Graduate School of Economics, Kobe University
Working Paper Series No. 327

# Effects of region-specific shocks on job matching efficiency: Evidence from the 2011 Tohoku Earthquake in Japan*

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February 13, 2019

**Abstract**

This paper examines whether region-specific shocks alter regional job matching efficiencies, that is, how efficiently job seekers match with vacancies. We adopt the Great East Japan Earthquake in March 2011 as a region-specific shock. We find that regional job matching efficiencies in the damaged area deteriorated in the aftermath of the disaster. This tendency was temporary and did not spatially diffuse. These results suggest that the composition of unemployment in terms of job search intensities changed in the directly damaged area, leading to temporarily higher search frictions. No composition change in unemployment occurred in other regions owing to the different characteristics of those local labor markets.

**Keywords:** Local labor market; Matching function; Spatial spillover; Difference in differences

**JEL classification:** J64; R12; R23

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* I would like to thank Kazufumi Yugami, Nobuaki Hamaguchi, and Shinya Horie for helpful comments. I would also like to thank Hirokazu Fujii of the Ministry of Health, Labour and Welfare, and the Employment Policy Division of Employment Security Bureau for their providing the data for Public Employment Security Office. Remaining errors are my own. This work was supported by JSPS KAKENHI Grant Number JP18J11560.

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## 1. Introduction

Some studies have recently revealed that the number of matches between unemployed job seekers and vacancies by firms in one region depends on the labor market conditions not only in their own region but also in neighboring regions (e.g., Burda and Profit, 1996; Burgess and Profit, 2001; Hynninen, 2005; Fahr and Sunde, 2006a,b; Haller and Heuermann, 2016; Higashi, 2018). This tendency is caused by inter-regional job search by job seekers with high search intensities. These results suggest that job seekers compare the job finding rates in their own region with those in surrounding regions, resulting in spatial (geographical) interdependence across local labor markets.

These findings suggest there are regional disparities in matching efficiencies, that is, how efficiently job seekers match with vacancies. Some studies find evidence supporting this conjecture by estimating the matching function, which represents the number of matches is determined by the numbers of unemployed job seekers and vacancies (Petrongolo and Pissarides, 2001). Coles and Smith (1996) find that some regional demographic factors significantly affect the number of matches in their matching function, suggesting that matching efficiencies vary across regions depending on the conditions in local labor markets. Indeed, Kano and Ohta (2005) explicitly reveal that matching efficiencies exhibit regional heterogeneity in Japan.

The above studies' data or specifications provide analyses under the assumption that regional matching efficiencies are static. In terms of the dynamic dimension, Ibourk et al. (2004) and Fahr and Sunde (2006a) find that the regional heterogeneity of matching efficiencies is quite stable over time as well as that regional demographic factors affect the regional heterogeneity of matching efficiencies.

Here, we can suppose that the regional heterogeneity of matching efficiencies could vary over time when exogenous shocks happen based on one stream of the literature.

For the case of overall shocks, for example, Barnichon and Figura (2015) verify that the negative labor demand shock of the Great Recession deteriorated the matching efficiency in the United States through a composition change in unemployment with different search intensities. This evidence seems to be supported by the finding of Haller and Heuermann (2016), who find that employment policy in Germany (i.e., the Hartz Reform) has magnified the spatial extent of inter-regional job search.

On the effects of region-specific exogenous shocks on the job matching process, Manning and Petrongolo (2017) reveal that positive region-specific labor demand shocks generate spatial spillover effects; in other words, outflows from unemployment in neighboring regions increase through inter-regional job search. Higashi (2018) shows that the Great East Japan Earthquake, which was a region-specific shock, boosted the spatial extent of inter-regional job search for job seekers living around the damaged area. These results suggest that region-specific shocks can change the regional heterogeneity of matching efficiencies with spatial spillovers through a composition change in unemployment.

This paper explores whether region-specific exogenous shocks alter regional matching efficiencies using panel data on the Japanese public employment referral service. We incorporate spatial spillover effects into our empirical models. To explore our research questions, the Great East Japan Earthquake in March 2011 is adopted as a region-specific exogenous shock. This earthquake generated a massive tsunami and a serious accident at a nuclear power plant, decimating the Pacific Coast area in northeast Japan and changing the conditions in the labor markets around the damaged area. To identify the effects of the earthquake on regional matching efficiencies, we use the difference-in-differences (DID) approach to compare before and after the earthquake. We also introduce a model that explores the transition of the effects of the earthquake over time, rather than only before and after. To incorporate spatial spillovers, we set two types of treatment groups for the direct and spatial spillover effects, namely the directly damaged area and its adjacent areas, following Belasen and Polachek (2009), who examine the effects of hurricanes on local labor markets.

We find that the regional matching efficiencies in the area directly damaged by the tsunami temporarily deteriorated. This tendency did not exhibit spatial spillover effects to neighboring regions unlike labor market tightness (i.e., the ratio of the stocks of vacancies to the unemployed), which became persistently larger and exhibited spatial spillovers. These results suggest that a composition change in unemployment in terms of search intensity in the area directly damaged by the tsunami generated higher search frictions. No spatial spillover effects were observed because no composition change might have occurred in an area not directly damaged by the tsunami, which may have different industrial structures from those in the directly damaged area. The spatial spillover effects of labor market tightness stemmed from labor shortages in the damaged area owing to reconstruction projects, which pulled job seekers from neighboring regions without a composition change.

The rest of this paper is organized as follows. Section 2 describes the regional job matching efficiency in the matching function. Then, we present the empirical models that identify the effects of the earthquake. Section 3 describes our data. Section 4 presents the estimation results on the effects of the earthquake on local labor markets and discusses the impacts on the matching efficiency. Section 5 concludes.

## 2. Model

### *2.1. Regional matching efficiency*

To describe the regional matching efficiency, we first specify the matching function. We assume that the matching function is a Cobb–Douglas form, which is often adopted by empirical studies (Petrongolo and Pissarides, 2001), as follows:

$$M_{it} = \mu_{it} U_{it-1}^{\eta_1} V_{it-1}^{\eta_2}, \tag{1}$$

where $M_{it}$ denotes the outflows from unemployment in region $i$ during period $t$. $U_{it-1}$ and $V_{it-1}$ are the stocks of unemployed job seekers and vacancies in region $i$ at the beginning of period $t$, respectively. $\eta_1$ and $\eta_2$ are the elasticities of the outflows from unemployment with respect to the stocks of unemployed and vacancies, respectively. Finally, $\mu_{it}$, our parameter of interest, represents the matching efficiency in region $i$ during period $t$.

We can consider that the matching efficiency corresponds to technology in the production function. If job seekers or vacancies have high search intensities, the matching efficiency in the economy improves. As a result, the number of matches of job seekers with vacancies increases (Pissarides, 2000).

Some previous studies empirically reveal that the composition of the attributes of unemployed job seekers, such as unemployment duration, reasons for unemployment, and individual characteristics, are significant factors determining matching efficiencies in the economy (e.g., Petrongolo, 2001; Sasaki et al., 2013; Barnichon and Figura, 2015). Their findings suggest that the heterogeneous attributes of unemployed job seekers have heterogeneous search intensities. We can suppose that if the composition of unemployment in one region varies, the matching efficiency there changes. Thus, region-specific exogenous shocks can trigger changing regional matching efficiencies through a composition change in unemployment.

A change in the regional heterogeneity of matching efficiencies would vary the intensities of inter-regional job search, generating spatial spillover effects from regions in which shocks are arising to neighboring regions. We describe how to empirically measure such spatial spillover effects in the following subsection.

The matching efficiencies across regions and time periods, $\mu_{it}$, are unobservable from the data. Therefore, we predict them by estimating the matching function. The parameters $\eta_1$ and $\eta_2$ are estimated using a regression of the log-linear form of equation (1). Given the estimated parameters, denoted as $\hat{\eta}_1$ and $\hat{\eta}_2$, the matching efficiencies are predicted as follows:

$$\widehat{\ln \mu_{it}} = \ln M_{it} - \hat{\eta}_1 \ln U_{it-1} - \hat{\eta}_2 \ln V_{it-1}. \tag{2}$$

Practically, we estimate the matching function in a log-linear form with a region fixed effect, $\psi_i$, and a time fixed effect, $\varphi_t$, given by

$$\ln M_{it} = \eta_1 \ln U_{it-1} + \eta_2 \ln V_{it-1} + \psi_i + \varphi_t + \varepsilon_{it}, \tag{3}$$

where $\varepsilon_{it}$ is an error term. The predicted log of the matching efficiency, $\widehat{\ln \mu_{it}}$, in equation (2) is obtained as a residual, $\hat{\varepsilon}_{it}$, derived from equation (3). The predicted matching efficiency is a form that excludes a time-invariant region-specific matching efficiency, $\psi_i$, and an all-region common time-specific matching efficiency, $\varphi_t$.

### *2.2. Identification of the effects of region-specific shocks*

To investigate the effects of region-specific exogenous shocks on regional matching efficiencies, we adopt the Great East Japan Earthquake in March 2011 as a natural experiment. This earthquake destroyed numerous buildings and many people fell victim. Furthermore, the resulting tsunami also caused a serious nuclear accident at the Fukushima Daiichi Nuclear Power Station. The Japanese government set the area surrounding the power station as an evacuation zone to protect people against radioactive contamination.

We utilize the DID approach to identify the effects of these series of disasters on local labor markets.[1] Panel (a) of Figure 1 illustrates the distribution of regions by the treatment and control groups for the DID estimation. We define two types of treatment groups based on the extent of damage. The first is the coastal area group, which suffered direct and serious damage from the tsunami. The second is the nuclear disaster area group, which contains the evacuation zones.[2] In the coastal area, residents have the option to remain living there or move to another region. By contrast, in the nuclear disaster area, residents in the evacuation zone must move because the government has prohibited them from living there. Moreover, the characteristics and degree of urgency of reconstruction projects differ between these treatment groups. While the tsunami destroyed buildings only physically, the nuclear disaster contaminated land through radioactivity. Therefore, the impacts of the earthquake on job matching are assumed to differ between the coastal area and nuclear disaster area.

[Figure 1 about here]

Spatial spillover effects from directly damaged regions to their neighboring regions could also arise through the spatial interactions among local labor markets. Focusing on the spatial spillover effects of disasters, Belasen and Polachek (2009) examine the impact of hurricanes on local labor markets in Florida by applying the DID approach. They define one treatment group that directly suffers from hurricanes and another adjacent to the directly damaged area, finding that the DID estimator in terms of the latter treatment group captures the spatial spillover effect. Applying their idea, we add

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[1] See Angrist and Pischke (2009) for the DID method in detail.

[2] The evacuation zones consist of three types of areas: the difficult-to-return zone, restricted residence area, and zone in preparation for the lifting of the evacuation order. The evacuation zones in this study are categorized as of December 31, 2013. The regional distribution of the evacuation zones is available from the website of the Ministry of Economy, Trade and Industry (http://www.meti.go.jp/earthquake/nuclear/hinan_history.html, accessed on December 12, 2018; in Japanese).

another two groups: adjacent to the coastal area and the adjacent to the nuclear disaster area. Then, our DID specification is given by

$$\begin{aligned} Y_{it} = \alpha + \beta_1 Coast_i + \beta_2 AdjCoast_i + \beta_3 Nuclear_i + \beta_4 AdjNuclear_i \\ + \gamma After_t \\ + (\delta_1 Coast_i + \delta_2 AdjCoast_i + \delta_3 Nuclear_i \\ + \delta_4 AdjNuclear_i) \times After_t + \xi_{it}, \end{aligned} \tag{4}$$

where $Y_{it}$ is the outcome (i.e., the predicted matching efficiency) in region $i$ during period $t$. $Coast_i$ is a dummy variable that takes one if region $i$ belongs to the coastal area group, and zero otherwise. $AdjCoast_i$ is a dummy variable taking one if region $i$ is in the adjacent to the coastal area group, and zero otherwise. Similarly, $Nuclear_i$ and $AdjNuclear_i$ are the nuclear disaster area group dummy and adjacent to the nuclear disaster area group dummy, respectively. $After_t$ is a dummy variable taking one if period $t$ is after March 2011, when the Great East Japan Earthquake occurred, and zero otherwise. We are interested in four parameters of the interaction terms of the treatment group dummies with $After_t$, which capture the effects of the disasters on the outcomes. $\delta_1$ and $\delta_2$ capture the direct and spatial spillover effects of the tsunami, respectively. $\delta_3$ and $\delta_4$ capture the direct and spatial spillover effects of the nuclear disaster, respectively. Lastly, $\alpha$ is a constant term, $\beta_1$ to $\beta_4$ are the coefficients of the treatment dummies, $\gamma$ is a coefficient of $After_t$, and $\xi_{it}$ is an error term.

Equation (4) compares the average levels of the outcomes before and after the earthquake. This equation cannot measure the transition of the level of outcomes over time. However, the magnitudes of the effects might change over time. Our data allow us to explore this dynamic dimension because there are a sufficient number of time periods (i.e., 72 months after the earthquake). Then, another specification is given by

$$
\begin{aligned}
Y_{it} = \alpha + \beta_1 Coast_i + \beta_2 AdjCoast_i + \beta_3 Nuclear_i + \beta_4 AdjNuclear_i \\
+ \sum_{\tau=Aug.2003}^{Mar.2016} [\gamma_\tau Time_\tau \\
+ (\delta_{1\tau} Coast_i + \delta_{2\tau} AdjCoast_i + \delta_{3\tau} Nuclear_i \\
+ \delta_{4\tau} AdjNuclear_i) \times Time_\tau] + \xi_{it},
\end{aligned}
\tag{5}
$$

where $Time_\tau$ is a time period dummy. An initial period dummy (i.e., July 2003 dummy in our data) is omitted as a benchmark. We focus on the transitions of the magnitudes of the parameters of the interaction terms, $\delta_{1\tau}$ to $\delta_{4\tau}$, over time.

## 3. Data

The Japanese monthly and regional panel data for our analyses come from the Report on Employment Service, provided by the Employment Security Bureau, Ministry of Health, Labour and Welfare. The monthly panel data are aggregated at the Public Employment Security Office (PESO) jurisdiction region unit. We utilize the records for the PESO jurisdiction regions in Iwate, Miyagi, and Fukushima Prefectures, which most seriously suffered from the Great East Japan Earthquake, as well as their surrounding prefectures.[3] Ultimately, we analyze monthly panel data from July 2003 to March 2016, which are the longest periods available, of 95 PESO jurisdiction regions.[4]

We obtain the following variables concerning job matching for our analysis: the

[3] The surrounding prefectures are Aomori, Akita, Yamagata, Ibaraki, Tochigi, Gunma, and Niigata Prefectures.

[4] To construct balanced panel data, we arrange the data as follows. First, certain types of PESOs that provide referral serves only for some job seekers (e.g., foreigners, older people, and women) are eliminated from our sample because their wider jurisdiction areas than general PESOs do not allow us to arrange a coherent regional unit. Second, some PESOs merged during the sample period; therefore, we reaggregate PESOs' records in each period as of 2015, when the last merger occurred. Higashi (2018) handles the same data in the same way.

stock of unemployed, stock of vacancies, and outflows from unemployment. The stock of unemployed (the original dataset labels these "active applicants") is the number of job seekers who register with the local PESOs. If job seekers are active, they remain in the records. If job seekers are inactive, they are removed from the records within about three months. The stock of vacancies (the original dataset labels these "active job openings") is the number of vacancies registered with the PESOs in the locations of the main or branch offices of firms with vacancies. Similar to the stock of the unemployed, inactive vacancies are removed from the records within about three months. Outflows from unemployment (the original dataset labels these "persons who found employment") represent the number of job seekers who match with vacancies through the mediation of PESOs during one month. Outflows from unemployment are counted in the records of the PESOs with which job seekers initially registered regardless of the vacancies with which they ultimately matched.

Our data have the following three features. First, they cannot identify full-time and part-time vacancies. Second, according to the 2000–2016 Survey on Employment Trends provided by the Ministry of Health, Labour and Welfare, only about 20% of workers find jobs through PESOs. Third, low-skilled job seekers and low-waged vacancies are mainly registered with PESOs (Kodama et al., 2004; Japan Institute for Labour Policy and Training, 2015). Despite such features, these data have the broadest coverage of job matching in the Japanese labor market. However, we must be mindful of these features when interpreting the results of our analyses.

As mentioned in Section 2.2, sample regions are classified into four treatment groups, namely the coastal area, adjacent to the coastal area, nuclear disaster area, and adjacent to the nuclear disaster area, as well as the control group.[5] Table 1 shows the summary statistics of the flow and stock variables for our analyses by these region groups. For all groups, labor market tightness increases after the earthquake. Even so, different region groups have different local labor market features. After the earthquake, excess labor demand (i.e., a value of labor market tightness above one) is observed for the coastal area, nuclear disaster area, and adjacent to the nuclear disaster area groups, but not for the adjacent to the coastal area and control groups. Furthermore, the rates of increase in labor market tightness are particularly large (i.e., more than double) for the coastal area and nuclear disaster area groups. These facts suggest that the earthquake results in serious labor shortages in those groups' regions. Hence, labor demand related to earthquake disaster reconstruction projects for those regions in the coastal area and nuclear disaster area groups tends to be higher.

[Table 1 about here]

Based on the descriptive evidence, we suppose that the catastrophic earthquake causes structural change in local labor markets. This structural change differs across region groups. Therefore, earthquakes, or more generally region-specific exogenous shocks, could have different regional effects on matching efficiencies. The next section explores this conjecture using regression analysis.

## 4. Results

### *4.1. The DID for the direct and spatial spillover effects*

We first discuss labor market tightness to comprehend the effects of the earthquake on local labor markets. Thereafter, we focus on the effects on regional

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[5] Table A1 lists the sample PESO jurisdictions regions by the treatment and control groups.

matching efficiency.

Table 2 provides the DID estimation results of the effects of the earthquake on labor market tightness. Column (1) shows the result of the model only with the coastal area as the treatment group. The parameter of the interaction term between the coastal area group dummy and the after-earthquake dummy is positive and significant, suggesting that local labor markets in tsunami-hit coastal areas face more labor shortages after the earthquake than the control group.

[Table 2 about here]

As shown in column (2), the DID model that also includes the adjacent to the coastal area treatment group finds a significantly positive spatial spillover effect, as represented by the parameter of the interaction term of the adjacent to the coastal area group dummy with the after-earthquake dummy as well as the direct effect. The magnitude of the spatial spillover effect is around half that of the direct effect. The tsunami's destruction of many buildings in coastal areas generated high labor demand for reconstruction projects.[6] As a result, labor demand inequality between the tsunami hit-area and other areas occurred. Therefore, local labor markets in the coastal area pulled job seekers from neighboring regions. At the same time, firms located adjacent to the coastal area also received demand for reconstruction projects in the coastal area. In addition, more out-migration from the coastal area occurred than in the other regions.[7] Consequently, the effects of the labor shortages in the coastal area diffused over neighboring regions. To sum up, we should consider the spatial spillover effects when estimating DID models using regional data since regions exhibit spatial interactions with each other.

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[6] See Higuchi et al. (2012) and Cabinet Office (2016).
[7] See Table A2.

The models in columns (1) and (2) do not identify the effects of the nuclear disaster. In other words, the coastal area and adjacent to the coastal area contain regions affected by the nuclear disaster.[8] The model in column (3) distinguishes the nuclear disaster area and adjacent to the nuclear disaster area from the others. The parameters of the interaction term of the nuclear disaster area and the interaction term of the adjacent to the nuclear disaster area are both positive and significant. With regard to the direct effect of the tsunami, the magnitude of the parameter of the interaction term of the coastal area falls, suggesting that if the model does not take the nuclear disaster into account, the impact of only the tsunami is overestimated. We find that the nuclear disaster leads to larger labor shortages than just the tsunami disaster.

The spatial spillover effect of the nuclear disaster is also larger than that for just the tsunami disaster (see column (3)). After the earthquake, the land around the Fukushima Daiichi Nuclear Power Station was contaminated by radioactivity, necessitating urgent decontamination.[9] However, the extraordinary characteristics of employment for dealing with the nuclear disaster generated more labor shortages. For example, firms conducting decommissioning work at the power plant always had to employ new workers because of the limitations on work days to reduce the risk to health from radioactive contamination.[10] Furthermore, jobs related to the decommissioning work and decontamination of land were unpopular for job seekers, since they were physically demanding and carried health risks.[11] Labor supply was also low because of

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[8] See panel (b) of Figure 1.
[9] See the website of the Japan Atomic Energy Commission (http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2011/siryo33/siryo1-2.pdf, accessed on January 17, 2019; in Japanese).
[10] See the website of the Tokyo Electric Power Company Holdings, Inc. (http://www.tepco.co.jp/decommission/progress/environment/index-j.html, accessed on January 17, 2019; in Japanese).
[11] See Kitamura (2014), Fukushima Minpo (2012), and Fukushima Minyu Shinbun

large out-migration from evacuation zones.

Second, we consider the effects on regional matching efficiencies predicted from the matching function of equation (3).[12] Table 3 contains the estimation results of the DID analysis for these regional matching efficiencies. According to the model only examining the effect of the tsunami in column (1), the parameter of the interaction term is significantly negative. One possible factor causing this negative effect on regional matching efficiencies is the change in the composition of the attributes of the unemployed registered with the PESOs in the coastal area.[13] In the case of overall shocks, Barnichon and Figura (2015), using U.S. data, reveal that a negative labor demand shock such as the Great Recession deteriorates matching efficiencies through the composition change in unemployment. We consider that a similar tendency arises in regions in the coastal area. This negative effect is also verified in the model by considering the spatial spillover effect in column (2). However, unlike labor market tightness, the spatial spillover effect is insignificant.

[Table 3 about here]

After incorporating the nuclear disaster, the spatial spillover effect of the tsunami becomes significantly negative, as shown in column (3). In terms of the nuclear disaster, the direct and spatial spillover effects are significantly negative and positive, respectively. The reason why the insignificant spatial spillover effect of the tsunami becomes significant after incorporating the nuclear disaster is that the positive spatial spillover effect of the nuclear disaster cancels out the negative spatial spillover effect of the tsunami. The positive spatial spillover effect of the nuclear disaster suggests that after the

(2018).

[12] Table A3 contains the estimation result of elasticities in the matching function.

[13] Another possibility is that the operations of the PESOs in the coastal area worsened.

earthquake, it became easier for job seekers in regions adjacent to the nuclear disaster area to succeed in matching vacancies.[14] To explore this point further, in the next subsection, we consider the transition of the level of outcomes over time.

### *4.2. Transition of the direct and spatial spillover effects over time*

Here, as before, we first focus on labor market tightness. Then, we discuss the matching efficiencies.

Figure 2 shows the estimation results of the transition of the effects of the earthquake on labor market tightness over time from equation (5). This figure plots the marginal effects by region group. Panel (a) provides the result of the model containing only the coastal area group as the treatment group to examine the direct effect of the tsunami. Before the earthquake in March 2011, labor market tightness in the coastal area and control groups exhibit a similar trend. After mid-2012, the gap in labor market tightness between the coastal area and control groups becomes statistically significant. Labor market tightness in the coastal area is persistently and significantly larger than that in the control group thereafter. Some periods exhibit a statistically significant gap between the coastal area and control groups before the earthquake; nevertheless, we conclude that the earthquake creates a structural change in labor market tightness in the coastal area compared with the control group, since the magnitude relation of labor market tightness is reversed.[15] This result for the coastal area (i.e., the direct effect) is

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[14] A region's matching efficiency is evaluated on the basis of job seekers registered with the PESO in the corresponding region, owing to the definition of the dependent variable (i.e., outflows from unemployment) in our data (see Section 3). In other words, a region's matching efficiency indicates how efficiently job seekers in the corresponding region succeed in matching with vacancies regardless of the locations of the vacancies.

[15] The same occurs for panels (b) and (c).

also confirmed after taking the spatial spillover effect into account, as shown in panel (b).

[Figure 2 about here]

In terms of the spatial spillover effect of the tsunami, panel (b) illustrates that labor market tightness in the adjacent to the coastal area group also becomes significantly larger than that in the control group after mid-2012. This magnitude is lower than that for the coastal area. The significant gap in labor market tightness between the adjacent to the coastal area and control groups disappears until 2014. In early 2014, the gap between the coastal and adjacent to the coastal areas also becomes not significantly different from zero. These results suggest that the tsunami directly generates larger labor shortages in the coastal area. This effect spreads to the adjacent to the coastal area, not immediately after the earthquake in March 2011, but about 15 months later.

Panel (c) shows the result of the model incorporating the nuclear disaster. Labor market tightness in the nuclear disaster area group is significantly larger than that for the control group after mid-2011. This change happens earlier than for the coastal area group. This large effect in the nuclear disaster area continues to be significant compared with the control group over time. Furthermore, after the earthquake, the effect in the nuclear disaster area is significantly larger than that in the coastal area until mid-2012. In terms of the adjacent to the coastal area and adjacent to the nuclear disaster area groups, we hardly find a statistically significant gap compared with the control group in most periods, even after the earthquake. Similar to the case for the DID in Table 2, the model ignoring the nuclear disaster overestimates the spatial spillover effect of the tsunami. Although statistical significance is incomplete, the ranking of the point estimates is stable over time after the earthquake. That is, the nuclear disaster area is the highest, followed by the coastal area, adjacent to the nuclear disaster area, adjacent to the coastal area, and control group in that order. These results are consistent with the DID estimations in Table 2, suggesting that, as mentioned in the previous subsection, the nuclear disaster leads to more severe labor shortages than the tsunami disaster. Such spatially heterogeneous labor market tightness owing to the earthquake could be associated with the different regional matching efficiencies.

Again, Figure 3 considers the effects on the matching efficiency. According to the result of the model with one treatment group (i.e., the coastal area) in panel (a), a significantly spectacular and temporal negative shock in the coastal area seems to arise in March and April 2011. However, we do not focus on this shock because it only captures the fact that some PESOs in the coastal area could not avoid shutting down during these months because of the effects of the tsunami.[16] It does not reflect the economic state but rather physical problems.

[Figure 3 about here]

Except for the shutdown effects of some PESOs, the tsunami disaster exhibits a negative direct effect on the matching efficiencies in the coastal area group between the middle and end of 2011. Other periods, however, show almost no differences in matching efficiencies between the coastal area and control groups. This direct effect in the coastal area group is also confirmed for the model taking the spatial spillover effect of the tsunami into account, as shown in panel (b).

In the coastal area, the marine product industry was damaged by the tsunami, causing a negative labor demand shock. As a result, the number of unemployed job

[16] See the press releases issued by the Ministry of Health, Labour and Welfare, "*Higashinihondaishinsai ni tomonau rodokijunkantokusho, HelloWork no kaicho jokyo nitsuite, dai 1–12 hou* (The status of opening of the Labor Standards Inspection Office and the HelloWork due to the Great East Japan Earthquake, no. 1–12)" (https://www.mhlw.go.jp/stf/houdou/2r98520000015q3n.html, accessed on December 1; in Japanese).

seekers who had previously worked in that industry increased there.[17] This fact allows us to make the following conjectures. Many unemployed workers in the coastal area might not be immediately able to find jobs other than in the marine product industry. A few months after the earthquake, they register themselves as job seekers with their local PESOs. In other words, the composition of the attributes of unemployed job seekers in terms of search intensities changes relative to before the earthquake. Such a composition change generates larger search frictions within the corresponding local labor markets, as mentioned in the previous subsection. After a while, matching efficiencies return to the previous level. This reflects that job seekers gradually find jobs by spending sufficient time searching. At the same time, job seekers with a better ability to find jobs, such as the unemployed who can afford to pay relatively high search costs and have higher skills, might leave the coastal area to search for jobs. Then, the average ability to find jobs by the job seekers remaining in the coastal area lowers. This is also a composition change in terms of the search intensities.

Unlike the direct effect of the tsunami, the negative spatial spillover effect of the tsunami is not observed, except for the effects of the shutdown of PESOs. This result indicates that the search frictions of the above conjecture do not spatially diffuse over regions. Job seekers residing in regions adjacent to the coastal area have relatively more success in finding jobs. It reflects that the significant composition change in unemployment is small. This is because the industrial structure there is different from that in the coastal area or those firms hardly suffered from the tsunami.

Panel (c) illustrates the result of the model incorporating the nuclear disaster. The transitions of the effects in the coastal area and adjacent to the coastal area groups

[17] Matsumoto (2012) refers to the relationship between employment and the Great East Japan Earthquake in detail.

are still similar to those in panels (a) and (b).

The result of the insignificant spatial spillover effect of the tsunami for the adjacent to the coastal area group in panel (c) conflicts with the DID result in column (3) of Table 3, reporting significantly negative effects. The reason is that the DID model captures the impacts of the PESOs' shutdown, which seems to be noise for our research. This DID result can result in misleading interpretations for this study. We find that exploring the transitions of the effects is therefore useful.

To be easily viewable, panel (c.1) abstracts only the lines for the nuclear disaster area, adjacent to the nuclear disaster area, and control groups from panel (c). The effect of the PESOs' shutdown is also observed in the nuclear disaster area. Unlike the case for the coastal area group, we cannot find a significant gap in matching efficiencies among the nuclear disaster area, adjacent to the nuclear disaster area, and control groups. Although statistical significance is not reached, the point estimates of the nuclear disaster area group seem to be lower than those of the control group for several months in 2011 and 2012. This result indicates that the search frictions in the nuclear disaster area rise slightly. However, it is difficult for us to distinguish this using our data since the standard errors in terms of the nuclear disaster area group, which contains only three regions, tend to be large.

## 5. Conclusion

This paper examined whether region-specific exogenous shocks alter regional job matching efficiencies using monthly regional panel data from the Japanese public employment referral service. As a region-specific shock, we adopted the Great East Japan Earthquake in March 2011. Sample regions were classified into two treatment groups, namely the coastal area, directly suffering from the tsunami, and nuclear disaster area groups. To capture the spatial spillover effects, we additionally introduced the adjacent to the coastal area and adjacent to the nuclear disaster area as further treatment groups.

Before discussing the regional matching efficiencies, we confirmed that the earthquake indeed exhibited persistent direct and spatial spillover effects on local labor market conditions; that is, labor market tightness in the four treatment groups turned out to be larger after the earthquake. These facts suggested that labor shortages owing to reconstruction projects arose in the directly damaged area and spatially diffused over other regions.

In terms of regional matching efficiencies, we found that those in the coastal area group temporally deteriorated after the earthquake, suggesting that higher search frictions arose in the area directly damaged by the tsunami, caused by a composition change in unemployment with regard to the search intensities there. After a while, the matching efficiencies recovered because job seekers gradually succeeded in finding jobs by spending sufficient time searching. Unlike labor market tightness, the spatial spillover effect of the tsunami was statistically insignificant, suggesting that the composition of unemployment did not change in the area not directly damaged by the tsunami owing to the different industrial structures. For the nuclear disaster, both the direct and the spatial spillover effects were insignificant. The point estimate for the direct effect seemed to be similar to that for the coastal area, although it was statistically insignificant. Regardless we could not emphasize, we considered that a composition change in unemployment might also have occurred in the nuclear disaster area.

Our findings provide regional employment policy implications to deal with region-specific exogenous shocks such as natural disasters. To improve regional matching efficiencies that have fallen because of exogenous shocks, it seems helpful for policymakers to center moderating search frictions owing to a composition change in unemployment on damaged areas. Specifically, policymakers should encourage job seekers to change occupations or industries if they are reluctant to do so even though they have the relevant skills. This policy seems to be feasible since our evidence shows that matching efficiencies recover after a while. What policymakers must do is induce this tendency earlier.

Another contribution is finding that we must pay attention when adopting the DID approach. If researchers estimate the DID model for panel data including uncertain spectacular shocks other than the research interest, they have a risk of misleading interpretations. To deal with this, we should confirm the transitions of the effects over time if the data have sufficient time periods.

Finally, a limitation of this study is that our analyses do not explicitly measure a composition change in unemployment. For further research, it would be useful to analyze panel data disaggregated at the levels of some attribute of the unemployed as well as at the region level. Such data must include periods with significant region-specific exogenous shocks.

## Appendix

[Tables A1–A3 here]

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Table 1: Summary statistics of the flow and stock variables for the estimations by region group

| Variable | Before the earthquake (July 2003–February 2011) | | | | After the earthquake (March 2011–March 2016) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Min | Max | Mean | Std. Dev. | Min | Max |
| *(a) Coastal area (7 regions)* | | | | | | | | |
| Outflows from unemployment | 272 | 109 | 87 | 605 | 292 | 137 | 42 | 814 |
| Stock of unemployment | 2493 | 1083 | 1195 | 5484 | 2463 | 1653 | 856 | 11205 |
| Stock of vacancies | 1285 | 819 | 353 | 5154 | 2408 | 1381 | 550 | 6123 |
| Labor market tightness | 0.50 | 0.15 | 0.16 | 1.30 | 1.13 | 0.48 | 0.17 | 2.26 |
| *(b) Adjacent to coastal area (11 regions)* | | | | | | | | |
| Outflows from unemployment | 432 | 281 | 95 | 1472 | 432 | 293 | 81 | 1588 |
| Stock of unemployment | 4618 | 3303 | 1144 | 14015 | 4001 | 3077 | 722 | 14032 |
| Stock of vacancies | 2891 | 2531 | 351 | 11642 | 3805 | 3047 | 469 | 12518 |
| Labor market tightness | 0.62 | 0.26 | 0.19 | 1.41 | 0.96 | 0.26 | 0.32 | 1.67 |
| *(c) Nuclear disaster area (3 regions)* | | | | | | | | |
| Outflows from unemployment | 530 | 124 | 277 | 858 | 501 | 204 | 141 | 944 |
| Stock of unemployment | 6390 | 2235 | 2853 | 12671 | 5231 | 2574 | 1266 | 10930 |
| Stock of vacancies | 4510 | 2043 | 1626 | 9554 | 6601 | 2759 | 1812 | 11455 |
| Labor market tightness | 0.72 | 0.25 | 0.27 | 1.35 | 1.48 | 0.60 | 0.39 | 2.96 |
| *(d) Adjacent to nuclear disaster area (7 regions)* | | | | | | | | |
| Outflows from unemployment | 500 | 353 | 90 | 1655 | 553 | 405 | 119 | 1907 |
| Stock of unemployment | 6905 | 6847 | 1084 | 28934 | 6364 | 6632 | 1190 | 30522 |
| Stock of vacancies | 5418 | 7374 | 453 | 32038 | 8007 | 10950 | 920 | 39148 |
| Labor market tightness | 0.67 | 0.29 | 0.12 | 1.61 | 1.08 | 0.41 | 0.27 | 2.11 |
| *(e) Control group (67 regions)* | | | | | | | | |
| Outflows from unemployment | 304 | 215 | 53 | 1426 | 305 | 213 | 41 | 1591 |
| Stock of unemployment | 3565 | 2742 | 575 | 16869 | 3245 | 2549 | 486 | 15735 |
| Stock of vacancies | 2697 | 2897 | 291 | 22875 | 2956 | 2797 | 424 | 16984 |
| Labor market tightness | 0.75 | 0.39 | 0.08 | 4.39 | 0.90 | 0.31 | 0.16 | 2.29 |

Table 2: Estimation results of the DID for the direct and spatial spillover effects of the earthquake on labor market tightness

| Variable | Dependent variable: Labor market tightness (1) | (2) | (3) |
|---|---|---|---|
| After | 0.188*** | 0.144*** | 0.141*** |
| | (0.006) | (0.007) | (0.007) |
| Coast | -0.136*** | -0.162*** | -0.254*** |
| | (0.009) | (0.009) | (0.008) |
| Coast×After | 0.492*** | 0.536*** | 0.487*** |
| | (0.025) | (0.025) | (0.025) |
| Adjacent to coast | | -0.136*** | -0.137*** |
| | | (0.008) | (0.009) |
| Adjacent to coast×After | | 0.236*** | 0.205*** |
| | | (0.014) | (0.015) |
| Nuclear | | | -0.032** |
| | | | (0.016) |
| Nuclear×After | | | 0.616*** |
| | | | (0.047) |
| Adjacent to nuclear | | | -0.084*** |
| | | | (0.012) |
| Adjacent to nuclear×After | | | 0.269*** |
| | | | (0.024) |
| Constant | 0.727*** | 0.752*** | 0.754*** |
| | (0.004) | (0.005) | (0.005) |
| Number of observations | 14535 | 14535 | 14535 |
| Adj. $R^2$ | 0.135 | 0.149 | 0.158 |

Notes: Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3: Estimation results of the DID for the direct and spatial spillover effects of the earthquake on the matching efficiency

| | Dependent variable: Matching efficiency | | |
|---|---|---|---|
| Variable | (1) | (2) | (3) |
| After | 0.005** | 0.004 | 0.004 |
| | (0.002) | (0.003) | (0.003) |
| Coast | 0.017*** | 0.017*** | 0.019*** |
| | (0.005) | (0.005) | (0.007) |
| Coast×After | -0.043*** | -0.043*** | -0.047*** |
| | (0.009) | (0.009) | (0.012) |
| Adjacent to coast | | -0.001 | 0.006 |
| | | (0.004) | (0.004) |
| Adjacent to coast×After | | 0.002 | -0.016** |
| | | (0.005) | (0.007) |
| Nuclear | | | 0.028*** |
| | | | (0.005) |
| Nuclear×After | | | -0.071*** |
| | | | (0.011) |
| Adjacent to nuclear | | | -0.021*** |
| | | | (0.004) |
| Adjacent to nuclear×After | | | 0.052*** |
| | | | (0.007) |
| Constant | -0.002 | -0.002 | -0.001 |
| | (0.002) | (0.002) | (0.002) |
| Number of observations | 14535 | 14535 | 14535 |
| Adj. $R^2$ | 0.002 | 0.002 | 0.007 |

Notes: Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Table A1: List of sample regions by group

| No. | PESO | (Pref.) | No. | PESO | (Pref.) |
|---|---|---|---|---|---|
| *(a) Coast* | | | | | |
| 3020 | Kamaishi | (3) | 4020 | Ishinomaki | (4) |
| 3030 | Miyako | (3) | 4030 | Shiogama | (4) |
| 3080 | Ofunato | (3) | 4080 | Kesennuma | (4) |
| 3100 | Kuji | (3) | | | |
| *(b) Adjacent to coast* | | | | | |
| 2020 | Hachinohe | (2) | 4040 | Furukawa | (4) |
| 3010 | Morioka | (3) | 4070 | Hasama | (4) |
| 3040 | Hanamaki | (3) | 6010 | Yamagata | (6) |
| 3050 | Ichinoseki | (3) | 6070 | Murayama | (6) |
| 3060 | Mizusawa | (3) | 7050 | Shirakawa | (7) |
| 3090 | Ninohe | (3) | | | |
| *(c) Nuclear* | | | | | |
| 7010 | Fukushima | (7) | 7120 | Soso | (7) |
| 7040 | Koriyama | (7) | | | |
| *(d) Adjacent to nuclear* | | | | | |
| 4010 | Sendai | (4) | 7030 | Aizuwakamatsu | (7) |
| 4050 | Ogawara | (4) | 7060 | Sukagawa | (7) |
| 6020 | Yonezawa | (6) | 7080 | Nihonmatsu | (7) |
| 7020 | Taira | (7) | | | |
| *(e) Control* | | | | | |
| 2010 | Aomori | (2) | 9010 | Utsunomiya | (9) |
| 2030 | Hirosaki | (2) | 9020 | Kanuma | (9) |
| 2040 | Mutsu | (2) | 9030 | Tochigi | (9) |
| 2050 | Noheji | (2) | 9040 | Sano | (9) |
| 2060 | Goshogawara | (2) | 9050 | Ashikaga | (9) |
| 2080 | Misawa | (2) | 9060 | Moka | (9) |
| 2090 | Kuroishi | (2) | 9070 | Yaita | (9) |
| 3070 | Kitakami | (3) | 9080 | Ohtawara | (9) |
| 4060 | Tsukidate | (4) | 9090 | Oyama | (9) |
| 5010 | Akita | (5) | 9110 | Nikko | (9) |
| 5020 | Noshiro | (5) | 9120 | Kuroiso | (9) |
| 5030 | Odate | (5) | 10010 | Maebashi | (10) |
| 5040 | Omagari | (5) | 10020 | Takasaki | (10) |
| 5050 | Honjo | (5) | 10030 | Kiryu | (10) |
| 5060 | Yokote | (5) | 10040 | Isesaki | (10) |

| | | | | | |
|---|---|---|---|---|---|
| 5070 | Yuzawa | (5) | 10050 | Ota | (10) |
| 5080 | Kazuno | (5) | 10060 | Tatebayashi | (10) |
| 6030 | Sakata | (6) | 10070 | Numata | (10) |
| 6040 | Tsuruoka | (6) | 10080 | Gunmatomioka | (10) |
| 6050 | Shinjo | (6) | 10090 | Fujioka | (10) |
| 6060 | Nagai | (6) | 10100 | Shibukawa | (10) |
| 6080 | Sagae | (6) | 15010 | Niigata | (15) |
| 8010 | Mito | (8) | 15020 | Nagaoka | (15) |
| 8020 | Hitachi | (8) | 15030 | Joetsu | (15) |
| 8030 | Chikusei | (8) | 15040 | Sanjo | (15) |
| 8040 | Tsuchiura | (8) | 15050 | Kashiwazaki | (15) |
| 8050 | Koga | (8) | 15060 | Shibata | (15) |
| 8060 | Joso | (8) | 15070 | Niitsu | (15) |
| 8080 | Ishioka | (8) | 15080 | Tokamachi | (15) |
| 8090 | Hitachiomiya | (8) | 15100 | Itoigawa | (15) |
| 8100 | Ryugasaki | (8) | 15110 | Maki | (15) |
| 8110 | Takahagi | (8) | 15120 | Minamiuonuma | (15) |
| 8120 | Hitachikashima | (8) | 15130 | Sado | (15) |
| | | | 15140 | Murakami | (15) |

Notes: Prefecture number is reported in parentheses. 2: Aomori, 3: Iwate, 4: Miyagi, 5: Akita, 6: Yamagata, 7: Fukushima, 8: Ibaraki, 9: Tochigi, 10: Gunma, and 15: Niigata.

Table A2: Net-migration by region group (persons in thousands)

| | Coast | Adjacent to coast | Nuclear | Adjacent to nuclear | Control |
|---|---|---|---|---|---|
| FY2010 | -3.4 | -6.3 | -1.6 | -2.2 | -15.6 |
| FY2011 | -18.4 | 1.6 | -21.5 | -3.6 | -15.9 |
| FY2012 | -4.4 | -3.0 | -8.2 | 4.0 | -21.9 |
| FY2013 | -3.2 | -2.9 | -1.9 | 2.9 | -26.9 |
| FY2014 | -2.5 | -4.3 | 0.1 | 1.4 | -26.8 |
| FY2015 | -3.2 | -5.7 | 0.2 | -0.8 | -29.0 |
| FY2016 | -2.5 | -5.2 | -2.6 | -1.8 | -28.0 |

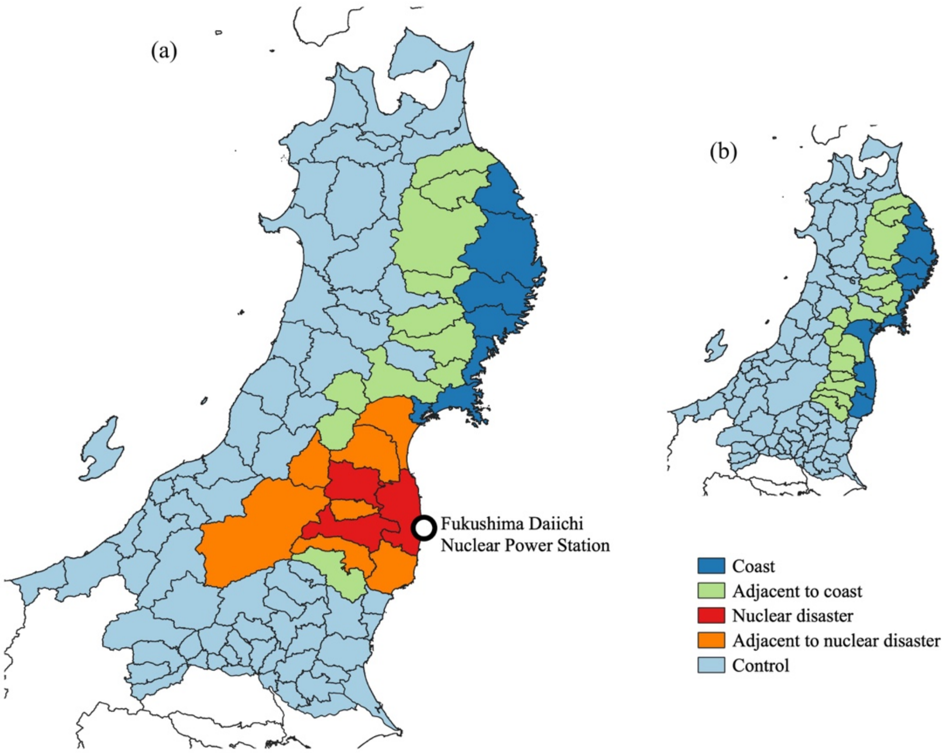
Notes: The Japanese fiscal year is from April 1 to March 31. A record of Yamatsuri-machi in Fukushima Prefecture, controlled by the Shirakawa PESO, is omitted owing to a loss of data.
Source: Author's calculation based on the Report on Internal Migration in Japan 2010–2016, provided by the Statistics Bureau, Ministry of Internal Affairs and Communications.

Table A3: Estimation result of the matching function

| Dependent variable: log of outflows from unemployment | |
|---|---|
| Variable | |
| $\ln U_{it-1}$ | 0.479*** |
| | (0.040) |
| $\ln V_{it-1}$ | 0.162*** |
| | (0.021) |
| Constant | 0.565* |
| | (0.323) |
| Number of observations | 14535 |
| Adj. $R^2$ | 0.607 |

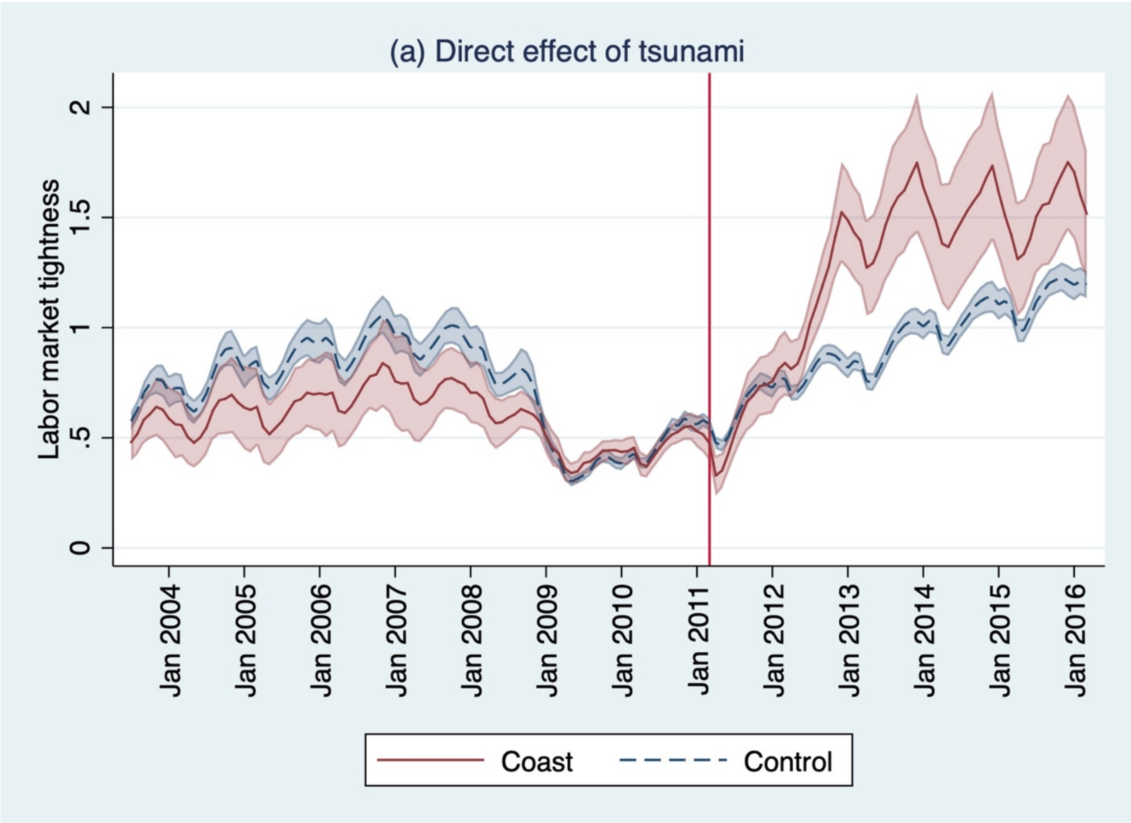
Notes: This model contains the region fixed effects and time dummies. Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

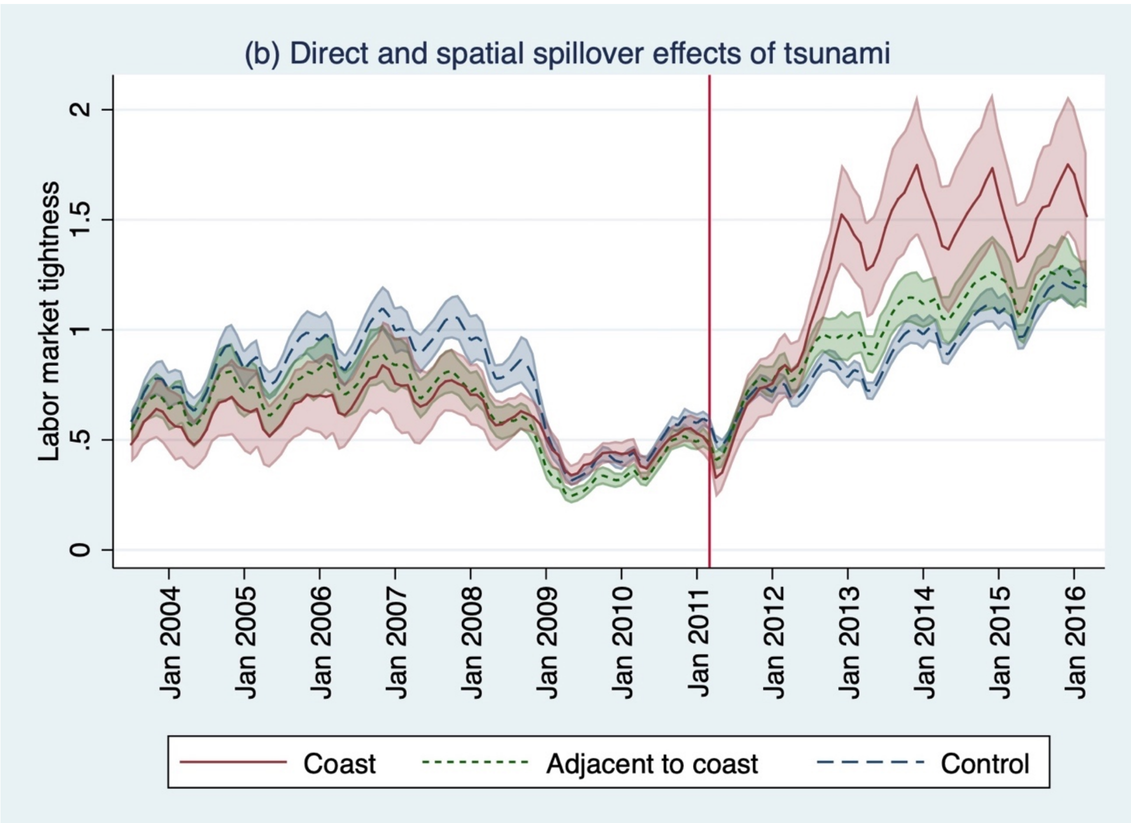
Figure 1: Distribution of the region groups

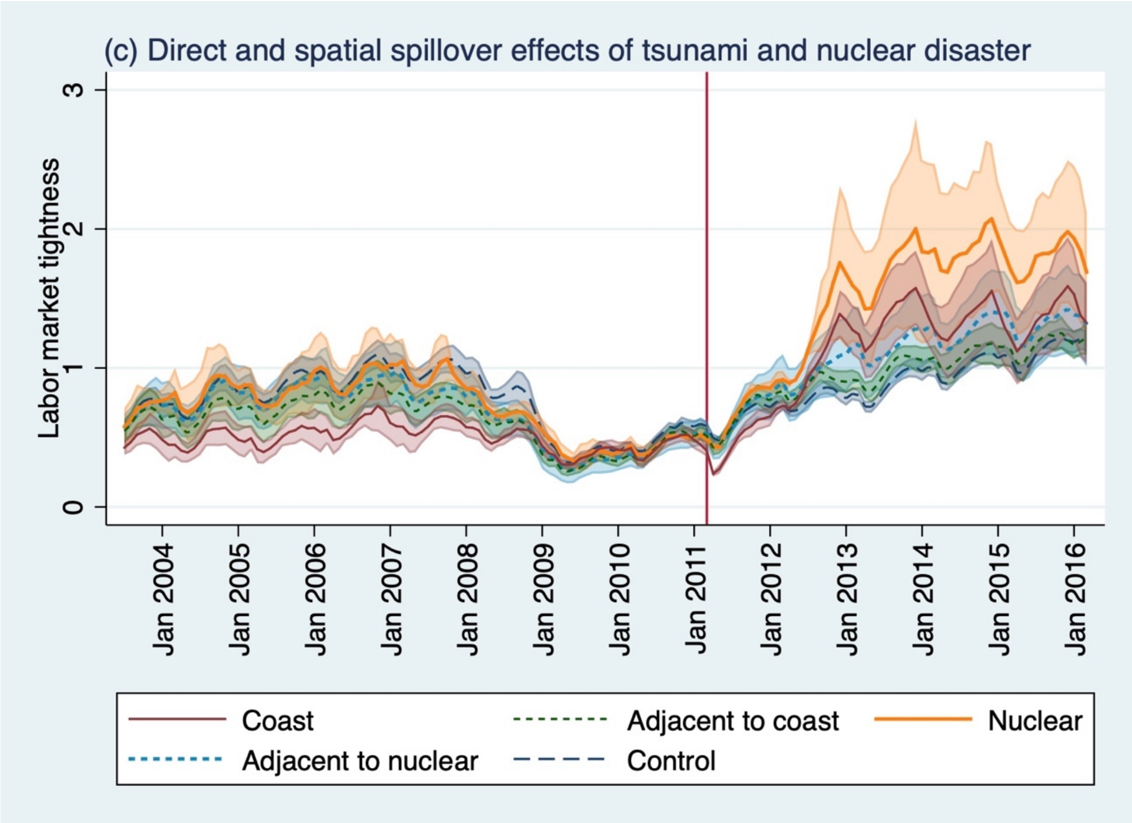



Notes: The region unit is the PESO jurisdiction. We create this figure by using the map data of the Administrative Zones Data 2015 (*Gyousei Kuiki Data Heisei 27 nen*) from the National Land Numerical Information download service, provided by the National Land Information Division, National Spatial Planning and Regional Policy Bureau, Ministry of Land, Infrastructure, Transport and Tourism (http://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-N03-v2_3.html, accessed on March 3, 2017).

Figure 2: Transition of the direct and spatial spillover effects of the earthquake on labor market tightness

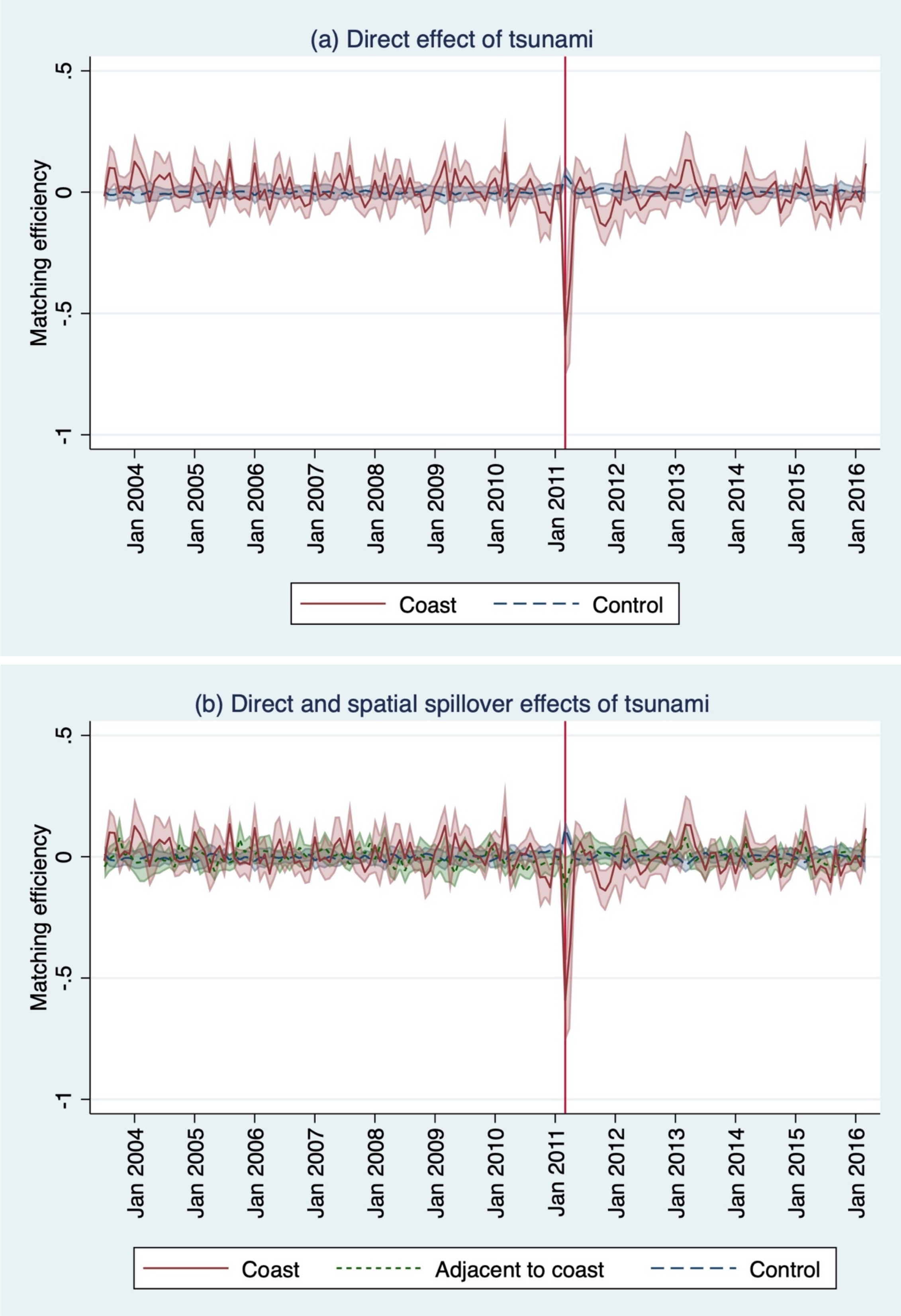


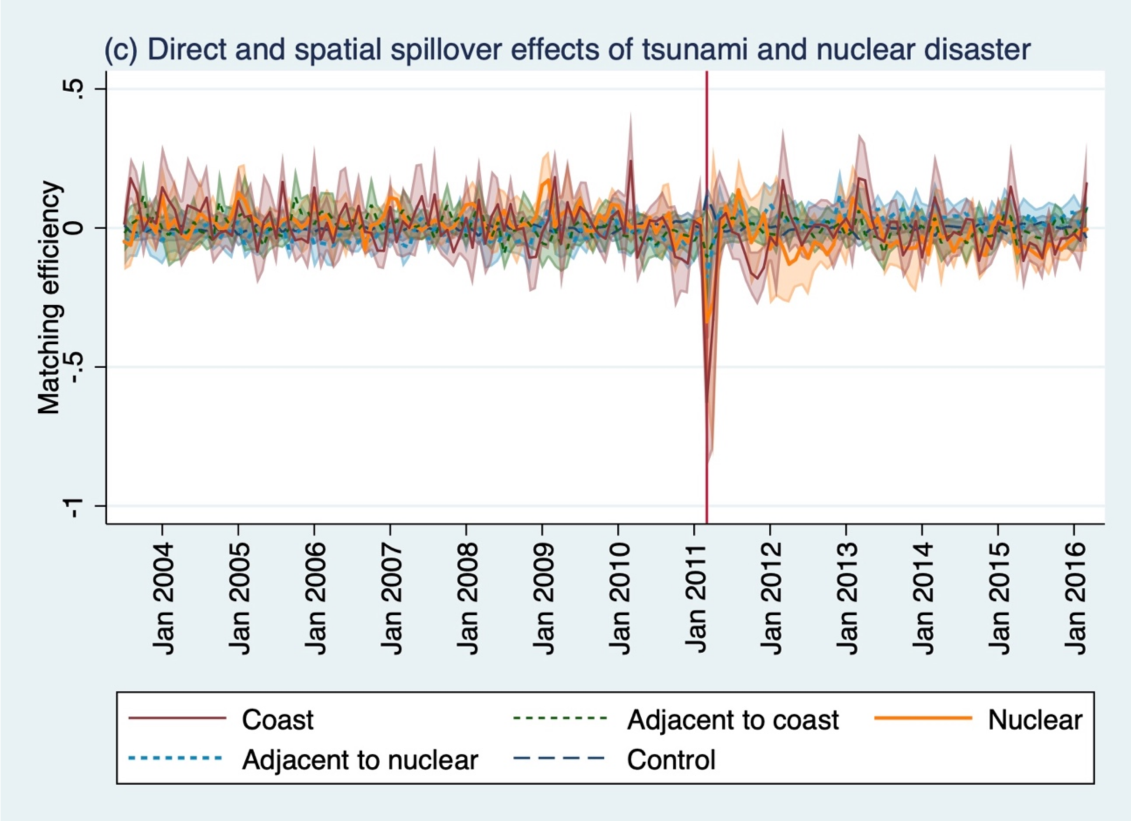



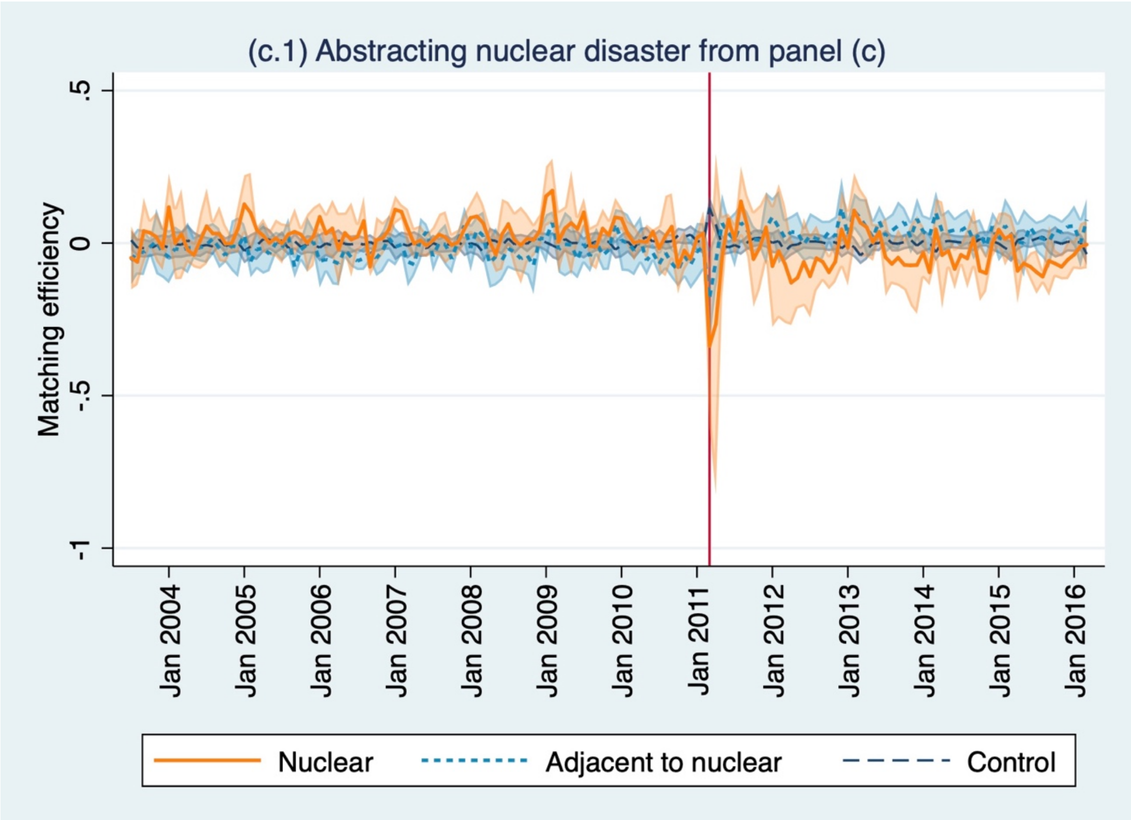



Notes: Shading represents the 95% confidence interval. Vertical line represents March 2011.

Figure 3: Transition of the direct and spatial spillover effects of the earthquake on the matching efficiency






Notes: Shading represents the 95% confidence interval. Vertical line represents March 2011.