Propagation of Shocks due to Natural Disasters through Global Supply Chains[*]

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Abstract

In this paper, we take Hurricane Sandy that hit the east coast of the United States in 2012 as a source of negative shocks and examine its indirect effects on the global economy through supply chains. More specifically, using firm-level data on global supply chains, we examine how sales growth of firms in and outside the US changes when their direct and indirect suppliers are damaged by the hurricane. Our results show that direct links with damaged suppliers and indirect links with them in two steps of supply chains lower sales growth of firms. Moreover, we observe that the negative effect on non-US firms is similar in size to the effect on US firms, concluding that negative shocks due to the hurricane propagated to firms indirectly damaged in the US as well as those outside the US through global supply chains. We further find that the negative effect is heterogeneous in size across firms depending on characteristics of their network. For example, the negative effect is smaller when the supply chain link is associated with a shareholding link, whereas it is larger when the supply chain link is associated with a research collaboration link. In addition, the negative effect on a firm's sales growth is larger when the firm's ego network is more dense or more diverse.

Keywords: global supply chains, propagation, disasters.

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1. Introduction

Recent studies find that negative shocks may propagate through input-output linkages to both upstream and downstream firms, leading to substantial damages in the whole economy (Acemoglu et al., 2012; Caliendo et al., 2014; Di Giovanni and Levchenko, 2010). Although these studies rely on input-output tables at the sectoral level, several recent studies utilize firm-level data with information on supply chain links to investigate this issue (Barrot and Sauvagnat, 2016; Carvalho et al., 2014; Lu et al., 2017). They find that negative shocks due to natural disasters affect production and financial performance of firms that are directly or indirectly connected with firms damaged directly by the disasters.

One shortcoming of these existing studies is that they focus on input-output linkages or supply chains within a country such as the United States and Japan, but do not incorporate propagation across countries, due to data limitation. However, because supply chains, production networks, and value chains have recently expanded rapidly beyond national borders (Baldwin, 2016), negative shocks may propagate across countries through such networks. The study by Boehm et al. (2015) is an exception, in that they examine propagation from parent firms damaged by a disaster to their overseas affiliates. However, propagation between unaffiliated firms is not explored in their study.

To fill the gap, this study utilizes a large firm-level dataset of major firms around the globe that contains detailed information on their supply chain ties to investigate how negative shocks due to natural disasters propagate across countries through the global supply chains. More specifically, we take Hurricane Sandy as a source of negative shocks and examine how sales of firms change when their direct and indirect customers or suppliers are located in areas affected by the hurricane. The Hurricane Sandy hit the east coast of the United States in 2012 and caused an economic loss of 50 billion US dollars, the second largest economic loss in the world since 2010 (EM-DAT, 2017). The dataset covers 58 thousand major firms in the world, including 10,000 in the United States, 3,400 in Japan, and 2,200 in the United Kingdom. In addition, we merge the dataset on the global supply chains with another large firm-level dataset that contains information on shareholding and patent co-application ties to examine how multi-level networks of firms amplify or lessen propagation of negative shocks through supply chains.

Our findings can be summarized as follows. First, we find that the growth rate of sales of customers of directly damaged firms after the hurricane was significantly lower than other firms, regardless of whether the customers are located in or outside the United States. This finding confirms international propagation of negative shocks through the global supply chains. Second, the sales growth of customers of customers of directly damaged firms (customers within two steps of supply chains) was also negatively affected. The effect on US firms (i.e., propagation within the country) is more substantial than that on non-US firms (i.e., propagation across countries). Third, a measure of firms' ego networks that is developed by Burt (2004) and inversely related to the level of diversity of direct and indirect partners has a positive impact on sales growth after the hurricane. In other words, when firms are connected with more diversified supply chain partners, their sales growth tends to be lower. This is probably because diversified ties can lead to a higher probability of having indirect ties with directly damaged firms and thus being affected by propagation of the negative shock. Finally, the negative effect of supply chain ties with directly damaged firms is alleviated when supply chain ties are associated with shareholding ties, while it is enhanced when supply chain ties are associated with research collaboration. This finding may indicate that importance of considering other types of relations that supply links are embedded in.

This study contributes to the literature in the following three ways. First, although some existing studies focus on either supply chains within a country or between parent firms and their overseas affiliates, as mentioned earlier, the present paper incorporates most major inter-firm transaction relations in the world including international and arm's-length relations. Second, as our data include the global network of major firms, we can investigate how the network structure of each firm, measured, for example, by Burt's constraint, contributes to shock propagation from natural disasters. Finally, we look into interactions between supply chains and other types of inter-firm networks, such as shareholding networks to see whether other types of links strengthen or alleviate negative effects through supply chains.

2. Empirical Strategy

2.1. Conceptual framework

When a natural disaster such as a hurricane or an earthquake hits firms' production plants, their production activities may be fully or partly disrupted due to destruction of physical capital (e.g., machinery and buildings) and lack of supply of water, gas, or electricity. When these directly damaged firms are suppliers of parts and components to other firms, the disaster may indirectly affect customers of the directly damaged firms because the customers lack supply of parts and components. Furthermore, because supply chains are multi-layered from final assemblers to the most upstream suppliers, the customers of directly damaged firms may be suppliers of some other firms. If this is the case, the negative shock due to the disaster may propagate to more downstream customers through supply chains. Therefore, our benchmark hypotheses are as follows.

Hypothesis 1: The sales growth of customers of firms damaged directly by a natural disaster is lower than otherwise due to supply chain disruptions.

Hypothesis 2: The sales growth of customers of customers (2-step customers) of firms damaged directly by a natural disaster is lower than otherwise due to supply chain disruptions.

In addition, because we will utilize data for firms in the world and global supply chains, we can distinguish between effects on customers in the United States, i.e., propagation within the country, and effects on customers outside the US, i.e., propagation across countries. However, it is not clear whether propagation effects within or beyond the country is larger. On one hand, firms outside the US linked with US firms are more likely to be well developed and linked with many local suppliers. Therefore, the customers may be able to substitute damaged US suppliers for undamaged local suppliers. On the other hand, parts and components supplied by US firms may be more specific to technology and knowledge in the US so that local suppliers outside the US may not substitute for US suppliers. The importance of input specificity in propagation of negative shocks has been argued by Barrot and Sauvagnat (2016). This presumption leads to the following hypothesis.

Hypothesis 3: The negative effect of damaged suppliers in the United States on customers in the United States may be larger or smaller than that on customers outside the US, depending on the specificity of the supplies.

Finally, we consider how other types of firm networks, particularly shareholding and research collaboration networks, affect propagation of shocks through supply chains. When suppliers are major shareholders of their customers, or vice versa, damaged suppliers are likely to allocate more from the limited amount of their parts and components to the affiliated customers than to unaffiliated customers to maximize profits of the affiliated firm group. By contrast, when suppliers and customers are engaged in research collaboration, parts and components transacted between them are likely to be specific to the firm pairs. Therefore, substituting for parts and components developed from research collaboration between suppliers and customers is more difficult than otherwise. Therefore, we obtain the last two hypotheses.

Hypothesis 4: The negative effect of damaged suppliers on their affiliated customers through shareholding ties is smaller than on unaffiliated customers.

Hypothesis 5: The negative effect of damaged suppliers on their customers that engage in research collaboration with the damaged suppliers is larger than on other customers without research collaboration.

2.2. Estimation equation

To test these hypotheses above, we consider the following estimation equation:

$$gS_{i(2011-t)} = \beta_0 + \beta_1 Supplier_{i2011} + \beta_2 X_{i2011} + \varepsilon_{it}\,. \tag{1}$$

The dependent variable, $gS_{i(t\text{-}2011)}$, is the growth rate of sales of firm i from 2011 to year t where t is either 2012 or 2013. We experiment with two cases because the Hurricane Sandy hit the US in October, 2012. Thus, immediate propagation is captured by sale growth from 2011 to 2012, whereas growth from 2011 to 2013 can capture longer-run propagation.

Supplier is the vector of key independent variables in terms of supply chain ties with suppliers directly hit by the Hurricane Sandy. We use two types of variables that measure supply chain ties with directly damaged suppliers: the log of the number of such suppliers plus one and the dummy variable that indicates the presence of such suppliers. When we use the former, we assume that the negative effect of damaged suppliers increases as the number of damaged suppliers rises. When we use the latter, we assume that the negative effect does not increase in the number of damaged suppliers because the lack of only one part or component leads to the complete halt of production lines. In other words, in the latter case, we assume input substitution is quite difficult. In addition to firm i's direct suppliers directly hit by the hurricane, *Supplier* includes measures of suppliers of firm *i*'s suppliers, or firm *i*'s indirect suppliers with two steps. In this case, we also use the number of two-step suppliers or their dummy. To further distinguish between propagation within the US and from the US to other countries, we separate each of the independent variables above into two, one of which is for customer firms in the US and the other for those outside the US.

The vector of the control variables X include four measures of the structure of the supply chain network, as described later in detail.

Other independent variables included in vector X are sales growth from 2006 to 2011, the number of workers in logs, the value of total assets in logs, sales per worker in logs, firm age, industry dummies, and country dummies.

2.3. Estimation method

To estimate equation (1), we use ordinary least squares (OLS) regression. This simple method is appropriate in the present case because the Hurricane Sandy is an exogenous shock and therefore whether a firm is linked to a damaged firm should is exogenously determined (after controlling for the total number of links the firm has).

3. Data

3.1. Data sources

This study uses two datasets, LiveData of FactSet Revere and Osiris and Orbis of Bureau van Dijk (BvD). We merge information from these three datasets because no existing firm-level dataset includes data on global supply chains, shareholder and research collaboration ties, together with financial performance all in one. LiveData includes information on supply chain relations collected from public sources such as financial reports and web sites. Because LiveData relies on publicly available information sources, firms covered in this dataset are mostly publicly listed firms. Although FactSet Revere originally focused on US firms, it recently expanded its coverage to other regions, including Europe and Asia. We utilize LiveData for 2011, one year before the Hurricane Sandy, to identify pre-disaster global supply chains that include *** firms and 66,553 supply chain ties. Among the *** firms, *** are located in the US, *** in Japan, *** in the United Kingdom, *** in Germany, and *** in China.

The other datasets, Osiris and Orbis, is an integration of firm-level data from a number of countries. Orbis covers 200 million firms around the world including non-listed small and medium enterprises, while Osiris is a subset of Orbis that mostly covers publicly listed firms. Because Osiris contains detailed financial information, we extract each firm's information about sales, the value of total assets, the number of employees, and firm age from Osiris. Orbis contains information about shareholding and patent-application relations between firms. Thus, we can identify shareholding and patent-application networks of firms in the world. Because patents are applied mostly by co-inventors, we utilize the patent-application network as a proxy for the research collaboration network. In Orbis, the number of shareholding ties in 2011 is ***, whereas the number of firms with any shareholding tie is ***. Among them, *** are located in the United

States, *** in Japan, *** in Germany, *** in the United Kingdom, and *** in China. Our data on patents are based on patents approved by any patent office in the world. However, it takes time for applied patents to be approved, we focus on currently registered patents that were applied during the period 2011-13. The total number of such patents owned by any institution that has an identification number in Orbis (i.e., firms and institutions, but not individuals) is 5,926,698, and among them, 167,793, or 2.8%, are owned by more than one firms or institutions. The number of firms that have any patent application tie with other firms is 21,902: 5,695 are located in the US, 4,555 in Japan, and 1 ,062 in China.

We merge LiveData, Osiris, and Orbis using the International Securities Identification Number (ISIN). Because ISINs are usually provided to publicly listed firms, we cannot merge most of non-listed firms in LiveData. Accordingly, the total number of observations for our benchmark regression is 2,748, among which 1,450 are in the US, 111 in Japan, 147 in the UK, 81 in Germany, and 46 in China (Table 1).

3.2. Variable construction

Our key variables related to supply chains are constructed using the full information of the global supply chains in 2011, one year before the Hurricane Sandy, identified in the LiveData of FactSet Revere, which are visualized in Figure 1. In other words, although the sample for our regression analysis is a sub-sample of firms in the LiveData that can be merged with the Osiris and Orbis data using ISIN, we compute measures of the global production network using all firms in the LiveData including firms dropped from the sample for the regressions. Accordingly, we compute the number of suppliers and suppliers of suppliers (hereafter, we call them "2-step suppliers") of each firm. To identify direct and indirect links with suppliers directly damaged by the Hurricane Sandy, we also compute the number of each firm's suppliers in the areas damaged by the hurricane and 2-step suppliers in the damaged areas. The areas damaged by the Hurricane Sandy are identified in FEMA Disaster Declaration Summary (Security, 2017). Further, we distinguish between each firm's suppliers and 2-step suppliers in the same country (hereafter, domestic suppliers) and those in other countries (foreign suppliers). To examine possible differences between propagation of negative shocks within the country and across countries, we incorporate into regressions the interaction term between a variable representing links with damaged suppliers and the dummy variable for non-US firms. In the regressions, we will use either the log of the number of the various types of suppliers plus one or the dummy variable for the presence of any such type of supplier.

In addition, we utilize four measures to represent characteristics of each firm's position in the global supply chains. The first two, the degree and PageRank, measures the centrality of each firm (or node in the terminology of network science). The degree is the number of links of each firm with others. A disadvantage of this measure is that it ignores the centrality of the firm's partners. The degree of a firm linked with k firms that are linked with many others and the degree of a firm linked with k firms that have no other partners are both k. To incorporate the centrality of a particular node's partners (or neighbors) into the centrality of the node, the largest eigenvector of the adjacent matrix of the network is often used as a centrality measure. However, this eigenvector centrality measure is not appropriate to a network which can be divided into several sub-networks without any link with each other because in that case, the eigenvector centrality is 0 for any node in sub-networks except for those in the largest sub-network. In addition, the eigenvector may not be uniquely determined for directed networks, such as supply chain and shareholding networks. To overcome these problems, Page et al. (1999) developed an extended eigenvector centrality measure, PageRank, that is often used to evaluate the centrality of web sites in the Internet.

Another network measure is Burt's constraint. Burt (1992, 2004) argues that nodes that link different groups in a network (or, in Burt's terminology, nodes that bridge "structural holes") have advantageous access to information and diverse opportunities. The reverse of high access to diverse cliques of otherwise disconnected nodes is quantified by Burt's constraint, which is defined as $\sum_j c_{ij} = \sum_j (p_{ij} + \sum_q p_{iq} p_{qj})^2,\ i \neq q \neq j$ where p_{ij} is 1/(the number of links of node i) (assuming that all links have the same weight). This constraint measure is larger when a node is linked with nodes which are linked with one another and the constraint is low for nodes linked with a variety of nodes that are not linked with each other.

Finally, we utilize the clustering coefficient, or the local transitivity, defined as the ratio of actual triplets with each node's partners to all possible triplets with its partners. This measure quantifies the proportion of a node's partners that are linked together. A large clustering coefficient implies that the node's partners are also highly linked, creating a cluster of nodes. Burt (2004) argues that when the ego-network, or the network of a particular node, is highly clustered, knowledge of the node and its neighbors is largely overlapped so that they cannot learn much from each other. This is related to the argument of Granovetter (1973), "strength of weak ties," that weak ties with outsiders are more helpful to obtain information.

Both Burt's constraint and local clustering are high, when the density of links around the node in focus is higher. The difference between the two measures emerges in case when firm has many partners that are connected to another dominant firm. When a firm has many partners who are all connected to another firm, such network composition can be characterized by low clustering (because such structure can be achieved by relatively small number of interconnecting links relative to the number of all possible links between the partners) but high constraint (because one firm dominates the whole network of the firm).

The dependent variables, i.e., sales growth from 2011 to 2012 or 2013, and other control variables, i.e., sales growth from 2006 to 2011, sales per worker in 2011, the number of workers in 2011, the value of total assets in 2011, and firm age, are taken from Osiris.

3.3. Descriptive statistics

The upper rows of Table 2 show summary statistics for the variables related to supply chains. The mean, minimum, median, and maximum number of suppliers are 6.64, 0, 3, and 233, respectively. The mean of the number of domestic and foreign suppliers is 3.46 and 2.24, indicating that the number of domestic suppliers is larger than that of foreign suppliers while the difference is not substantial. This is because firms included in the LiveData are mostly publicly listed firms that are more likely to be internationalized to a large extent. The average number of damaged suppliers in total is 0.38, whereas it is 0.62 and 0.11 for US and non-US firms, respectively. Looking at the mean of the dummy variable for damaged suppliers, we find 18.6% of all firms in the world in our data are directly connected to suppliers directly damaged by the hurricane. Distinguishing between US and non-US firms, the share of firms linked with damaged firms is 27.7% for US firms and 8.4% for non-US firms. Further, 45.2%, or almost a half, of firms in the world are indirectly connected to directly damaged suppliers within only two steps of supply chain ties. This finding that most firm pairs are indirectly connected within a few steps of supply chain relations is consistent with previous findings using other datasets. For example, Saito (2012) finds that 62% of firms in Japan are connected to firms in the areas hit by the Great East Japan earthquake in 2011, which constitute only 2% of firms, within two steps. Even after distinguishing between US and non-US firms, we find that 56% of US firms and 33% of non-US firms are linked with damaged firms in two steps. That is, firms outside the US are closely connected with damaged firms through global supply chains.

The bottom rows of Table 2 indicate summary statistics of these network measures and other control variables. The median sales growth is 7.7%, whereas the median number of workers and firm age are 2,555 and 22 years, respectively. These figures show that our sample firms are mostly established, large, and growing firms, as we repeatedly mentioned.

4. Results

4.1. Balancing tests

As we mentioned in Section 2.3, we will rely on OLS estimations. To check whether OLS estimations lead to unbiased estimates, we run OLS to test whether supply chain links with damaged suppliers predict sales growth before the disaster, including only country and industry dummies as additional independent variables. Table 3 shows that either the dummy for any direct link or two-step link with suppliers directly damaged by the hurricane has no significant correlation with sales growth before the hurricane. This result indicates that direct and indirect links with damaged suppliers are randomly allocated to firms and hence that our key variables of interest, the number of and the dummy for links with damaged suppliers, are uncorrelated with the error term in equation (1). Therefore, our use of OLS estimations can be justified.

4.2. Benchmark results

Table 4 shows the results from the benchmark estimations using the number of suppliers in logs as the key dependent variables. The dependent variable is sales growth from 2011 to 2012 in columns (1) and (2) to examine immediate propagation effects, while it is sales growth from 2011 to 2013 in columns (3) and (4) to check longer-term effects. Columns (1) and (3) do not distinguish between propagation within the US and across countries, while (2) and (4) do distinguish them by incorporating the interaction terms between the number of direct and 2-step links with damaged suppliers and the dummy variable for non-US firms.

The negative and significant effects of links with damaged suppliers in columns (1) and (3) indicate that customers directly connected with suppliers damaged by the hurricane experienced lower sales growth after the hurricane, probably because of shortage of supplies. The fact that the coefficient in column (3) is smaller in absolute terms than that in (1) suggests that the negative propagation effect through supply chains declined in a year, a finding consistent with that of Barrot and Sauvagnat (2016) for domestic supply chains within the US. Further, in columns (2) and (4), we find that the coefficients on the interaction terms are always insignificant, concluding that customers in the US and outside the US are equally affected by the negative shock from their US suppliers damaged by the hurricane. Compared with the effect of direct links with damaged suppliers, the effect of indirect 2-step links is negative but unclear. Their effect is found significant only in column (4) when we incorporate its interaction term with the non-US dummy in the regression of sales growth to 2013.

In Table 5, we use dummy variables for various types of links with damaged suppliers. The results for direct links with damaged suppliers, shown in the first two rows, are consistent with the results from Table 4. However, the effect of indirect 2-step links with damaged suppliers is now negative and highly significant in all specifications, and the interaction term with non-US dummy is positive and significant in column (4). Judging from all eight specifications, it is most likely that 2-step links with damaged firms have a negative effect particularly on US customers while their effect on non-US firms is smaller.

Results on some other variables are worth noting. First, the constraint measure of Burt (1992) has no significant effect on sales growth in all specifications. Although this finding is inconsistent with some previous studies such as Burt (2004), Phelps (2010), and Todo et al. (2016) that found positive effects of diversity of ego-networks on performance of firms and individuals, this is probably due to differences between normal and emergency periods. When firms are connected with a diverse of suppliers, it is more likely to be indirectly connected with damaged firms. Because our estimation specifications do not include indirect links with damaged suppliers in more than 2 steps, the constraint measure picks up this possible negative effect, which cancels out the standard positive effect of diversity. Todo et al. (2015) find that the effect of network diversity and density on firm performance after a disaster in the short run (a few weeks) differs from that in the medium run (half a year). Second, the local clustering coefficient always has a negative and significant effect on sales growth. This is consistent with some previous studies such as Granovetter (1973) and Villena et al. (2011) that found negative effects of density of ego networks and strong ties. Third, PageRank and the degree centrality often have a positive effect, indicating that firms located in the center of the global supply chains are more likely to grow faster.

4.3. Heterogeneous effects

Because the negative propagation effect may differ in size depending on characteristics of firms' networks, we examine the possibility of heterogeneity in two ways. First, we check whether the negative effect is alleviated or amplified by other types of networks (hypotheses 4 and 5) by incorporating the number of or the dummy variable for supply chain links with damaged suppliers associated with shareholding or research collaboration links. The results show in Table 6 indicate that shareholding links are more likely to alleviate negative effects of damaged suppliers, probably because suppliers provide more parts and components to customers affiliated through shareholding ties to maximize total profits of the firm group. By contrast, research collaboration links tend to substantially amplify the negative propagation effects, probably because research collaboration between suppliers and customers is most likely to be conducted to develop parts and components specific to customers' products.

Second, we examine how the structure of each firm's ego-network affects propagation by incorporating the interaction term between the dummy for links with damaged suppliers and Burt's constraint measure or the local clustering coefficient. The results in Table 7 demonstrate that the negative effect of damaged direct suppliers is larger when Burt's constraint is smaller, i.e., the ego-network is more diverse, or the local clustering coefficient is larger, i.e., the ego-network is denser. We interpret this evidence as showing that when firms are connected with more diverse partners, the chance to be affected indirectly by distant neighbors in the global supply chains is higher, as argued above. Moreover, in a dense sub-network which includes a supplier directly damaged by the hurricane, the negative effect of the damaged supplier can spread to a particular firm in the sub-network through various paths and is thus intensified.

5. Conclusions

In this paper, we take Hurricane Sandy that hit the east coast of the United States in 2012 as a source of negative shocks and examine its indirect effects on the global economy through supply chains. More specifically, using firm-level data on global supply chains, we examine how sales growth of firms in and outside the US changes when their direct and indirect suppliers are damaged by the hurricane.

Our results show that direct links with damaged suppliers and indirect links with them in two steps of supply chains lower sales growth of firms. Moreover, we observe that the negative effect on non-US firms is similar in size to the effect on US firms, concluding that negative shocks due to the hurricane propagated to firms indirectly damaged in the US as well as those outside the US through global supply chains. We further find that the negative effect is heterogeneous in size across firms depending on characteristics of their network. For example, the negative effect is smaller when the supply chain link is associated with a shareholding link, whereas it is larger when the supply chain link is associated with a research collaboration link. In addition, the negative effect on a firm's sales growth is larger when the firm's ego network is more dense or more diverse.

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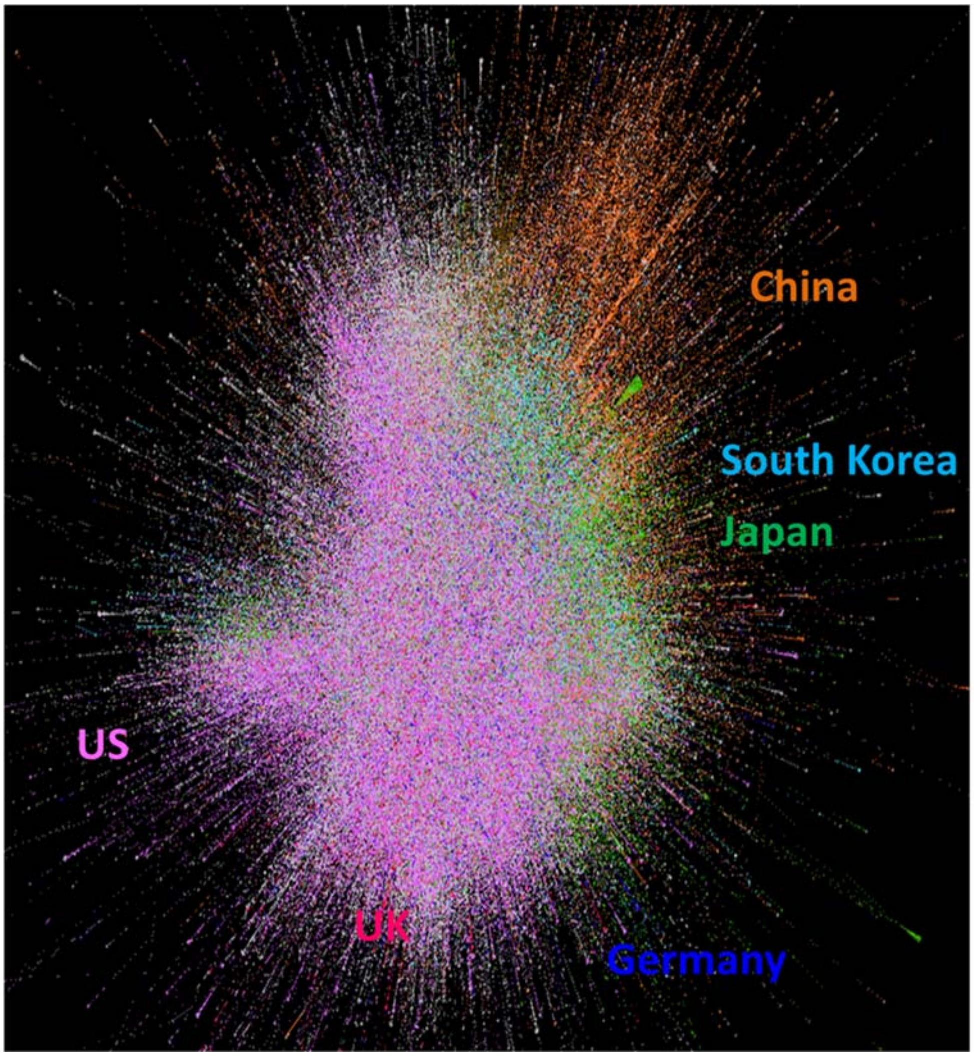
Figure 1: Visualization of Global Supply Chains



Source: LiveData of FactSet Revere

Note:

Table 1: Number of firms by country of location

Country	Number of firms	% in total
Bermuda	14	0.51
Brazil	20	0.73
Canada	11	0.40
Switzerland	46	1.67
Chile	20	0.73
China	284	10.33
Germany	81	2.95
Spain	10	0.36
France	96	3.49
United Kingdom	147	5.35
Indonesia	98	3.57
Ireland	10	0.36
Israel	43	1.56
Italy	30	1.09
Japan	111	4.04
Cayman Islands	13	0.47
Oman	13	0.47
Russia	13	0.47
Saudi Arabia	20	0.73
Sweden	29	1.06
Turkey	62	2.26
Taiwan	29	1.06
United States	1,450	52.77
Total	2,748	100

Table 2: Summary Statistics

Variable	Mean	S.D.	Min.	Median	Max
Links with supplier in 2011					
# of suppliers	6.640	14.653	0	3	233
-- in logs	1.379	1.034	0	1.386	5.455
# of domestic suppliers	3.456	10.027	0	1	189
-- in logs	0.824	0.953	0	0.693	5.247
# of foreign suppliers	2.238	5.892	0	1	133
-- in logs	0.676	0.838	0	0.693	4.898
# of suppliers in 2 steps	80.969	157.548	0	11	1341
-- in logs	2.548	2.161	0	2.485	7.202
# of domestic suppliers in 2 steps	39.455	93.812	0	3	879
-- in logs	1.881	1.922	0	1.386	6.780
# of foreign suppliers in 2 steps	36.530	71.330	0	3	602
-- in logs	1.917	1.931	0	1.386	6.402
Links with damaged suppliers in 2011					
# of links with damaged suppliers	0.381	1.298	0	0	24
-- in logs	0.180	0.427	0	0	3.219
Dummy	0.186	0.389	0	0	1
# of 2-step links with damaged suppliers	4.640	11.053	0	0	110
-- in logs	0.867	1.157	0	0	4.710
Dummy	0.452	0.498	0	0	1
# of shareholding links with damaged suppliers	0.002	0.047	0	0	1
-- in logs	0.002	0.032	0	0	0.693
Dummy	0.002	0.047	0	0	1
# of patent application links with damaged suppliers	0.001	0.033	0	0	1
-- in logs	0.001	0.023	0	0	0.693
Dummy	0.001	0.033	0	0	1
Other networks measures in 2011					
Burt's constraint	0.189	0.172	0.005	0.126	1
Local clustering coefficient	0.058	0.127	0	0.010	1
PageRank	0	0	0	0	0.003
Firm pre-disaster attributes					
Sales growth from 2006 to 2011	0.124	0.313	-0.598	0.077	10.111
Sales per worker in 2011	1046	13844	2	282	496205
-- in logs	5.701	1.050	0.412	5.644	13.115
# of workers in 2011	12320	52542	3	2555	2200000
-- in logs	7.758	1.931	1.099	7.846	14.604
Value of total assets in 2011	4674462	14486913	1156	927936	270441984
-- in logs	13.708	1.893	7.053	13.741	19.416
Firm age	33.453	30.897	6	22	347

Notes: $N = 2748$. 2-step suppliers of a firm are defined as suppliers of suppliers of the firm. Impacted suppliers are defined as suppliers in areas hit by the Hurricane Sandy.

Table 3: Balancing Tests

	(1)	(2)	(3)	(4)
	Dependent variable:			
	Sales growth from 2009 to 2011		Sales growth from 2006 to 2011	
Dummy for any link with damaged suppliers	0.0188		-0.00712	
	(0.0474)		(0.0157)	
Dummy for any 2-step link with damaged suppliers		0.00621		0.00535
		(0.0371)		(0.0123)
Observations	2,739	2,739	2,748	2,748
R-squared	0.013	0.013	0.063	0.063

Notes: Robust standard errors are in parentheses. Industry and country dummies are included, but the results are not reported for brevity of presentation.

Table 4: Effects of the Number of Damaged Suppliers

	(1)	(2)	(3)	(4)
	Dependent variable:			
	Sales growth from 2011 to 2012		Sales growth from 2011 to 2013	
# of links with damaged suppliers (log)	-0.0458*	-0.0814***	-0.0108**	-0.00965**
	(0.0235)	(0.0209)	(0.00416)	(0.00419)
# of links with damaged suppliers (log) * non-US dummy		-0.00962		-0.0162
		(0.0505)		(0.0157)
# of 2-step links with damaged suppliers (log)	-0.0139	-0.0185	-0.00332	-0.00816*
	(0.0157)	(0.0247)	(0.00490)	(0.00434)
# of 2-step links with damaged suppliers (log) * non-US dummy		-0.0172		0.00435
		(0.0222)		(0.00748)
Constraint	0.0445	0.0392	0.0132	0.0173
	(0.0698)	(0.0672)	(0.0192)	(0.0217)
Local clustering coefficient	-0.165**	-0.167**	-0.0845***	-0.0878***
	(0.0715)	(0.0800)	(0.0184)	(0.0175)
PageRank	278.2	246.7	83.99**	81.82*
	(183.4)	(182.7)	(33.17)	(43.29)
# of suppliers (log)	0.0636		-0.0116**	
	(0.0472)		(0.00547)	
# of domestic suppliers (log)		0.0851*		-0.00476
		(0.0442)		(0.00735)
# of foreign suppliers (log)		0.0535***		-0.0132*
		(0.0111)		(0.00666)
# of suppliers in 2 steps (log)	0.00770		0.00504*	
	(0.00696)		(0.00296)	
# of domestic suppliers in 2 steps (log)		0.00265		0.0149***
		(0.0134)		(0.00407)
# of foreign suppliers in 2 steps (log)		0.00499		-0.00594
		(0.0161)		(0.00403)
Sales growth 2006-11	-0.00482	0.00105	0.0383	0.0374
	(0.0413)	(0.0401)	(0.0399)	(0.0399)
Sales per worker (log)	-0.419***	-0.422***	-0.0757***	-0.0747***
	(0.128)	(0.129)	(0.0166)	(0.0167)
# of employees (log)	-0.372***	-0.376***	-0.0631***	-0.0626***
	(0.102)	(0.102)	(0.0117)	(0.0118)
Total assets (log)	0.313***	0.308***	0.0635***	0.0634***
	(0.0854)	(0.0844)	(0.0109)	(0.0107)
Firm age	0.000137	9.03e-05	-9.57e-05	-8.07e-05
	(0.000301)	(0.000330)	(0.000179)	(0.000179)
Observations	2,748	2,748	2,641	2,641
R-squared	0.062	0.063	0.080	0.083

Notes: Robust standard errors clustered at the country level are in parentheses. * **, and *** signify statistical significance at the 10, 5, and 1% level. Industry and country dummies are included, but the results are not reported for brevity of presentation.

Table 5: Effects of the Dummy Variable for Links with Damaged Suppliers

	(1)	(2)	(3)	(4)
	Dependent variable			
	Sales growth from 2011 to 2012		Sales growth from 2011 to 2013	
Dummy for any link with damaged suppliers	-0.0531**	-0.0747***	-0.0114***	-0.0125***
	(0.0203)	(0.0179)	(0.00325)	(0.00300)
Dummy for any link with damaged suppliers * non-US dummy		0.00123		-0.0115
		(0.0425)		(0.0133)
Dummy for any 2-step link with damaged suppliers	-0.118***	-0.119***	-0.0474***	-0.0568***
	(0.0400)	(0.0404)	(0.0118)	(0.00581)
Dummy for any 2-step link with damaged suppliers * non-US dummy		0.0117		0.0269**
		(0.0410)		(0.0131)
Constraint	0.0412	0.0367	0.0111	0.0165
	(0.0721)	(0.0653)	(0.0188)	(0.0210)
Local clustering coefficient	-0.176**	-0.181**	-0.0884***	-0.0937***
	(0.0789)	(0.0887)	(0.0184)	(0.0175)
PageRank	214.7*	160.8	65.86***	58.70**
	(112.2)	(105.1)	(22.88)	(28.70)
Observations	2,748	2,748	2,641	2,641
R-squared	0.063	0.064	0.083	0.086

Notes: Robust standard errors clustered at the country level are in parentheses. * **, and *** signify statistical significance at the 10, 5, and 1% level. Industry and country dummies and the control variables used in Table 4 are included, but the results are not reported for brevity of presentation.

Table 6: Heterogeneous Effects (1)

	(1)	(2)	(3)	(4)
	Dependent variable			
	Sales growth from 2011 to 2012		Sales growth from 2011 to 2013	
# of links with damaged suppliers (log)	-0.0507**		-0.0121***	
	(0.0231)		(0.00350)	
# of supply chain links with damaged suppliers associated with shareholding links	0.201***		0.0197	
	(0.0499)		(0.0131)	
# of supply chain links with damaged suppliers associated with research collaboration links	-0.275		-0.101***	
	(0.165)		(0.0247)	
Dummy for any link with damaged suppliers		-0.0562***		-0.0128***
		(0.0185)		(0.00328)
Dummy for any supply chain link with damaged suppliers associated with shareholding links		0.117***		0.00819
		(0.0320)		(0.00889)
Dummy for any supply chain links with damaged suppliers associated with research collaboration links		-0.263*		-0.0876***
		(0.133)		(0.0161)
Observations	2,748	2,748	2,641	2,641
R-squared	0.062	0.062	0.080	0.080

Notes: Robust standard errors clustered at the country level are in parentheses. * **, and *** signify statistical significance at the 10, 5, and 1% level. Industry and country dummies and the control variables used in Table 4 are included, but the results are not reported for brevity of presentation.

Table 7: Heterogeneous Effects (2)

	(1)	(2)	(3)	(4)
	Dependent variable			
	Sales growth from 2011 to 2012		Sales growth from 2011 to 2013	
Dummy for any link with damaged suppliers	-0.104**	-0.0269*	-0.0369***	-0.000470
	(0.0468)	(0.0154)	(0.00858)	(0.00562)
Dummy for any 2-step link with damaged suppliers	-0.112***	-0.118***	-0.0517***	-0.0523***
	(0.0383)	(0.0405)	(0.0115)	(0.0141)
Dummy for any link with damaged suppliers * constraint	0.384		0.196***	
	(0.267)		(0.0662)	
Dummy for any 2-step link with damaged suppliers * constraint	-0.0275		0.0198	
	(0.0749)		(0.0636)	
Dummy for any link with damaged suppliers * local clustering coefficient		-0.451*		-0.196**
		(0.256)		(0.0821)
Dummy for any 2-step link with damaged suppliers * local clustering coefficient		0.0198		0.111
		(0.0926)		(0.0777)
Constraint	0.0280	0.0382	-0.00287	0.0101
	(0.0631)	(0.0693)	(0.0174)	(0.0184)
Local clustering coefficient	-0.174**	-0.147*	-0.0876***	-0.103***
	(0.0746)	(0.0773)	(0.0198)	(0.0277)
Observations	2,748	2,748	2,641	2,641
R-squared	0.063	0.063	0.084	0.084

Notes: Robust standard errors clustered at the country level are in parentheses. * **, and *** signify statistical significance at the 10, 5, and 1% level. Industry and country dummies and the control variables used in Table 4 are included, but the results are not reported for brevity of presentation.