RIETI Discussion Paper Series 17-E-054

Supply Chain Disruptions and Trade Credit

LU Yi
Tsinghua University

OGURA Yoshiaki
Waseda University

TODO Yasuyuki
RIETI

ZHU Lianming
Waseda University

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

RIETI Discussion Paper Series 17-E-054

March 2017

Supply Chain Disruptions and Trade Credit*

LU Yi
Tsinghua University
and National University of Singapore

OGURA Yoshiaki
Waseda University

TODO Yasuyuki
Research Institute of Economy, Trade and Industry
and Waseda University

ZHU Lianming
Waseda University

Abstract

It has been shown that input-output linkages along supply chains affect firms' performance such as sales, productivity, and innovative capacity. This paper explores a new aspect in the literature, examining how supply chain relations influence financial transactions between firms. More specifically, this paper, using an exhaustive dataset on buyer-supplier networks in Japan, studies whether supply chain disruptions due to the Great East Japan earthquake in 2011 affected firms' utilization of trade credit. We find evidence showing that customers who were affected by the earthquake imposed a larger amount of trade credit on their suppliers (i.e., utilized fewer cash transactions) even two years after the earthquake. In addition, trade credit of indirect suppliers (e.g., suppliers of suppliers) of affected customers also increased, indicating that the effect of supply chain disruptions on trade credit propagates through production linkages. We further find heterogeneous effects of the supply chain disruptions on firms' trade credit; the effect is larger for suppliers with a better financial performance before the disaster.

Keywords: Supply chains, Trade credit, Disaster
JEL classification: L14, G30

*This research was conducted as part of the "Empirical Analysis on Determinants and Impacts of Formation of Firm Networks" project undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The authors would like to thank JSPS Kakenhi Grant (No. 25101003) and Waseda University for financial support. The opinions expressed and arguments employed in this paper are the sole responsibility of the authors and do not necessarily reflect those of National University of Singapore, RIETI, Waseda University, or any institution with which the authors are affiliated.

1 Introduction

The modern production processes are becoming more complex and usually consist of multiple stages. Production of goods and services are increasingly organized along the supply chains where intermediate inputs flow through many firms. Understanding how the role of supply chain as a mechanism to propagate in the aggregate economy has attracted a lot of attention among academics and policymakers. For example, many industrial policies were adopted by policymakers with the aim of promoting firms in a certain industry influential to the aggregate economy. A large literature has investigated how sectoral and regional linkages can explain the aggregate business cycle fluctuations (Di Giovanni and Levchenko 2010; Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi 2012; Caliendo, Parro, Rossi-Hansberg, and Sarte 2014). However, studies on how firm's input-supply linkages along the supply chain affect firm performance in the comovement are scant. There are two potential reasons. The first reason is a lack of data which provides relatively complete information on firm-level input-output linkages. The second is the difficulty in identifying plausible exogenous micro-level shocks in firm-level data.

In this paper, we explore whether firm-level shocks propagate in the production processes. We quantify the propagation of firm-level shocks along the supply chains and study whether these shocks to customers would affect their suppliers' financial performance. To deal with the identification challenges, we use a natural disaster as an exogenous shock to examine how firms alter their financial performance when firm's production networks are disrupted. Specifically, we use the exogenous nature of the Great East Japan Earthquake of 2011. Using the government notifications in the aftermath of the earthquake, we can designate 41 municipalities as severely affected areas by the earthquake. We use precise information on firm addresses prior to the earthquake to identify whether or not firms are located in the disaster-hit area, which creates variations across firms for identification.

We examine the effect of the presence of firm-level input-output linkages in propagating disruptions on firm's trade credit. Specifically, we compare the utilization of trade credit between firms with one of their customers located in the disaster-hit areas (our treatment group) and firms that none of their customers located in the earthquake areas (our control group). To check whether or not the treatment and the control group are systematically different *ex ante*, we conduct a balancing test by following the spirit of Lee and Lemieux (2010) for the validity check of the regression discontinuity framework. We control for significant firm's pre-determinants, i.e., firm sales, number of employees, output-labor ratio, and capital-labor ratio to alleviate the concern that some pre-existing firm characteristics between the treatment and control groups might differently affect firm's trade credit after the earthquake.

Trade credit is recognized as an important source of liquidity insurance. Firms can use trade credit networks to extract liquidity from their customers and suppliers by adjusting their accounts receivable or accounts payable. When there is a liquidity shock, firm's utilization of trade credit may work as a liquidity insurance mechanism by postponing payments to their suppliers. In the corporate finance literature, a seminal study by Kiyotaki and Moore (1997) shows a theoretical possibility of the shock propagation through a trade-credit network and the possible incentive for a supplier to reschedule its receivable claim for a temporarily distressed customer. Recent empirical studies found evidence supportive of these predictions. Jacobson and von Schedvin (2015) find chain defaults of trade credits. Several studies find evidence that such a propagation stops at a firm with abundant cash and available credit (Boissay and Gropp 2013; Garcia-Appendini and Montriol-Garriga 2013; Casey and O'Toole 2014; Garbó-Valverde et al 2016). The identification strategy of these studies hinges on the assumption that the shock from the global financial crisis or a customer's default is an exogenous shock. Our study reinforces these findings by providing another firm evidence for this chain effect by looking at the propagation of the increased dependence on trade credits through supply networks in response to a purely exogenous shock brought by a natural disaster.

The analyses yield three classes of results. First, we find that customers located in the earthquake areas impose a larger amount of trade credit on their suppliers (i.e., utilize fewer cash transactions) even two years after the earthquake. Second, trade credit of indirect suppliers (e.g., suppliers of suppliers) of affected customers also increase, indicating that the effect of supply chain disruptions on trade credit propagates through production linkages. Furthermore, the propagating disruption effect of firm's intermediate customer is the largest, with this effect diminishing with the distance to firm's indirect customer. Third, to understand the positive effect of supply chain disruptions on firm's trade credit, we examine the heterogeneous disruption effect across firm's financial health. Our empirical results show that the positive effect is more pronounced for suppliers with a better financial performance. As financially healthier firms are easier to get bank loans, they can afford the costly delays in the collection of receivables from their customers.

Our paper closely relates to studies that exploit natural disasters to explore the effect of firm-level input-output linkages in propagating disruptions. Barrot and Sauvagnat (2016) use the occurrence of natural disasters in the U.S. to identify firm-level networks disruptions and show that affected suppliers impose substantial output losses on their customers. Carvalho, Nirei, Saito, and Tahbaz-Salehi (2016) find evidence that the earthquake imposes negative effects on growth rates of firms with both downstream customers and upstream suppliers located in the disaster areas. Boehm, Flaaen, and Nayar (2016) show that firms that imported intermediates from Japanese firms that were affected by the earthquake experienced substantial drops in production. Uesugi et al. (2012) examine the effect of the Great Hanshin-Awaji Earthquake on firm performances and found evidence that investment is much smaller for firms that had transaction relationships with earthquake-affected financial institutions. Our paper departs from the literature by studying how micro-level supply chain disruptions affect firm's financial decisions.

The remainder of the paper is organized as follows. Section 2 lays out the background of the 2011 Great East Japan Earthquake. Section 3 describes the identification strategies. Section 4 describes the data in detail. Section 5 presents our main empirical results. Section 6 presents the heterogeneity of the effects. Section 7 concludes.

2 Background

The Great East Japan Earthquake, also known as the 2011 Tohoku Earthquake, occurred on Friday 11 March 2011. The earthquake was reported a magnitude scale of 9.0. It was the fourth largest earthquake since modern record-keeping in the world, and the most powerful earthquake on record in Japan. The earthquake triggered powerful tsunami, and caused 15,893 deaths, 6,152 injured, and 2,572 people missing across more than twenty prefectures (Japanese National Police Agency, 2015). The earthquake and tsunami caused severe damage to buildings in north-eastern Japan: 127,290 buildings were totally collapsed, 272,788 buildings were half-collapsed, and 747,989 buildings were partially damaged (Japanese National Police Agency, 2014).

The earthquake and tsunami also caused nuclear accidents. The incident damaged several reactors in the Fukushima Daiichi Nuclear Power plant (NPP), and the government designated the 20km radius from NPP as the areas of evacuation within 20km radius from NPP on March 12, 2011. More than 56,000 residents within 20km radius around the NPP were evacuated to other municipalities.

Figure 1 plots the areas severely affected by the earthquake and the evacuation areas around the Fukushima Daiichi Nuclear Power plant. Figure 2 plots the flooded areas affected by the tsunami.

[Insert Figure 1 and 2 here]

The earthquake and tsunami also caused severe production losses in the Tohoku area. As reported by Wakasugi and Tanaka (2013) using Surveys on Firms in Tohoku Areas (Aomori, Iwate, Miyagi, Fukushima, Ibaraki, and Tochigi prefectures) conducted by the Research Institute of Economy, Trade and Industry in December 2012, nine months after the earthquake, among 2,117 surveyed plants, 1,376 plants were collapsed by the earthquake and 115 plants were partially destroyed by the tsunami.

3 Estimation Strategy

3.1 Identification

To identify the effect on the firm's trade credit of a disruption to at least one of the firm's customer, we use the 2011 Great East Japan Earthquake as a plausible exogenous shock and compare firm's trade credit of customer located in the earthquake-hit area with that of customer in the rest of the area.

The specification for our OLS estimation is:

$$y_{f,r,2013} = \alpha_r + \alpha_s + \beta ShockCustomer_{f,r,2010} + \varepsilon_{f,r,2013}, \quad (1)$$

where f, r, and s denote firm, city, and industry, respectively; $y_{f,2013}$ is firm's trade credit (i.e., measured by the ratio of receivables to total assets) of firm f in region r in year 2013; α_r and α_s are city and industry fixed effects, respectively; and $\varepsilon_{f,r,2013}$ is the error term. $ShockCustomer_{f,r,2010}$ is our regress of interest, capturing whether firm f's customer is located in the area hit by the earthquake. Specifically, $ShockCustomer_{f,r,2010}$ takes the value of 1 if at least one of the firms' customer is in the disaster area in the year 2010, i.e., prior to the earthquake. The standard errors are clustered at the city level.

3.2 Identifying Assumption and Checks

Our identifying assumption requires that conditional on prefecture and industry fixed effects, our regressor of interest ($ShockCustomer_{f,r,2010}$) is uncorrelated with the error term ($\varepsilon_{f,r,2013}$), i.e., $cov(ShockCustomer_{f,r,2010}, \varepsilon_{f,r,2013}|\alpha_r, \alpha_s) = 0$. Alternatively, firms are balanced across regions in the pre-disaster period. Hence, ex post difference in firm performance can then be attributed to the natural disaster. To check whether this balancing has been achieved in our estimation framework, we conduct an analysis following Lee and Lemieux (2010) for the validity check of the regression discontinuity framework. Specifically, we lay out a battery of firm's pre-determined characteristics and examine whether firms in the disaster-hit areas and the rest of the areas are balanced or not.

Table 1 presents the regression results. We examine the balancing of firm's sales, capital, number of employees, capital-labor ratio, output-labor ratio, number of suppliers, number of customers, 5-year sales growth, capital growth, and employment growth. We consistently find that all of the firm's predeterminants are well-balanced, i.e., firms in the earthquake-hit areas are comparable to those in the rest of the areas. As a robustness check, we control for the firm's pre-determined characteristics in the analysis; that is, we add $\mathbf{X}'_{f,r,2010}$ in equation (1), where $\mathbf{X}'_{f,r,2010}$ is a vector of firm characteristics in 2010 listed in Table 1.

[Insert Table 1 here]

The augmented estimation equation is:

$$y_{f,r,2013} = \alpha_r + \alpha_s + \beta ShockCustomer_{f,r,2010} + \mathbf{X}'_{f,r,2010}\boldsymbol{\theta} + \varepsilon_{f,r,2013}. \tag{2}$$

4 Data

Supplier-customer relationship data. The main data used in this study are based on three databases collected by the Tokyo Shoko Research (TSR) and licensed to the Research Institute of Economy, Trade and Industry (RIETI): the TSR Company Information Database for basic firm characteristics such as sales, the TSR Financial Database for financial information such as account receivable, and the TSR Company Linkage Database for supply chain linkages. In particular, we utilize the TSR Company Information Database and the TSR Company Linkage Database licensed to RIETI in 2006, 2011 and 2015 and the TSR Financial Database licensed to RIETI in 2015. Because of the time lag between the year of licensing and the year of data collection, these databases provide us information on basic firm characteristics and supply chain linkages in 2005 and 2010, six years and one year before the earthquake respectively, and 2013, two years after that, and on financial information in 2013.[1]

The number of firms covered in the surveys is approximately 1.16 million in 2010 and 1.61 million in 2013. The surveys cover information such as firm location, industry affiliation, sales, and the number of employees for 2010 and 2013, but only financial information such as cash, receivables, and total assets for 2013.

The dataset also has information on a maximum of 24 domestic suppliers of material and intermediates and up to 24 domestic customers of products for each firm. Since a customer of a supplier can be identified on both directions, the upper limit of the number of suppliers

[1] These data have been widely used by economic researchers in recent years, e.g., Bernard, Moxnes, and Saito (2016), Todo, Matous, and Inoue (2016), Furusawa, Inui, Ito, and Tang (2016), and Carvalho, Nirei, Saito, and Tahbaz-Salehi (2016).

and customers can exceed 24. To maximize firm's supplier-customer networks, we conduct a two-way matching method (i.e., using information reported by the supplier about the customers, and information reported by the customer about the suppliers) to construct the domestic production network in Japan. The maximum number of suppliers and customers in 2010 is 7,926 and 12,057, respectively. The corresponding number in 2013 is 10,504 and 12,621, respectively.

Firms in disaster area. We follow Carvalho, Nirei, Saito, and Tahbaz-Salehi (2016) and identify the disaster areas using three government notifications.[2] The three notifications designate 41 municipalities as severely affected areas by the earthquake and the restricted areas around the Fukushima Daiichi Nuclear Power plant (NPP). Among these 41 municipalities, 31 municipalities are designated as severely affected areas, 5 municipalities as restricted areas around NPP, and 5 municipalities as both areas.[3]

To pin down whether or not a firm is located within the disaster-hit municipalities, we match firms against the name of municipalities which firms include in their addresses. The 2010 data contains approximately 3.02 percent of the firms located in the disaster-hit areas; the corresponding number for the 2013 data is 2.93 percent.

5 Empirical Findings

5.1 Baseline Results

The estimation results are reported in column 1 of Table 2. With industry and city fixed effects included, we find that our regressor of interest, $ShockCustomer_{f,r,2010}$, is statistically significant and positive, indicating that the disruptions to firms' customers increase their trade credit. Turning to the economic magnitude of the effect, we find that firm's trade credit increases by 1.5 percentage point. As the mean value of the outcome variable is 9.1%, our findings imply that the disruptions to firms' customers increase their trade credit by

[2]The three notifications include "The Act on Special Financial support to Deal with the Designated Disaster of Extreme Severity, Article 41-2", issued on April 28, 2011 by the Ministry of Land, Infrastructure, Transport and Tourism; two decrees, issued by the Prime Minister's office on April 21 and 22, 2011.

[3]The disaster-hit municipalities include Hachinohe-city, Miyako-city, Ōfunato-city, Rikuzentakata-city, Kamaishi-city, Ōtsuchitown, Yamada-town, Iwaizumi-town, Tanohata-village, Noda-village, Sendai-city, Ishinomaki-city, Kesennuma-city, Natori-city, Iwanuma-city, Tome-city, Higashimatsushima-city, Ōsaki-city, Watari-town, Yamamoto-town, Shichigahamatown, Onagawa-town, Minamisanriku-town, Fukushima-city, Kōriyama-city, Iwaki-city, Sukagawa-city, Sōma-city, Minamisōma-city, Hirono-town, Naraha-town, Tomioka-town, Ōkuma-town, Futaba-town, Namie-town, Shinchi-town, Tamura-city, Kawamata-town, Kawauchi-village, Katsurao-village, and Iitate-village.

17.16 percent relative to the mean.

[Insert Table 2 here]

5.2 Robustness Checks

Inclusion of firm's pre-determinants. As a robustness check, we include firm's pre-determined characteristics, i.e., firm's number of employees, output, capital-labor ratio, number of suppliers, and number of customers. The estimation results are presented in column 2 of Table 2. We find consistent results that the coefficient of $ShockCustomer_{f,r,2010}$ is statistically significant and positive.

Alternative definition of disaster area. We repeat our analysis using areas that were flooded by the tsunami as the disaster area. To identify whether or not a firm is located in the flooded area, we use the map of the flooded area provided by the Center for Spatial Information Science (CSIS) at the University of Tokyo. We further obtain precise geographical information on firm locations (i.e., the coordinates) using address matching service provided by CSIS. Matching firm coordinates with the map of flooded area allows us to identify 3,570 firms located in the disaster area. The estimation result is reported in column 3. We consistently find that $ShockCustomer_{f,r,2010}$ is statistically significant and positive, with magnitude close to our main results, implying that our aforementioned results are not driven by specific definition of the disaster area.

[Insert Table 3 here]

Single-plant firms. One potential concern is that our TSR data only provides information on firms other than plants and our results might be driven by multi-plant firms with plants located in the disaster area. We thus conduct a robustness check by restricting our regression sample to single-plant firms. The estimation result is reported in column 4. The coefficient of $ShockCustomer_{f,r,2010}$ is still statistically significant and positive.

Alternative measure of presence of trade credit. To alleviate the concern that our results depend on the measure of the persence of trade credit, we use an alternative definition, i.e., ratio of accounts receivable to sales to check for the robustness. We still find that the results are robust.

5.3 Indirect Propagation Effect

To identify the indirect effect of disruptions of customers (i.e., customer's customer) on firm's trade credit, we turn to examine the propagation of the shock along the input-supply linkages. The specification of our estimation is extended as:

$$y_{f,r,2013} = \alpha_r + \alpha_s + \sum_{i=1}^{4} \beta_i ShockCustomer^i_{f,r,2010} + \varepsilon_{f,r,2013}, \quad (3)$$

where i is the step from the firms to their customers. Here, we compare firms of customers located within distance i ($i = 1, 2, 3, 4$) away from the disaster area (i.e., our treatment group) with firms of customers located 5 or more steps away from the disaster area (i.e., our control group). The mean average from $ShockCustomer^1_{f,r,2010}$ to $ShockCustomer^4_{f,r,2010}$ is 5.59%, 47.85%, 78.16%, and 89.98%, respectively.

The estimation results are presented in Table 3. The coefficients for $ShockCustomer^i_{f,r,2010}$ are all positive and statistically significant, indicating that the direct and indirect customers of firms in the disaster area increase trade credit in the post-earthquake period. Alternatively, the disruption caused by the earthquake propagates not only to firm's direct customer ($ShockCustomer^1_{f,r,2010}$), but also to firm's indirect customer (i.e., customer's customer) all the way to step 4 ($ShockCustomer^2_{f,r,2010}$, $ShockCustomer^3_{f,r,2010}$, and $ShockCustomer^4_{f,r,2010}$).

To gauge the economic magnitude of the estimated effect, we find there is a decreasing trend of the propagation effect. The disruption effect of firm's intermediate customer is the largest, and this effect diminishes with the distance to firm's indirect customer.

[Insert Table 3 here]

5.4 Heterogeneous Effects

To investigate whether and how the effects of disruption caused by the earthquake on firm's trade credit may differ across firm's financial health, we conduct the following estimation specification:

$$\begin{aligned} y_{f,r,2013} &= \alpha_r + \alpha_s + \gamma ShockCustomer_{f,r,2010} \times FinHealth_{f,r,2010} + \eta ShockCustomer_{f,r,2010} \\ &\quad + \delta FinHealth_{f,r,2010} + \varepsilon_{f,r,2013}. \end{aligned} \quad (4)$$

$$\begin{aligned} y_{f,r,2013} &= \alpha_r + \alpha_s + \sum_{i=1}^{4} \gamma_i ShockCustomer_{f,r,2010} \times FinHealth_{f,r,2010} \\ &\quad + \sum_{i=1}^{4} \eta_i ShockCustomer_{f,r,2010} + \delta FinHealth_{f,r,2010} + \varepsilon_{f,r,2013}. \end{aligned} \quad (5)$$

To measure firm's financial health, we rely on the score evaluated by the TSR company in the year prior to the earthquake. TSR company evaluates a firm based on the four items: firm's managerial ability (score range: 0–20), growth (0–25), stability (0–45), and openness (0–10). Then, a total score (0–100) can be derived from adding the four scaled scores together. The total score measures the comprehensive capability of a firm, with a higher score indicating that the firm is more financial healthy. We construct a dummy variable, $FinHealth_{f,r,2010}$, which takes the value of 1 if firm's total score is above 50.

As shown in Table 4, the interaction between disruption at least one of the customer's there are statistically and economically significant differences in the disruption effects between the firms with good and poor financial health. The coefficients of the indirect effect of supply chain disruptions are statistically significant between firms with different financial statement. The disruption effect is stronger for firms with better financial performance, indicating that financial healthier firms can afford and are more willing to allow delays in receivables from their customers.

[Insert Table 4 here]

6 Discussion

The above results imply the following process was at work. A firm cannot receive a cash repayment from a disaster-hit customer because of the disruption of the customer's operation and financing due to the damage to its main bank as well as the customer herself. If this firm is credit-constrained and does not have alternative access to liquidity, it cannot but ask for a postponement of the payment to its supplier. The supplier increases its receivables if it believes that the customer can recover from the temporal distress in the future and it can finance to cover the delayed payment, as shown in Kiyotaki and Moore (1997). If the supplier holds cash or has an access to bank loans enough to cover all the amount of the delayed payment, the propagation of the increased receivables stops. Otherwise, the supplier also has to ask for a postponement of payment to its suppliers. Thus, the propagation of the increased trade credit continues until the shock is absorbed by an unconstrained firm with sufficient access to internal or external liquidity.

The resulting increase in suppliers' receivables can remain for a long time even if the disaster-hit customer's sales recover to the pre-disaster level quickly. Since the sales after the recovery cannot generate cash enough to cover the cash repayment for the sum of the extended payables at the disaster and the recent payables after the recovery, it is very likely that the increased amount of payables due to the disaster remains in the suppliers' balance sheet. The customer can repay all these accumulated payables if it can obtain sufficient external finance. However, the disaster-hit customer should have more urgent needs for the reconstruction of damaged equipment and buildings by using such external funds. Thus, the supplier's receivables remain higher than that before the disaster for a long time.

In addition, when a customer does not complete a payment for a long time, its suppliers eventually have to write off accounts receivable (i.e., eliminates the amount from the balance sheet), but it is not easy usually and takes time, a few years in some cases, to make sure that the account receivable become a bad debt. Thus, it is reasonable that we found positive effects on accounts receivable even two years after the earthquake.[4]

7 Conclusion

This paper studies the presence of firm-level input-output linkages in propagating of shocks in the production processes. Using supplier-customer links data which captures an almost complete picture of production networks in Japan with the exogenous shock of the Great East Japan Earthquake in 2011, we find evidence in support of propagation of firm-level shocks in the production networks. We focus on the impact of input disruptions on firm's financial decisions, and provide evidence that customers that were affected by the earthquake impose substantial trade credit increases on their suppliers (i.e., utilize fewer cash transactions) by 1.5 percentage point even two years after the earthquake, which accounts to an 17.16% increase relative to the sample mean. Furthermore, trade credit of indirect suppliers (e.g., suppliers of suppliers) of affected customers also increase, indicating that the effect of supply chain disruptions on trade credit propagates through production linkages. To further shed light on how firm's trade credit is affected by input disruptions, we investigate the heterogeneous effects of the supply chain disruptions on firm's trade credit and have shown that the positive effect is larger for suppliers with a better financial performance before the disaster.

Our paper provides a step towards understanding the effect of supplier-customer linkages on firm's financial decisions. The analysis using firm-to-bank networks would help understand the mechanism underlying input disruption effects. Furthermore, this paper explores the effects on firm's trade credit two years after the earthquake. The short-run effect is left for future research.

[4] According to the National Tax Agency of Japan, if customers go bankrupt suppliers have to write it off in that year. If the transaction with the customers continues, it is not possible for suppliers to write if off and they have to wait for one year after the transaction stops before writing off the accounts receivable.

References

[1] Acemoglu, Daron, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi (2012), "The Network Origins of Aggregate Fluctuations." *Econometrica*, 80(5), 1977–2016.

[2] Barrot, Jean-Noël and Julien Sauvagnat (2016), "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks." *Quarterly Journal of Economics*, 131, 1543–1592.

[3] Bernard, Andrew B., Andreas Moxnes, and Yukiko U. Saito (2016), "Production Networks, Geography and Firm Performance." NBER Working Paper No. 21082.

[4] Boehm, Christoph, Aaron Flaaen, and Nitya Pandalai-Nayar (2016), "Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tōhoku Earthquake." Working Paper.

[5] Boissay,Frederic and Reint Gropp (2013), "Payment Defaults and Interfirm Liquidity Provision." *Review of Finance*, 17, 1853–1894.

[6] Carbó-Valverde Santiago, Francisco Rodríguez-Fernández, and Gregory F. Udell (2016), "Trade Credit, the Financial Crisis, and SME Access to Finance." *Journal of Money, Credit, and Banking*, 48(1), 113–143.

[7] Caliendo, Lorenzo, Fernando Parro, Esteban Rossi-Hansberg, and Pierre-Daniel Sarte (2014), "The Impact of Regional and Sectoral Productivity Changes on the US Economy." NBER Working Paper No. 20168.

[8] Carvalho, Vasco M., Makoto Nireiz, Yukiko U. Saito, and Alireza Tahbaz-Salehi (2016),"Supply Chain Disruptions: Evidence from the Great East Japan Earthquake." Becker Friedman Institute for Research in Economics Working Paper No. 2017–01.

[9] Casey, Eddie and Conor M. O'Toole (2014), "Bank Lending Constraints, Trade Credit and Alternative Financing during the Financial Crisis: Evidence from European SMEs." *Journal of Corporate Finance*, 27, 173–193.

[10] Di Giovanni, Julian, and Andrei A. Levchenko (2010), "Putting the Parts Together: Trade, Vertical Linkages, and Business Cycle Comovement." *American Economic Journal: Macroeconomics*, 2, 95–124.

[11] Garcia-Appendini, Emilia and Judit Montoriol-Garriga (2013), "Firms as Liquidity Providers: Evidence from the 2007-2008 Financial Crisis." *Journal of Financial Economics*, 109, 272–291.

[12] Jacobson, Tor and Erik von Schedvin (2015), "Trade Credit and the Propagation of Corporate Failure: An Empirical Analysis." *Econometrica*, 83(4), 1315–1371.

[13] Furusawa, Taiji, Keiko Ito, Tomohiko Inui, and Heiwai Tang (2016), "Offshoring, Relationship-Specificity, and Domestic Production Networks." Working Paper.

[14] Kiyotaki, Nobuhiko and John Moore (1997), "Credit Chains."Mimeo., University of Minnesota, and London School of Economics.

[15] Lee, David S. and Thomas Lemieux (2010), "Regression Discontinuity Designs in Economics." *Journal of Economic Literature*, 48(2), 281–355.

[16] Todo, Yasuyuki, Petr Matous, and Hiroyasu Inoue (2016), "The Strength of Long Ties and the Weakness of Strong Ties: Knowledge Diffusion through Supply Chain Networks." *Research Policy*, 45(9), 1890–1906.

[17] Uesugi, Iichiro, Hirofumi Uchida, Taisuke Uchino, Arito Ono, Makoto Hazama, Kaoru Hosono, and Daisuke Miyakawa (2012), "Natural Disasters and Firm Dynamics." RIETI Policy Discussion Paper Series 12-P-001.

[18] Wakasugi, Ryuhei and Ayumu Tanaka (2013), "Determinants of the Reconstruction Period from the Great East Japan Earthquake: Evidence from Manufacturing Firms in Tohoku." RIETI Discussion Paper Series 13-J-002.

Figure 1A: Earthquake Affected Areas (Map of Japan)

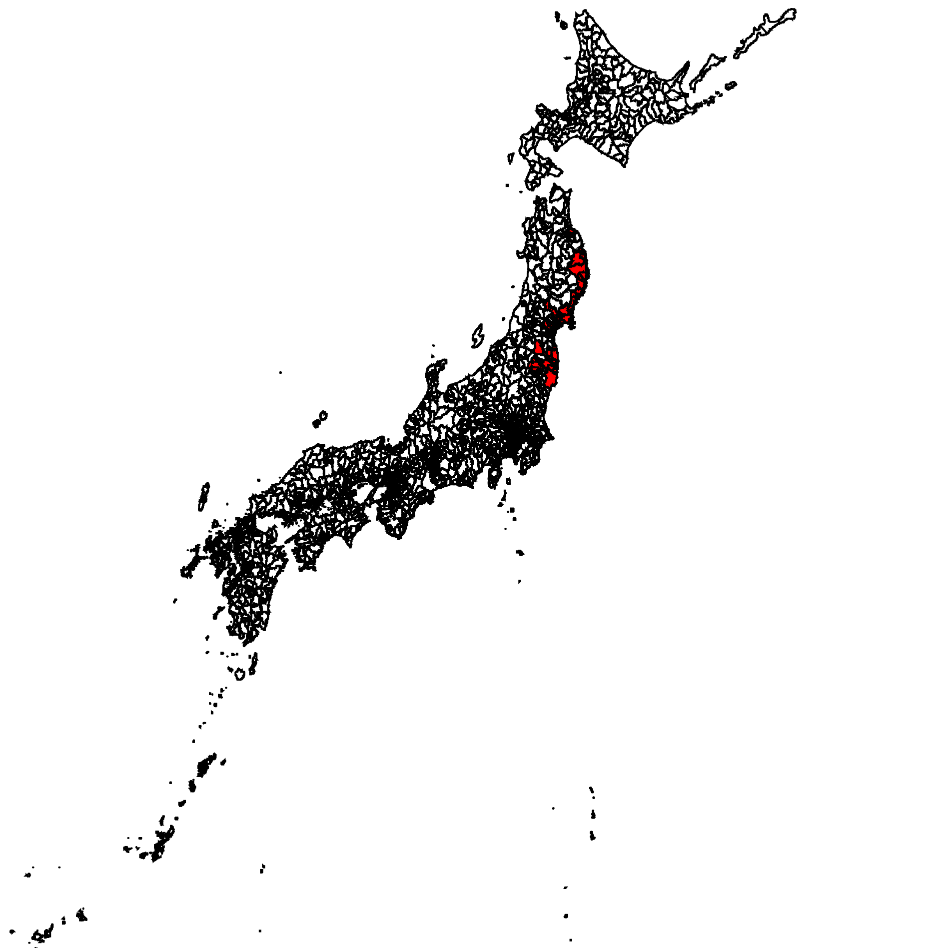

Figure 1B: Earthquake Affected Area (Map of Tohoku Areas)

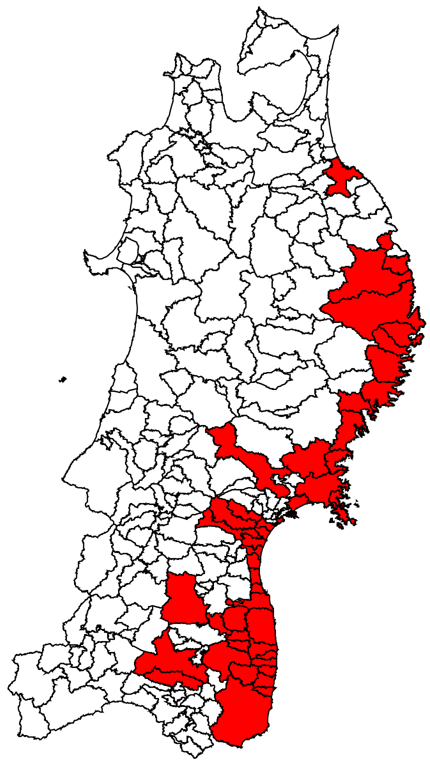

Figure 2: Flooded Area Casued by the Tsunami

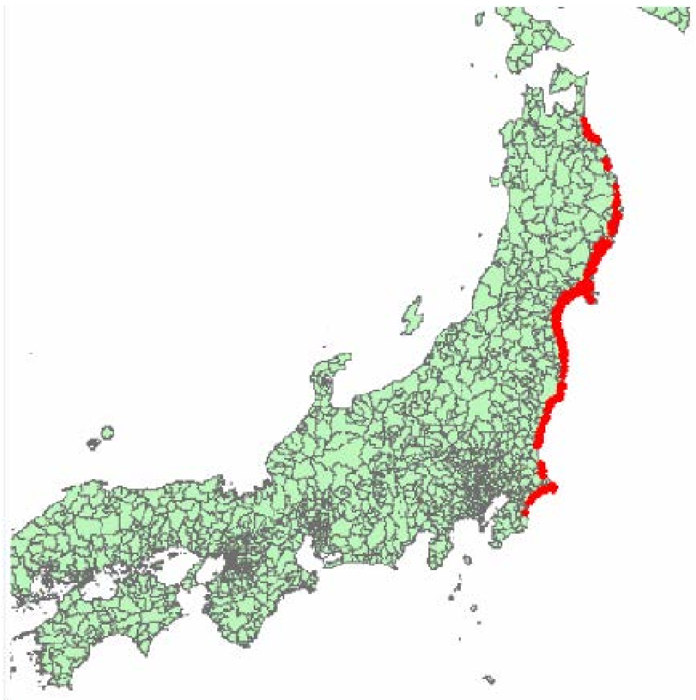

Table 1 Balancing Test

	(1)	(2)
	Affected areas	Non-affected areas
Log sales	11.51	11.69
	(1.58)	(1.66)
Log capital	9.01	9.17
	(1.13)	(1.22)
Log employment	1.88	1.91
	(1.23)	(1.28)
Log capital-labor ratio	7.06	7.19
	(1.09)	(1.11)
Log output-labor ratio	9.63	9.79
	(0.97)	(0.99)
Number of suppliers	4.03	4.29
	(13.92)	(31.48)
Number of customers	3.95	4.29
	(25.70)	(30.48)
Sales growth rate (5-year)	–0.18	–0.19
	(0.55)	(0.59)
Capital growth rate (5-year)	0.04	0.03
	(0.29)	(0.28)
Employment growth rate (5-year)	–0.04	–0.05
	(0.46)	(0.45)

Note: Mean of firm pre-determinants for the earthquake affected areas and non-affected areas are presented. Standard deviations are presented in parentheses.

Table 2 Supply Chain Disruptions and Trade Credit

	(1)	(2)	(3)	(4)	(5)
	Benchmark	Pre-determinants	Flooded areas	Single-plant firms	Account receivables to sales
ShockCustomer 1	0.014***	0.007***	0.014***	0.011***	0.004**
	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)
City FEs	X	X	X	X	X
Industry FEs	X	X	X	X	X
Pre-determinants		X			
Observations	213,801	196,484	213,801	35,439	211,836

Note: Standard errors are clustered at the city level in parentheses.

Table 3 Indirect Effect

	(1)	(2)
Dependent variable: accounts receivable/total assets		
ShockCustomer 1	0.013***	0.007***
	(0.001)	(0.001)
ShockCustomer 2	0.008***	0.003***
	(0.001)	(0.001)
ShockCustomer 3	0.006***	0.003***
	(0.001)	(0.001)
ShockCustomer 4	0.002**	0.003***
	(0.001)	(0.001)
City FEs	X	X
Industry FEs	X	X
Pre-determinants		X
Observations	213,801	196,484

Note: Standard errors are clustered at the city level in parentheses.

Table 4 Firm's Financial Health

	(1)	(2)
Dependent variable: accounts receivable/total assets		
*ShockCustomer 1 * Credit*	0.005**	0.005**
	(0.002)	(0.002)
*ShockCustomer 2 * Credit*		0.002**
		(0.001)
*ShockCustomer 3 * Credit*		0.005***
		(0.001)
*ShockCustomer 4 * Credit*		0.002
		(0.002)
ShockCustomer 1	0.010***	0.009***
	(0.002)	(0.002)
ShockCustomer 2		0.007***
		(0.001)
ShockCustomer 3		0.005***
		(0.001)
ShockCustomer 4		0.001
		(0.001)
Firm's financial health	0.005***	–0.003**
	(0.001)	(0.002)
City FEs	X	X
Industry FEs	X	X
Observations	212,805	212,805

Note: Standard errors are clustered at the city level in parentheses.