068 | *** | (0.017) | -0.033 | (0.028) |
| | Unexplained | -0.060 | ** | (0.030) | -0.019 | (0.054) |
| Hanshin-Awaji area | Difference | -0.111 | *** | (0.036) | -0.047 | (0.062) |
| | Explained | -0.050 | *** | (0.019) | -0.004 | (0.032) |
| | Unexplained | -0.062 | * | (0.032) | -0.043 | (0.058) |

Note: The upper panel shows the results using the whole sample and the lower panel shows the results using samples restricted to Hanshin-Awaji area. Wage differences for male (female) workers are summarized in the left (right) columns. “Difference” indicates the mean wage differentials between disaster victims and non-victims, which is decomposed into “Explained” and “Unexplained” components. standard error in parentheses. *, **, and *** indicate significance at 10, 5, and 1%, respectively.

Table 3. Machado–Mata–Melly decomposition of the wage difference for males

| Males | Whole Sample | | | Hanshin and Awaji areas | | |
|---|---|---|---|---|---|---|
| | Difference | Explained | Unexplained | Difference | Explained | Unexplained |
| Quantile .1 | 0.166*** | 0.112 | 0.054 | 0.154*** | 0.087 | 0.067 |
| Quantile .2 | 0.152*** | 0.090 | 0.062 | 0.150*** | 0.073 | 0.077* |
| Quantile .3 | 0.165*** | 0.088*** | 0.077*** | 0.155*** | 0.069* | 0.086** |
| Quantile .4 | 0.165*** | 0.085*** | 0.079*** | 0.150*** | 0.066 | 0.084** |
| Quantile .5 | 0.151*** | 0.073*** | 0.078*** | 0.136*** | 0.055 | 0.081** |
| Quantile .6 | 0.142*** | 0.067*** | 0.075*** | 0.126*** | 0.049 | 0.078** |
| Quantile .7 | 0.129*** | 0.067** | 0.061** | 0.116*** | 0.047 | 0.070* |
| Quantile .8 | 0.111*** | 0.061** | 0.050* | 0.096*** | 0.040 | 0.056 |
| Quantile .9 | 0.067*** | 0.048 | 0.019 | 0.049*** | 0.030 | 0.019 |

Note: This presents the results of the Machado–Mata–Melly decomposition of the wage difference of males. The left (right) columns show the results of the whole sample (subsample). “Difference” indicates the wage differentials in each quantile between disaster victims and non-victims, which is decomposed into “Explained” and “Unexplained” components. *, **, and *** indicate significance at 10, 5, and 1%, respectively.

Table 4. Machado–Mata–Melly decomposition of the wage difference for females

| Females | Whole Sample | | | Hanshin and Awaji areas | | |
|---|---|---|---|---|---|---|
| | Difference | Explained | Unexplained | Difference | Explained | Unexplained |
| Quantile .1 | 0.039 | 0.029 | 0.010 | 0.050 | -0.017 | 0.067 |
| Quantile .2 | -0.042 | 0.023 | -0.065 | -0.083 | -0.004 | -0.079 |
| Quantile .3 | -0.038 | 0.019 | -0.057 | -0.057 | -0.002 | -0.055 |
| Quantile .4 | 0.010 | 0.028 | -0.018 | -0.013 | 0.010 | -0.023 |
| Quantile .5 | 0.022 | 0.018 | 0.004 | 0.017 | 0.009 | 0.008 |
| Quantile .6 | 0.063** | 0.024 | 0.039 | 0.070* | 0.017 | 0.053 |
| Quantile .7 | 0.093*** | 0.032 | 0.060 | 0.108*** | 0.029 | 0.080 |
| Quantile .8 | 0.110*** | 0.027 | 0.083* | 0.114*** | 0.026 | 0.088* |
| Quantile .9 | 0.160*** | 0.033 | 0.126*** | 0.173*** | 0.035 | 0.138*** |

Note: This presents the results of the Machado–Mata–Melly decomposition of the wage difference of females. The left (right) columns show the results of the whole sample (subsample). “Difference” indicates the wage differentials in each quantile between disaster victims and non-victims, which is decomposed into “Explained” and “Unexplained” components. *, **, and *** indicate significance at 10, 5, and 1%, respectively.

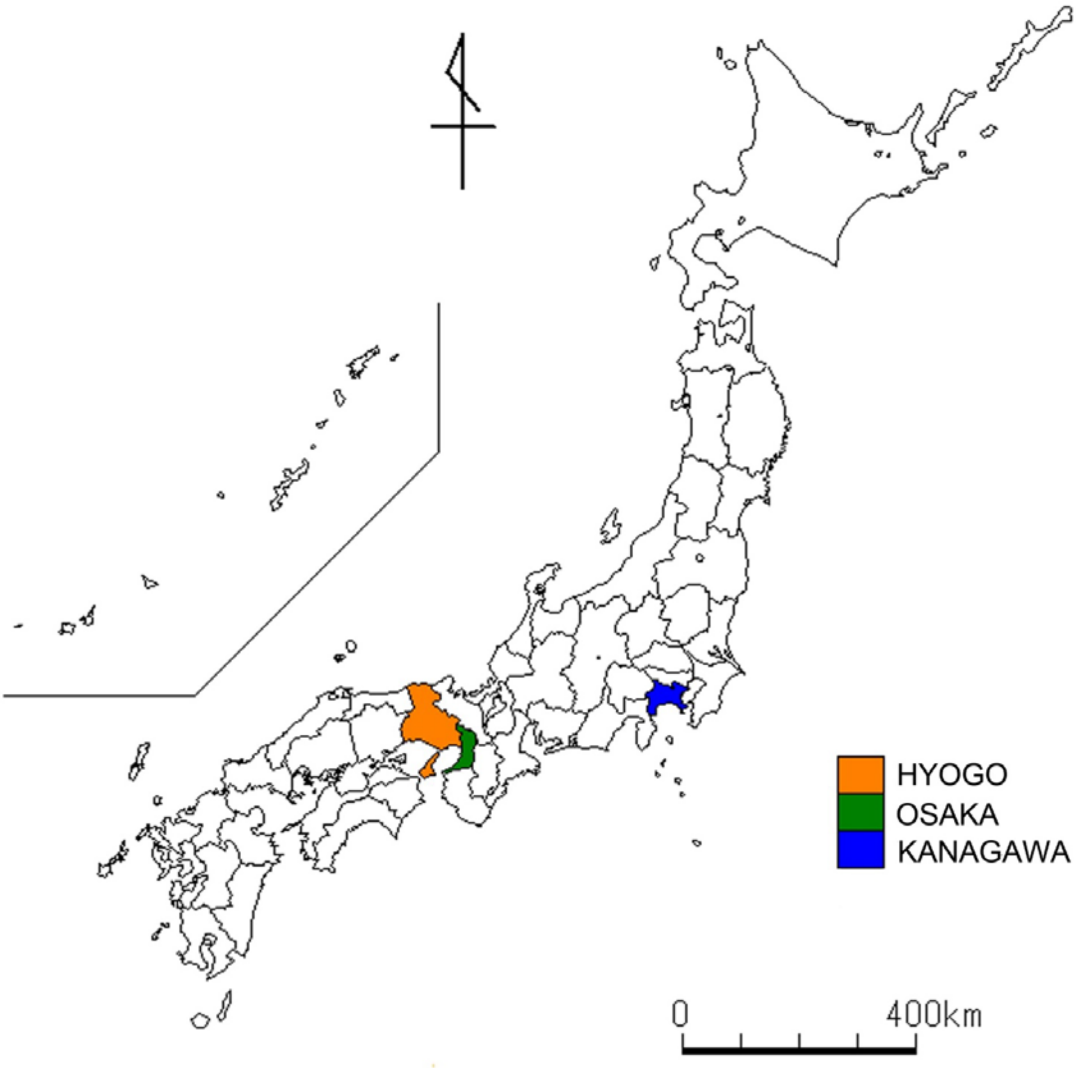
Table 5. Gender difference in wage distribution (unit: Japanese Yen)

| | Whole | | Hanshin-Awaji Area | |
|---|---|---|---|---|
| Percentile | Males | Females | Males | Females |
| 10 | 824.18 | 412.09 | 805.86 | 412.09 |
| 20 | 1246.44 | 721.15 | 1201.92 | 721.15 |
| 30 | 1550.87 | 1068.38 | 1442.31 | 978.12 |
| 40 | 1923.08 | 1282.05 | 1885.37 | 1254.18 |
| 50 | 2243.59 | 1442.31 | 2206.81 | 1442.31 |
| 60 | 2518.32 | 1518.22 | 2447.55 | 1479.29 |
| 70 | 2991.45 | 1814.22 | 2926.42 | 1797.43 |
| 80 | 3461.54 | 2289.38 | 3461.54 | 2236.14 |
| 90 | 4326.92 | 2719.78 | 4230.77 | 2692.31 |
| Obs | 2824 | 824 | 1731 | 544 |

Table 6. Individual backgrounds of victims

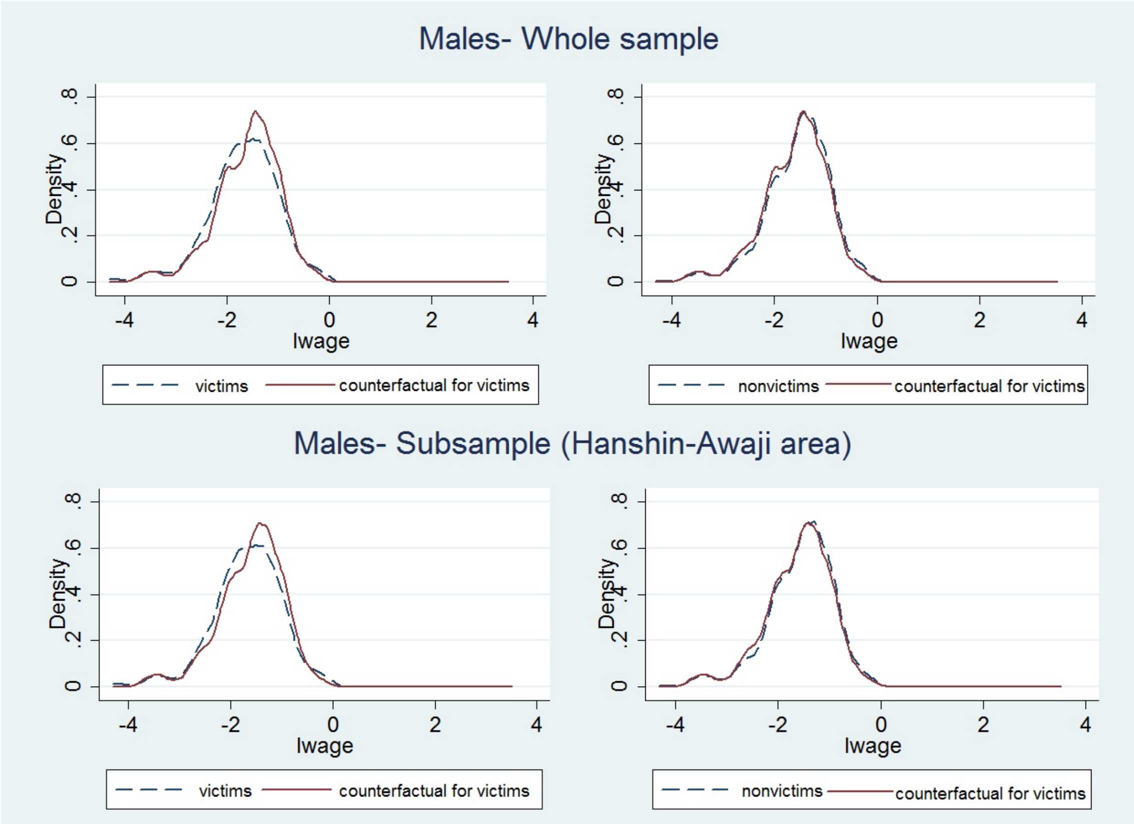
| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | Low wage (25 percentile and below) | Middle wage (between 25 and 75 percentiles) | High wage (above 75 percentile) | Low wage (25 percentile and below) | Middle wage (between 25 and 75 percentiles) | High wage (above 75 percentile) |
| **Educational status** | | | | | | |
| Lower than high school graduates | 3.7% | 2.8% | 2.9% | 6.3% | 2.8% | 0.0% |
| Equal to and higher than university graduates | 43.0% | 47.2% | 69.2% | 28.1% | 29.6% | 30.6% |
| **Type of employment** | | | | | | |
| Employee of private company or organization | 63.6% | 77.8% | 70.2% | 93.8% | 88.7% | 83.3% |
| Government employee | 4.7% | 10.8% | 19.2% | 0.0% | 1.4% | 13.9% |
| Management position | 1.9% | 2.8% | 2.9% | 0.0% | 0.0% | 0.0% |
| Self-employed | 17.8% | 6.1% | 6.7% | 0.0% | 1.4% | 2.8% |
| Family employee in self-employed business | 11.2% | 0.9% | 0.0% | 6.3% | 2.8% | 0.0% |
| Unknown/forgotten | 0.9% | 1.4% | 1.0% | 0.0% | 5.6% | 0.0% |
| **Industry** | | | | | | |
| Agriculture and related industries | 0.0% | 0.5% | 0.0% | 0.0% | 0.0% | 0.0% |
| Mining | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Construction | 8.4% | 6.6% | 1.0% | 12.5% | 1.4% | 0.0% |
| Manufacturing | 12.1% | 21.7% | 25.0% | 12.5% | 23.9% | 16.7% |
| Wholesale trade/Retail trade | 16.8% | 12.7% | 6.7% | 12.5% | 8.5% | 2.8% |
| Finance and insurance | 4.7% | 3.8% | 7.7% | 6.3% | 7.0% | 5.6% |
| Real estate | 0.9% | 2.4% | 1.0% | 0.0% | 8.5% | 5.6% |
| Transportation/Telecommunications | 9.3% | 8.0% | 3.8% | 3.1% | 4.2% | 0.0% |
| Utilities | 1.9% | 0.9% | 3.8% | 0.0% | 0.0% | 0.0% |
| Services | 30.8% | 16.5% | 10.6% | 18.8% | 25.4% | 22.2% |
| Education | 3.7% | 6.1% | 6.7% | 3.1% | 2.8% | 5.6% |
| Medical, health care, and welfare | 0.9% | 5.2% | 6.7% | 6.3% | 9.9% | 13.9% |
| Government employee | 1.9% | 7.1% | 15.4% | 3.1% | 0.0% | 11.1% |
| Others | 8.4% | 8.0% | 10.6% | 21.9% | 5.6% | 16.7% |
| Unknown/forgotten | 0.0% | 0.5% | 1.0% | 0.0% | 2.8% | 0.0% |

Figure 1. Areas used for the analyses



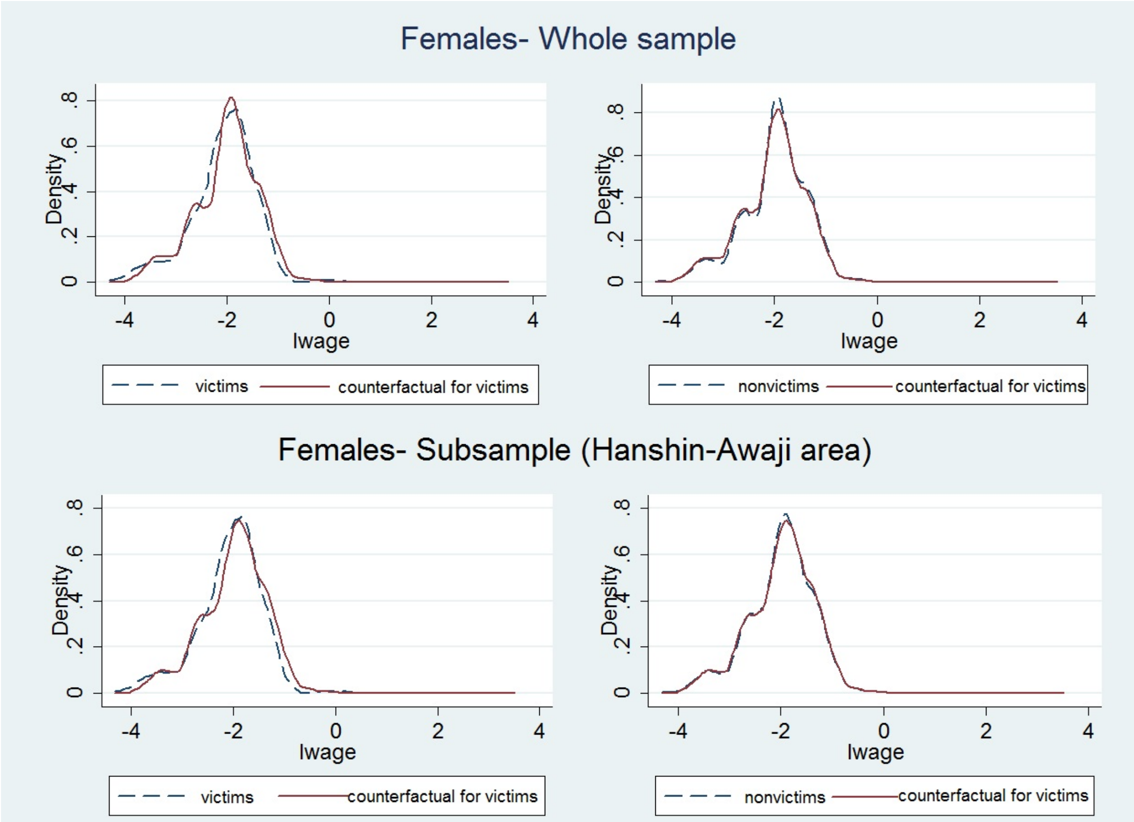

Note: This figure is a map of Japan. The orange-colored area is Hyogo Prefecture, where the Hanshin–Awaji earthquake struck. This prefecture includes 10 cities and 10 municipalities that the Japanese government officially declared to be the most severely damaged region. The green-colored is Osaka prefecture and the blue-colored is Kanagawa prefecture.

Figure 2. DFL decomposition of the wage distribution for males




Note: Four figures indicate the wage distributions for male workers. The left figures indicate disaster victims and the counterfactual for victims and the right figures indicate non-victims side and the counterfactual for victims. The difference between upper panels and lower panels are a sample composition: upper panels using whole sample and lower panels using the subsample residing in the Hanshin and Awaji areas. In each figure, the dashed line represents the actual distribution for victims or non-victims while the solid line indicates the counterfactual distribution for victims calculated by the DFL method.

Figure 3. DFL decomposition of the wage distribution for females




Note: Four figures indicate the wage distributions for female workers. The left figures indicate disaster victims and the counterfactual for victims and the right figures indicate non-victims side and the counterfactual for victims. The difference between upper panels and lower panels are a sample composition: upper panels using whole sample and lower panels using the subsample residing in the Hanshin and Awaji areas. In each figure, the dashed line represents the actual distribution for victims or non-victims while the solid line indicates the counterfactual distribution for victims calculated by the DFL method.

## Appendix. Outline of the survey

| | |
|---|---|
| Survey Method | ・ Internet survey (Nikkei Research. Inc.) |
| Screening | ・ A screening survey was conducted across the country before the main survey. survey questionnaires were delivered to the targets and responses were collected, according to the distribution of the screening survey. |
| Regional range | ・ Nationwide |
| Population | ・ Residents in the following municipalities at the time of the earthquake in 1995; Kobe, Itami, Amagasaki, Nishinomiya, Ashiya, Takaraduka, Kawanishi, Akashi, Miki, Sumoto, Tuna-cho, Awaji-cho, Hokutan-sho, Ichinomiya-cho, Goshiki-cho, Higahiura-cho, MIdori-cho, Nishitan-cho, Mihara-cho, Nantan-cho, Yokohama, Osaka, Suita, Takatsuki, and Sakai.<br>・ Males and females aged from 20 to 80 years old who live in Japan as of March 15, 2012. |
| Sample design | ・ Via monitors developed exclusively for the research conducted online<br>・ Demographic and regional information for sample layout and allocation such as prefecture, municipalities, sex, and age are not considered.<br>・ No of scheduled collection: 8500s (Hanshin: 5100s, Yokohama: 1700s, Osaka: 1100s, Suita: 300s, Takatsuki: 150s, Sakai: 150s) |
| Valid response | ・ No. of those who completed the survey: 10,715s （Yokohama: 1,698s, Osaka: 1,358s, Suita: 208s, Takatsuki: 219s, Sakai: 366s, Hanshin: 6,866s）<br>・ No. of eligible survey responses: 10,387s （Yokohama: 1,646s, Osaka: 1,316s, Suita: 203s, Takatsuki: 216s, Sakai: 356s, Hanshin: 6,650s） |
| Time periods | ・ March 15, 2012 to March 23, 2012 |