DP

RIETI Discussion Paper Series 17-E-089

The Effects of Supply Chain Disruptions Caused by the Great East Japan Earthquake on Workers

KONDO Ayako
University of Tokyo

RIETI
Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

RIETI Discussion Paper Series 17-E-089
June 2017

The Effects of Supply Chain Disruptions Caused by the Great East Japan Earthquake on Workers[1]

KONDO Ayako
Institute of Social Science, University of Tokyo

Abstract

The Great East Japan Earthquake affected not only local workers employed by establishments that were directly damaged, but also those of their trading partners through supply chain disruptions. I estimate the effect of such indirect shocks to workers on their job separation, inter-industry mobility, geographical relocation, and employment status in the following years. I find that such shocks increased job separation in the study period. This increased job separation did not increase inter-industry mobility, but rather induced relocation to other prefectures. The effect on employment status was mixed. Although the self-reported indicator of being affected by the earthquake is significantly correlated with negative outcomes such as high unemployment, the proxy for the production decline at the prefecture-industry level is uncorrelated with employment status. This result implies that people who faced a negative employment shock may have attributed it to the exogenous event, which could cause substantial bias in the self-reported data on the effect of disasters.

Keywords: Great East Japan Earthquake, Supply chain, Employment
JEL classification: J01, J62, J61

[1]This study is conducted as a part of the "Transformation of the Japanese Labor Market: Toward a labor market for all" project undertaken at the Research Institute of Economy, Trade and Industry (RIETI). It is also supported by the Japan Society for the Promotion of Science (JSPS) Grant in Aid for Scientific Research (B) No. 15K17072 (PI: Ayako Kondo). The use of microdata was approved by the Statistics Bureau of the Ministry of Internal Affairs and Communications based on this grant. I also thank the Mitsubishi Research Institute for sharing the inter-prefecture input-output table. I am grateful to Yuji Genda and the seminar participants at the Policy Modeling Workshop, Keio University, and Kyushu University for their useful suggestions.

1. Introduction

The Great East Japan Earthquake on March 11, 2011 and subsequent tsunami destroyed many buildings and resulted in a 15% reduction in industrial output in the following months.[1] Although the direct damage was concentrated on the east coast of the Tohoku and Kanto regions, businesses in other areas of Japan were also affected through supply chain disruptions. This production decline led to a substantial reduction in labor demand, at least in the short run. Then, how did workers respond to such labor demand shocks?

During the months following the earthquake, the mass media reported the growing concern of the public about the widespread negative effects on employment, especially for non-regular workers, caused by such supply chain disruptions.[2] However, there is no clear evidence of the existence of such indirect effects on employment. On the one hand, studies of the effect of the Great East Japan Earthquake on employment focus on the three most affected prefectures (Higuchi et al. 2012, Ohta 2014) or those people forced to evacuate (Genda 2014).[3] On the other hand, many studies document the indirect effect through supply chain disruptions on output (Okiyama et al. 2012, Cavalho et al. 2016, Tokui et al. 2015, Dekle et al. 2016), but ignore the effect on employment.[4]

This study aims to bridge this gap in the literature by examining the effect of the labor demand shocks caused by the Great East Japan Earthquake on workers' job

---

[1] See the Industrial Production Index published by the Ministry of Economy, Trade and Industry.

[2] *Asahi shinbun*, March 29, 2011 (http://www.asahi.com/special/10005/TKY201103290116.html), *President*, May 2011 (http://president.jp/articles/-/3003), *Toyo-keizai online*, May 18, 2011 (http://toyokeizai.net/articles/-/6965).

[3] Genda (2014) examines which people tend to report that their employment was affected by the earthquake. In this way, he uses the subjective indicator of being affected by the earthquake as a dependent variable, whereas I use it as an explanatory variable. He shows that men and young people are more likely to report that their jobs were affected by the earthquake, whereas college-educated and regular employees are less likely to do so.

[4] The only exception of which I am aware is the research note by Nakano (2011). He estimates the impact of the decline in production on employment in nine regions of Japan, using the inter-regional input-output (I-O) table. However, as he acknowledges, his estimates are based on preliminary data that came available two months after the earthquake. Probably because of errors in these preliminary sources, his estimate of the nationwide loss of employment is much larger than the actual change in employment reported in other studies published later (Higuchi et al. 2012, Ohta 2014).

separation, inter-industry and geographical mobility, and employment status in the following year. In particular, I focus on the indirect shocks caused by supply chain disruptions on workers who lived in prefectures that were not directly damaged by the tsunami. Employment Status Survey (ESS) 2012 provides self-reported data on the repercussions of the Great East Japan Earthquake on the job held at that time.[5] About 5.5% of workers experienced changes such as temporary suspension, shorter working hours, and lower earnings, even in those areas not directly damaged by the tsunami. However, such self-reported data may be biased if some workers attribute the negative shocks actually caused by other factors to the earthquake. To mitigate this problem, I calculate the upper bound of the production decline at the industry-prefecture level based on the inter-prefecture I-O table and estimate its effect on individual workers' outcomes.

I find that the temporary decline in labor demand caused by supply chain disruptions induced workers to quit their jobs. Except for regular employees who experienced temporary suspension, the job separation hazard is positively correlated with both indicators for the self-reported repercussions and the estimated upper bound of the production decline at the industry-prefecture level.

Then, where did the workers who left their jobs go? Did they move to industries or prefectures that were less affected or did they ultimately suffer from unemployment? To answer this question, I examine industry and prefecture mobility and find that increased job separation did not lead to higher inter-industry mobility, but rather induced moves to other prefectures.

The effects on employment status in October 2012, 18 months after the earthquake, are mixed. People who answered that their job was affected by the earthquake are less likely to be employed or in regular employment and more likely to be unemployed or out of the labor force. By contrast, the estimated upper bound for the production decline at the prefecture-industry level is uncorrelated with employment status. This result implies that the self-reported data may be biased, because workers or their employers who faced a negative shock attributed it to the earthquake, even if this was not the true cause.

---

[5] As I explain in Section 2.1, the question asks about the repercussions from both the direct physical damage and supply chain disruptions. However, very few workers in my sample should have been affected by the direct physical damage since I exclude workers who lived in the prefectures hit by the tsunami.

The rest of the paper is organized as follows. Section 2 explains data sources and how I constructed the variables. Section 3 describes the empirical model, and Section 4 presents the results. Section 5 concludes.

2. Data

2.1 ESS 2012 and self-reported data of the repercussions to the job held at the time of the earthquake

The ESS is a cross-sectional household survey conducted by the Statistics Bureau of Japan every five years. It asks questions about employment status and, if employed, the job characteristics and earnings of each adult household member as well as the basic demographic characteristics such as age, gender, and educational background. Furthermore, information on the previous job is available for individuals who have ever quit a job. In addition to these regular questions, the ESS conducted in October 2012 asked whether and how individuals were affected by the Great East Japan Earthquake.

By using the year and month in which (i) each individual started his or her current job and (ii) he or she quit his or her previous job, I retrieved information on the job held at the time of the earthquake. The survey also asks whether the individual has ever moved, and if yes, the year and month of the move and the prefecture of the previous residence. By using these variables, the prefecture of residence at the time of the earthquake is identified. Individuals with missing information and those who were not employed at the time of the earthquake are dropped from the sample. Furthermore, I limit the sample to people aged 20–70 on the survey date. The Appendix describes this data construction process in detail.

Furthermore, I exclude people who lived in prefectures that were directly damaged by the tsunami, even though such residents are thought to be affected more than those in other prefectures for two reasons. First, I focus on the effect through supply chain disruptions, whereas people in these prefectures may have been forced to change jobs because of direct damage to their employers or families. Second, existing studies have already focused on directly damaged prefectures. Hence, the following six prefectures are dropped: Aomori, Iwate, Miyagi, Fukushima, Ibaraki, and Chiba.[6]

[6] Although human damage was concentrated on Iwate, Miyagi, and Fukushima, coastal buildings in the other three prefectures also suffered substantial damage. The

The question about the effect of the Great East Japan Earthquake on employment is "Was your main job at that time affected by damage to your workplace?" The respondent chooses one of the following answers: (1) not affected, (2) temporarily suspended, (3) lost job permanently, (4) affected in other ways (shorter working hours, change in shifts, wage cuts, etc.), and (5) not employed at that time. The survey instruction clearly states that "damage" includes damage to other branches of the company and supply chain disruptions.[7] Although damage also includes the direct physical damage from the earthquake, such direct damage was rare in areas other than the prefectures directly hit by the tsunami.[8]

Table 1 presents the summary statistics. Very few workers answered that they lost their jobs because of the earthquake. By contrast, 1.6% of workers experienced temporary suspension and 3.8% were affected in other ways. A non-negligible number of workers were affected by supply chain disruptions, even in those areas not directly hit by the tsunami, although the immediate impact on employment was limited.

I use these variables as a proxy for the labor demand shocks their employers faced right after the earthquake, presumably because of supply chain disruptions. There are two possible channels through which temporary suspension or other changes (e.g., shift changes) can induce workers to leave their jobs in the future. First, these changes may make workers unsatisfied with their jobs, thereby inducing voluntary separation. In particular, reduced working hours lead to a substantial earnings loss, especially for non-regular workers on hourly wage contracts. Second, assuming that these changes were caused by a reduction in production, this may reduce the firm's profit and lead to employment adjustments with some time lag.

---

ratios of workers who worked in establishments in areas affected by the tsunami are as follows: 6% in Aomori, 12% in Iwate, 20% in Miyagi, 7% in Fukushima, 5% in Ibaraki, and 1% in Chiba.

7 It also states that "damage" does not include any effects of limits on electricity usage, including planned outages. Nonetheless, some respondents may have ignored the instruction. In particular, many workers were forced to change their shifts because the government asked large manufacturing companies to avoid operations in peak-time, and some of them may have answered (4).

8 According to the survey instruction, in addition to the direct damage to the workplace and indirect effect through supply chain disruptions, damage also includes the direct damage on the individual's family and home and evacuation order because of the nuclear power plant accident. This ambiguity in the source of damage is another reason why I exclude people who lived in the prefectures hit by the tsunami.

An important limitation of the self-reported data is potential bias from workers' or employers' self-justification. Some workers who had to leave their jobs for other reasons may believe that they lost their jobs because of the earthquake since this is easier to accept. In addition, employers may blame the earthquake for the worse business conditions, even if this is not the true reason. Then, the self-reported effect of the earthquake on employment may be correlated with the unobservable negative shocks on employment status.

Figure 1 plots the ratio of people who answered that their employment was affected in each prefecture. As expected, the ratio is higher in the remaining prefectures in the Tohoku and Kanto regions. That said, more than 2% of the working population were affected in most of Japan. Further, a few remote prefectures such as Mie and Hiroshima were affected more than other prefectures.

2.2 Upper bound of the production decline caused by supply chain disruptions

As explained in the last subsection, the self-reported data may be biased if workers who faced shocks caused by other factors actually attribute this to the earthquake. Thus, I also use the estimated production decline caused by supply chain disruptions at the industry-prefecture level constructed from various data sources. This variable should be independent of any shocks at the individual level caused by other reasons.

In the remainder of this subsection, I explain how I constructed this variable. I start with the estimation of the direct physical damage from the tsunami and nuclear power plant accident and then describe how the upper bound of the indirect damage from supply chain disruptions was calculated. Finally, I merge these data with the ESS and present summary plots.

2.2.1 Direct physical damage from the tsunami and nuclear power plant accident

From various data sources, I constructed data on the direct physical damage from the earthquake by industry for the six prefectures hit by the tsunami. Since industries are coded in different ways in different data sources, I recoded industries to the 45 industries in the inter-prefecture I-O table, which are used in the next subsection. To avoid confusion with other industry coding, hereafter I refer to the 45 industries as the I-O industries.

Let D_A^I denote the proportion of production facilities of I-O industry I in prefecture A made unavailable by the earthquake. D_A^I includes both physical damage by the tsunami and the evacuation order following the nuclear power plant accident.[9] The official statistics for this damage are available at the municipality level, and I converted these into the I-O industry and prefecture level.

First, I defined the ratio of workers whose workplace was damaged by the tsunami as follows. The Statistics Bureau of Japan published the number of workers employed by establishments in the area flooded by the tsunami by municipality and by the 19 major industries.[10] However, the 19 major industries are too coarse; in particular, there are no subindustries within manufacturing and large variation in the damage caused by the tsunami across manufacturing sectors. Therefore, I exploited the different employment compositions at the sector level in each municipality to capture the variation within manufacturing. Each sector's damage at the prefecture level was calculated as a weighted average of the municipality-level damage rates with the employment share of each municipality within the sector-prefecture cell as the weight.

The Economic Census in 2009 provided the number of employees for each three-digit industry in each municipality. To obtain the estimated number of employees whose workplace was damaged by the tsunami by these three-digit industries and municipalities, I multiplied the number of all employees in each three-digit-industry-municipality cell by the ratio of employees in the establishments destroyed by the tsunami of the corresponding major industry and municipality.

Next, to incorporate the evacuation order following the nuclear power plant accident, I assumed that all establishments in the municipalities under the evacuation order[11] stopped production. Thus, for these municipalities, all workers in all industries were affected.

---

[9] I omit damage caused by the earthquake itself because data by industry and municipality or prefecture are unavailable. I believe, however, that this omission would not cause a serious problem since more than 90% of building damage was caused by the tsunami, as summarized in chapter 3 of Saito (2015).

[10] These numbers are based on the Economic Census 2009, also conducted by the Statistics Bureau. Thus, strictly speaking, they are the numbers of establishments that existed in 2009 in areas destroyed by the tsunami in 2011. The file is available at http://www.stat.go.jp/info/shinsai/zuhyou/jigyou2.xls (browsed on 2017/2/8).

[11] Following Genda (2014), 11 municipalities are classified in this category: Tamura, Minamisoma, Kawamata, Naraha, Tomioka, Kawauchi, Okuma, Futaba, Namie, Kuzuo, and Iidate.

Then, I aggregated the estimated numbers of employees whose workplace was damaged by the tsunami or nuclear power plant accident to the I-O industry and prefecture level. Let the subscripts i, $\tilde{I}$, and m denote a three-digit industry included in I-O industry I, a major industry that includes I-O industry I, and a municipality included in prefecture A, respectively. $emp_{i,m}$ is the number of employees in three-digit industry i and municipality m, $tsu_{\tilde{I},m}$ is the ratio of employees in the establishments destroyed by the tsunami of major industry $\tilde{I}$ and municipality m, and eva_m is an indicator that takes 1 if municipality m is under the evacuation order. Then, D_A^I is written as follows:

$$D_A^I = \frac{\sum_{m \in A} \sum_{i \in I} emp_{i,m} * \max\{tsu_{\tilde{I},m}, eva_m\}}{\sum_{m \in A} \sum_{i \in I} emp_{i,m}} \ldots (1)$$

2.2.2 Upper bound of the production decline caused by supply chain disruptions at the I-O industry and prefecture level

By using D_A^I defined in the previous subsection, I calculated the upper bound of indirect damage through the supply chain. If an input good from the area directly damaged by the tsunami was not substitutable with different good (i.e., the production functions were Leontief) and firms were unable to procure the same good from other areas, the decline in input caused by the direct damage to the supplier would reduce output proportionally. This approach is similar to "the first-stage bottleneck effect" proposed by Tokui et al. (2015).[12]

In reality, the production function is not Leontief and the firm could also purchase the same input goods produced in other regions in Japan or import from abroad. Therefore, the estimated upper bound of damage should be interpreted as a rough proxy that is correlated with the actual production decline. Thus, I pay little attention to the size of the coefficient of this variable, instead focusing on its sign.

Specifically, let ${I^I}_{AB}{}^J$ denote the purchase of input goods from industry I in prefecture A by industry J in prefecture B.[13] Then, the ratio of input goods purchased

---

[12] An important difference is that I ignored the second and higher order impact for simplicity, as my main purpose is not to estimate the production loss accurately.

[13] This inter-prefecture I-O table was developed by the Mitsubishi Research Institute, based on the inter-regional I-O table 2005 published by the Ministry of Economy, Trade and Industry. This is an updated version of the I-O table based on the 2000 data by Miyagi et al. (2003) and also used by Okiyama et al. (2012). Tokui et al. (2015) use a different prefecture-level I-O table; however, their table is also based

from the area affected by the earthquake to the total purchase from industry I by industry J in prefecture B can be written as follows:

$$\widetilde{D}_B^{IJ} = \frac{\sum_p I_{pB}^{IJ} D_p^I}{\sum_p I_{pB}^{IJ}} \dots (2)$$

This is a weighted average of the direct damage in the input sector, with the share of each prefecture in the total input as the weight.

Then, I defined the upper bound of the decline in output in industry J in prefecture B caused by the earthquake as the maximum amount of damage to each input good. Let dam_B^J denote this upper bound in the form of the share of the total output of industry J in prefecture B, which can be written as follows:

$$\mathrm{dam}_B^J = \max\{\widetilde{D}_B^{1J}, \widetilde{D}_B^{2J}, \dots \widetilde{D}_B^{45J}\} \quad ..(3)$$

Among studies of the indirect effect of the Great East Japan Earthquake through supply chain disruptions on output, Tokui et al. (2015) is the closest to this study in the sense that they explicitly distinguish tsunami-affected prefectures from the rest of Tohoku and Kanto in addition to making the assumption of Leontief production technology. While other studies use the inter-regional I-O table (Dekle et al. 2016) or firm-level data (Cavalho et al. 2016), regardless of the unit of observation, all show substantial effects on output caused by supply chain disruptions. I chose to use the inter-prefecture I-O table rather than the inter-regional one because nine regions are too coarse to control for the industry fixed effects.

2.2.3 Merging industry-prefecture-level data with the ESS

The estimated production decline caused by supply chain disruptions are merged with individual-level data from the ESS using the industry and prefecture at the time of the earthquake. However, the industry of the previous job is available only for the major 19 industries in the ESS. Therefore, the 45 industries were aggregated to these major industries. This is an important limitation of the ESS data. Thus, in the Appendix, I use the Labour Force Survey to check whether disaggregating industries changes the results qualitatively. The crosswalk of industry codes is also presented in the Appendix.

---

on the inter-regional I-O table 2005.

Figure 2 plots the average dam_B^J of the workers who lived in each prefecture at the time of the earthquake, using the merged data. As in Figure 1, the damage is concentrated in the Tohoku and Kanto regions. However, in the other regions, the distribution is not similar to the self-reported indicator shown in Figure 1.

To see the correlation between the self-reported indicators and dam_B^J, I estimated the following logit model:

$$R_{iJB}^{k} = 1 \;\; if \;\; R_{JB}^{k*} = \alpha dam_B^J + \beta' X_{iJB} + \theta_J + \mu_B + \varepsilon_{iJB} > 0$$

$$R_{iJB}^{k} = 0 \;\; otherwise$$

… (4)

where R_{iJB}^{k} represents the dummy variables of losing the job permanently (R_{iJB}^{l}), temporary suspension (R_{iJB}^{t}), or being affected in other ways (R_{iJB}^{o}) for individual i who lived in prefecture B and was employed in industry J at the time of the earthquake. X_{iJB} includes the female dummy interacted with the dummies for the type of employment at the time of the earthquake,[14] potential experience and its square, dummies for age>60 and its interaction with potential experience,[15] and education dummies. Standard errors are clustered at the industry-prefecture level (i.e., ε_{iJB} are allowed to be correlated within each industry-prefecture cell).

Table 2 shows the estimated α. dam_B^J is positively correlated with the self-reported indicators. However, the coefficient is not statistically significant when the outcome is temporary suspension, and significant only at the 10% level for being affected in other ways. Since very few people lost their jobs permanently, the effects on temporary suspension and being affected in other ways are more important for interpreting the result. Thus, the correlation between the self-reported indicators of repercussions from the earthquake and the industry-prefecture level decline in output are positive but only marginally significant.

3. Empirical model

14 I include these interaction terms because the correlations between the self-reported indicators and type of employment are different for men and women. Male regular employees are more likely to answer that their jobs were affected than male non-regular employees or self-employed, while female regular employees are less likely to do so.

15 These variables are included to capture the discontinuity in employment security at the mandatory retirement age.

I start with the effects of the self-reported repercussions from the earthquake on the probability of leaving the job held at the time of the earthquake. Specifically, I estimate the following Cox's proportional hazard model:

$$\mathrm{h}\left(\mathrm{t}|R_{iJB}^{t}, R_{iJB}^{O}, X_{iJB}\right) = \lambda(\mathrm{t})\exp(\alpha_1 R_{iJB}^{t} + \alpha_2 R_{iJB}^{O} + \beta' X_{iJB} + \theta_J + \mu_B) \quad \ldots (5)$$

The hazard of leaving the job, $\mathrm{h}\left(\mathrm{t}|R_{iJB}^{t}, R_{iJB}^{O}, X_{iJB}\right)$, is the probability density associated with the individual leaving his or her job in the t-th month after March 2011, when the Great East Japan Earthquake occurred, conditional on not having left the job since March 2011. I exclude from the sample those who lost their jobs permanently ($\mathrm{i.e.}, R_{iJB}^{l} = 1$) because they must have left their jobs by definition. The other explanatory variables are the same as in equation (4), and the standard errors are clustered at the industry-prefecture level.

I also examine the effect of the production decline caused by supply chain disruptions on the job separation hazard, using the following Cox's proportional hazard model:

$$\mathrm{h}\left(\mathrm{t}|\mathrm{dam}_{B}^{J}, X_{iJB}\right) = \lambda(\mathrm{t})\exp(\alpha dam_{B}^{J} + \beta' X_{iJB} + \theta_J + \mu_B) \quad \ldots (6)$$

Here, the sample includes those with $R_{iJB}^{l} = 1$. Except that R_{iJB}^{t} and R_{iJB}^{O} are replaced with dam_{B}^{J}, the explanatory variables are the same as in equations (4) and (5). After examining the effects on job separation, I turn to inter-industry and inter-prefecture mobility. If supply chain disruptions affected some industries or prefectures more negatively than others, workers may have wanted to move to a different industry or a different prefecture.

To check industry mobility, I estimate the following logit models:

$$M_{iJB} = 1 \quad if \quad = \alpha_1 R_{iJB}^{l} + \alpha_2 R_{iJB}^{t} + \alpha_3 R_{iJB}^{O} + \beta' X_{iJB} + \theta_J + \mu_B + \varepsilon_{iJB} > 0$$
$$M_{iJB} = 0 \quad otherwise$$
$$\ldots (7)$$

$$M_{iJB} = 1 \quad if \quad = \alpha dam_{B}^{J} + \beta' X_{iJB} + \theta_J + \mu_B + \varepsilon_{iJB} > 0$$
$$M_{iJB} = 0 \quad otherwise$$
$$\ldots (8)$$

where M_{ijp} takes one if individual i is employed in an industry other than that of the job held at the time of the earthquake. The other explanatory variables are the same as in the other regressions.

I estimate the same models with all individuals as well as a subsample of workers who changed their jobs after the earthquake. The estimates with all individuals represent the changes in the number of people who move across industries and those with the subsample are interpreted as the change in the probability of industry change conditional on changing jobs.

The effects on mobility across prefectures are estimated by using the same model as equations (7) and (8), replacing the left-hand side with a dummy for moving away from the prefecture of residence at the time of the earthquake.

Lastly, I examine the effects on employment status in October 2012. Specifically, I estimate the same logit model as equations (7) and (8), replacing the dependent variable with dummy variables for being employed, a regular employee, unemployed, and out of the labor force.

For some specifications, I also present a subsample analysis. First, I divide the sample by the type of employment at the time of the earthquake[16] to examine whether non-regular employees were more vulnerable to the shocks caused by supply chain disruptions, as reported by the mass media. Second, I examine workers younger than 35 and older than 60.[17] Young workers may be more likely to move to other industries and prefectures, but the effects on their employment status may be limited. By contrast, workers older than 60, the prevailing mandatory retirement age, may be more likely to lose jobs and become unemployed or move out of the labor force.

4. Results

4.1 Effects on job separation

Table 3 presents the estimated α_1 and α_2 from equation (5), that is the effects of the self-reported repercussions of the earthquake on job separation. Interestingly, the effect of temporary suspension is negative for regular employees but positive for non-regular employees. Firms may thus have used "temporary suspension" for different purposes for regular and non-regular employees. On the one hand, firms severely affected may have used temporary suspension to avoid downsizing or

[16] I divide the sample into three groups: regular employees, non-regular employees, and self-employed. However, I do not report the result of the self-employed sample because the sample size is too small and concentrated on a few industries such as retail trade.

[17] I use age on the survey date in October 2012. The results change little if I use age at the time of the earthquake.

bankruptcy and retain the employment of workers, mainly regular employees. In such cases, workers can often receive compensation from government subsidies such as the Employment Adjustment Subsidy. On the other hand, firms that treat non-regular workers as a buffer for employment adjustment may have simply reduced the working hours of non-regular workers to zero without any financial compensation.

Interestingly, the negative effect for regular employees and positive effect for non-regular employees occurred at different timings. I interacted the self-reported repercussions in equation (5) with the dummies for the quarters since the earthquake. Table 4 presents the results; the negative effect for regular workers mainly occurred early, while the positive effect occurred later. Indeed, the effects of temporary suspension on job separation one year after the earthquake are significantly positive for all subgroups, even regular employees. This finding might reflect self-reporting bias; that is, people who decided to leave their jobs recently presumably experienced some negative shocks with the job and attributed such shocks to the occurrence of the earthquake.

The effects of being affected by other ways are positive for all subsamples and statistically significant except for regular employees. The effect is larger for non-regular employees and old workers. Table 4 shows that the positive effect on job separation peaks in the second quarter. However, the effect becomes larger and statistically significant again after April 2012, suggesting the same self-reporting bias as for temporary suspension.

Table 5 presents the estimated α in equation (6), the effect of the estimated upper bound of the production decline because of supply chain disruptions. The production decline increased job separation. Although the effect becomes statistically insignificant when the sample is divided by type of employment, the point estimates change little. Despite the popular belief that non-regular employees were more vulnerable, the effect is slightly smaller for non-regular workers. This is in contrast to the results in Table 3, where the effect of self-reported repercussion affects non-regular workers more. This difference suggests the existence of self-reporting bias.

The effect is larger for young workers and smaller and not statistically significant for old workers. This is not surprising because younger workers are in general more mobile than older workers. This result Table 6 shows that the effect is strongest in the first quarter and fades away within a year.

Combining the results reported in Tables 3–6, I find that supply chain disruptions caused by the earthquake actually increased the job separation rate even in areas not directly damaged. Table 6 suggests that the effect of supply chain disruptions faded within a year, but Table 4 shows that people who reported that their jobs were affected were more likely to have quit their jobs after April 2012. This finding may reflect self-reporting bias rather than the true effect of supply chain disruptions.

4.2 Effects on industry and geographical mobility

So far, I have shown that supply chain disruptions caused by the earthquake increased the job separation rate of affected workers. In this subsection, I examine whether increased job separation led to rises in industry and geographical mobility.

Let us begin with mobility across industry. Table 7 shows the effects of the self-reported repercussions (panel a) and estimated production decline at the industry-prefecture level (panel b) on the probability of working in a different industry than the job held at the time of the earthquake. Note that the sample includes those who did not quit a job and those who were not employed at the time of the survey.

Workers who permanently lost their jobs held at the time of the earthquake are more likely to be working in a different industry. This result is robust across subsamples. That said, only 303 people lost their jobs permanently in my sample and thus the overall impact on the labor market is small. Temporary suspension and being affected in other ways do not increase the probability of working in a different industry, except for non-regular employees. The negative effect of temporary suspension for regular employees may come from the negative effect on job separation shown in Table 3. The coefficients of the estimated production decline at the industry-prefecture level are positive but not statistically significant, except for young workers.

Furthermore, Table 8 shows the effects on the probability of moving to a different industry conditional on changing jobs since the earthquake. That is, the sample is limited to those who quit their jobs and started to work in a different job. The coefficients are not statistically significant. This finding suggests that the weakly positive effects on the overall probability of working in a different industry (see Table 7) are simply driven by the increased number of people who quit their previous jobs. Those who left their jobs because of supply chain disruptions caused by the earthquake are no more likely to move to other industries than those who left their jobs for other reasons.

Turning to geographical mobility, Table 9 shows the effects on the probability of moving to a different prefecture. Both self-reported repercussions and the industry-prefecture level production decline have a significantly positive effect on inter-prefecture mobility. For the subsamples, the effects of self-reported repercussions are always positive. Although some of the coefficients are not statistically significant, the point estimates differ little from the results for the full sample. By contrast, the effect of the industry-prefecture level production decline is clearly weaker for young workers and non-regular workers. One potential reason for the weaker effects for them is that they are more likely to be able to find a job within the same prefecture. Generally, it is easier for younger workers to change jobs, and the labor market for non-regular job is more local.

To summarize, supply chain disruptions do not increase inter-industry mobility more than the increase in job separation. In other words, people who left their jobs because of supply chain disruptions are no more likely to move across industries. Nonetheless, the overall probability of working in a different industry slightly increases because it reduces the number of people who did not move and thus never changed industry. The evidence for geographical mobility is clearer: workers affected by the earthquake tend to move to a different prefecture.

4.3 Effects on employment status in October 2012

Table 10 presents the effects on employment status in October 2012, the reference period of the ESS. Specifically, I focus on the following four outcomes: employed, regular employee, unemployed, and out of the labor force. Panel a of Table 10 shows that people who answered that their job was affected by the earthquake are less likely to be employed or regular employees and more likely to be unemployed or out of the labor force. The estimated coefficients are statistically significant except for the effects of temporary suspension on regular employment and out of the labor force.

The naïve interpretation of Panel a in Table 10 is that the Great East Japan Earthquake indeed had a substantial negative impact on workers affected through supply chain disruptions. However, Panel b shows that the estimated damage at the industry-prefecture level is not significantly correlated with these outcomes. This result implies that the production decline right after the earthquake did not have long-term effects on workers in the affected sectors.

These findings are robust to limiting the samples by the type of employment at the time of the earthquake or age. Table 11 presents the subsample analyses of the effect on employment. The results change little across the subsamples. In particular, despite the impression from the mass media that many non-regular workers lost their jobs because of the production decline caused by the earthquake and supply chain disruptions, the long-term effects were actually negligible. I also ran the same subsample analyses with outcome variables and the results changed little from those for the full sample.[18]

The stark contrast between the effects of the self-reported indicators and the industry-prefecture level variable implies that whether an individual thinks his or her job was affected by the earthquake is strongly correlated with random shocks in employment in October 2012. This may be because people who faced a negative shock tend to attribute it to exogenous events to avoid blaming themselves. Another possibility is that employers, rather than workers, used the earthquake as an excuse for downsizing or wage cuts.

Such self-justification of employers and workers can also reconcile the media reports that many people lost their jobs due to the earthquake, apparently contradicting this study's findings. That is, the worker or employer believes that the earthquake caused the trouble, even if this is not the true cause, and the media report a story consistent with such a belief.

5. Conclusion

Studies of the Great East Japan Earthquake have shown that supply chain disruptions affected the economic activities of firms outside directly affected areas. This study examined whether such disruptions in the production process affect employment and found increases in job separation and moves across prefectures as well as a weak increase in inter-industry mobility, which can be fully explained by the increases in job separation. However, the production decline did not affect employment status 18 months after the earthquake. The effect of the Great East Japan

[18] The subsample results for regular employment, unemployment, and out of the labor force are available upon request.

Earthquake on the labor market outside directly affected areas thus seems to be limited.

This study also showed that although the self-reported data show a strong correlation with employment status 18 months later, such a correlation is spurious. Such self-reporting bias is also consistent with the positive correlation between the self-reported indicators and job separation hazard within six months of the survey date. A lesson from this is that the naïve use of self-reported data may overstate the impact of natural disasters, or any exogenous shocks, on individuals' economic outcomes. Therefore, it is particularly important for policymakers to be aware of such biases since overstating the impact of natural disasters may lead to excessive spending on rehabilitation projects.

Reference

Cavalho, Vasco M., Makoto Nirei, Yukiko Saito, and Alireza Tahbaz-Salehi, 2016. "Supply Chain Disruptions: Evidence from the Great East Japan Earthquake" CEPR Discussion Paper 11711.

Dekle, Robert, Eunpyo Hong, and Wei Xie, 2016. The Regional Spillover Effects of the Tohoku Earthquake. RIETI Discussion Paper 16-E-049.

Genda, Yuji, 2014. The Effects of the Great East Japan Earthquake on Jobs. *The Japanese Journal of Labor Studies*, No653, 100-120 (in Japanese).

Higuchi, Yoshio, Tomohiko Inui, Toshiaki Hosoi, Isao Takabe, and Atsushi Kawakami, 2012. The Effects of the Great East Japan Earthquake on the Labor Market: Increased Mismatches in Employment in the Disaster Areas. *The Japanese Journal of Labor Studies*, No622, 4-16 (in Japanese).

Miyagi, Toshihiko, Yoshifumi Ishikawa, Shohei Yuri and Kazuyuki Tsuchiya, 2003. The Construction of Interregional Input-Output Table at Prefecture Level Using Intraregional Input-Output Tables. *Doboku Keikaku Kenkyu Ronbunshu*, 20, 87-95 (in Japanese).

Nakano, Satoshi 2011. "*Higashinohon daishinsai ga koyo ni ataeru macro teki eikyo no shisan* (estimates for the macro impact of the Great East Japan Earthquake on employment), special column published on JILPT website http://www.jil.go.jp/tokusyu/sinsai/column/04_nakano.pdf

Ohta, Souichi 2014. "*Rodo shijo kara mita shinsai chokugo, fukko katei niokeru keizai jokyo* (Economic situation right after the earthquake and in the process of recovery from the persective of labor market)", Makoto Saito eds, *Shinsai to Keizai* (Economy and the earthquake), Toyokeizai.

Okiyama, Mitsuru, Suminori Tokunaga, Yuko Akune, 2012. Multiplier Analysis of the Impact of a Negative Supply Shock Caused by the Great East Japan Earthquake and Subsequent Rebuilding Policies: Utilizing the two-regional SAM, RIETI Discussion Paper 12-J-024 (in Japanese).

Saito, Makoto. 2015. *Shinsai Fukko no Seiji Keizaigaku* (Political economy of earthquake restoration), Nihonhyoron-sha, Tokyo.

Tokui, Joji, Kazuyasu Kawasaki, and Tsutomu Miyagawa, 2015. The Economic Impact of Supply Chain Disruptions from the Great East Japan Earthquake, RIETI Discussion Paper 15-E-094.

Table 1 Summary statistics

Sample size	391,796
Self-reported repercussions on the job held at the time of the earthquake	
Lost the job permanently	0.08%
Temporary suspension	1.61%
Affected in other ways (changes in working hours, pay cuts, etc.)	3.81%
Upper bound of the production decline due to supply chain disruptions, estimated at the industry-prefecture level (see Section 2.2)	4.54%
Changes since the earthquake	
Left the job held at the time of the earthquake	9.89%
Employed in a different industry	2.99%
Relocated to a different prefecture	1.51%
Status in October 2012	
Employed	95.38%
Regular employee	52.28%
Unemployed	1.97%
Out of the labor force	2.65%
Type of employment at the time of the earthquake	
Regular employee	60.37%
Non-regular employee	28.23%
Self-employed and family worker	11.40%
Demographic characteristics	
Female	43.6%
Potential experience	29.07
Age	46.93
Education: Junior high school	9.2%
Education: High school	44.7%
Education: Vocational school (*senmon*)	12.7%
Education: Junior college	9.6%
Education: Four-year college or graduate school	23.2%

Note: the sample is limited to those employed at the time of the earthquake and for whom all the necessary variables are available.

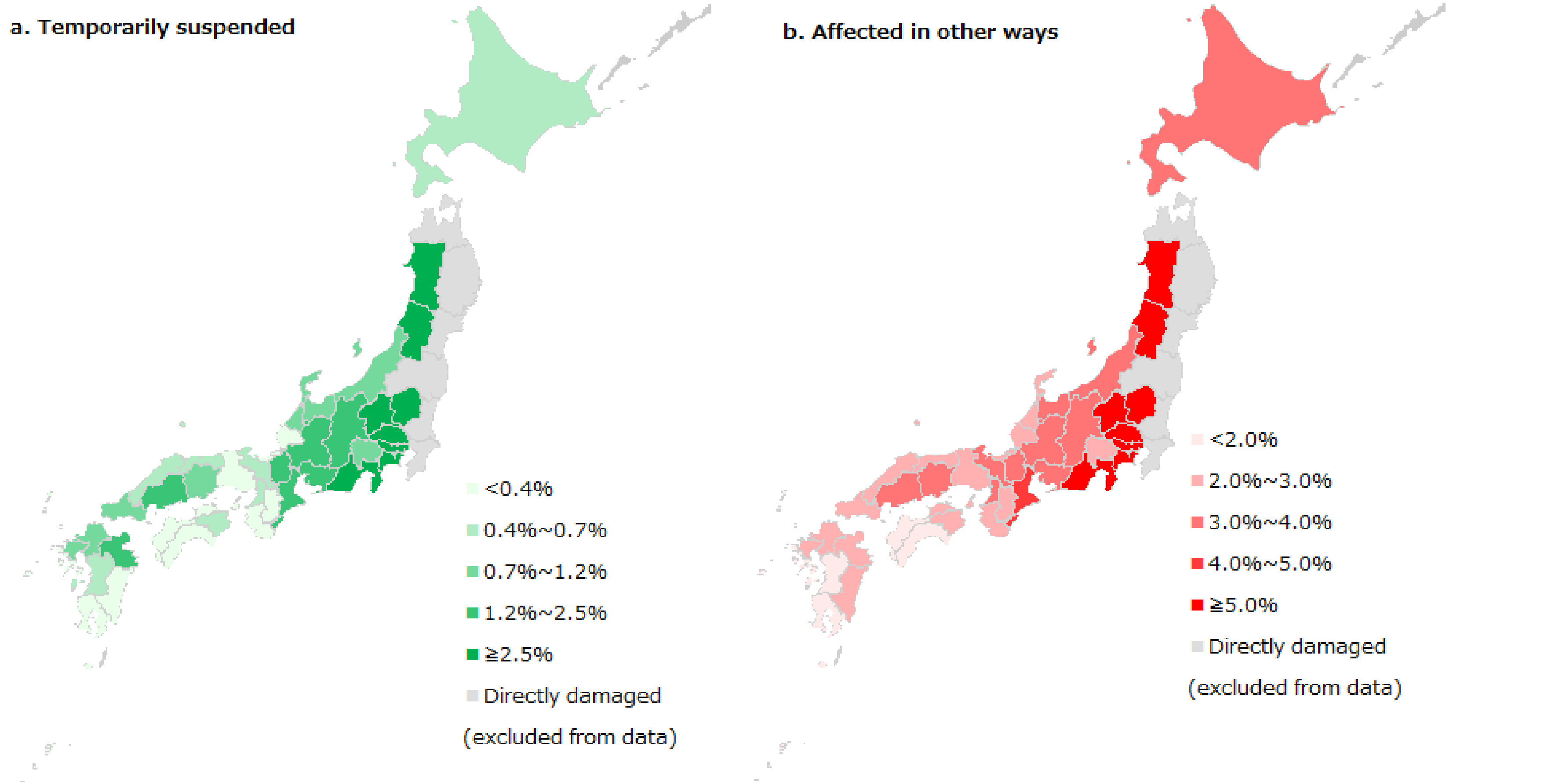

Figure 1: Geographical distribution of workers who reported that their job was temporarily suspended or affected in other ways by the Great East Japan Earthquake

Note: Average of individuals in each prefecture from the ESS. The sample is restricted to individuals employed in March 2011 and who did not evacuate. Sampling weights are applied.

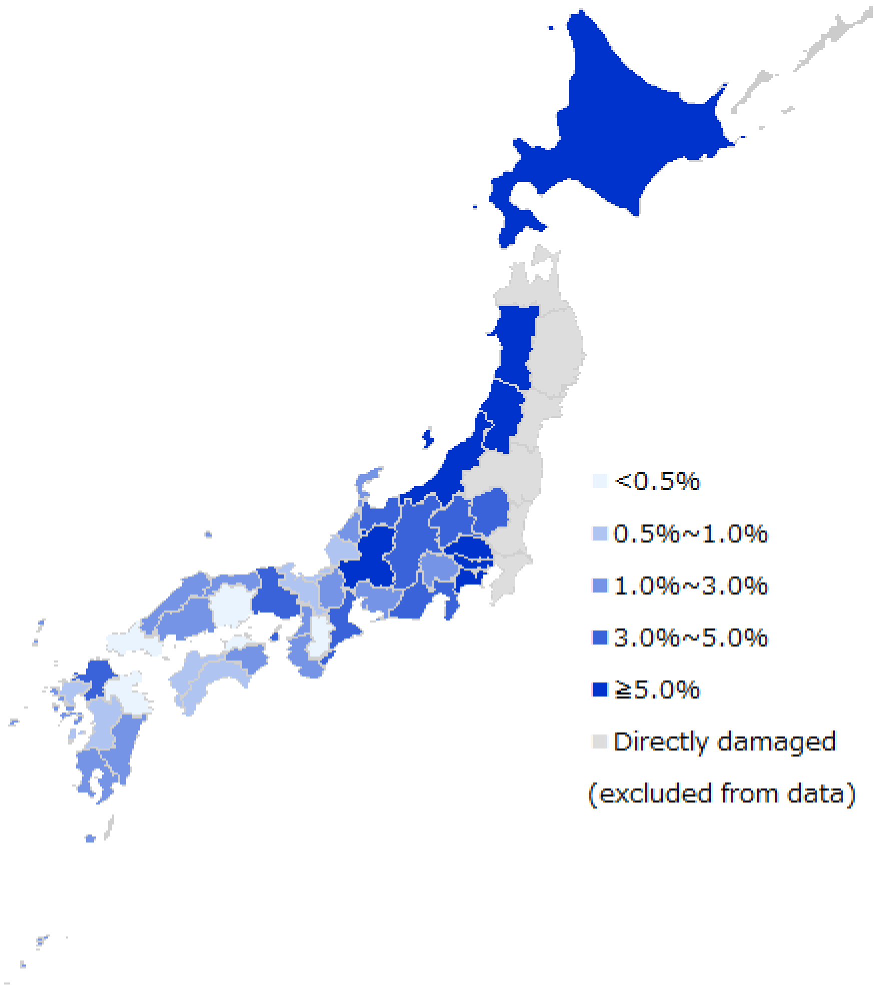

Figure 2: Geographical distribution of the maximum reduction in production because of supply chain disruptions, estimated at the industry-prefecture level
Note: Average of individuals in each prefecture from the ESS. The sample is restricted to individuals employed in March 2011 and who did not evacuate. Sampling weights are applied.

Table 2 Effect of the industry-prefecture-level decline in production because of supply chain disruptions on self-reported repercussions on the job held at the time of the earthquake

	Lost the job permanently	Temporary suspension	Affected in other ways
Coefficient of dam_B^J	9.695***	1.691	1.653*
[standard errors]	[2.483]	[1.813]	[0.973]
(marginal effect at the mean of X)	(0.009)	(0.025)	(0.059)
Observations	391,796	391,796	391,796

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3 Effects of "temporary suspension" and "affected in other ways" on the job separation hazard

	(1) All	(2) Regular Employee	(3) Non-regular employee	(4) Younger than 35	(5) Older than 60
Temporary suspension	0.069	-0.137**	0.206***	0.089	-0.086
	[0.045]	[0.067]	[0.056]	[0.063]	[0.096]
Affected in other ways	0.108***	0.054	0.218***	0.118***	0.241***
	[0.029]	[0.041]	[0.039]	[0.042]	[0.051]
Number of individuals	391,372	236,343	110,377	84,748	80,201

Note: Cox's proportional hazard model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 4 Effects of "temporary suspension" and "other" on the job separation hazard, allowing for the effects to vary over time

	(1) All	(2) Regular Employee	(3) Non-regular employee	(4) Younger than 35	(5) Older than 60
Temporary suspension	-0.001	-0.377**	0.195	0.113	-0.571*
* April to June 2011	[0.096]	[0.175]	[0.119]	[0.111]	[0.315]
Temporary suspension	0.141	-0.154	0.328**	0.054	-0.068
* July to Sept. 2011	[0.118]	[0.227]	[0.148]	[0.174]	[0.341]
Temporary suspension	-0.025	0.083	-0.145	-0.018	-0.551
* Oct. to Dec. 2011	[0.097]	[0.153]	[0.154]	[0.170]	[0.342]
Temporary suspension	-0.132	-0.589***	0.132	-0.113	-0.114
* January to March 2012	[0.090]	[0.144]	[0.115]	[0.129]	[0.182]
Temporary suspension	0.287***	0.205**	0.373***	0.282***	0.326**
* April 2012 to date	[0.070]	[0.104]	[0.098]	[0.108]	[0.162]
Affected in other ways	-0.03	-0.077	0.048	0.057	0.051
* April to June 2011	[0.055]	[0.077]	[0.083]	[0.083]	[0.128]
Affected in other ways	0.263***	0.145	0.448***	0.127	0.423***
* July to Sept. 2011	[0.090]	[0.115]	[0.119]	[0.142]	[0.164]
Affected in other ways	0.131*	0.042	0.271**	0.208**	0.113
* Oct. to Dec. 2011	[0.071]	[0.110]	[0.106]	[0.097]	[0.160]
Affected in other ways	0.022	-0.011	0.117	0.028	0.119
* January to March 2012	[0.058]	[0.076]	[0.087]	[0.090]	[0.103]
Affected in other ways	0.214***	0.181***	0.306***	0.189**	0.486***
* April 2012 to date	[0.050]	[0.069]	[0.076]	[0.080]	[0.086]
Number of individuals	391,372	236,343	110,377	84,748	80,201

Note: Cox's proportional hazard model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5 Effects of supply chain disruptions at the industry-prefecture level on the job separation hazard

	(1) All	(2) Regular Employee	(3) Non-regular employee	(4) Younger than 35	(5) Older than 60
Estimated upper bound of the production decline due to supply chain disruptions	0.754***	0.642	0.509	1.151**	0.331
	[0.258]	[0.399]	[0.352]	[0.455]	[0.537]
Number of individuals	391,674	236,472	110, 527	84,847	80,251

Note: Cox's proportional hazard model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6 Effects of supply chain disruptions at the industry-prefecture level on the job separation hazard, allowing for the effects to vary over time

	(1) All	(2) Regular Employee	(3) Non-regular employee	(4) Younger than 35	(5) Older than 60
Supply chain disruptions	1.159***	1.108**	0.861**	1.567***	0.485
* April to June 2011	[0.332]	[0.490]	[0.409]	[0.512]	[0.667]
Supply chain disruptions	0.406	0.030	0.230	0.439	0.295
* July to Sept. 2011	[0.389]	[0.525]	[0.530]	[0.612]	[0.723]
Supply chain disruptions	0.997***	0.848	0.906*	1.305**	0.913
* Oct. to Dec. 2011	[0.365]	[0.517]	[0.482]	[0.616]	[0.675]
Supply chain disruptions	0.548*	0.520	0.202	1.295**	0.077
* January to March 2012	[0.320]	[0.497]	[0.454]	[0.555]	[0.683]
Supply chain disruptions	0.574	0.442	0.351	0.806	0.163
* April 2012 to date	[0.350]	[0.462]	[0.451]	[0.517]	[0.620]
Number of individuals	391,674	236,472	110, 527	84,847	80,251

Note: Cox's proportional hazard model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7 Effects on the probability of working in a different industry than the job held at the time of the earthquake

a. Self-reported repercussions on the job held at the time of the earthquake

Subsample	(1) All	(2) Regular employee	(3) Non-regular employee	(4) Age 35 or younger	(5) Age 60 or older
Lost the job permanently	2.886***	3.432***	2.358***	2.610***	2.617***
	[0.145]	[0.196]	[0.212]	[0.289]	[0.395]
Temporary suspension	0.021	-0.227**	0.191**	-0.001	-0.215
	[0.070]	[0.114]	[0.093]	[0.108]	[0.264]
Affected in other ways	0.047	-0.038	0.188**	0.044	-0.176
	[0.051]	[0.068]	[0.077]	[0.078]	[0.164]
Number of observations	391,458	236,363	110,400	84,753	80,241

b. Estimated upper bound of the production decline due to supply chain disruptions at the industry-prefecture level

Subsample	(1) All	(2) Regular employee	(3) Non-regular employee	(4) Age 35 or younger	(5) Age 60 or older
Supply chain disruptions	0.911	0.313	1.076	1.469**	-0.783
	[0.595]	[0.884]	[0.733]	[0.575]	[1.624]
Number of observations	391,458	236,363	110,400	84,753	80,241

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8 Effects on the probability of moving to a different industry conditional on changing jobs since the earthquake

a. Self-reported repercussions on the job held at the time of the earthquake

Subsample	(1) All	(2) Regular employee	(3) Non-regular employee	(4) Age 35 or younger	(5) Age 60 or older
Lost the job permanently	0.132	0.36	-0.069	0.261	0.211
	[0.158]	[0.228]	[0.225]	[0.304]	[0.638]
Temporary suspension	-0.005	-0.077	0.075	0.048	-0.158
	[0.117]	[0.182]	[0.164]	[0.167]	[0.398]
Affected in other ways	0.088	0.052	0.106	0.006	-0.069
	[0.077]	[0.103]	[0.129]	[0.114]	[0.258]
Number of observations	20,309	10,286	9,354	7,617	3,494

b. Estimated upper bound of the production decline due to supply chain disruptions at the industry-prefecture level

Subsample	(1) All	(2) Regular employee	(3) Non-regular employee	(4) Age 35 or younger	(5) Age 60 or older
Supply chain disruptions	-0.094	-0.502	0.142	-0.134	-1.480
	[0.797]	[0.967]	[1.202]	[1.120]	[1.849]
Number of observations	20,309	10,286	9,354	7,617	3,494

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9 Effects on the probability of moving to a different prefecture

a. Self-reported repercussions on the job held at the time of the earthquake

Subsample	(1) All	(2) Regular employee	(3) Non-regular employee	(4) Age 35 or younger	(5) Age 60 or older
Lost the job permanently	1.703***	1.182***	2.178***	1.619***	1.029
	[0.188]	[0.315]	[0.251]	[0.257]	[1.061]
Temporary suspension	0.338***	0.242**	0.589***	0.386***	0.42
	[0.085]	[0.102]	[0.158]	[0.122]	[0.389]
Affected in other ways	0.234***	0.231***	0.217	0.266***	0.228
	[0.058]	[0.063]	[0.156]	[0.080]	[0.222]
Number of observations	391,796	236,523	110,116	84,875	69,938

b. Estimated upper bound of the production decline due to supply chain disruptions at the industry-prefecture level

Subsample	(1) All	(2) Regular employee	(3) Non-regular employee	(4) Age 35 or younger	(5) Age 60 or older
Supply chain disruptions	1.459*	1.648*	0.372	0.0004	4.591*
	[0.859]	[0.953]	[1.746]	[1.092]	[2.693]
Number of observations	391,796	236,523	110,116	84,875	69,938

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 10 Effects on employment status in October 2012

a. Self-reported repercussions on the job held at the time of the earthquake

Dependent variables	(1) Employed	(2) Regular employee	(3) Unemployed	(4) Out of labor force
Lost the job permanently	-2.629***	-1.875***	2.345***	2.232***
	[0.153]	[0.232]	[0.157]	[0.173]
Temporary suspension	-0.147**	0.073	0.206**	0.047
	[0.073]	[0.076]	[0.097]	[0.099]
Affected in other ways	-0.245***	-0.183***	0.281***	0.191***
	[0.044]	[0.035]	[0.058]	[0.058]
Number of observations	391,796	391,796	391,796	391,796

b. Estimated upper bound of the production decline due to supply chain disruptions at the industry-prefecture level

	(1) Employed	(2) Regular employee	(3) Unemployed	(4) Out of labor force
Supply chain disruptions	-0.512	0.226	0.039	0.790
	[0.500]	[0.496]	[0.710]	[0.546]
Number of observations	391,796	391,796	391,796	391,796

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 11 Effects on the probability of being employed in October 2012, by subsample

a. Self-reported repercussions on the job held at the time of the earthquake

Subsample	(1) Regular employee at the time of the earthquake	(2) Non-regular employee at the time of the earthquake	(3) Age 35 or younger	(4) Age 60 or older
Lost the job permanently	-2.894***	-2.059***	-1.970***	-2.825***
	[0.221]	[0.159]	[0.245]	[0.321]
Temporary suspension	0.053	-0.264***	-0.246**	0.034
	[0.116]	[0.089]	[0.103]	[0.133]
Affected in other ways	-0.205***	-0.320***	-0.271***	-0.430***
	[0.060]	[0.060]	[0.078]	[0.066]
Number of observations	236,523	110,566	84,875	80,301

b. Estimated upper bound of the production decline due to supply chain disruptions at the industry-prefecture level

Subsample	(1) Regular employee at the time of the earthquake	(2) Non-regular employee at the time of the earthquake	(3) Age 35 or younger	(4) Age 60 or older
Supply chain disruptions	-0.655	0.059	-0.223	-0.683
	[0.739]	[0.591]	[0.963]	[0.768]
Number of observations	236,523	110,566	84,875	80,301

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix

A1. Sample restrictions and identification of the job held at the time of the earthquake

The raw data of the ESS include more than 950,000 individuals older than 15. From these, I exclude those younger than 20 or older than 70 because few of these respondents are employed and if they are employed, they are likely to be outliers.

Next, I create the variable "prefecture of residence at the time of the earthquake" based on the following two variables: when the individual started to live in the current residence and the prefecture of the previous residence. If the individual started to live in the current residence before March 2011, the current residence is the residence at the time of the earthquake. If the individual started to live in the current residence after April 2011, I assume that the previous residence is the residence at the time of the earthquake. Those with missing information on these variables are dropped from the sample.

Then, I limit the sample to those who had a job at the time of the earthquake and answered the question on the effect of the earthquake on employment. At this point, the sample size roughly halved. For those employed at the time of the earthquake, I retrieve information on the job at the time of the earthquake in the following way. First, if the individual was employed on the survey date and started the current job before March 2011, the current job is that held at the time of the earthquake. Next, for individuals who started their jobs after April 2011 or were not employed on the survey date, I check if the previous job was that held at the time of the earthquake using information on the year and month in which the individual quit his or her previous job and the tenure of the previous job. Altogether, 11,925 individuals are dropped because of missing variables and 9,222 are dropped because they started their previous jobs after April 2011 (i.e., the individual has changed jobs more than twice since then).

Furthermore, individuals whose job at the time of the earthquake was in the public sector or in an unclassified industry are dropped because the estimated damage at the industry-prefecture level is not available for them. Further, those with missing ages and educational backgrounds are also dropped. Lastly, I drop people who lived in the six prefectures hit by the tsunami and those forced to evacuate because of direct damage to their families and homes as well as their employers.

Table A1 summarizes the number of dropped observations and remaining sample size. Note that dispatched workers are supposed to answer based on the industry of the company to which they are dispatched. However, if they have been employed by the same temporary help agency since the earthquake, there is no information about the previous workplace or even whether they moved across companies. Thus, the industry of the job held at the time of the earthquake may contain errors for dispatched workers. I believe, however, that such errors are negligible given that only 1% of the sample are dispatched workers.

A2. Robustness checks using the Monthly Labour Force Survey (LFS)

An important limitation of the ESS is that the industry of the previous job is available only for the 19 major industries. Substantial variation in dam_B^J, the estimated production decline because of supply chain disruptions, may be lost by aggregating the 45 industries in the inter-prefecture I-O table into the 19 major industries. In particular, there are no subsectors within the manufacturing sector in the ESS, whereas the 45 industries in the I-O table include 23 manufacturing subsectors with substantial variation across them.

To check whether this aggregation changes the results qualitatively, I use the LFS for the supplemental analyses. The LFS is a cross-sectional survey conducted monthly by the Statistics Bureau of Japan. The special questionnaire, distributed to about 25,000 individuals each month, asks about detailed employment status (regular or non-regular) and collects information on the previous job if the individual quit in the past three years in addition to the demographic characteristics available from the basic questionnaire. Although the self-reported data on the effect of the earthquake on employment are unavailable, it is feasible to merge the estimated upper bound of the production decline at the industry-prefecture level. Unlike the ESS, the industry of the previous job is available at a finer level, and the classification within manufacturing is similar to that in the I-O table. Thus, I can exploit the variation in dam_B^J within the manufacturing sector.

Unlike the ESS, however, I have to use the prefecture of the current residence because there is no other information on the residential location. Thus, as the time between the earthquake and survey date becomes longer, the measurement errors in the prefecture increase. Therefore, I limit the data period to April 2011 to December 2012. Table A2 reports the summary statistics, which are similar to those of the ESS.

To simplify the analysis, I estimate the same logit model as in equation (8), with the following dependent variables: dummy variables for having left the job held at the time of the earthquake, being employed in a different industry, employed, regular employee, unemployed, and out of the labor force. Not that the dummy for moving to other prefectures is not available.

Table A3 presents the results. Except for the effect on industry mobility, which becomes statistically significant, the results are qualitatively the same as the ESS results. The lack of significant effects on employment status on the survey date is not attributable to the aggregation of industries.

A3. Industry crosswalk

See Table A4.

Table A1: Sample restrictions on the ESS

	Dropped observations	Remaining sample size
Raw data		956,569
Younger than 20 or older than 70	255,268	701,301
Residence at the time of the earthquake unavailable	10,351	690,950
Non-response to the question about the effect of the earthquake on employment	10,430	680,520
Not working at the time of the earthquake	195,029	485,491
Missing employment history	11,925	473,566
Unable to identify employment status at the time of the earthquake because the individual has changed jobs more than twice since then	9,222	464,344
The job at the time of the earthquake was in the public sector or in an unclassified industry	9,671	454,673
Education is missing	1,924	452,749
Potential experience<0	201	452548
Lived in Aomori, Iwate, Miyagi, Fukushima, Ibaraki, or Chiba.	60,332	392,216
Evacuated	420	391,796

Table A2 Summary Statistics of the LFS sample

Sample size	188,871
Upper bound of the production decline because of supply chain disruptions estimated at the industry-prefecture level (see Section 2.2)	4.81%
Changes since the earthquake	
Left the job held at the time of the earthquake	9.07%
Employed in a different industry	2.92%
Status in October 2012	
Employed	95.33%
Regular employee	51.24%
Unemployed	1.81%
Out of the labor force	2.86%
Type of employment at the time of the earthquake	
Regular employee	56.79%
Non-regular employee	29.36%
Self-employed and family worker	13.85%
Demographic characteristics	
Female	43.4%
Potential experience	29.52
Age	47.4
Education: Junior high school or high school	57.2%
Education: Vocational school (*senmon*) or junior college	18.0%
Education: Four-year college or graduate school	24.8%

Table A3 Estimated effects of the production decline because of supply chain disruptions, LFS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Having left the job	Working in another industry	Working in another industry conditional on job change	Employed	Regular employee	Unemployed	Out of the labor force
Estimated upper bound of the production decline because of supply chain disruptions	0.724*	0.757*	0.774	-0.150	-0.238	-0.300	0.362
	[0.397]	[0.419]	[0.966]	[0.448]	[0.563]	[0.699]	[0.611]
Number of individuals	177,404	177,404	16,930	177,404	177,404	177,266	177,404

Note: Logit model. The other explanatory variables omitted from the table are the female dummy interacted with the dummies for the type of employment at the time of the earthquake, potential experience and its square, dummies for age>60 and its interaction with potential experience, education dummies, and industry- and prefecture-fixed effects. Standard errors are clustered at the industry-prefecture level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table A4 Industry crosswalk

ESS		Inter-prefecture I-O table		LFS	
1	Agriculture	1	Agriculture	01	Agriculture
2	Forestry	2	Forestry	02	Forestry
3	Fishery	3	Fishery	03	Fishery except aquaculture
				04	Aquaculture
4	Mining	4	Mining	05	Mining and quarrying of stone and gravel
5	Construction	29	Construction	06	Construction
		30	Public engineering		
6	Manufacturing	5	Food and tobacco	09	Food
				10	Beverages, tobacco and feed
		6	Textile	11	Textile mill products
		7	Lumber and wood products	12	Lumber and wood products, except furniture
		8	Furniture and fixtures	13	Furniture and fixtures
		9	Pulp, paper and paper products	14	Pulp, paper and paper products
		10	Printing and publishing	15	Printing and allied industries
		11	Chemical and allied products	16	Chemical and allied products
		12	Petroleum and coal products	17	Petroleum and coal products
		13	Plastic products	18	Plastic products, except otherwise classified
		14	Rubber products	19	Rubber products
		15	Leather products	20	Leather tanning, leather products and fur

					skins
		16	Ceramic, stone and clay products	21	Ceramic, stone and clay products
		17	Iron and steel	22	Iron and steel
		18	Non-ferrous metals	23	Non-ferrous metals and products
		19	Metal products	24	Fabricated metal products
		20	General machinery	25	General-purpose machinery
				26	Production machinery
		21	Machinery for office and service industry	27	Business oriented machinery
		27	Precision instruments		
		23	Information and communication electronics equipment	28	Electronic parts, devices and electronic circuits
				30	Information and communication electronics equipment
		22	Household electric appliances	29	Electrical machinery, equipment and supplies
		24	Other electrical equipment		
		25	Cars	31	Transportation equipment
		26	Other transportation equipment		
		28	Miscellaneous manufacturing products	32	Miscellaneous manufacturing industries
7	Electricity, Gas, Heat supply and Water	31	Electricity	33	Electricity, Gas, Heat supply and Water
		32	Gas and heat supply		

		33	Water supply and waste disposal business		
	NA	33	Water supply and waste disposal business	88	Waste disposal business
8	Information and communications	38	Communication and broadcasting	37	Communications
				38	Broadcasting
				39	Information services
				40	Internet based services
				41	Video picture, sound information, Character information production and distribution
9	Transport and postal activities	37	Transport	42	Railway transport
				43	Road passenger transport
				44	Road freight transport
				45	Water transport
				46	Air transport
				47	Warehousing
				48	Services incidental to transport
			NA	49	Postal activities
10	Wholesale and Retail trade	34	Commerce	50	Wholesale trade
				56	Retail trade, general merchandise
				57	Retail trade (dry goods, apparel and apparel accessories)
				58	Retail trade (food and beverage)
				59	Machinery and equipment
				60	Miscellaneous retail trade

11	Finance and Insurance	35	Finance and Insurance	62	Finance and Insurance
12	Real estate and goods rental and leasing	36	Real estate	68	Real estate
				70	Goods rental and leasing
13 & 19	Scientific research, professional and technical services & Services, N.E.C	43	Business services	71	Scientific and development research institutes
				72	Professional services, N.E.C
				73	Advertising
				74	Technical services, N.E.C
				89	Automobile maintenance services
				90	Machine, ETC. repair services, except otherwise
				91	Employment and worker dispatching services
				92	Miscellaneous business services
				79	Miscellaneous living-related and personal services
				80	Services for amusement and hobbies
16	Education, learning support	40	Education and research	81	School education
				82	Miscellaneous education, learning support
17	Medical, health care and welfare	41	Medical service, health, social	83	Medical and other health services

			security and nursing care	84	Public health and hygiene
				85	Social insurance and social welfare
18	Compound services	42	Other public services	86	Postal services
				87	Cooperative association, N.E.C
				93	Political, business and cultural organizations
				94	Religion