

Supply Chain Disruptions: Evidence from the Great East Japan Earthquake

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At the backbone of any modern economy lies an intricately linked web of supply chain relationships, with each firm relying on the flow of goods from a variety of suppliers and in turn selling its products to other downstream firms. Even though essential for the performance of any modern economy, the intertwined nature of supply chains can overly expose a country’s economic performance to disruptions caused by natural disasters, military conflicts or terrorist attacks.

Over the past decade, concerns regarding the possibility of such severe disruptions have grown significantly, to the extent that in 2012 the White House issued what is known as the *National Strategy for Global Supply Chain Security* with the dual goal of “promoting the efficient and secure movement of goods” and “fostering a resilient supply chain”. Similar ongoing policy initiatives have been undertaken by the European Union and Japan.

Despite these recent initiatives, there has been little systematic empirical work to document whether supply chain disruptions are important from a macroeconomic perspective, specially to the extent that would justify the implementation of policy initiatives at the national level. In other words, even though it is well-documented that supply chain disruptions can have severe implications for individual firms or industries, there is substantially less evidence on whether and how such disruptions can lead to macroeconomic downturns in a large, diversified economy like the United States or Japan.

In this paper, we use a novel large-scale dataset on Japanese firm-level supply chain networks together with information on firm-level exposures to a large, but localized, natural-disaster — namely, the Great East Japan earthquake — to conduct a systematic empirical study of the macroeconomic impact of supply chain disruptions. More specifically, based on information on firm location, we exploit the heterogeneous exposure of firms to the earthquake in order to obtain measures of firm-level disruptions. We then combine the latter with extensive micro-data on inter-firm transactions to trace out and quantify the impact of these shocks along the supply chain.

There is already a large stream of literature that studies disruption risks in supply chains, both from theoretical and empirical perspective. On the theoretical side, studies such as [Tomlin \(2006\)](#), [Babich et al. \(2007\)](#) [Wang et al. \(2010\)](#) and [Tang and Kouvelis \(2011\)](#) (to name a few examples) provide models of how firms’ sourcing decisions in the presence of disruption risk can impact the overall performance of the supply chain. However, with the exception of the recent work of [Federgruen and Hu \(2014\)](#), most of this literature focuses on supply chains consisting of a handful of firms or tiers. In contrast, our theoretical model provides a framework for the study of general supply chain networks, with arbitrary number of firms, tiers and inter-firm linkages. On the empirical side, recent works such as [Hendricks and Singhal \(2005\)](#) and [Jain, Girotra, and Netessine \(2013\)](#) provide evidence on the effect of

supply chain disruptions on firms' performance as well as the operational impacts of global sourcing. Whereas most of this literature focuses on firm or industry-level effects, our work — to the best of our knowledge — is the first study to measure the macroeconomic impacts of supply chain disruptions and provide a systematic empirical analysis of such phenomena at a national scale.

In the rest of this extended abstract, we present our benchmark model and a summary of our empirical findings.

Overview of the Model and Empirical Results

We start the paper by providing a theoretical framework to study the propagation of shocks in general supply chain networks, allowing for an arbitrary number of firms, tiers and inter-firm linkages. Our framework, which generalizes the supply chain network model of [Acemoglu et al. \(2012\)](#), enables us to specify a very general pattern of substitutability and complementarity between a firm's different inputs. We provide a characterization of the impact of a shock to a given firm on any other firm as a function of the intricate details of the underlying supply chain network. Our theoretical results suggest that the impact of supply chain disruptions on a firm's downstream customers are stronger than their impact on the firm's upstream suppliers. We also show that the combination of such upstream and downstream effects can lead to non-trivial patterns for propagation of disruptions throughout the supply chain.

We then test the implications of our model by the means of a large-scale empirical analysis, using the Great East Japan Earthquake of the 2011 as an exogenous shock to firms located on the northeastern coast of Japan.

The data employed in this paper comes from a proprietary dataset by Tokyo Shoko Research Ltd. (TSR for short), which collects information on employment, the number of establishments, the industries each firm belongs to, three years of sales and profits, the resulting credit-score and the physical address of the firm's headquarters. The dataset covers 900,000 Japanese firms (corresponding to roughly half the firms in the country) and covers the years 2010, 2011, and 2012. Crucially, the TSR data also includes a list of each firm's most important suppliers and customers, enabling us to construct a detailed map of the underlying supply chain network.

In addition to the firm-level dataset provided to us by TSR, we also employ a dataset collected by the Geospatial Information Authority of Japan, which contains information on the extent of flooding in the aftermath of the tsunami. Using an address matching service provided by the Center for Spatial Information Science at the University of Tokyo, we match firms' headquarters address to longitude and latitude data. This enables us to identify firms that were located in the tsunami-hit region, and hence were disrupted as a result.

Using a difference-in-differences approach, we find that the performance of firms who were immediate customers to firms affected by the tsunami was negatively affected in the year following the

earthquake. More specifically, we find that having a supplier in the earthquake hit area leads to a loss of 3% in terms of sales growth relative to firms who had no direct input-transactions with earthquake-hit firms. We also find evidence for smaller but nevertheless significant upstream propagation: having a customer in the earthquake hit areas leads to a loss of 1% in terms of sales growth, an observation consistent with the theoretical predictions of our model. Both upstream and downstream effects are particularly strong for firms whose suppliers or customers had exited the market in the aftermath of the earthquake. Additionally, we show that these losses cascade downstream, thus affecting firms that are only indirect customers of the disrupted firms. While we find that this effect decays with network distance, the total number of firms affected is large enough to translate this large but localized disaster into a substantial macroeconomic effect: our calculations suggest that the propagation of the earthquake and tsunami shock over supply chain linkages can account for approximately 1% reduction in Japan's GDP growth rate in the year following the earthquake (above and beyond the direct impact on the firms in the earthquake-hit region).

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