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**The Effect of Transaction  
Partners' Location on Firms'  
Relocation Choice: A Natural  
Experiment using a Massive  
Earthquake in Japan**

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# **The effect of transaction partners' location on firms' relocation choice: A natural experiment using a massive earthquake in Japan\***

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# **The effect of transaction partners' location on firms' relocation choice: A natural experiment using a massive earthquake in Japan**

## **Abstract**

This study examines the role that the location of transaction partners plays in firms' location choice. To alleviate endogeneity concerns, we use data of Japanese firms that were forced to relocate due to the massive Tohoku earthquake in 2011. We find that firms tended to relocate to cities where their customers were located rather than where their suppliers were located. Firms also tended to relocate to cities where their banks were located. The positive role that the presence of customers and banks played in firms' relocation choice was weaker if their customers and banks were also damaged by the earthquake.

*Keywords:* relocation; agglomeration; transaction partners; Tohoku earthquake

*JEL classification:* R30, L14, G20

## 1. Introduction

Firms are located unevenly across regions for various reasons. One of the most important factors for a firm's location choice is agglomeration economies (Marshall, 1890). Following Marshall's insights, studies have investigated more specific factors giving rise to agglomeration economies, such as the clustering of intermediate goods producers (Holmes, 1999), input costs (Carlton, 1983; Liu et al., 2010), aggregate demand for the product (Head and Mayer, 2004), and the availability of financial services (Davis and Henderson, 2008; Strauss-Kahn and Vives, 2009).<sup>1</sup>

In this study, we focus on another agglomeration factor that may affect firms' location choice: the presence of incumbent transaction partners.<sup>2</sup> On the one hand, firms often establish special and irreplaceable relationships with transaction partners, such as their suppliers, customers, and lenders, through relation-specific (or differentiated) investments, products, or services (Williamson, 1975, 1985). This relation-specificity may induce firms to locate closer to their transaction partners in order to reduce transaction costs and enhance communication and information sharing. On the other hand, it is also possible that the special relationships work adversely, because too close a relationship may invite a hold-up problem (Klein et al., 1978; Rajan,

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<sup>1</sup> Regarding the literature on agglomeration economies, see Duranton and Puga (2004), Puga (2010), and Rosenthal and Strange (2004).

<sup>2</sup> Throughout this study, we define transaction partners to include suppliers, customers, and banks. In addition, the term "customer" refers to another firm or organization (such as a local government or cooperatives) to which the firm provides goods or services and does not include individual consumers.

1992). In this case, firms would prefer keeping a distance from their transaction partners. Thus, whether firms locate close to their transaction partners is an important empirical question. Although the importance of input and/or output linkages in firms' location choice has been investigated in many studies using aggregate data (e.g., Holmes, 1999; Head and Mayer, 2004; Davis and Henderson, 2008; Strauss-Kahn and Vives, 2009), relatively few studies have investigated the importance of firm-specific transaction partners using micro data (with notable exceptions including Head et al., 1995; Yamashita et al., 2014; Fukuda et al., 2019).

To identify the role that the location of transaction partners plays in firms' location choice, this study specifically examines the relocation of firms' headquarters, addressing two endogeneity concerns. First, firms' relocation decisions are typically not random and estimations that examine the role of transaction partners' location may be biased unless the decision of whether to relocate is properly considered (sample selection bias). Second, firms may choose their transaction partners and relocation destinations simultaneously, which can lead to reverse causality. That is, firms' decision on where to relocate may affect the selection of transaction partners. While some studies address one of these concerns (e.g., Strauss-Kahn and Vives (2009), who address the sample selection bias), to the best of our knowledge, no studies address both.

This study attempts to overcome these endogeneity issues by focusing on firms that were forced to relocate their headquarters due to a massive earthquake. The Tohoku earthquake that occurred on March 11, 2011 in Japan forced a substantial number of firms to move from their original location in the wake of the destruction brought by the tsunami and the nuclear disaster at the Fukushima power plant triggered by the earthquake. The quasi-natural experiment provided

by the earthquake allows us to identify the role that the location of transaction partners play in firms' choice of where to relocate. Specifically, we focus on firms relocating due to the earthquake to circumvent possible sample selection bias. Because these firms tried to resume their operations as soon as possible, it is likely that they chose their relocation destination based on existing transactional relationships before the earthquake. Therefore, reverse causality is also unlikely to play a major role in our analysis.

We run conditional logit estimations using various alternative location-specific variables representing the presence of transaction partners in a particular location to examine the effect of transaction partners' location on firms' relocation choice. Specifically, we use two types of variables: one indicating whether a firm has a main transaction partner in a particular city, and another representing the number of transaction partners – both main and non-main – in a particular city.

The major findings of this study are threefold. First, after the earthquake, damaged firms tended to relocate their headquarters to cities where they had incumbent customers. In contrast, the presence of suppliers did not influence firms' relocation choice. Second, firms tended to relocate to cities where their incumbent banks were located. Moreover, the presence of banks played a larger role in firms' relocation choice than the presence of customers. These results hold for a battery of robustness tests. Third, the positive effect of incumbent customers and banks on firms' relocation choice were weaker if these partners were located in areas severely damaged by the earthquake. This finding indicates that the gravity of transaction partners on a firm's location choice depended on their health. On balance, our findings suggest that firms chose to locate close

to incumbent transaction partners as long as these partners did not suffer any damage themselves.

The main contribution of this paper is that it provides evidence of the effect of transaction partners' location on firms' relocation choice. While some previous studies reported a positive correlation between transaction partners' location and firms' location choices (Yamashita et al. (2014) for foreign direct investment (FDI) and Fukuda et al. (2019) for relocation), they did not address the endogeneity issues that potentially lead to biased estimates. Unlike these studies, we identify the causal link by focusing on firms forced to relocate due to the Tohoku earthquake, and show that the effect is heterogeneous across partner types. That said, our findings may to some extent reflect the specific setting we examine, so that our study is not without limitations, which we discuss in the concluding section.

The remainder of the study is organized as follows. Section 2 reviews the related literature. Section 3 outlines our data and sample selection and shows relocation patterns and distances to transaction partners. Section 4 then examines how the earthquake affected the likelihood of relocation, confirming the validity of our identification assumption. Section 5 describes our empirical framework to examine the determinants of firms' choice of where to relocate and explains our key variables. The empirical results are reported in Section 6, while Section 7 concludes the paper.

## **2. Literature review**

This study is closely related to three strands of the literature: the literature on firms' location choice, the literature on lender–borrower distance, and the literature on natural disasters and firm

behavior. In this section, we briefly review these three strands and explain our contributions.

### *2.1 Literature on location choice*

Our study is related to a broad literature on firms' location choice. Previous studies have focused on a variety of contexts, such as the location of new establishments, FDI, and the relocation of headquarters and establishments. Among various factors, agglomeration has attracted particular attention (Yi, 2018; Siodla, 2021), and some studies within this literature specifically investigate the importance of input and output linkages. One strand of research uses aggregate-level data to study factors such as the clustering of intermediate goods producers (Holmes, 1999), aggregate demand for the product (Head and Mayer, 2004), and the availability of financial services (Davis and Henderson, 2008; Strauss-Kahn and Vives, 2009). Another strand uses industry-region-level data to assess the extent to which inter-industry "co-agglomeration" patterns are affected by Marshallian forces (Ellison et al., 2010)—i.e., proximity to customers and suppliers, labor market pooling, and technology spillovers—or whether such forces affect the location decisions of new firms (Glaeser and Kerr, 2009; Jofre-Monseny et al., 2011). In contrast to these studies, which investigate inter-industry relationships, our study examines firm-level linkages. Specifically, we analyze whether the presence of customers, suppliers, and lender banks influences firms' relocation decisions.

Among studies investigating the effect of transaction partners, some examine the agglomeration of *keiretsu* firms as a key determinant of the location choice of FDI by Japanese manufacturing firms (Head et al., 1995; Belderbos and Carree, 2002; Head and Mayer, 2004).

Apart from their focus on FDI instead of relocation, our study differs from these studies in terms of identification strategy, as they do not address the potential self-selection bias in firms' location decisions, which is also relevant to relocation given evidence that firm-internal factors are the main determinants of relocation (Van Dijk and Pellenbarg, 2000). The present study circumvents this self-selection issue by examining firms that were forced to relocate due to the severe damage from the Tohoku earthquake. To the best of our knowledge, only Strauss-Kahn and Vives (2009) explicitly address the self-selection problem using a three-level nested logit model.

The study closest to ours is Fukuda et al. (2019), who, referring to the present study, examine the effect of incumbent transaction partners on the relocation choice of Japanese small and medium-sized enterprises (SMEs). While they use a three-level nested logit model like Strauss-Kahn and Vives (2009), their study suffers from a sample selection problem, as their sample includes only firms that relocated voluntarily. In contrast, we focus on firms that were forced to relocate due to the earthquake, thereby mitigating this bias. Our analysis is also less susceptible to reverse causality, as firms affected by the earthquake were unlikely to change existing transaction relationships in their effort to resume business operations quickly.

## *2.2 Literature on lender-borrower distance*

The second strand of related literature is that on geographical proximity between lenders and borrowers. Theory predicts that a longer lender-borrower distance makes it difficult for banks to collect “soft” information on borrowers, suggesting that only local lenders can underwrite loans to opaque borrowers (Stein, 2002).

Consistent with this prediction, empirical studies have found that geographical proximity between borrowers and lenders is an important determinant of the pricing and availability of loans as well as the continuation of bank-firm relationships (Petersen and Rajan, 1994; Degryse and Ongena, 2005; Agarwal and Hauswald, 2010; Hollander and Verriest, 2016; Nguyen, 2019; Herpfer et al., 2023). However, to the best of our knowledge, no study has examined the effect of banks' location on borrowers' relocation choice, except for the abovementioned study by Fukuda et al. (2019). There are some studies that find that the availability of financial services is one of the key determinants of the relocation choice for firms' headquarters (Davis and Henderson, 2008; Strauss-Kahn and Vives, 2009), but their focus is on the agglomeration of financial services. This study is the first to investigate the causal effect of the location of incumbent banks on borrowing firms' relocation choice.

### *2.3 Literature on natural disasters and firm behavior*

Third, this study is related to the literature on the effect of natural disasters on firm behavior. While we specifically focus on firms' relocation, there are studies on the effect of natural disasters on other aspects of firm dynamics. These include studies on the speed of the recovery (De Mel et al., 2012; Todo et al., 2015), employment and wages (Belasen and Polachek, 2008; Leiter et al., 2009; Tanaka, 2015; Indaco et al. 2021), investment (Leiter et al., 2009; Tanaka, 2015; Hosono et al., 2016), and productivity (Leiter et al., 2009; Cole et al., 2019). Some studies go further and examine whether damage to their transaction partners hampered the recovery of damaged firms (Todo et al., 2015; Kashiwagi et al., 2021; Carvalho et al., 2021). However, there are relatively

few studies that examine the impact of a natural disaster on firm relocation. An exception is the study by Indaco et al. (2021), which found that firms that suffered damage from Hurricane Sandy were more likely to relocate their establishments. The present study is complementary to Indaco et al. (2021) in that we examine where, not whether, firms relocate their headquarters when forced to do so by a natural disaster.

### **3. Data**

#### *3.1. Data sources*

The main source of our dataset is the firm-level database compiled by Teikoku Databank Ltd. (hereafter TDB database), a leading business credit research company in Japan. Because of its broad coverage, the majority of firms in the TDB database are SMEs. The TDB database contains information on a variety of firm attributes including the address of their headquarters, the identity and addresses of their suppliers and customers, and the identity of bank branches with which firms transact. When a firm transacts with more than one transaction partner, the TDB ranks the partners in the order of importance to the firm. Based on this, we assume that the top-listed firm or bank is the firm's main transaction partner (i.e., main supplier/customer/bank).<sup>3</sup>

We supplement the TDB data with information on the addresses of the headquarters and branches of banks from the Nihon Kinyu Meikan (Almanac of Financial Institutions in Japan)

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<sup>3</sup> See Appendix D for more details on how we identify firms' transaction partners using information from the TDB database.

compiled by Nikkin Co., Ltd. We also use the Economic Census by the Statistics Bureau, Ministry of Internal Affairs and Communications, to construct proxies for agglomeration at the regional level, such as the number of establishments and plants in a city.<sup>4</sup>

### *3.2. Sample selection*

The Tohoku earthquake caused serious damage in the six prefectures that make up Japan's Tohoku region, namely, Aomori, Iwate, Miyagi, Akita, Yamagata, and Fukushima. To construct our sample from the TDB database, we first identify non-financial firms headquartered in these six prefectures that were in operation both in the year before the earthquake (March 2010–February 2011) and in the two-years after the earthquake (March 2011–February 2013).<sup>5</sup> Based on this selection procedure, we identify 87,908 firms.<sup>6</sup> We then identify 59 earthquake-affected cities based on the Japanese Government's Act on Special Financial Support to Deal with a Designated

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<sup>4</sup> The Census data are available at the city/town/village level, and at the ward level for large cities such as Sendai. For brevity, we refer to these data as “city-level” data throughout this study.

<sup>5</sup> In order to examine firms' relocation after the earthquake, which occurred in March 2011, we define each year as the period from March to February. For example, year 2011 refers to March 2011– February 2012 and is referred to as the year after the earthquake.

<sup>6</sup> The total of 87,908 firms excludes 5,388 firms (5.8% of those with identified pre-earthquake locations) for which the location after the earthquake could not be identified in the TDB database. This likely reflects the difficulty of conducting credit research following the earthquake rather than a high rate of firm exits, since the exit rate among affected firms was quite low (Uchida, 2014).

Disaster of Extreme Severity (as of February 22, 2012)<sup>7</sup> and on the Planned Evacuation Zone / Emergency Evacuation Preparation Zone for the severe accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company (as of April 22, 2011).<sup>8</sup> As shown in the shaded area of Figure 1, the earthquake-affected cities are mostly located along the Pacific coast. Among firms whose addresses after the earthquake are available, we find that 36,096 firms were located in these 59 cities.

Even within the affected area, there was significant variation in the severity of the damage caused by the earthquake, and some firms with limited damage may have relocated for other reasons. Therefore, to ensure that we focus on firms that were forced to relocate due to damage from the earthquake, we restrict the sample to those in the most severely affected areas. Specifically, we focus on 4,741 firms that before the earthquake were located in the areas affected by the tsunami or the area within a 30 km radius of the Fukushima Daiichi Nuclear Power Station (i.e., the Planned Evacuation Zone). To identify firms whose headquarters were located in the tsunami-affected area, we use information from the Geospatial Information Authority of Japan (GIS).<sup>9</sup> The locations of tsunami- and nuclear accident-affected firms are shown in Appendix

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<sup>7</sup> See the website (in Japanese) of the Ministry of Land, Infrastructure, Transport and Tourism ([https://www.mlit.go.jp/report/press/house03\\_hh\\_000070.html](https://www.mlit.go.jp/report/press/house03_hh_000070.html)) on this act.

<sup>8</sup> See the website (in Japanese) of the Cabinet Office (<http://www.kantei.go.jp/saigai/20110411keikakuhinan.html>) on details of these zones.

<sup>9</sup> The GIS dataset on the boundaries of the area affected by the tsunami was downloaded from the website of a research project on the earthquake at the University of Tokyo at the time.

Figure A1.

Next, we identify firms that relocated their headquarters after the earthquake. We assume that a firm relocated if the Euclidian (straight-line) distance between its headquarters before and after the earthquake exceeds 0.1 km. To obtain this distance, we use the CSV Address Matching Service provided by the Center for Spatial Information Science at the University of Tokyo. Specifically, we geocode firms' headquarters address from 2008 to 2012 to determine its latitude and longitude in each year. A firm is regarded as having "relocated" in a particular year if the distance between its headquarters in that year and the previous year exceeds 0.1 km. We identify 1,122 firms that relocated from the most severely affected areas (23.7% of the 4,741 firms located in these areas), while 3,619 firms did not relocate. Most of these 1,122 firms moved to either Iwate, Miyagi, or Fukushima prefecture. We focus on these firms in our analysis. Due to missing data for some variables used in the analysis, the number of observations decreases to 1,044. The characteristics of these 1,044 firms that relocated as well as those of their suppliers and customers are described in Appendix B.

### *3.3. Relocation patterns and distances to transaction partners*

Panel A of Table 1 presents summary statistics on the relocation patterns of the 1,044 firms that moved from the severely affected areas. The mean relocation distance was 12.3 km, while the median was 3.9 km, and 71% of the firms relocated within the same city. These results suggest that firms in severely affected areas tended to relocate over short distances. Appendix Table A1, Panel A presents the same statistics by sector. Firms in the wholesale and retail sectors

tended to relocate over shorter distances, whereas those in the construction and manufacturing sectors moved relatively farther. Relocation distances varied considerably within the service sector.

Next, Panel B of Table 1 presents summary statistics on the distances between firms that relocated and their suppliers, customers, and banks before the earthquake. The mean (median) distance to suppliers was 238.3 km (135.0 km), while the mean (median) distance to customers was 220.4 km (114.8 km). There was no substantial difference between the mean distances to main and non-main suppliers, whereas the mean distance to main customers was about 10 km shorter than that to non-main customers. In contrast, the mean (median) distance to banks was much shorter, at 10.9 km (2.8 km). The mean distance was shorter for main banks than for non-main banks, although the medians were similar. Geographical proximity seems to matter more vis-à-vis banks than vis-à-vis suppliers or customers.

Sectoral breakdowns reported in Appendix Table A1, Panel B indicate that the importance of geographical proximity to transaction partners varies across sectors. For example, construction firms tended to be located close to both suppliers and customers, whereas wholesale and retail firms tended to be located farther away from suppliers but closer to customers.

#### **4. The earthquake and the probability of relocation**

Before our main analysis examining where firms relocated, we examine the extent to which damage from the earthquake affected firms' probability of relocation. This allows us to examine the validity of our identification assumption that the relocations of firms that had resided in the

most severely affected areas before the earthquake were forced relocations. Specifically, if we find a discontinuous increase in the likelihood of relocation after the earthquake in the most severely affected areas, this supports our empirical assumption that these relocations were exogenous.

For this examination, we use a broader sample of firms than in Section 3.2, where we selected sample firms for the conditional logit estimations. We focus on firms located in the six Tohoku prefectures between 2008 and 2012, with each year defined as March of the given year to February of the following year (e.g., 2008 refers to March 2008–February 2009). We estimate a linear probability model using a sample of firms located in the 59 earthquake-affected cities designated under the Japanese Government’s Act on Special Financial Support to Deal with a Designated Disaster of Extreme Severity (denoted by the dummy variable *DISASTER*), tsunami-affected areas (*TSUNAMI*), nuclear accident-affected areas (*NUCLEAR*), as well as firms in areas not falling under any of these three categories.<sup>10</sup> The dependent variable is *Relocated*, which equals one if a firm relocated more than 0.1 km, and zero otherwise. The independent variable is either *DISASTER*, *TSUNAMI*, or *NUCLEAR*. We run separate regressions for each year and type of damage, and plot the resulting coefficient estimates.

Figure 2 presents the coefficient estimates and 95% confidence intervals from the linear probability models. Although the average relocation probability of firms located in the

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<sup>10</sup> Note that *DISASTER* is not a superset of *TSUNAMI* and *NUCLEAR* for the sample firms in this section. This is because the sample includes firms located outside the 59 earthquake-affected cities, and some of these firms were affected by the tsunami.

earthquake-affected area (*DISASTER*=1) before the earthquake was 0.2–0.5 percentage points higher than that of firms in undamaged areas and this difference is statistically significant, it was not too dissimilar from firms in other areas. However, this difference increased to 2.7 percentage points in 2011. Moreover, the difference in the cumulative relocation probability vis-à-vis undamaged firms over the two-year period following the earthquake (2011–2012) increased to 4.8 percentage points.<sup>11</sup>

Next, focusing on firms located in the most severely affected areas, the average relocation probabilities of firms in the tsunami-affected area (*TSUNAMI*=1) and the nuclear accident-affected area (*NUCLEAR*=1) exhibit qualitatively similar patterns to those of firms with *DISASTER*=1. However, the coefficient estimates are much larger: the difference in the cumulative relocation probability is now 17.6 percentage points for *TSUNAMI* and 82.1 percentage points for *NUCLEAR*. Overall, these results indicate that the severe damage inflicted by the earthquake led to a substantial increase in firm relocations.<sup>12</sup> This observation lends support to our identification assumption that firm relocations in our sample are primarily exogenously

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<sup>11</sup> In the analysis below, we use firms' relocation during the two-year period after the earthquake (March 2011–February 2013) because there is a time lag between when a firm actually relocated and when the TDB recorded the firm's relocation, and it is only the latter information that is available to us. In particular, it was difficult for TDB to identify firms' addresses immediately after the earthquake, especially for firms that were located in the tsunami- and nuclear accident-affected areas.

<sup>12</sup> This finding is consistent with Indaco et al. (2021) and Siodla (2021), who find increased relocations following natural disasters.

determined, resulting from damage due to the earthquake, rather than endogenously determined.

## 5. Methodology and variables

### 5.1. Empirical framework

This section presents the empirical framework for our analysis of firms' choice of where to relocate. Studies on location choices (e.g., Carlton, 1983) assume that the probability that a firm chooses a particular location can be derived from individual firms' profit maximization. Following these studies, we assume that when choosing where to relocate, each firm chooses the city that would yield the highest profit among the possible alternative choices. Specifically, following Head et al. (1995), we assume that the profitability of firm  $i$  in industry  $j$  when choosing city  $c$  is given by the following reduced form equation:

$$\pi_{ic} = \theta_c + \alpha_1 \theta_{jc} + \sum_k \alpha_k TR_{ic}^k + \alpha_2 \theta_{ic} + \varepsilon_{ic} \quad (1)$$

In this equation, the vector  $\theta_c$  represents a set of variables defined at the city level that capture the attractiveness of city  $c$  and that are assumed to be identical for all firms and industries.  $\theta_c$ , for instance, reflects the quality of infrastructure or the price of input factors such as labor and raw materials in the city. In addition, the attractiveness of a city may also vary across industries, as indicated by industry localization, for example. The vector  $\theta_{jc}$  captures this industry-specific attractiveness of city  $c$  for firms in industry  $j$ .

The vector  $TR_{ic}^k$  represents our main independent variables that capture the effect of the presence of specific transaction partners  $k$  (= suppliers, customers, or banks) in city  $c$  for firm  $i$ . Because each firm has its own transaction partners,  $TR_{ic}^k$  is a firm-level variable that varies across

firms in the same city and industry.

In addition to  $TR_{ic}^k$ , we also include a vector  $\theta_{ic}$  that represents a set of variables to control for the firm-specific attractiveness of city  $c$ , such as the physical or cultural proximity between city  $c$  and the city where firm  $i$  was originally located.

We estimate the parameters employing a conditional logit framework. Based on equation (1), the framework assumes that the probability that firm  $i$  relocates to city  $c$  is given by the following logit expression:

$$\Pr(\text{City relocated}_{ic}) = \exp(\pi_{ic}) / \sum_{x \in C} \exp(\pi_{ix}) \quad (2)$$

In this expression, the choice set  $C$  represents all possible candidate cities for relocation. We estimate the coefficients in equation (1) using maximum likelihood techniques taking this logit expression into account.

In our estimation, we restrict our choice set  $C$  to the 61 cities in Iwate, Miyagi, and Fukushima prefectures to which at least one firm in our sample moved after the earthquake. These 61 cities vary substantially in size, from large urban centers with a few hundred thousand residents (e.g., Iwaki) to small municipalities with only a few thousand residents (e.g., Kawauchi).<sup>13</sup> As noted in Section 3.2, almost all of the firms in the most affected areas that relocated after the earthquake moved to these three prefectures. Omitting from the choice set the cities outside of the three prefectures that the remaining firms moved to is unlikely to affect the estimation results.

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<sup>13</sup> As noted in footnote 4, these 61 units include not only cities but also towns, villages, and the wards of large cities.

Meanwhile, as mentioned, the number of firms in our sample is 1,044. Because the unit of observation for the conditional logit estimation is firm-city pairs, the actual number of observations for our baseline estimation is the product of the number of firms and that of cities, which is 63,684 ( $=1,044 \times 61$ ). Since each firm generates 61 observations, the error terms may be correlated across alternatives within the same firm — a well-recognized concern in discrete choice models with multiple observations per decision maker (Train, 2009; MacKinnon et al., 2023). We therefore cluster standard errors at the firm level.

It is worth noting that in conditional logit estimation, the likelihood function is independent of firm-fixed effects. That is, we obtain estimates for alternative specific variables (e.g., the presence of main transaction partners) without having to estimate firm fixed effects (Hamerle et al., 1995). As marginal effects rest on an assumption that fixed effects are zero, we report the raw coefficients instead. In addition, following Head et al. (1995) and other studies employing a conditional logit framework, we take logarithms of continuous variables to compute their average probability elasticities. Specifically, we multiply the estimated coefficients by  $\frac{S-1}{S}$ , where  $S$  stands for the number of alternative location choices (61 cities in our case) to obtain the elasticity of the probability that a firm chooses a city with respect to a given variable (e.g., the number of transaction partners), averaged over all firms and all cities.<sup>14</sup>

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<sup>14</sup> The derivation of the average probability elasticity follows Head et al. (1995). The elasticity of the probability that firm  $i$  relocates to city  $c$  with respect to, for example, the number of transaction partners of type  $k$  (denoted as  $TR_{ic}^k$ ) is given by:

## 5.2. Variables

This subsection outlines the dependent and independent variables in our empirical analysis.

Appendix Tables A2 and A3 provide their definitions and summary statistics, respectively.

### 5.2.1. Dependent variable

The dependent variable for our conditional logit estimation is the dummy variable *City relocated*, which takes a value of one if firm  $i$  relocated to city  $c$  and zero otherwise. Appendix Figure A2 shows that cities that lost firms after the earthquake are concentrated in coastal areas and around the Fukushima power plant, whereas destination cities are more regionally diversified.

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$$E_{ic}^k = \frac{\partial \Pr(\text{City relocated}_{ic})}{\partial TR_{ic}^k} \cdot \frac{TR_{ic}^k}{\Pr(\text{City relocated}_{ic})}.$$

Differentiating equation (2), we obtain:

$$E_{ic}^k = \Pr(\text{City relocated}_{ic}) \cdot \frac{\alpha_k}{TR_{ic}^k} \{1 - \Pr(\text{City relocated}_{ic})\} \cdot \frac{TR_{ic}^k}{\Pr(\text{City relocated}_{ic})} = \alpha_k \{1 - \Pr(\text{City relocated}_{ic})\}.$$

Summing over all  $N$  firms and  $S$  cities, we obtain:

$$E^k = \sum_i \sum_c E_{ic}^k = \alpha_k N(S - 1).$$

The average probability elasticity is then obtained by dividing this sum by the total number of firm-cities,  $NS$ , yielding:

$$\bar{E}^k = \alpha_k \frac{S-1}{S}.$$

### 5.2.2. Main independent variables

The main independent variables in this study are those capturing the presence of a firm's transaction partners in a particular city, i.e.,  $TR_{ic}^k$  in equation (1), where  $k$  represents either suppliers, customers, or banks. From the TDB database, we construct the following two sets of variables for  $TR_{ic}^k$ .

First, we construct dummy variables that denote the presence of the headquarters of the main supplier and the main customer of a firm, as well as the presence of the branch of the main bank that a firm transacts with. These are labeled *Main supplier*, *Main customer*, and *Main bank*, respectively. These dummies equal one if the candidate city was home to the firm's main supplier, main customer, or main bank branch before the earthquake, and zero otherwise.<sup>15</sup> If a firm's main transaction partner is not identified in the TDB database, or is located outside the 61 cities in our choice set, we set the dummy variable to take a value of zero for all of the 61 candidate cities. We revisit the validity of this treatment for missing values in Section 6.2.

Second, as an alternative to the variables for the presence of the main transaction partners, we also use variables to take into account the number of transaction partners. Specifically, for each candidate city, we count the number of suppliers, customers, and banks, including both main and non-main partners, and take the natural logarithms of each count plus one. We label

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<sup>15</sup> To avoid endogeneity issues, we use the location of transaction partners before the earthquake. Approximately 8% (10%) of firms with identifiable main suppliers (customers) before the earthquake changed their main supplier (customer) afterwards.

these variables *Log number of suppliers*, *Log number of customers*, and *Log number of banks* respectively.<sup>16</sup> These variables represent the degree of agglomeration of transaction partners. Following previous studies (e.g., Head et al., 1995), when taking the logarithm, we add one to take account of cities with zero transaction partners.<sup>17</sup>

Because there could potentially be multicollinearity between the dummy variables (e.g., *Main supplier*) and the count variables (e.g., *Log number of suppliers*), we use these two sets of key variables alternately in our estimations. We expect that the presence of main partners and the number of transaction partners have a positive impact on a firm's relocation choice, if the benefit of locating closer to transaction partners outweighs the cost of doing so because of the hold-up problem, for example.

### 5.2.3. Control variables

In addition to the above-mentioned main variables, we also control for factors that have been considered in previous studies (i.e.,  $\theta_c$ ,  $\theta_{jc}$ ,  $\theta_{ic}$  in equation (1)). In particular, we include two key controls: whether the destination is the same as the firm's pre-relocation city (*City before relocation*) and the log distance between the original and candidate city (*Log moving distance*), capturing strong inertia and distance-related frictions. Details on the construction of the control

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<sup>16</sup> For *Log number of banks*, we count the number of bank branches that a firm transacted with in each city before the earthquake.

<sup>17</sup> Since many cities have zero transaction partners, the resulting elasticities should be interpreted as approximate measures, particularly when the number of partners is small.

variables are provided in Appendix C.1.

One important point to note is that we employ two alternative approaches to control for the general attractiveness of city  $c$  to the average firm irrespective of industry (i.e., variables for  $\theta_c$ ). First, we include three variables for city-level characteristics that might play a role in firms' relocation decisions, such as the overall agglomeration of firms across all industries. Second, following Head et al. (1995), we alternatively include fixed effects, which likely circumvent the issues associated with omitted variable biases. In the estimations below, we use these two approaches alternately.

## 6. Estimation results

### 6.1. Baseline estimation results

The results of the baseline conditional logit estimation are presented in Table 2. The table reports coefficient estimates and their standard errors, with standard errors clustered at the firm level. Columns (1) and (2) show the results for the specification including the three city-specific variables to control for the attractiveness of a city,  $\theta_c$ , while columns (3) and (4) show the results when we instead use city fixed effects. In columns (1) and (3), we examine the effect of the presences of main transaction partners, while in columns (2) and (4) we examine the effect of the number (agglomeration) of incumbent transaction partners.

The estimation results in Table 2 show that the presence of firms' customers has a positive effect on firms' relocation choice. That is, the coefficients on *Main customer* in columns (1) and (3) are significantly positive, while those on *Log number of customers* in columns (2) and

(4) are insignificant although their p-values are 0.114 and 0.106 and thus qualitatively similar to those of *Main customer*. These results suggest that firms that were severely damaged by the Tohoku earthquake headed for areas where their customers were located, especially where their main customers were.

In contrast, the coefficients on *Main supplier* and *Log number of suppliers* are not statistically significant in any specification, suggesting that the presence of incumbent suppliers did not affect firms' relocation choice. The underlying mechanisms that may explain this contrasting pattern between customers and suppliers are examined in greater detail in Section 6.3.

Turning to the effect of incumbent banks, we find that *Main bank* and *Log number of banks* have a positive effect on firms' relocation choice. The results in columns (2) and (4) indicate that a 1 percentage point increase in the number of bank branches with which a firm transacts increases the probability of the firm relocating to the same city by 1.1–1.5 percentage points ( $1.117 \times 60/61$  and  $1.516 \times 60/61$ ).<sup>18</sup> These results indicate that the presence of the main bank and the agglomeration of lending banks have a positive effect on firms' relocation choice.

While it is difficult to identify the exact mechanism behind the positive effect of incumbent banks on firms' location choice, there are several possible explanations. First, as discussed above, the literature on relationship lending suggests that banks invest in relationship-specific capital to accumulate soft information on their client firms. If the precision of such soft information is inversely related to the physical distance between a firm and a bank, then firms

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<sup>18</sup> See Section 5.1 for the derivation of the average probability elasticity.

may want to relocate to an area near their bank in order to reduce the degree of information asymmetry and increase the availability of credit. Second, because transaction costs are positively related to physical distance, firms may decide to head to an area where their banks are located to save costs. Further, banks may have rich information regarding the local real estate market, which may have been particularly useful for firms searching for a location for their new headquarters after the earthquake. Consistent with this conjecture, using data from a survey on Japanese SMEs, Yamori et al. (2013) report that more than 20% of survey firms responded that advice or information about real estate provided by the main bank was useful.

The estimation results for other covariates are in line with prior expectations. For details, see Appendix C.2.

## 6.2. Robustness checks

The estimation results in Table 2 show that the presence of incumbent customers and banks affects the relocation choices of firms that were severely impacted by the earthquake. To assess the robustness of these findings, we conduct a series of additional analyses.

First, we address concerns about potential sample selection bias and/or measurement errors arising from missing values in the supplier- and customer-related variables. As mentioned in Section 5.2.2, if a firm's transaction partners are not identified in the TDB database, we set a value of zero for the transaction partner variables  $TR_{ic}^k$  for all 61 candidate cities. This approach may introduce bias, particularly because the numbers of firms for which supplier and customer information is available are relatively small, especially among smaller and younger firms, due to

data limitations in the TDB database. Specifically, information on suppliers and customers is available for 287 and 248 firms, respectively, based on TDB's Comprehensive Credit Reporting (CCR) dataset, which records a firm's suppliers and customers. In contrast, information on banks is available for 1,037 firms using another TDB dataset, COSMOS2.

To address potential issues arising from missing supplier and customer information, we use the COSMOS2 dataset. COSMOS2 allows us to identify a larger number of firms' suppliers and customers, although it comes with certain limitations. Specifically, company codes are not available for the suppliers and customers that are listed in COSMOS2, which creates the risk of incorrectly matching firms, and the number of reported suppliers or customers is capped at five. Using COSMOS2, we construct alternative *imputed* supplier- and customer-related variables. With this imputation, the number of firms with identified suppliers and customers increases to 691 and 586, respectively. Moreover, concerns about sample selection bias, namely, that only large firms have identifiable transaction partners, are mitigated: the average number of employees for firms with identified suppliers drops to 16.8 when using both the CCR and COSMOS2, compared to 26.6 when using the CCR alone. For further details on the construction and imputation of the supplier- and customer-related variables, see Appendix D.

Using the imputed variables for suppliers and customers, we re-estimate the baseline models. The results, presented in Table 3, are qualitatively similar to those in Table 2. Specifically, the coefficients on the customer-related variables are positive and statistically significant across all four specifications. The levels of statistical significance are higher than those in Table 2, suggesting that the gravity of incumbent customers may be even stronger than initially estimated.

In contrast, the coefficients on supplier-related variables continue to be statistically insignificant, and those on bank-related variables remain positive and significant. Taken together, these findings suggest that the positive effect of incumbent customers and the lack of a significant effect of incumbent suppliers observed in the baseline estimations are unlikely to be driven by weak identification or incomplete reporting of transaction partners in our dataset.<sup>19</sup>

In addition to the analysis in Table 3, we conduct a series of estimations using different subsamples to further assess the robustness of the baseline results reported in Table 2. These estimations address potential concerns related to firms that have multiple establishments, the independence of irrelevant alternatives (IIA) assumption in conditional logit estimation, and the possibility that our baseline results are driven by firms that remained within their pre-relocation city.<sup>20</sup> The results of these robustness checks, reported in Appendix E, consistently support the

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<sup>19</sup> We further verified that our results are robust to restricting the sample to firms with non-missing transaction-partner information (results available upon request).

<sup>20</sup> Because about 70 percent of the sample firms moved within their original city, one might suspect that the same-city presence of transaction partners discourages firms from relocating outside in the first place. In Appendix Table E3, we restrict the sample to the 303 firms that moved to a different city and confirm that the geographical proximity of transaction-partners continues to attract firms even within this subsample. An additional firm-level logit analysis (available upon request) shows that the retention effect of same-city co-location operates primarily through banks, which are typically located within the same city as the firm, while the same effect is less operative in practice for suppliers and customers, which are typically located far away from the firm (Table 1, Panel B).

main findings.

### *6.3. Subsample estimation results*

To further investigate why the presence of customers has a greater impact on firms' relocation decisions than that of suppliers, we rerun the baseline estimations using subsamples split by firms' sector and age.<sup>21</sup> The sector-based subsamples are constructed for the construction, manufacturing, wholesale, retail, and service sectors. The age-based subsamples divide firms into two groups: those older and younger than the median (25 years). In each subsample estimation, the choice set is restricted to cities among the 61 cities used in the baseline estimations to which the sample firms actually relocated. The results of these subsample estimations are presented in Table 4. For brevity, the table reports the results using the main transaction partner variables and omits the estimates for control variables. The corresponding results using the number of transaction partners, reported in Appendix Table A4, are mostly consistent with the findings below.

The main findings from the subsample estimations are twofold. First, the presence of a main customer had a positive effect for firms in the service sector. Interestingly, the presence of

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<sup>21</sup> In addition to these subsample estimations, we constructed agglomeration indices à la Duranton and Overman (2005) for the top five main supplier and customer industries of our sample firms and examined whether the spatial dispersion of supplier industries or the agglomeration of customer industries could account for our baseline estimation results. However, we did not find any evidence consistent with this agglomeration-based explanation (results not reported). We thank the editor for suggesting the use of Duranton and Overman's agglomeration indices.

a main supplier had a negative effect in the relocation decisions of service sector firms. A positive effect of the presence of a main customer was also observed in the wholesale sector subsample. We do not find any customer-related effects for manufacturing and retail firms. Second, the positive effect of customer presence was observed only among younger firms, and the negative effect of supplier presence was also evident among this group.

There are several possible explanations for these findings. One is that close communication and frequent information exchange with customers may be more important for service-sector firms than for firms in the other sectors, as services are intangible and require intensive interaction with customers.<sup>22</sup> Another possible explanation is that firms may prefer to keep a distance from their main supplier to avoid hold-up problems. While we cannot directly test this hypothesis due to the unobservability of firms' bargaining power, it is plausible that younger firms have weaker bargaining power than older firms. If so, the estimation results for younger firms are consistent with a bargaining-power-based explanation. Regarding the heterogeneous gravity of customers and suppliers across sectors, we note that in the wholesale, retail, and service sectors, suppliers tended to be larger (in terms of the number of employees) than customers, whereas suppliers tended to be smaller than customers in the construction and manufacturing sectors. For example, among service firms, the average number of employees for suppliers located in the 61 cities we examined was 202 compared to 168 for customers. This pattern again aligns

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<sup>22</sup> It is worth noting that the suppliers for the service-sector firms in our sample are predominantly in the wholesale (45%) and manufacturing (25%) sectors, suggesting that these service firms are less likely to require intensive interactions with their suppliers.

with the bargaining power-based interpretation.

#### 6.4. *Effects of earthquake damage to transaction partners*

Thus far, we have not taken transaction partners' own situation into account, especially whether they suffered any damage from the earthquake. However, if a firm's transaction partners were also damaged by the earthquake, relocating to the city where their damaged partners were located may not have been attractive for the firm. Therefore, in this subsection, we examine whether damage to firms' transaction partners had any effect on firms' relocation.

We identify damaged transaction partners as those located in the tsunami-affected area or within a 30 km radius of the Fukushima power station. Using this information, we redefine the variables for transaction partners. For example, for the variable representing the presence of the main supplier, we replace *Main supplier* with *Undamaged main supplier* and *Damaged main supplier*. Similarly, we replace *Log number of suppliers* with *Log number of undamaged suppliers* and *Log number of damaged suppliers*. The customer- and bank-related variables are redefined in the same way. In essence, we compare the gravity of a transaction partner that was located in the damaged area within a city to that of another transaction partner that was located in the undamaged area within the same city.

Table 5 presents the estimation results. For brevity, the table reports the results using the main transaction partner variables; the corresponding results using the number of transaction partners, reported in Appendix Table A5, are mostly consistent with the findings below. In line with the above conjecture, the coefficients on the main customer variables are positive and

significant only when the customers were not damaged. Similarly, the coefficients on the main bank variables are positive and significant when banks were not damaged. The coefficient for damaged main banks in column (2) is also positive and significant, but it is much smaller in size than that for undamaged banks, which suggests that the gravity of damaged main banks was weaker than that of undamaged main banks. Finally, we find that the coefficients on the main supplier variables are insignificant.

## **7. Conclusion**

This study examined the causal effect of the presence of transaction partners – suppliers, customers, and banks – on the relocation of firms’ headquarters. By focusing on firms that suffered severe damage from the Tohoku earthquake and were forced to relocate, we addressed possible self-selection bias and reverse causality inherent in firms’ relocation choice. We found that firms tended to relocate to cities where their customers were. Interestingly, we did not find any such effect for suppliers. We also found that firms tended to relocate to cities where their lender banks were present. Additional analysis showed that the positive effects of incumbent customers and banks on firms’ relocation disappeared or became weaker if the customers and banks themselves were damaged by the earthquake. This finding suggests that transaction partners exert gravity effects in firms’ relocation choice only when the transaction partners are healthy.

Two possible caveats of this study should be noted. First, omitted variable bias may persist. The location of a firm’s transaction partners may reflect unobserved, industry-specific location attributes that our industry-level agglomeration variables may not fully control for.

Importantly, however, Section 6.4 shows that the effects of incumbent transaction partners disappear or weaken when those partners were damaged by the earthquake. This damage-contingent pattern argues against the concern that unobserved factors are driving our results. Second, the external validity of our findings is limited, as firms forced to relocate after a disaster may have different priorities—such as the rapid resumption of operations—from firms relocating under normal circumstances. The extent to which our findings generalize to voluntary relocation decisions remains an open question.<sup>23</sup>

Finally, the analysis in this study raises several questions. First, although we found heterogeneous effects across customers, suppliers, and banks, we did not identify the channels through which incumbent transaction partners affected firms' relocation decisions. Second, an important issue in formulating economic policy is whether firms' ex-post performance improves or deteriorates after forced relocation. On the one hand, firms may not move in normal times even if relocation would improve performance, due to fixed relocation costs, for example. On the other hand, a disaster may force firms to relocate even if staying would have been optimal. We leave these issues for future research.

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<sup>23</sup> Appendix Table F1 presents estimation results for undamaged firms in Iwate, Miyagi, and Fukushima prefectures before the earthquake. Unlike the baseline results, the coefficients on the customer-related variables are insignificant. However, it remains unclear whether this difference reflects possible sample selection and simultaneity bias, which we seek to address, or whether the estimation results for firms that were forced to relocate due to the earthquake do not generalize to relocation decisions under normal circumstances.

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**Table 1. Relocation patterns and distances to transaction partners**

***Panel A: Relocation distances and share of firms that relocated within the same city***

|               | No. obs. | Mean | Std. dev. | Min | p25 | p50 | p75  | Max   | Number (percentage)<br>of firms that relocated within<br>the same city |       |
|---------------|----------|------|-----------|-----|-----|-----|------|-------|------------------------------------------------------------------------|-------|
| Entire sample | 1,044    | 12.3 | 20.2      | 0.1 | 1.7 | 3.9 | 10.5 | 145.9 | 741                                                                    | 71.0% |

***Panel B: Distances to transaction partners***

|           |                           | No. obs. | Mean  | Std. dev. | Min | p25  | p50   | p75   | Max     |
|-----------|---------------------------|----------|-------|-----------|-----|------|-------|-------|---------|
| Suppliers | Entire sample             | 1,758    | 238.3 | 259.3     | 0.0 | 17.4 | 135.0 | 389.6 | 1,975.1 |
|           | <i>By main / non-main</i> |          |       |           |     |      |       |       |         |
|           | Main suppliers            | 287      | 238.5 | 241.6     | 0.0 | 14.3 | 158.2 | 366.7 | 996.5   |
|           | Non-main suppliers        | 1,471    | 238.2 | 262.7     | 0.0 | 20.0 | 128.6 | 396.1 | 1,975.1 |
| Customers | Entire sample             | 1,569    | 220.4 | 247.7     | 0.0 | 11.2 | 114.8 | 357.8 | 1,472.7 |
|           | <i>By main / non-main</i> |          |       |           |     |      |       |       |         |
|           | Main customers            | 248      | 212.4 | 229.7     | 0.0 | 9.6  | 129.1 | 351.8 | 1,330.9 |
|           | Non-main customers        | 1,321    | 221.9 | 251.0     | 0.0 | 11.6 | 111.7 | 360.5 | 1,472.7 |
| Banks     | Entire sample             | 2,022    | 10.9  | 32.3      | 0.0 | 1.1  | 2.8   | 7.7   | 536.9   |
|           | <i>By main / non-main</i> |          |       |           |     |      |       |       |         |
|           | Main banks                | 1,028    | 6.9   | 17.7      | 0.0 | 1.1  | 3.0   | 7.5   | 309.8   |
|           | Non-main banks            | 994      | 15.2  | 42.0      | 0.0 | 1.1  | 2.6   | 8.4   | 536.9   |

*Notes:* This table presents summary statistics for the sample firms used in the baseline estimations (Table 2). Panel A reports relocation distances (in kilometers) and the number and percentage of firms that relocated within the same city; the unit of observation is the firm. Panel B reports distances (in kilometers) to the headquarters of suppliers and customers, as well as to the bank branches with which each firm transacted; the unit of observation is the firm–transaction partner pair. Sectoral breakdowns are reported in Appendix Table A1.

**Table 2. Baseline estimation**

|                                                          | Dependent variable: <i>City relocated</i> |                       |                       |                       |
|----------------------------------------------------------|-------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                          | (1)                                       | (2)                   | (3)                   | (4)                   |
| <i>Main supplier</i>                                     | -0.454<br>(0.464)                         |                       | -0.591<br>(0.461)     |                       |
| <i>Main customer</i>                                     | 0.932 *<br>(0.480)                        |                       | 0.990 **<br>(0.499)   |                       |
| <i>Main bank</i>                                         | 1.131 ***<br>(0.156)                      |                       | 1.274 ***<br>(0.173)  |                       |
| <i>Log number of suppliers</i>                           |                                           | -0.153<br>(0.340)     |                       | -0.359<br>(0.311)     |
| <i>Log number of customers</i>                           |                                           | 0.586<br>(0.371)      |                       | 0.571<br>(0.353)      |
| <i>Log number of banks</i>                               |                                           | 1.117 ***<br>(0.216)  |                       | 1.516 ***<br>(0.227)  |
| <i>City before relocation</i>                            | 1.013 ***<br>(0.166)                      | 1.013 ***<br>(0.168)  | 0.623 ***<br>(0.175)  | 0.511 ***<br>(0.180)  |
| <i>Log moving distance</i>                               | -1.990 ***<br>(0.096)                     | -1.968 ***<br>(0.097) | -2.306 ***<br>(0.126) | -2.288 ***<br>(0.124) |
| <i>Log ratio of firms in tsunami area</i>                | -1.262 ***<br>(0.327)                     | -1.200 ***<br>(0.322) |                       |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -8.100 ***<br>(1.000)                     | -7.985 ***<br>(0.978) |                       |                       |
| <i>Log number of establishments in the same industry</i> | 0.304 ***<br>(0.117)                      | 0.302 **<br>(0.118)   | 0.255 *<br>(0.143)    | 0.259 *<br>(0.148)    |
| <i>Log number of establishments in all industries</i>    | 0.464 ***<br>(0.117)                      | 0.455 ***<br>(0.117)  |                       |                       |
| City fixed effects                                       | No                                        | No                    | Yes                   | Yes                   |
| No. of observations                                      | 63,684                                    | 63,684                | 63,684                | 63,684                |
| No. of cities                                            | 61                                        | 61                    | 61                    | 61                    |
| No. of firms                                             | 1,044                                     | 1,044                 | 1,044                 | 1,044                 |
| Pseudo R2                                                | 0.7338                                    | 0.7311                | 0.76                  | 0.7593                |
| Log likelihood                                           | -1142.30                                  | -1154.27              | -1029.86              | -1032.81              |

*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choices. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair (1,044 firms × 61 cities = 63,684 observations).

**Table 3. Baseline estimation with imputed data**

|                                                          | Dependent variable: <i>City relocated</i> |                       |                       |                       |
|----------------------------------------------------------|-------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                          | (1)                                       | (2)                   | (3)                   | (4)                   |
| <i>Main supplier</i>                                     | 0.058<br>(0.296)                          |                       | -0.096<br>(0.293)     |                       |
| <i>Main customer</i>                                     | 1.125 ***<br>(0.314)                      |                       | 1.216 ***<br>(0.329)  |                       |
| <i>Main bank</i>                                         | 1.106 ***<br>(0.155)                      |                       | 1.255 ***<br>(0.172)  |                       |
| <i>Log number of suppliers</i>                           |                                           | 0.316<br>(0.253)      |                       | 0.137<br>(0.245)      |
| <i>Log number of customers</i>                           |                                           | 0.768 ***<br>(0.272)  |                       | 0.830 ***<br>(0.276)  |
| <i>Log number of banks</i>                               |                                           | 1.041 ***<br>(0.222)  |                       | 1.434 ***<br>(0.231)  |
| <i>City before relocation</i>                            | 1.003 ***<br>(0.166)                      | 0.987 ***<br>(0.167)  | 0.603 ***<br>(0.175)  | 0.484 ***<br>(0.177)  |
| <i>Log moving distance</i>                               | -1.969 ***<br>(0.096)                     | -1.936 ***<br>(0.097) | -2.292 ***<br>(0.124) | -2.266 ***<br>(0.123) |
| <i>Log ratio of firms in tsunami area</i>                | -1.270 ***<br>(0.327)                     | -1.189 ***<br>(0.321) |                       |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -8.170 ***<br>(1.036)                     | -8.046 ***<br>(1.020) |                       |                       |
| <i>Log number of establishments in the same industry</i> | 0.307 ***<br>(0.118)                      | 0.298 **<br>(0.119)   | 0.262 *<br>(0.143)    | 0.259 *<br>(0.148)    |
| <i>Log number of establishments in all industries</i>    | 0.437 ***<br>(0.117)                      | 0.419 ***<br>(0.117)  |                       |                       |
| City fixed effects                                       | No                                        | No                    | Yes                   | Yes                   |
| No. of observations                                      | 63,684                                    | 63,684                | 63,684                | 63,684                |
| No. of cities                                            | 61                                        | 61                    | 61                    | 61                    |
| No. of firms                                             | 1,044                                     | 1,044                 | 1,044                 | 1,044                 |
| Pseudo R2                                                | 0.7351                                    | 0.7324                | 0.7614                | 0.7605                |
| Log likelihood                                           | -1136.79                                  | -1148.38              | -1023.85              | -1027.76              |

*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choices, using alternative supplier- and customer-related variables. The construction of these alternative variables is described in Section 6.2 and Appendix D. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm-city pair (1,044 firms × 61 cities = 63,684 observations).

**Table 4. Subsample estimation**

**Panel A: By sector**

| Dependent variable: <i>City relocated</i> |                       |                       |                      |                     |                      |                      |                      |                      |                        |                        |
|-------------------------------------------|-----------------------|-----------------------|----------------------|---------------------|----------------------|----------------------|----------------------|----------------------|------------------------|------------------------|
|                                           | Construction          |                       | Manufacturing        |                     | Wholesale            |                      | Retail               |                      | Service                |                        |
|                                           | (1)                   | (2)                   | (3)                  | (4)                 | (5)                  | (6)                  | (7)                  | (8)                  | (9)                    | (10)                   |
| <i>Main supplier</i>                      | 0.2174<br>(0.7829)    | 0.0217<br>(0.9836)    | 0.3908<br>(0.8233)   | 0.1754<br>(1.0097)  | -0.9890<br>(0.8054)  | -0.5080<br>(0.8601)  | 0.3366<br>(0.6628)   | 0.5775<br>(0.8652)   | -2.8094***<br>(0.7809) | -3.1803***<br>(1.2252) |
| <i>Main customer</i>                      | 0.7263<br>(0.4912)    | 0.9919<br>(0.6410)    | -1.2067<br>(1.0923)  | -1.2040<br>(1.1681) | 1.9625*<br>(1.1578)  | 2.3715**<br>(1.1853) | 0.3283<br>(1.8552)   | 0.3929<br>(1.3363)   | 4.1756***<br>(0.6015)  | 5.9147***<br>(1.0960)  |
| <i>Main bank</i>                          | 1.4050***<br>(0.2734) | 1.6911***<br>(0.3235) | 0.7128**<br>(0.3491) | 0.7099*<br>(0.4230) | 1.5290**<br>(0.6164) | 1.9949*<br>(1.0656)  | 0.9165**<br>(0.4065) | 0.9567**<br>(0.4241) | 1.2114***<br>(0.4130)  | 1.0844**<br>(0.5279)   |
| Controls                                  | Yes                   | Yes                   | Yes                  | Yes                 | Yes                  | Yes                  | Yes                  | Yes                  | Yes                    | Yes                    |
| City FE                                   | No                    | Yes                   | No                   | Yes                 | No                   | Yes                  | No                   | Yes                  | No                     | Yes                    |
| No. of observations                       | 14,212                | 14,212                | 5,143                | 5,143               | 3,915                | 3,915                | 5,239                | 5,239                | 6,031                  | 6,031                  |
| No. of cities                             | 44                    | 44                    | 37                   | 37                  | 27                   | 27                   | 31                   | 31                   | 37                     | 37                     |
| No. of firms                              | 323                   | 323                   | 139                  | 139                 | 145                  | 145                  | 169                  | 169                  | 163                    | 163                    |
| Pseudo R-squared                          | 0.706                 | 0.738                 | 0.645                | 0.690               | 0.781                | 0.826                | 0.801                | 0.832                | 0.781                  | 0.809                  |
| Log likelihood                            | -358.9                | -320.0                | -178.2               | -155.6              | -104.5               | -83.22               | -115.6               | -97.77               | -128.8                 | -112.4                 |

**Panel B: By firm age**

| Dependent variable: <i>City relocated</i> |                       |                        |                       |                       |
|-------------------------------------------|-----------------------|------------------------|-----------------------|-----------------------|
|                                           | Younger firms         |                        | Older firms           |                       |
|                                           | (1)                   | (2)                    | (3)                   | (4)                   |
| <i>Main supplier</i>                      | -1.5038**<br>(0.6725) | -1.8506***<br>(0.6754) | 0.4448<br>(0.4590)    | 0.3986<br>(0.4585)    |
| <i>Main customer</i>                      | 1.4129**<br>(0.6525)  | 1.3919*<br>(0.7897)    | 0.8840<br>(0.6002)    | 0.8951<br>(0.6278)    |
| <i>Main bank</i>                          | 1.0186***<br>(0.2164) | 1.0810***<br>(0.2407)  | 1.0013***<br>(0.2447) | 1.4013***<br>(0.2983) |
| Controls                                  | Yes                   | Yes                    | Yes                   | Yes                   |
| City FE                                   | No                    | Yes                    | No                    | Yes                   |
| No. of observations                       | 22,400                | 22,400                 | 23,700                | 23,700                |
| No. of cities                             | 50                    | 50                     | 50                    | 50                    |
| No. of firms                              | 448                   | 448                    | 474                   | 474                   |
| Pseudo R-squared                          | 0.690                 | 0.719                  | 0.730                 | 0.767                 |
| Log likelihood                            | -543.1                | -491.6                 | -500.9                | -431.8                |

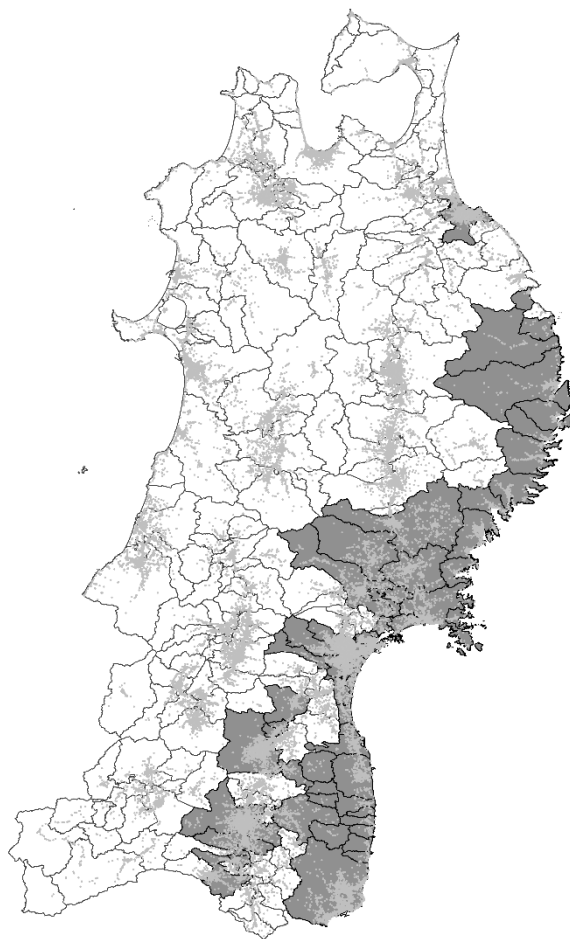
*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choices, using subsamples by sector (construction, manufacturing, wholesale, retail, and services) or by firm age (younger or older than the median of 25 years). Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair. The number of observations differs across subsamples and is reported in the bottom rows labeled “No. of observations,” “No. of cities,” and “No. of firms.” Appendix Table A4 presents the results of the same estimation but using the logarithm of the number of suppliers, customers, and banks as the key explanatory variables.

**Table 5. Effect of undamaged and damaged transaction partners**

|                                                          | Dependent variable: <i>City relocated</i> |                       |
|----------------------------------------------------------|-------------------------------------------|-----------------------|
|                                                          | (1)                                       | (2)                   |
| <i>Undamaged main supplier</i>                           | -0.393<br>(0.533)                         | -0.603<br>(0.552)     |
| <i>Damaged main supplier</i>                             | -0.522<br>(0.712)                         | -0.583<br>(0.705)     |
| <i>Undamaged main customer</i>                           | 1.302 ***<br>(0.485)                      | 1.403 **<br>(0.563)   |
| <i>Damaged main customer</i>                             | 0.030<br>(0.726)                          | 0.208<br>(0.581)      |
| <i>Undamaged main bank</i>                               | 1.449 ***<br>(0.161)                      | 1.564 ***<br>(0.203)  |
| <i>Damaged main bank</i>                                 | 0.304<br>(0.283)                          | 0.632 **<br>(0.271)   |
| <i>City before relocation</i>                            | 1.064 ***<br>(0.170)                      | 0.687 ***<br>(0.179)  |
| <i>Log moving distance</i>                               | -2.035 ***<br>(0.099)                     | -2.322 ***<br>(0.126) |
| <i>Log ratio of firms in tsunami area</i>                | -0.978 ***<br>(0.336)                     |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -7.274 ***<br>(0.878)                     |                       |
| <i>Log number of establishments in the same industry</i> | 0.302 **<br>(0.120)                       | 0.262 *<br>(0.146)    |
| <i>Log number of establishments in all industries</i>    | 0.492 ***<br>(0.120)                      |                       |
| City fixed effects                                       | No                                        | Yes                   |
| No. of observations                                      | 63,684                                    | 63,684                |
| No. of cities                                            | 61                                        | 61                    |
| No. of firms                                             | 1,044                                     | 1,044                 |
| Pseudo R2                                                | 0.7364                                    | 0.7615                |
| Log likelihood                                           | -1131.24                                  | -1023.37              |

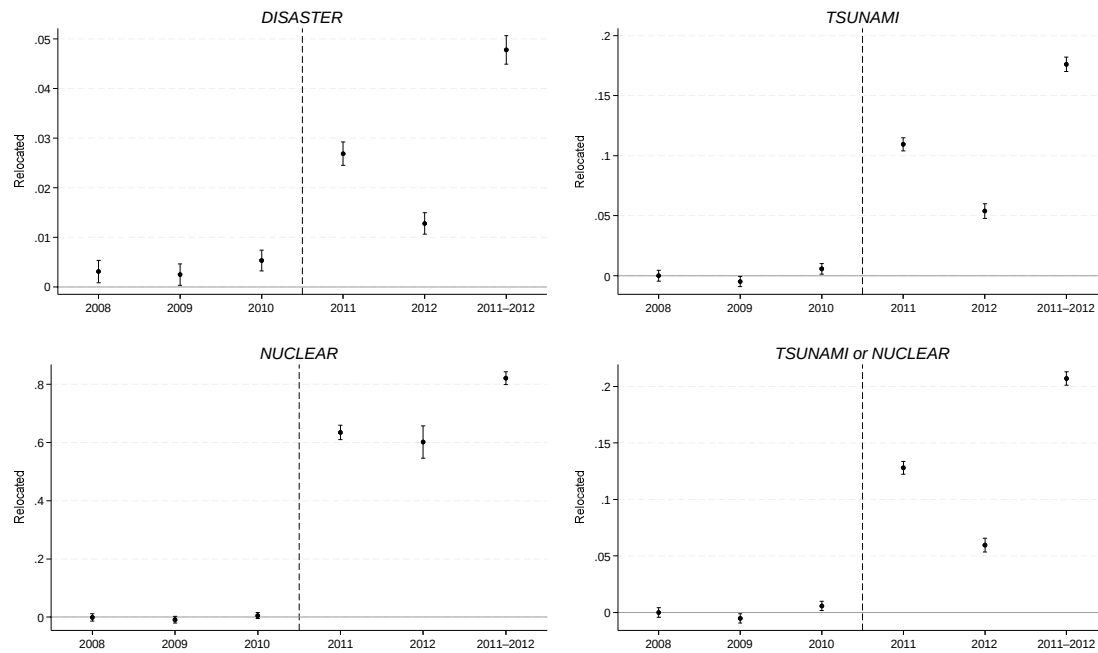
*Notes:* This table presents the results of the conditional logit estimation of firms' relocation choices by differentiating between undamaged and damaged transaction partners (see Table A2 for definitions). Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair (1,044 firms × 61 cities = 63,684 observations). Appendix Table A5 presents the results of the same estimation but using the logarithm of the number of suppliers, customers, and banks as the key explanatory variables.

**Figure 1. Earthquake affected areas**



*Notes:* This figure shows the 59 “affected” cities designated by the Japanese Government’s Act Concerning Special Financial Support to Deal with a Designated Disaster of Extreme Severity as of February 22, 2012, and the Planned Evacuation Zone / Emergency Evacuation Preparation Zone for the severe accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company as of April 22, 2011. The areas shaded in gray represent the 59 affected cities. The circles represent the pre-earthquake locations of the firms in our data set.

**Figure 2. Relocation probability over time: Damaged vs. undamaged firms**



*Notes:* This figure presents coefficient estimates and 95% confidence intervals from a linear probability model. The dependent variable is the dummy variable *Relocated*, which takes a value of one if a firm relocated over a distance of more than 0.1 km, and the independent variable is a dummy indicating whether a firm was affected by the earthquake (based on the *DISASTER*, *TSUNAMI*, or *NUCLEAR* criteria). The control group consists of firms not affected based on any of the three damage criteria. The dummy variable *DISASTER* equals one if a firm was located in one of the 59 cities designated by the Japanese Government's Act Concerning Special Financial Support to Deal with a Designated Disaster of Extreme Severity (as of February 22, 2012) or in the Planned Evacuation Zone / Emergency Evacuation Preparation Zone for the severe accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company (as of April 22, 2011). The dummy variable *TSUNAMI* equals one if a firm was located in the tsunami-affected area as identified by a map available on the website of a research project on the Tohoku earthquake at the University of Tokyo at that time. The dummy variable *NUCLEAR* equals one if a firm was located within a 30 km radius of the Fukushima Daiichi Nuclear Power Station. Years are defined as running from March of the given year to February of the following year (e.g., 2008 refers to March 2008–February 2009).

## **Appendices for Online Publication**

## **Appendix A. Supplementary tables and figures**

This appendix presents supplementary tables and figures to the main text.

**Table A1. Relocation patterns and distances to transaction partners: By sector*****Panel A: Relocation distances and share of firms that relocated within the same city***

|                                                     | No. obs. | Mean | Std. dev. | Min | p25 | p50 | p75  | Max   | Number (percentage)<br>of firms that relocated within<br>the same city |       |
|-----------------------------------------------------|----------|------|-----------|-----|-----|-----|------|-------|------------------------------------------------------------------------|-------|
| Entire sample                                       | 1,044    | 12.3 | 20.2      | 0.1 | 1.7 | 3.9 | 10.5 | 145.9 | 741                                                                    | 71.0% |
| Agriculture, fishery, forestry, mining              | 16       | 13.3 | 20.5      | 0.2 | 0.8 | 2.6 | 15.8 | 68.9  | 10                                                                     | 62.5% |
| Construction                                        | 322      | 15.4 | 21.0      | 0.2 | 2.5 | 5.7 | 18.5 | 127.3 | 201                                                                    | 62.4% |
| Manufacturing                                       | 139      | 14.6 | 21.7      | 0.1 | 1.7 | 5.1 | 13.9 | 93.4  | 93                                                                     | 66.9% |
| Utilities, ICT, transportation                      | 73       | 15.6 | 28.5      | 0.3 | 2.0 | 4.6 | 10.0 | 145.9 | 46                                                                     | 63.0% |
| Wholesale                                           | 147      | 6.9  | 10.7      | 0.1 | 1.4 | 3.2 | 6.9  | 66.5  | 119                                                                    | 81.0% |
| Retail                                              | 159      | 6.8  | 12.6      | 0.1 | 0.9 | 2.4 | 5.8  | 73.7  | 131                                                                    | 82.4% |
| Finance, real estate, rental and leasing            | 27       | 14.5 | 28.1      | 0.2 | 1.0 | 2.5 | 8.4  | 117.9 | 19                                                                     | 70.4% |
| Services                                            | 161      | 12.3 | 22.1      | 0.1 | 1.8 | 3.4 | 9.1  | 123.3 | 122                                                                    | 75.8% |
| Professional and technical services                 | 25       | 19.3 | 23.9      | 0.2 | 2.9 | 8.1 | 29.5 | 72.3  | 12                                                                     | 48.0% |
| Accommodations, eating and drinking services        | 11       | 13.7 | 21.5      | 0.1 | 0.9 | 5.9 | 11.4 | 70.0  | 7                                                                      | 63.6% |
| Living-related and personal services                | 17       | 14.2 | 20.2      | 0.1 | 2.9 | 4.3 | 16.2 | 69.7  | 12                                                                     | 70.6% |
| Education, medical care, welfare, compound services | 46       | 15.4 | 30.2      | 0.5 | 1.8 | 3.3 | 8.0  | 123.3 | 36                                                                     | 78.3% |
| Other services                                      | 62       | 6.3  | 11.6      | 0.1 | 1.6 | 2.6 | 6.9  | 78.3  | 55                                                                     | 88.7% |

***Panel B: Distances to transaction partners***

| <b>Suppliers</b>                                    | No. obs. | Mean  | Std. dev. | Min  | p25  | p50   | p75   | Max     |
|-----------------------------------------------------|----------|-------|-----------|------|------|-------|-------|---------|
| Entire sample                                       | 1,758    | 238.3 | 259.3     | 0.0  | 17.4 | 135.0 | 389.6 | 1,975.1 |
| Agriculture, fishery, forestry, mining              | 35       | 201.4 | 221.1     | 0.0  | 1.9  | 68.3  | 362.3 | 824.0   |
| Construction                                        | 327      | 124.2 | 187.7     | 0.0  | 7.7  | 45.6  | 157.9 | 1,175.5 |
| Manufacturing                                       | 457      | 229.2 | 236.4     | 0.0  | 11.3 | 171.0 | 407.5 | 1,448.3 |
| Utilities, ICT, transportation                      | 156      | 278.7 | 317.5     | 0.0  | 20.9 | 127.5 | 430.1 | 1,975.1 |
| Wholesale                                           | 405      | 305.9 | 271.0     | 0.0  | 53.9 | 304.3 | 413.1 | 1,512.5 |
| Retail                                              | 263      | 279.9 | 276.8     | 0.5  | 62.7 | 216.2 | 421.4 | 1,347.9 |
| Finance, real estate, rental and leasing            | 19       | 223.1 | 207.6     | 0.0  | 43.8 | 101.7 | 434.2 | 687.7   |
| Services                                            | 96       | 221.8 | 259.7     | 0.1  | 15.6 | 99.4  | 351.3 | 1,328.8 |
| Professional and technical services                 | 2        | 15.0  | 0.5       | 14.6 | 14.6 | 15.0  | 15.4  | 15.4    |
| Accommodations, eating and drinking services        | 22       | 265.2 | 266.9     | 0.4  | 4.1  | 238.9 | 353.3 | 917.3   |
| Living-related and personal services                | 18       | 211.3 | 268.3     | 8.6  | 14.1 | 88.9  | 249.6 | 979.7   |
| Education, medical care, welfare, compound services | 24       | 93.9  | 111.6     | 0.5  | 11.8 | 77.7  | 108.8 | 419.0   |
| Other services                                      | 30       | 312.3 | 301.5     | 0.1  | 88.4 | 327.4 | 420.8 | 1,328.8 |

| <b>Customers</b>                                    | No. obs. | Mean  | Std. dev. | Min   | p25   | p50   | p75   | Max     |
|-----------------------------------------------------|----------|-------|-----------|-------|-------|-------|-------|---------|
| Entire sample                                       | 1,569    | 220.4 | 247.7     | 0.0   | 11.2  | 114.8 | 357.8 | 1,472.7 |
| Agriculture, fishery, forestry, mining              | 18       | 321.5 | 453.7     | 0.2   | 4.6   | 211.9 | 412.9 | 1,472.7 |
| Construction                                        | 407      | 138.4 | 179.1     | 0.0   | 8.7   | 44.2  | 243.5 | 893.5   |
| Manufacturing                                       | 500      | 296.9 | 254.6     | 0.0   | 68.4  | 305.3 | 426.3 | 1,453.7 |
| Utilities, ICT, transportation                      | 187      | 290.6 | 286.2     | 0.0   | 15.4  | 306.5 | 433.9 | 1,355.4 |
| Wholesale                                           | 341      | 184.8 | 226.8     | 0.0   | 6.8   | 65.2  | 349.4 | 1,330.9 |
| Retail                                              | 38       | 91.0  | 216.1     | 0.0   | 1.3   | 4.3   | 54.4  | 1,120.6 |
| Finance, real estate, rental and leasing            | 17       | 257.2 | 317.3     | 0.8   | 2.3   | 235.5 | 431.9 | 1,263.8 |
| Services                                            | 61       | 164.3 | 233.0     | 0.2   | 1.6   | 32.7  | 308.0 | 886.1   |
| Professional and technical services                 | 6        | 227.6 | 115.5     | 6.4   | 232.3 | 243.7 | 318.2 | 321.2   |
| Accommodations, eating and drinking services        | 5        | 367.9 | 113.7     | 272.5 | 294.4 | 340.2 | 373.9 | 558.7   |
| Living-related and personal services                | 2        | 665.5 | 19.5      | 651.7 | 651.7 | 665.5 | 679.3 | 679.3   |
| Education, medical care, welfare, compound services | 29       | 116.0 | 233.9     | 0.2   | 1.3   | 6.5   | 39.8  | 886.1   |
| Other services                                      | 19       | 111.6 | 204.6     | 0.4   | 1.0   | 11.2  | 93.4  | 722.3   |

| <b>Banks</b>                                        | No. obs. | Mean | Std. dev. | Min | p25 | p50 | p75  | Max   |
|-----------------------------------------------------|----------|------|-----------|-----|-----|-----|------|-------|
| Entire sample                                       | 2,022    | 10.9 | 32.3      | 0.0 | 1.1 | 2.8 | 7.7  | 536.9 |
| Agriculture, fishery, forestry, mining              | 24       | 39.9 | 87.1      | 0.3 | 1.3 | 2.8 | 37.3 | 412.1 |
| Construction                                        | 565      | 7.9  | 25.0      | 0.0 | 1.2 | 3.1 | 7.3  | 348.8 |
| Manufacturing                                       | 316      | 15.7 | 37.1      | 0.1 | 1.5 | 3.0 | 8.4  | 249.4 |
| Utilities, ICT, transportation                      | 152      | 11.4 | 20.9      | 0.1 | 1.8 | 3.3 | 12.2 | 105.4 |
| Wholesale                                           | 290      | 13.7 | 44.1      | 0.0 | 1.2 | 2.7 | 7.7  | 536.9 |
| Retail                                              | 329      | 7.0  | 15.5      | 0.0 | 0.6 | 2.0 | 6.3  | 137.2 |
| Finance, real estate, rental and leasing            | 53       | 4.3  | 16.2      | 0.1 | 0.6 | 1.2 | 2.3  | 118.2 |
| Services                                            | 293      | 12.0 | 36.4      | 0.0 | 1.1 | 2.6 | 7.3  | 309.8 |
| Professional and technical services                 | 38       | 9.9  | 24.4      | 0.0 | 1.5 | 3.2 | 5.4  | 136.7 |
| Accommodations, eating and drinking services        | 23       | 48.2 | 101.0     | 0.0 | 0.3 | 3.2 | 46.7 | 309.8 |
| Living-related and personal services                | 32       | 16.9 | 38.4      | 0.1 | 1.3 | 3.2 | 8.2  | 186.4 |
| Education, medical care, welfare, compound services | 87       | 9.7  | 22.6      | 0.0 | 1.3 | 2.6 | 7.5  | 159.2 |
| Other services                                      | 113      | 5.7  | 11.3      | 0.1 | 1.0 | 2.1 | 6.9  | 94.2  |

*Notes:* This table presents summary statistics for the sample firms used in the baseline estimations (Table 2), broken down by the relocating firm's sector. Panel A reports relocation distances (in kilometers) and the number and percentage of firms that relocated within the same city; the unit of observation is the firm. Panel B reports distances (in kilometers) to the headquarters of suppliers and customers, as well as to the bank branches with which each firm transacted; the unit of observation is the firm–transaction partner pair. See Table 1 for the corresponding statistics for the entire sample and breakdowns by main/non-main partners.

**Table A2. Definitions of variables**

| Variable                                                 | Definition                                                                                                                                                                                                                                                                               |
|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>City relocated</i>                                    | Dummy variable that takes a value of one for the city where the firm relocated after the earthquake.                                                                                                                                                                                     |
| <i>Main supplier</i>                                     | Dummy variable indicating whether a firm's main supplier (headquarters) was located in the city before the earthquake. Damaged main supplier and undamaged main supplier are defined analogously, depending on whether the supplier's headquarters was in the damaged or undamaged area. |
| <i>Main customer</i>                                     | Dummy variable indicating whether a firm's main customer (headquarters) was located in the city before the earthquake. Damaged main customer and undamaged main customer are defined analogously, depending on whether the customer's headquarters was in the damaged or undamaged area. |
| <i>Main bank</i>                                         | Dummy variable indicating whether a firm's main bank (the branch the firm transacts with) was located in the city before the earthquake. Damaged main bank and undamaged main bank are defined analogously, depending on whether the bank's branch was in the damaged or undamaged area. |
| <i>Log number of suppliers</i>                           | Log of the number of incumbent suppliers (headquarters) plus 1 in the city before the earthquake. Log number of damaged suppliers and log number of undamaged suppliers are defined analogously, based on whether the suppliers' headquarters were in the damaged or undamaged area.     |
| <i>Log number of customers</i>                           | Log of the number of incumbent customers (headquarters) plus 1 in the city before the earthquake. Log number of damaged customers and log number of undamaged customers are defined analogously, based on whether the customers' headquarters were in the damaged or undamaged area.     |
| <i>Log number of banks</i>                               | Log of the number of incumbent banks (the branch the firm transacts with) plus 1 in the city before the earthquake. Log number of damaged banks and log number of undamaged banks are defined analogously, based on whether the banks' branches were in the damaged or undamaged area.   |
| <i>City before relocation</i>                            | Dummy variable that takes a value of one for the city where the firm was headquartered before the relocation.                                                                                                                                                                            |
| <i>Log moving distance</i>                               | Log of the Euclidian distance between a firm's headquarters and a candidate city plus 1.                                                                                                                                                                                                 |
| <i>Log ratio of firms in tsunami area</i>                | Log of the ratio of firms (headquarters) located in the tsunami-affected area plus 1 to total firms.                                                                                                                                                                                     |
| <i>Log ratio of firms in nuclear accident area</i>       | Log of the ratio of firms (headquarters) located in the nuclear accident-affected area plus 1 to total firms.                                                                                                                                                                            |
| <i>Log number of establishments in the same industry</i> | Log of the number of establishments that belong to the same industry in a city.                                                                                                                                                                                                          |
| <i>Log number of establishments in all industries</i>    | Log of the number of all establishments in a city.                                                                                                                                                                                                                                       |

*Notes:* This table provides definitions of the variables used in the baseline estimations (Table 2). Damaged transaction partners (suppliers, customers, and banks) are those whose headquarters were located in the tsunami-affected area or within a 30 km radius of the Fukushima power station; undamaged transaction partners are those located outside these areas.

**Table A3. Summary statistics**

| Variable                                                 | Mean      | Std. dev. | Min.    | Max.      |
|----------------------------------------------------------|-----------|-----------|---------|-----------|
| <i>City relocated</i>                                    | 0.01639   | 0.12698   | 0       | 1         |
| <i>Main supplier</i>                                     | 0.00214   | 0.04616   | 0       | 1         |
| <i>Undamaged main supplier</i>                           | 0.00129   | 0.03586   | 0       | 1         |
| <i>Damaged main supplier</i>                             | 0.00085   | 0.02911   | 0       | 1         |
| <i>Main customer</i>                                     | 0.00181   | 0.04246   | 0       | 1         |
| <i>Undamaged main customer</i>                           | 0.00113   | 0.03361   | 0       | 1         |
| <i>Damaged main customer</i>                             | 0.00068   | 0.02598   | 0       | 1         |
| <i>Main bank</i>                                         | 0.01431   | 0.11875   | 0       | 1         |
| <i>Undamaged main bank</i>                               | 0.00771   | 0.08747   | 0       | 1         |
| <i>Damaged main bank</i>                                 | 0.00660   | 0.08094   | 0       | 1         |
| <i>Log number of suppliers</i>                           | 0.00775   | 0.08498   | 0       | 2.19722   |
| <i>Log number of undamaged suppliers</i>                 | 0.00518   | 0.06529   | 0       | 1.79176   |
| <i>Log number of damaged suppliers</i>                   | 0.00286   | 0.05350   | 0       | 1.94591   |
| <i>Log number of customers</i>                           | 0.00645   | 0.07938   | 0       | 2.39790   |
| <i>Log number of undamaged customers</i>                 | 0.00414   | 0.05825   | 0       | 1.94591   |
| <i>Log number of damaged customers</i>                   | 0.00266   | 0.05316   | 0       | 2.19722   |
| <i>Log number of banks</i>                               | 0.01613   | 0.12428   | 0       | 1.79176   |
| <i>Log number of undamaged banks</i>                     | 0.00917   | 0.08878   | 0       | 1.60944   |
| <i>Log number of damaged banks</i>                       | 0.00778   | 0.08462   | 0       | 1.60944   |
| <i>City before relocation</i>                            | 0.01463   | 0.12009   | 0       | 1         |
| <i>Log moving distance</i>                               | 4.47165   | 0.83218   | 0       | 5.94046   |
| <i>Log ratio of firms in tsunami area</i>                | 0.15746   | 0.20777   | 0       | 0.61387   |
| <i>Log ratio of firms in nuclear accident area</i>       | 0.01507   | 0.09046   | 0       | 0.69315   |
| <i>Log number of establishments in the same industry</i> | 3.46139   | 1.61040   | 0       | 7.98684   |
| <i>Log number of establishments in all industries</i>    | 7.51297   | 1.21031   | 4.82028 | 9.83403   |
| Raw figures for log variables                            |           |           |         |           |
| <i>Number of suppliers</i>                               | 0.01325   | 0.16467   | 0       | 8         |
| <i>Number of undamaged suppliers</i>                     | 0.00817   | 0.10951   | 0       | 5         |
| <i>Number of damaged suppliers</i>                       | 0.00509   | 0.10753   | 0       | 6         |
| <i>Number of customers</i>                               | 0.01151   | 0.17239   | 0       | 10        |
| <i>Number of undamaged customers</i>                     | 0.00653   | 0.09956   | 0       | 6         |
| <i>Number of damaged customers</i>                       | 0.00498   | 0.11671   | 0       | 8         |
| <i>Number of banks</i>                                   | 0.02786   | 0.23162   | 0       | 5         |
| <i>Number of undamaged banks</i>                         | 0.01482   | 0.15327   | 0       | 4         |
| <i>Number of damaged banks</i>                           | 0.01303   | 0.15116   | 0       | 4         |
| <i>Moving distance</i>                                   | 112.43990 | 70.80829  | 0       | 379.10940 |
| <i>Ratio of firms in tsunami area</i>                    | 0.19743   | 0.26848   | 0       | 0.84756   |
| <i>Ratio of firms in nuclear accident area</i>           | 0.02038   | 0.12889   | 0       | 1         |
| <i>Number of establishments in the same industry</i>     | 93.19193  | 157.29050 | 1       | 2942      |
| <i>Number of establishments in all industries</i>        | 3596.869  | 4378.287  | 124     | 18658     |

Notes: This table presents summary statistics for the variables used in the baseline estimations (Table 2). The unit of observation is the firm–city pair (1,044 firms × 61 cities = 63,684 observations).

**Table A4. Subsample estimation (alternative specification)**

**Panel A: By sector**

|                                | Dependent variable: <i>City relocated</i> |                       |                     |                     |                      |                      |                      |                       |                        |                        |
|--------------------------------|-------------------------------------------|-----------------------|---------------------|---------------------|----------------------|----------------------|----------------------|-----------------------|------------------------|------------------------|
|                                | Construction                              |                       | Manufacturing       |                     | Wholesale            |                      | Retail               |                       | Service                |                        |
|                                | (1)                                       | (2)                   | (3)                 | (4)                 | (5)                  | (6)                  | (7)                  | (8)                   | (9)                    | (10)                   |
| <i>Log number of suppliers</i> | 0.8899<br>(0.6290)                        | 0.5080<br>(0.7203)    | -0.0298<br>(0.4090) | -0.2183<br>(0.4472) | -0.1710<br>(0.9520)  | -0.1708<br>(0.8274)  | 0.1803<br>(0.6818)   | -0.2971<br>(0.8226)   | -2.6781***<br>(0.7475) | -4.0058***<br>(0.9236) |
| <i>Log number of customers</i> | 0.8869*<br>(0.5001)                       | 1.1679*<br>(0.6356)   | -0.3520<br>(0.6399) | -0.7087<br>(0.6716) | 0.5194<br>(0.7766)   | 0.8506<br>(0.8012)   | -0.2223<br>(1.5332)  | -0.1632<br>(1.3454)   | 5.6432***<br>(1.1479)  | 4.9447***<br>(1.5818)  |
| <i>Log number of banks</i>     | 1.5698***<br>(0.3516)                     | 2.0358***<br>(0.3729) | -0.6957<br>(0.6377) | -0.2116<br>(0.5642) | 1.4875**<br>(0.7201) | 2.0084**<br>(0.9634) | 1.3395**<br>(0.5699) | 1.8798***<br>(0.6241) | 1.9194***<br>(0.6393)  | 2.2490***<br>(0.6699)  |
| Controls                       | Yes                                       | Yes                   | Yes                 | Yes                 | Yes                  | Yes                  | Yes                  | Yes                   | Yes                    | Yes                    |
| City FE                        | No                                        | Yes                   | No                  | Yes                 | No                   | Yes                  | No                   | Yes                   | No                     | Yes                    |
| No. of observations            | 14,212                                    | 14,212                | 5,143               | 5,143               | 3,915                | 3,915                | 5,239                | 5,239                 | 6,031                  | 6,031                  |
| No. of cities                  | 44                                        | 44                    | 37                  | 37                  | 27                   | 27                   | 31                   | 31                    | 37                     | 37                     |
| No. of firms                   | 323                                       | 323                   | 139                 | 139                 | 145                  | 145                  | 169                  | 169                   | 163                    | 163                    |
| Pseudo R-squared               | 0.706                                     | 0.739                 | 0.642               | 0.689               | 0.776                | 0.823                | 0.804                | 0.837                 | 0.789                  | 0.820                  |
| Log likelihood                 | -359.3                                    | -319.0                | -179.5              | -156.2              | -107.0               | -84.77               | -113.8               | -94.60                | -123.9                 | -106.0                 |

**Panel B: By firm age**

| Dependent variable: <i>City relocated</i> |                       |                       |                     |                       |
|-------------------------------------------|-----------------------|-----------------------|---------------------|-----------------------|
|                                           | Younger firms         |                       | Older firms         |                       |
|                                           | (1)                   | (2)                   | (3)                 | (4)                   |
| <i>Log number of suppliers</i>            | -0.9037*<br>(0.5235)  | -1.1834**<br>(0.5351) | 0.4229<br>(0.3558)  | 0.1602<br>(0.3253)    |
| <i>Log number of customers</i>            | 1.1777***<br>(0.4520) | 1.2158**<br>(0.5545)  | 0.4752<br>(0.5019)  | 0.4837<br>(0.4704)    |
| <i>Log number of banks</i>                | 1.2282***<br>(0.2855) | 1.6470***<br>(0.3005) | 0.6661*<br>(0.3597) | 1.2097***<br>(0.3492) |
| Controls                                  | Yes                   | Yes                   | Yes                 | Yes                   |
| City FE                                   | No                    | Yes                   | No                  | Yes                   |
| No. of observations                       | 22,400                | 22,400                | 23,700              | 23,700                |
| No. of cities                             | 50                    | 50                    | 50                  | 50                    |
| No. of firms                              | 448                   | 448                   | 474                 | 474                   |
| Pseudo R-squared                          | 0.690                 | 0.723                 | 0.726               | 0.764                 |
| Log likelihood                            | -542.5                | -485.1                | -508.3              | -438.2                |

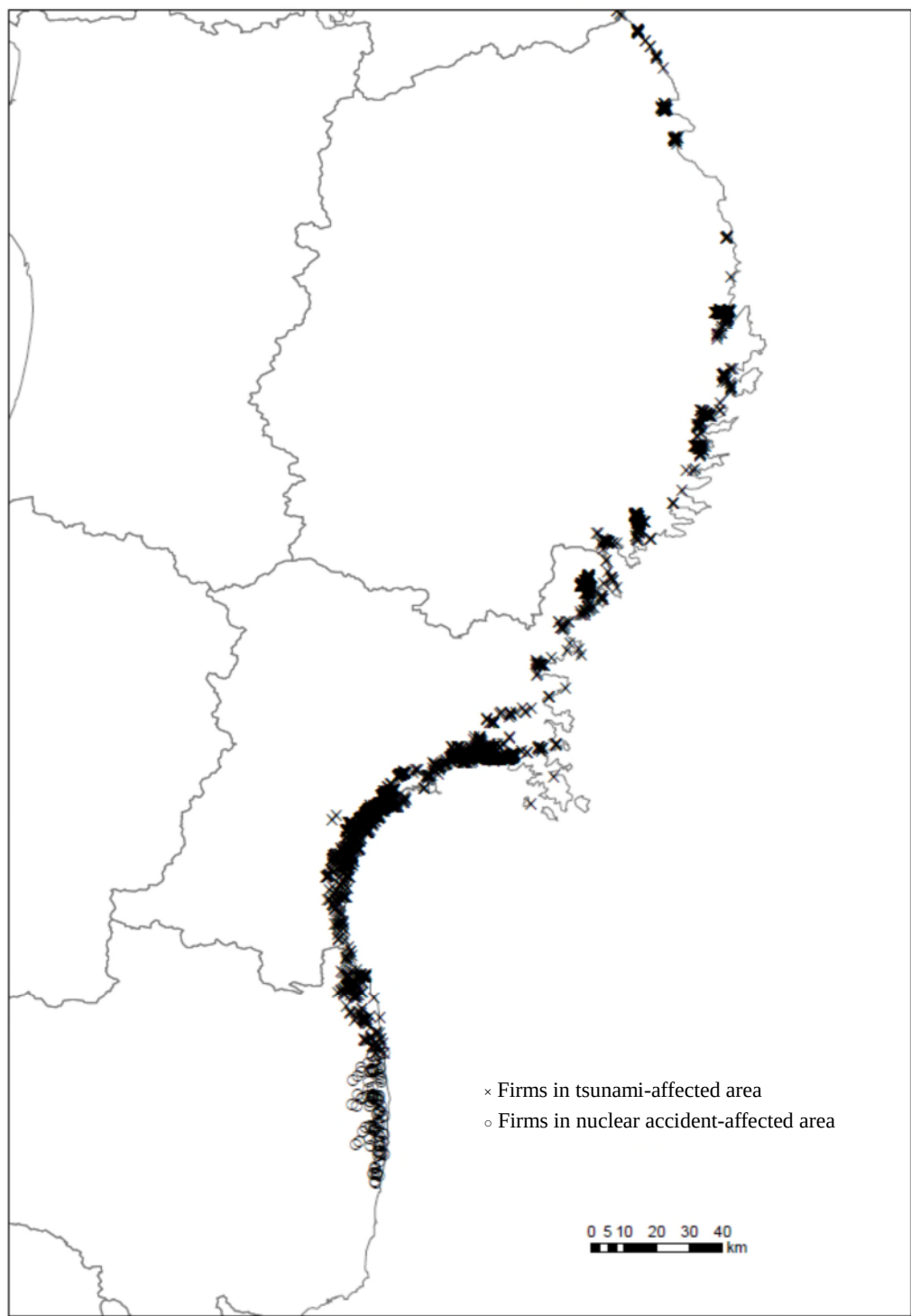
*Notes:* This table presents the results of the conditional logit estimation identical to Table 4, but using the logarithm of the number of suppliers, customers, and banks as the key explanatory variables, for subsamples by sector (construction, manufacturing, wholesale, retail, and services) or by firm age (younger or older than the median of 25 years). Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair. The number of observations differs across subsamples and is reported in the bottom rows labeled “No. of observations,” “No. of cities,” and “No. of firms.”

**Table A5. Effect of undamaged and damaged transaction partners (alternative specification)**

|                                                          | Dependent variable: <i>City relocated</i> |                       |
|----------------------------------------------------------|-------------------------------------------|-----------------------|
|                                                          | (1)                                       | (2)                   |
| <i>Log number of undamaged suppliers</i>                 | 0.366<br>(0.335)                          | 0.088<br>(0.340)      |
| <i>Log number of damaged suppliers</i>                   | -0.687<br>(0.471)                         | -0.732<br>(0.468)     |
| <i>Log number of undamaged customers</i>                 | 1.124 ***<br>(0.436)                      | 1.185 **<br>(0.502)   |
| <i>Log number of damaged customers</i>                   | -0.173<br>(0.440)                         | -0.213<br>(0.390)     |
| <i>Log number of undamaged banks</i>                     | 1.639 ***<br>(0.218)                      | 1.870 ***<br>(0.260)  |
| <i>Log number of damaged banks</i>                       | -0.257<br>(0.306)                         | 0.395<br>(0.333)      |
| <i>City before relocation</i>                            | 1.109 ***<br>(0.166)                      | 0.636 ***<br>(0.181)  |
| <i>Log moving distance</i>                               | -2.090 ***<br>(0.103)                     | -2.343 ***<br>(0.125) |
| <i>Log ratio of firms in tsunami area</i>                | -0.744 **<br>(0.329)                      |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -7.014 ***<br>(0.849)                     |                       |
| <i>Log number of establishments in the same industry</i> | 0.313 ***<br>(0.119)                      | 0.292 *<br>(0.153)    |
| <i>Log number of establishments in all industries</i>    | 0.478 ***<br>(0.120)                      |                       |
| City fixed effects                                       | No                                        | Yes                   |
| No. of observations                                      | 63,684                                    | 63,684                |
| No. of cities                                            | 61                                        | 61                    |
| No. of firms                                             | 1,044                                     | 1,044                 |
| Pseudo R2                                                | 0.7373                                    | 0.7618                |
| Log likelihood                                           | -1127.61                                  | -1022.15              |

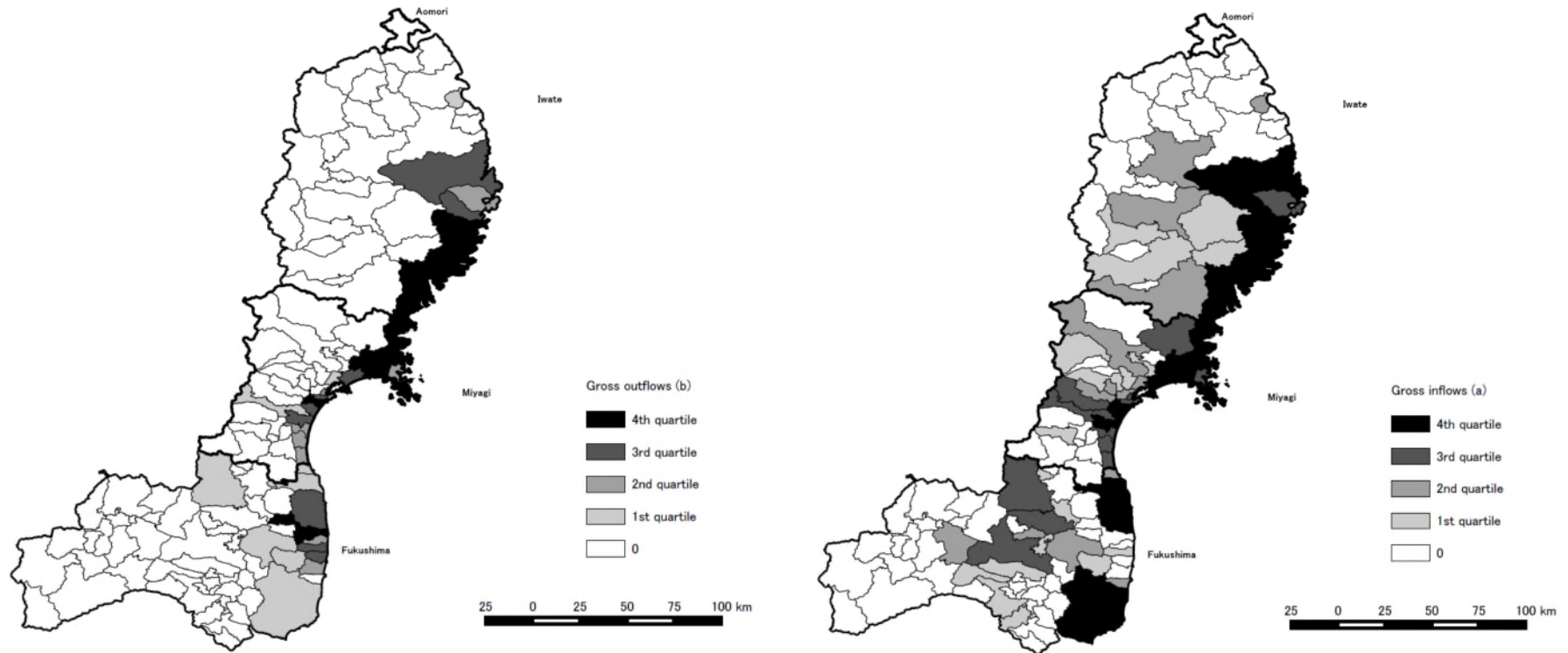
*Notes:* This table presents the results of the conditional logit estimation identical to Table 5 (see Table A2 for definitions of undamaged and damaged transaction partners), but using the logarithm of the number of suppliers, customers, and banks as the key explanatory variables. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair (1,044 firms × 61 cities = 63,684 observations).

**Figure A1. Firms in the tsunami and nuclear accident areas**



*Notes:* This figure shows the pre-earthquake locations of firms that were located in the most severely affected areas, namely, those directly affected by the tsunami and the nuclear accident. The X-marks and circles show the locations of the tsunami- and nuclear-affected firms, respectively.

**Figure A2. Distribution of cities from which firms relocated (gross outflows) and to which firms relocated (gross inflows)**



*Notes:* The figure shows the distribution of cities to which firms relocated (left panel) and from which firms relocated (right panel). Cities are divided into quartiles in terms of the number of firms they received (gross inflows) or lost (gross outflows) out of the 1,044 sample firms. Darker shaded areas represent cities that received/lost a larger number of firms, while cities in white registered no inflows/outflows.

## **Appendix B. Characteristics of firms that relocated and their suppliers and customers**

This appendix describes the characteristics of the 1,044 firms that relocated, along with those of their suppliers and customers. Table B1, Panel A presents summary statistics for these firms and their transaction partners. Note that the number of observations differs across these types of transaction partners, as both the number of partners per firm and the numbers of firms for which pre-earthquake suppliers and customers can be identified vary. Specifically, the numbers of firms for which at least one supplier and customer can be identified in the TDB database are 287 and 248, respectively.<sup>24</sup> For comparison, the number of firms for which we can identify banks is 1,037.

The firms that relocated had a mean of 13.7 employees and an average age of 27.1 years. In contrast, their suppliers had an average of 772.4 employees and a firm age of 45.9 years, while their customers had an average of 1583.5 employees and a firm age of 45.4 years. These figures indicate that the 1,044 firms that relocated and that we focus on were considerably smaller and younger than their suppliers and customers. The sample firms' customers tended to be larger than their suppliers, but this varies depending on the sector, as we explained in Section 6.3 in the main text.

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<sup>24</sup> The numbers of firms for which suppliers and customers are identified are relatively small, as such information is lacking for many small firms in TDB's Comprehensive Credit Reporting (CCR) dataset. To address the issue of extensive missing values in supplier- and customer-related variables, we use another dataset from TDB, COSMOS2, to impute the missing values. For details, see Appendix D. Estimation results using the imputed supplier- and customer-related variables are presented in Section 6.2 of the main text.

The sectoral composition of the 1,044 firms that relocated is as follows (Table B1, Panel B). The construction sector makes up the largest share, accounting for 30.8%, followed by services (15.4%), retail (15.2%), wholesale (14.1%), and manufacturing (13.3%). Turning to the sector composition of suppliers, more than half belonged to the wholesale sector (54.9%), with manufacturing being the second most common sector (23.6%). As for customers, the sectoral distribution is more dispersed: wholesale represents the largest share (28.0%), followed by manufacturing (23.7%) and construction (22.3%).

**Table B1. Characteristics of relocating firms and their suppliers and customers*****Panel A: Summary statistics***

|                            |                      | No. obs. | Mean     | Std. dev. | Min. | p25   | p50   | p75    | Max.      |
|----------------------------|----------------------|----------|----------|-----------|------|-------|-------|--------|-----------|
| Number of employees        | Firms that relocated | 1,044    | 13.7     | 25.8      | 0    | 2     | 5     | 14     | 300       |
|                            | Suppliers            | 1,747    | 772.4    | 2647.9    | 0    | 22    | 96    | 419    | 42,167    |
|                            | Customers            | 1,498    | 1583.5   | 7594.3    | 0    | 30    | 97    | 400    | 140,846   |
| Sales amount (million yen) | Firms that relocated | 1,044    | 332.3    | 1013.1    | 0    | 40    | 100   | 270    | 18,564    |
|                            | Suppliers            | 1,747    | 96374.1  | 383556.1  | 1    | 943   | 6,036 | 48,551 | 7,359,322 |
|                            | Customers            | 1,498    | 171627.0 | 681432.4  | 1    | 1,145 | 5,811 | 43,237 | 8,236,241 |
| Firm age                   | Firms that relocated | 922      | 27.1     | 14.8      | 1    | 16    | 25    | 38     | 70        |
|                            | Suppliers            | 1,738    | 45.9     | 20.8      | 1    | 31    | 47    | 61     | 124       |
|                            | Customers            | 1,492    | 45.4     | 20.4      | 3    | 31    | 44    | 61     | 131       |

**Panel B: Sectoral composition**

|                                                     | Firms that relocated |       | Suppliers |       | Customers |       |
|-----------------------------------------------------|----------------------|-------|-----------|-------|-----------|-------|
| Entire sample                                       | 1,044                |       | 1,765     |       | 1,505     |       |
| Agriculture, fishery, forestry, mining              | 16                   | 1.5%  | 7         | 0.4%  | 29        | 1.9%  |
| Construction                                        | 322                  | 30.8% | 85        | 4.8%  | 335       | 22.3% |
| Manufacturing                                       | 139                  | 13.3% | 417       | 23.6% | 356       | 23.7% |
| Utilities, ICT, transportation                      | 73                   | 7.0%  | 54        | 3.1%  | 115       | 7.6%  |
| Wholesale                                           | 147                  | 14.1% | 969       | 54.9% | 421       | 28.0% |
| Retail                                              | 159                  | 15.2% | 89        | 5.0%  | 120       | 8.0%  |
| Finance, real estate, rental and leasing            | 27                   | 2.6%  | 32        | 1.8%  | 20        | 1.3%  |
| Services                                            | 161                  | 15.4% | 112       | 6.3%  | 109       | 7.2%  |
| Professional and technical services                 | 25                   | 2.4%  | 14        | 0.8%  | 10        | 0.7%  |
| Accommodations, eating and drinking services        | 11                   | 1.1%  | 5         | 0.3%  | 20        | 1.3%  |
| Living-related and personal services                | 17                   | 1.6%  | 4         | 0.2%  | 12        | 0.8%  |
| Education, medical care, welfare, compound services | 46                   | 4.4%  | 71        | 4.0%  | 53        | 3.5%  |
| Other services                                      | 62                   | 5.9%  | 18        | 1.0%  | 14        | 0.9%  |

*Notes:* This table presents summary statistics on the number of employees, annual sales (in millions of yen), firm age since establishment, and sector for the sample firms used in the baseline estimations (Table 2), as well as for each firm's suppliers and customers. The unit of observation is the firm.

## Appendix C. Construction of control variables and baseline results

This appendix describes how the control variables used in the baseline estimation are constructed and presents their estimation results.

### C.1. Construction of control variables

**Attractiveness of a city to the average firm ( $\theta_c$ ):** As we noted in Section 5.2.3, we take two alternative approaches to measure the attractiveness of city  $c$  to the average firm irrespective of the industry. First, we include the following three variables that potentially affect firms' location choice. *Log number of establishments in all industries* denotes the natural logarithm of the number of establishments of all industries in the city. This variable is to control for the general agglomeration (or urbanization) effect and is constructed from the 2009 Economic Census. Although the expected sign of this effect is positive (Davis and Henderson 2008, Strauss-Kahn and Vives 2009), it might also be negative if this variable captures the cost of congestion such as high input factor prices. The two other variables we use to gauge a city's attractiveness – or unattractiveness – measure the extent of damage it suffered due to the earthquake. The first is *Log ratio of firms in tsunami area*, which is defined as the natural logarithm of the number of firms in tsunami-affected areas plus one divided by the total number of firms in the city, representing the log of the ratio of tsunami-affected firms in each city. The second is *Log ratio of firms in nuclear accident area*, which is the natural logarithm of the number of firms located within a 30 km radius of the Fukushima Daiichi Nuclear Power Plant in a city plus one divided by the total number of

firms in the city before the earthquake.<sup>25</sup> We expect that both *Log ratio of firms in tsunami area* and *Log ratio of firms in nuclear accident area* have a negative impact on the probability that a firm chooses a particular city for relocation.

Second, following Head et al. (1995), we alternatively use city dummies to control for city fixed effects. Head et al. (1995) argue that this approach is superior to using specific proxies (such as the three variables just outlined) for region-specific characteristics, because the latter inherently is subject to omitted variable biases that might give rise to correlation between covariates and error terms. Controlling for city-specific fixed effects circumvents this issue. Although using city-fixed effects has the advantage of avoiding omitted variable bias, it has the disadvantage that it does not allow us to estimate the effect of specific city-level variables that might be of interest in understanding the determinants of firms' choice of where to relocate. Therefore, we alternately estimate equation (1) either with the three variables above or with city-fixed effects.

**Industry-specific attractiveness of a city ( $\theta_{jc}$ ):** We use the natural logarithm of the number of establishments in firm  $i$ 's industry  $j$  in city  $c$  for vector  $\theta_{jc}$ . This variable, labeled *Log number of establishments in the same industry*, is constructed from the 2009 Economic Census. Previous studies (e.g., Head et al. 1995) use this variable to capture the effects of the industry-specific agglomeration in each city. Many extant studies provide evidence of industry-specific

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<sup>25</sup> Note that *Log ratio of firms in tsunami area* and *Log ratio of firms in nuclear accident area* differ from *TSUNAMI* and *NUCLEAR* in Section 4 and Figure 2, which are firm-level dummy variables.

agglomeration effects (positive externalities), and we expect *Log number of establishments in the same industry* to have a positive impact on firms' relocation choice.

**Firm-specific attractiveness of a city ( $\theta_{ic}$ ):** We construct two variables for vector  $\theta_{ic}$  that capture strong inertia and distance-related frictions in relocation decisions. *City before relocation* is a dummy variable that takes one if city  $c$  is the same city in which firm  $i$  was already located before the earthquake, and zero otherwise. Meanwhile, *Log moving distance* is the natural logarithm of the Euclidian distance in kilometers between a firm's headquarters before the earthquake and each of the 61 candidate cities. These variables are to control for possible gravity effects that attract firms to their original location. If relocating firms (or their owners) have a preference for the original (pre-earthquake) location or have built up a social network indispensable for business, they are less likely to relocate to a remote city. We therefore expect *City before relocation* and *Log moving distance* to have a positive and a negative effect respectively on firms' choice of a city.

## C.2. Baseline estimation results for the control variables

The estimation results for the control variables in Table 2 are as follows. First, regarding the effect of city-level variables ( $\theta_c$ ) in columns (1) and (2), the effect of *Log number of establishments in all industries* is positive and significant, which suggests that the benefits of moving to a larger city (the positive agglomeration effects) exceed the costs of congestion effects. The effects of the other city-level variables, *Log ratio of firms in tsunami area* and *Log ratio of firms in nuclear accident area*, are negative and significant, suggesting that firms were less likely to move to a city that had been severely damaged by the earthquake.

Second, as for the city-industry level variables ( $\theta_{jc}$ ), *Log number of establishments in the same industry* has a positive and significant impact on firms' relocation choice, suggesting that the benefits of industry agglomeration outweigh the costs of congestion effects.

Finally, with respect to the firm-specific city variables, *City before relocation* is positive and significant while *Log moving distance* is negative and significant, indicating that firms were less likely to relocate to distant cities. These findings are consistent with studies reporting that firms tend to move a relatively short distance when they relocate (Stam, 2007; Knoben, 2011; Hellwig, 2022).

## **Appendix D. Imputation of supplier- and customer-related variables**

This appendix explains the construction of the supplier- and customer-related variables, as well as the dataset used. Section D.1 describes the variables used in the baseline estimations in Section 6.1, while Section D.2 describes those used in the robustness checks in Section 6.2.

### **D.1. Variables for baseline estimations**

The TDB database consists of two main datasets: the Comprehensive Credit Reporting (CCR) and COSMOS2. The CCR contains detailed information on firms, including their financial statements, lists of the firms' suppliers and customers (with the company codes assigned by TDB), and real estate ownership certificates. We use the CCR records from January 2008 to March 2011 to identify each firm's suppliers and customers prior to the Tohoku earthquake. Using the company codes of suppliers and customers, we can identify their characteristics including their

locations.<sup>26</sup> The CCR also records the main supplier and customer among the suppliers and customers listed for each firm.

COSMOS2 contains basic firm profiles, such as firms' address, characteristics (e.g. industry, number of employees, sales amount), credit score, and the names of the bank branches they transact with, including the bank branch codes assigned by the Japanese Bankers' Association. We use COSMOS2 records from January 2008 to March 2011 to identify each firm's banks before the earthquake. Among the banks listed for each firm, we assume that the top-listed bank is its main bank. Additionally, we use the *Nihon Kinyu Meikan* (Almanac of Financial Institutions in Japan) compiled by Nikkin Co., Ltd. to obtain the addresses of bank branches.

In our sample of 1,044 firms, the numbers of firms for which at least one supplier and one customer prior to the earthquake can be identified from the CCR are 287 and 248, respectively. Among these, 254 firms had suppliers that were located in the 61 cities used as the choice set in the main estimation. Similarly, 213 firms had customers located in the 61 cities. The number of firms for which at least one bank can be identified from COSMOS2 is 1,037, of which 935 firms had banks located in the 61 cities.

## **D.2. Imputed variables for robustness check**

As mentioned above, the number of firms for which suppliers and customers can be identified using the CCR dataset is limited. This is because the CCR records are compiled by TDB researchers upon request from clients on a paid basis. As a result, information on suppliers and

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<sup>26</sup> The TDB database does not provide information on the amount of purchases from suppliers or sales to customers.

customers is missing for many small firms in our sample, raising potential concerns about sample selection bias and/or measurement error. To address this issue, we supplement the data using information from COSMOS2, which contains the names of up to five suppliers and customers for each firm. We use these names to impute missing supplier and customer information.

The imputation procedure is as follows. First, for firms whose suppliers and customers we were unable to identify in the CCR, we extracted the names of suppliers and customers from COSMOS2. Second, using TDB's company search service, we retrieve the TDB company codes corresponding to the names identified in the previous step.<sup>27</sup> Third, we use these company codes to identify the addresses of each supplier and customer. To determine the main supplier and customer, we assume that the top-listed supplier and customer in each firm's record is the main partner. If the top-listed firm is not a specific company (e.g., listed as "general consumers" or "local construction companies"), we instead treat the second-listed firm as the main partner.

As a result of this imputation, the number of firms for which at least one supplier and one customer could be identified increased to 691 and 586, respectively. The average size of firms with identified suppliers and customers using both the CCR and COSMOS2 is smaller than that of firms using the CCR alone. The robustness checks using the imputed supplier- and customer-related variables are presented in Section 6.2.

While COSMOS2 enables us to impute missing values and increase the number of firms with identified suppliers and customers, this comes with certain limitations. Specifically, since

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<sup>27</sup> <https://www.tdb.co.jp/service/u/1000.jsp>

company codes are not available for any of the listed suppliers and customers in COSMOS2, there is a risk of incorrect matching. In addition, since the number of reported suppliers or customers is capped at five, the variables capturing their counts may underestimate the true value.

## **Appendix E. Robustness estimations**

In this appendix, we present the estimation results that were briefly discussed in Section 6.2. Specifically, to assess the robustness of the baseline results reported in Table 2, we conduct additional estimations that address potential concerns related to firms that have multiple establishments, the independence of irrelevant alternatives (IIA) assumption, and the possibility that our baseline results are driven by firms that remained within their pre-relocation city.

First, a possible concern about the baseline estimation (Table 2) is that the positive effect of the presence of incumbent transaction partners captures the tendency of damaged firms to move to a place where they already had other establishments. This may be the case when firms owned multiple establishments and the other establishments (non-headquarters) were located close to their customers and/or lender banks. To address this concern, we focus on a subsample consisting of single-establishment firms only and rerun our estimations.

Table E1 shows the results for the subsample of single-establishment firms. In all specifications (columns (1)–(4)), the coefficients on the incumbent customer- and bank-related variables are positive and statistically significant, which is consistent with the results in Table 2. In addition, the quantitative impacts are similar to those in Table 2, although the coefficients on *Main customer* and *Log number of customers* in Table E1 are 20–30% larger. The coefficients on

supplier-related variables remain insignificant. In sum, it is unlikely that the positive effect of incumbent customers and banks on firms' relocation choice obtained in Table 2 is an artifact of the gravity of firms' other establishments.

Second, another possible concern is that the independence of irrelevant alternatives (IIA) assumption may be violated in the conditional logit estimation. Under the IIA assumption, the ratio of the logit probability of any two alternatives is independent of the addition or deletion of any other alternative. Because cities in our choice set are heterogeneous in size and characteristics, some pairs of cities may be closer substitutes than others, potentially violating the IIA assumption. As highlighted by Yamashita et al. (2014), the inclusion of city fixed effects as in columns (3) and (4) in Table 2 provides a partial remedy, because they absorb unobservable city-specific factors in equation (1). To address any remaining concern, we implement another subsample estimation in which the IIA assumption is more likely to hold, namely, we restrict the choice set (candidate cities to which firms might relocate) to "big" cities that received at least ten incoming firms after the earthquake.

Table E2 presents the estimation results based on this subsample analysis. The results are qualitatively similar to those in Table 2. The coefficients on *Main customer* is positive and significant, while those on *Log number of customers* are insignificant. The coefficients on *Main bank* and *Log number of banks* are positive, statistically significant, and similar in size to those in Table 2. The coefficients on supplier-related variables remain insignificant.

Third, a further potential concern regards the definition of relocation in our analysis. About 70 percent of sample firms relocated within their pre-relocation city, so the baseline results

in Table 2 could be driven by firms that relocated nearby and whose incumbent customers and bank branches were also located nearby. Although we include *City before relocation* and *Log moving distance* to control for the gravity associated with firms' hometown and short distance, to eliminate any remaining concern, we restrict our sample to the 303 firms that relocated to a city other than their pre-relocation city and rerun the baseline conditional logit estimation. For each firm in this subsample, the choice set consists of either 56 or 57 cities, depending on whether its pre-relocation city was also a destination city for the other relocating firms, yielding a total of 17,095 firm–city observations.

Table E3 presents the results for this subsample analysis. In all specifications, the coefficients on the incumbent supplier-, customer-, and bank-related variables are qualitatively similar to those in Table 2. Thus, our main results in Table 2 are robust to restricting the sample to firms that relocated to a different city.

**Table E1. Subsample estimation: Single establishment firms**

|                                                          | Dependent variable: <i>City relocated</i> |                       |                       |                       |
|----------------------------------------------------------|-------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                          | (1)                                       | (2)                   | (3)                   | (4)                   |
| <i>Main supplier</i>                                     | -0.330<br>(0.464)                         |                       | -0.469<br>(0.472)     |                       |
| <i>Main customer</i>                                     | 1.233 **<br>(0.522)                       |                       | 1.316 **<br>(0.557)   |                       |
| <i>Main bank</i>                                         | 1.115 ***<br>(0.159)                      |                       | 1.285 ***<br>(0.180)  |                       |
| <i>Log number of suppliers</i>                           |                                           | -0.316<br>(0.439)     |                       | -0.471<br>(0.394)     |
| <i>Log number of customers</i>                           |                                           | 0.732 *<br>(0.423)    |                       | 0.723 *<br>(0.396)    |
| <i>Log number of banks</i>                               |                                           | 1.185 ***<br>(0.220)  |                       | 1.600 ***<br>(0.234)  |
| <i>City before relocation</i>                            | 1.059 ***<br>(0.170)                      | 1.047 ***<br>(0.172)  | 0.649 ***<br>(0.181)  | 0.528 ***<br>(0.186)  |
| <i>Log moving distance</i>                               | -1.973 ***<br>(0.101)                     | -1.948 ***<br>(0.102) | -2.308 ***<br>(0.130) | -2.291 ***<br>(0.130) |
| <i>Log ratio of firms in tsunami area</i>                | -1.292 ***<br>(0.336)                     | -1.224 ***<br>(0.330) |                       |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -7.787 ***<br>(1.025)                     | -7.691 ***<br>(1.000) |                       |                       |
| <i>Log number of establishments in the same industry</i> | 0.286 **<br>(0.117)                       | 0.290 **<br>(0.124)   | 0.256 *<br>(0.123)    | 0.268 *<br>(0.152)    |
| <i>Log number of establishments in all industries</i>    | 0.459 ***<br>(0.117)                      | 0.447 ***<br>(0.124)  |                       |                       |
| City fixed effects                                       | No                                        | No                    | Yes                   | Yes                   |
| No. of observations                                      | 58,500                                    | 58,500                | 58,500                | 58,500                |
| No. of cities                                            | 60                                        | 60                    | 60                    | 60                    |
| No. of firms                                             | 975                                       | 975                   | 975                   | 975                   |
| Pseudo R2                                                | 0.7337                                    | 0.7314                | 0.76                  | 0.7598                |
| Log likelihood                                           | -1062.95                                  | -1072.37              | -958.091              | -958.094              |

*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choices, using a subsample of firms with a single establishment. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair (975 firms × 60 cities = 58,500 observations).

**Table E2. Subsample estimation: Firms that relocated to “big” cities**

|                                                          | Dependent variable: <i>City relocated</i> |                        |                       |                       |
|----------------------------------------------------------|-------------------------------------------|------------------------|-----------------------|-----------------------|
|                                                          | (1)                                       | (2)                    | (3)                   | (4)                   |
| <i>Main supplier</i>                                     | -0.661<br>(0.490)                         |                        | -0.735<br>(0.494)     |                       |
| <i>Main customer</i>                                     | 1.171 ***<br>(0.425)                      |                        | 1.362 ***<br>(0.468)  |                       |
| <i>Main bank</i>                                         | 1.153 ***<br>(0.185)                      |                        | 1.297 ***<br>(0.201)  |                       |
| <i>Log number of suppliers</i>                           |                                           | -0.126<br>(0.376)      |                       | -0.312<br>(0.382)     |
| <i>Log number of customers</i>                           |                                           | 0.605<br>(0.417)       |                       | 0.586<br>(0.412)      |
| <i>Log number of banks</i>                               |                                           | 1.196 ***<br>(0.254)   |                       | 1.587 ***<br>(0.258)  |
| <i>City before relocation</i>                            | 0.805 ***<br>(0.184)                      | 0.797 ***<br>(0.184)   | 0.573 ***<br>(0.189)  | 0.464 **<br>(0.190)   |
| <i>Log moving distance</i>                               | -2.312 ***<br>(0.146)                     | -2.286 ***<br>(0.147)  | -2.438 ***<br>(0.152) | -2.403 ***<br>(0.150) |
| <i>Log ratio of firms in tsunami area</i>                | -4.021 ***<br>(0.594)                     | -3.999 ***<br>(0.597)  |                       |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -10.652 ***<br>(2.012)                    | -10.755 ***<br>(2.054) |                       |                       |
| <i>Log number of establishments in the same industry</i> | 0.458 ***<br>(0.117)                      | 0.458 ***<br>(0.141)   | 0.341 **<br>(0.140)   | 0.360 **<br>(0.157)   |
| <i>Log number of establishments in all industries</i>    | -0.157<br>(0.117)                         | -0.178<br>(0.152)      |                       |                       |
| City fixed effects                                       | No                                        | No                     | Yes                   | Yes                   |
| No. of observations                                      | 25,812                                    | 25,812                 | 25,812                | 25,812                |
| No. of cities                                            | 27                                        | 27                     | 27                    | 27                    |
| No. of firms                                             | 956                                       | 956                    | 956                   | 956                   |
| Pseudo R2                                                | 0.7839                                    | 0.7809                 | 0.8032                | 0.8018                |
| Log likelihood                                           | -680.836                                  | -690.474               | -620.201              | -624.435              |

*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choices, using a subsample of firms that relocated to 27 “big” cities that attracted at least 10 relocating firms after the Tohoku earthquake. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm–city pair (956 firms × 27 cities = 25,817 observations).

**Table E3. Subsample estimation: Firms that relocated to different cities**

|                                                          | Dependent variable: <i>City relocated</i> |                       |                       |                       |
|----------------------------------------------------------|-------------------------------------------|-----------------------|-----------------------|-----------------------|
|                                                          | (1)                                       | (2)                   | (3)                   | (4)                   |
| <i>Main supplier</i>                                     | -0.949<br>(1.234)                         |                       | -1.295<br>(1.333)     |                       |
| <i>Main customer</i>                                     | 1.271 **<br>(0.524)                       |                       | 1.372 **<br>(0.615)   |                       |
| <i>Main bank</i>                                         | 1.190 ***<br>(0.294)                      |                       | 1.201 ***<br>(0.346)  |                       |
| <i>Log number of suppliers</i>                           |                                           | -0.023<br>(0.390)     |                       | -0.313<br>(0.438)     |
| <i>Log number of customers</i>                           |                                           | 0.561<br>(0.441)      |                       | 0.663<br>(0.487)      |
| <i>Log number of banks</i>                               |                                           | 1.650 ***<br>(0.336)  |                       | 1.905 ***<br>(0.396)  |
| <i>Log moving distance</i>                               | -2.750 ***<br>(0.142)                     | -2.701 ***<br>(0.142) | -3.198 ***<br>(0.234) | -3.104 ***<br>(0.234) |
| <i>Log ratio of firms in tsunami area</i>                | -2.369 ***<br>(0.468)                     | -2.248 ***<br>(0.469) |                       |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -7.979 ***<br>(1.407)                     | -8.060 ***<br>(1.417) |                       |                       |
| <i>Log number of establishments in the same industry</i> | 0.370 ***<br>(0.117)                      | 0.389 ***<br>(0.140)  | 0.374 *<br>(0.141)    | 0.389 **<br>(0.195)   |
| <i>Log number of establishments in all industries</i>    | 0.600 ***<br>(0.117)                      | 0.553 ***<br>(0.145)  |                       |                       |
| City fixed effects                                       | No                                        | No                    | Yes                   | Yes                   |
| No. of observations                                      | 17,095                                    | 17,095                | 17,095                | 17,095                |
| Maximum no. of cities                                    | 57                                        | 57                    | 57                    | 57                    |
| No. of firms                                             | 303                                       | 303                   | 303                   | 303                   |
| Pseudo R2                                                | 0.4343                                    | 0.439                 | 0.4885                | 0.4947                |
| Log likelihood                                           | -691.25                                   | -685.47               | -625.03               | -617.44               |

*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choice, using a subsample of firms that relocated to a city other than their pre-relocation location. The number of cities in the choice set is either 56 or 57, depending on whether a firm's pre-relocation city was a destination city for other relocating firms or not. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm-city pair: 303 firms with either 56 or 57 cities in the choice set, totaling 17,095 observations.

## **Appendix F. Estimations using undamaged firms**

In this appendix, we present estimation results using a sample of undamaged firms. As of now, we no longer have access to the systematically selected sample of undamaged firms from the original TDB database. However, we have data on 362 undamaged firms that were located in Iwate, Miyagi, or Fukushima prefectures before the earthquake and relocated to one of the 61 cities that also served as relocation destinations for damaged firms in the baseline estimation. Undamaged firms are defined as those that were not located, prior to the earthquake, in any of the 59 earthquake-affected cities designated under the Japanese Government's Act on Special Financial Support to Deal with a Designated Disaster of Extreme Severity or the Planned Evacuation Zone / Emergency Evacuation Preparation Zone for the severe accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company, or in areas affected by the tsunami or nuclear accident. Since these 362 firms relocated to 22 distinct cities after the earthquake, the number of firm-city pair observations used in the estimation is 7,964 (362 firms  $\times$  22 cities).

Table F1 presents the estimation results. Unlike the baseline results, the coefficients on customer-related variables are statistically insignificant, suggesting that the presence of incumbent customers did not affect the relocation decisions of undamaged firms. In contrast, consistent with the baseline results, the coefficients on supplier-related variables remain insignificant, while those on bank-related variables are significant.

We note that the estimation results should be interpreted with caution, as they are based on a limited and non-systematically selected sample of undamaged firms. Nonetheless, there are

two possible explanations for the observed differences in estimation results between damaged and undamaged firms. First, the results for undamaged firms may suffer from sample selection or simultaneity bias, which our research aims to address. Second, the baseline results may lack external validity, i.e., they may not generalize to relocation decisions under normal circumstances. Determining which of these explanations is more plausible remains an important question for future research.

**Table F1. Estimation using a sample of undamaged firms**

|                                                          | Dependent variable: <i>City relocated</i> |                        |                       |                       |
|----------------------------------------------------------|-------------------------------------------|------------------------|-----------------------|-----------------------|
|                                                          | (1)                                       | (2)                    | (3)                   | (4)                   |
| <i>Main supplier</i>                                     | -0.807<br>(0.978)                         |                        | -0.890<br>(0.989)     |                       |
| <i>Main customer</i>                                     | -0.860<br>(0.791)                         |                        | -0.674<br>(0.924)     |                       |
| <i>Main bank</i>                                         | 1.393 ***<br>(0.418)                      |                        | 1.474 ***<br>(0.442)  |                       |
| <i>Log number of suppliers</i>                           |                                           | -0.140<br>(0.585)      |                       | -0.151<br>(0.610)     |
| <i>Log number of customers</i>                           |                                           | -0.641<br>(0.753)      |                       | -0.688<br>(0.874)     |
| <i>Log number of banks</i>                               |                                           | 1.474 ***<br>(0.449)   |                       | 1.510 ***<br>(0.423)  |
| <i>City before relocation</i>                            | 1.475 ***<br>(0.419)                      | 1.442 ***<br>(0.412)   | 1.300 **<br>(0.515)   | 1.332 ***<br>(0.509)  |
| <i>Log moving distance</i>                               | -1.910 ***<br>(0.296)                     | -1.908 ***<br>(0.290)  | -1.964 ***<br>(0.262) | -1.957 ***<br>(0.251) |
| <i>Log ratio of firms in tsunami area</i>                | 1.415<br>(2.373)                          | 1.506<br>(2.282)       |                       |                       |
| <i>Log ratio of firms in nuclear accident area</i>       | -955.368<br>(3204.616)                    | -960.899<br>(2967.357) |                       |                       |
| <i>Log number of establishments in the same industry</i> | 0.238<br>(0.117)                          | 0.292<br>(0.341)       | 0.207<br>(0.342)      | 0.280<br>(0.380)      |
| <i>Log number of establishments in all industries</i>    | 0.470<br>(0.117)                          | 0.376<br>(0.355)       |                       |                       |
| City fixed effects                                       | No                                        | No                     | Yes                   | Yes                   |
| No. of observations                                      | 7,964                                     | 7,964                  | 7,964                 | 7,964                 |
| No. of cities                                            | 22                                        | 22                     | 22                    | 22                    |
| No. of firms                                             | 362                                       | 362                    | 362                   | 362                   |
| Pseudo R2                                                | 0.9128                                    | 0.9125                 | 0.9152                | 0.9149                |
| Log likelihood                                           | -97.619                                   | -97.899                | -94.907               | -95.253               |

*Notes:* This table presents the results of the baseline conditional logit estimation of firms' relocation choices, using a sample of undamaged firms in Iwate, Miyagi or Fukushima. Undamaged firms are those whose headquarters were not located in the 59 affected cities or areas affected by the tsunami or the nuclear accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company. Standard errors clustered at the firm level are shown in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The unit of observation is the firm-city pair (362 firms × 22 cities = 7,964 observations).

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