Mitigating International Supply-chain Risk with Inventories and Fast Transport*

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This Draft: December 2, 2020

1 Research question

This project will study how firms prepare for and adjust to the risks involved in trading with distant suppliers and the associated lengthy transit times. We will focus on the role of both idiosyncratic supply and demand risks as well as aggregate risks. We will study the ways that firms differ in their abilities to make investments to mitigate these risks. Our analysis will focus on the use of inventories and alternative modes of transport to smooth out supply disruptions and take advantage of surges in demand. Inventories and mode of transport have been key margins of adjustment during recent large supply disruptions. Our work will generalize the lessons learned from these experiences and apply them to a broad range of supply-chain risks.

Inventories

Compared with their domestic counterparts, inventories play a much larger role in the operations of globally engaged firms. Alessandria et al. (2010b) and Nadais (2017) document that firms involved in international trade, either through importing inputs or exporting, hold substantially more inventories than firms not involved in trade. These higher inventory levels are a response to the higher fixed transactions costs, longer delivery lags, and greater uncertainty in international transactions.[1] This additional uncertainty may be related to delivery lags, trade policy, or exchange rates.

In choosing to take part in foreign markets, the costs and benefits of investments in logistics and distribution are likely to be as important as the availability of lower-cost or higher-quality inputs. In recent work, Khan et al. (2020) finds that higher logistical costs substantially erode the firm-level productivity gains from trade found in previous research. We will explore precisely how these logistical costs influence the decision to

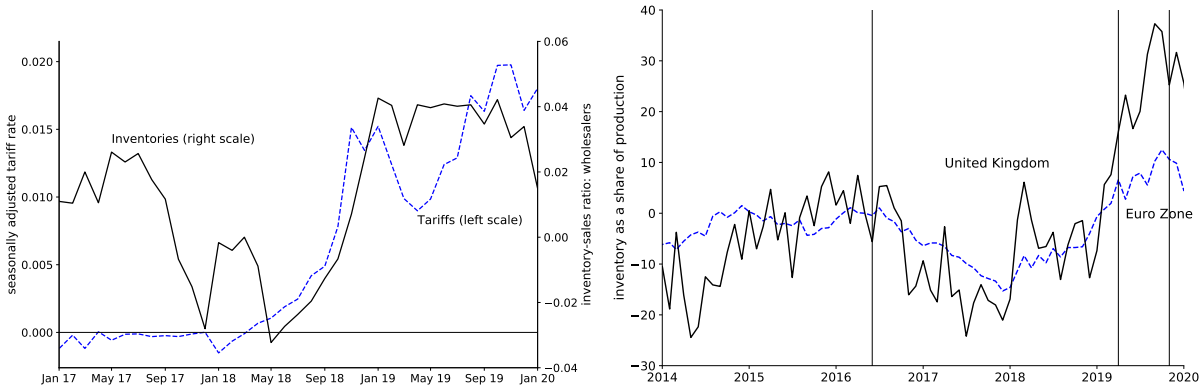
*We thank Armen Khederlarian and Shafaat Khan for helpful discussions.

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[1] A substantial share of these inventories are products in transit. For example, it takes more than 20 days to ship autos from Japan to the U.S. West Coast.

expand into foreign markets and how firms develop better inventory management capabilities to mitigate the risk associated with inputs from distant markets.

Figure 1: Inventories and trade policy



(a) U.S. tariffs on Chinese goods

(b) Brexit

Inventories have been critical in the adjustment to several recent unanticipated and anticipated "shocks." In response to uncertain possible increases in tariffs from Congress voting to not renew China's MFN status, Alessandria et al. (2019) shows that the products most at risk are stockpiled in advance of the vote. Likewise, Khan et al. (2019) shows that in advance of a cut in tariffs, firms delay purchasing and run down their inventories. In the aggregate, Figure 1a shows that wholesale inventories rose about 10 percent in advance of the second phase of U.S. tariffs on China. Figure 1b shows that, in advance of the United Kingdom's exit from the European Union, there were substantial increases in inventories in both the European Union and the United Kingdom around the projected exit dates. Both cases show clear evidence that firms use their inventories to prepare for possible supply disruptions.

These forces are also important at business-cycle frequencies. The impact of COVID-induced lockdowns on consumers and producers was dramatically mitigated by the stockpiling behavior of consumers in advance of the spread of the disease and the ability of firms to run down their stocks. We observe this same behavior during the 2008 recession. Auto sales in the Unites States of imported or domestically-produced Japanese autos fell substantially more than imports or production—the adjustment occurred in inventories. Figure 2 shows these dynamics around the Tōhoku earthquake. Even though production and exports of autos from Japan to the United States fell dramatically in March 2011, sales of Japanese autos in the United States fell substantially less and with a lag. One key reason sales fell with a lag was the large stock of autos in transit, which shows up as U.S. imports lagging Japanese exports, and speaks to the importance of shipping times as a possible mitigating factor for supply shocks.

Transportation substitution

Another critical margin of adjustment to a supply disturbance is the mode of transport. Unlike domestic transactions, there is much greater flexibility in the mode of transport for

distant international transactions. For example, a key margin of adjustment to a COVID-driven surge in demand was shifting trade of personal protective equipment (PPE) from seaborne to air shipment. Figure 3 shows that the share of U.S. imports of PPE shipped by air rose from less than 15 percent to nearly 60 percent with the onset of the disease. While there are extra costs associated with faster shipment—particularly when everyone seeks to make this shift at the same time—it is an effective way to increase capacity when demand is high or supply is disrupted.[2] The Tōhoku earthquake and tsunami provides another example. Following the tsunami, there was a substantial shift to air shipment of essential inputs to either keep factories running or restart critical product lines.

Figure 2: Japanese autos

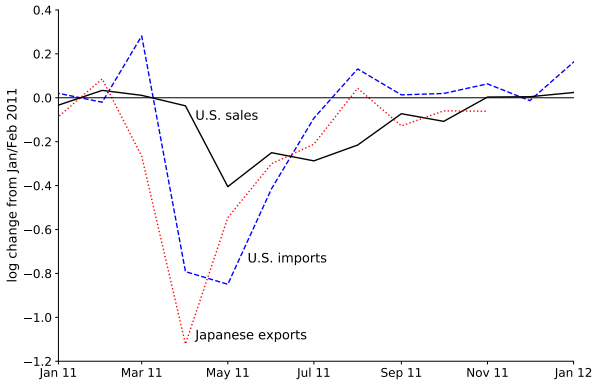
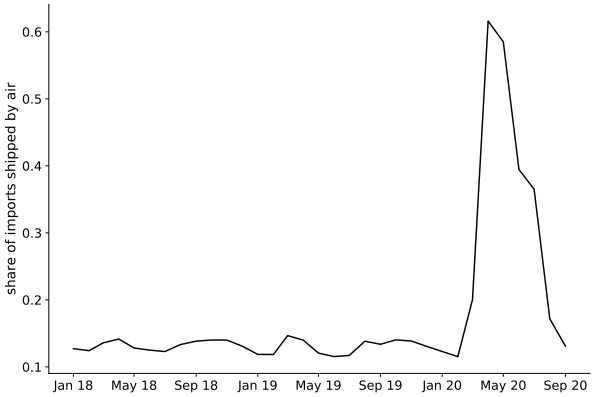


Figure 3: PPE imports by air



The proposed research will identify the modal substitution patterns that are critical to industries during supply and demand shocks. How substitutable are transportation modes in a crisis? How do substitution patterns differ in the short and the long run?

Identifying at-risk supply chains

Products and possible trading partners will differ dramatically in the characteristics that make inventories and transport mode adjustment effective margins of risk mitigation. For instance, crude oil is shipped via tanker or pipeline and there is little room for substitution into air transport. Electronics may ship by vessel during normal times but lightweight, critical goods could be expedited through air transport. Likewise, crude oil does not depreciate much in storage while electronics have short product life cycles and depreciate more quickly leading to very different inventory adjustment dynamics.[3]

The proposed research will characterize industries and supply chains by their abilities to use inventories and alternative transportation modes to respond to supply disruptions or surges in demand. We seek to understand how these margins of adjustment differ across critical industries such as manufacturing, chemicals, and information technology.

[2]This was particularly evident with COVID, as air-freight rates more than quadrupled from China to North America early in the crises and are nearly twice their pre-crises levels in December.

[3]Oil storage costs are generally low, except in times of extreme macroeconomic distress. We observed this phenomenon early in the COVID pandemic, when supply vastly outpaced demand and oil prices were briefly negative.

2 Data and models

Our empirical analysis will be organized around a stochastic multi-input sS ordering model, building on the work of Alessandria et al. (2010a). The model will allow us to infer how firms view the risks and costs of supply disruptions. We plan to use high-frequency and highly-disaggregated trade data from the United States and customs data from select U.S. trade partners (Colombia, Chile, and Peru) from 1990 to 2020. The U.S. trade data follows the HS10 nomenclature and contains information on the port of entry and mode of transport. We expect to identify supply disturbances from global events (e.g., September 11, 2001, the financial crisis, the Tōhoku earthquake, the COVID pandemic) and idiosyncratic events (e.g., trade policy). We plan to construct a dynamic firm-decision model that allows for uncertainty in exchange rates, demand, trade policy, and delivery times, including some stochastic processes with fat-tailed distributions (such as with disaster risk). The firm chooses order frequency, inventory levels, shipping modes, and whether to source from domestic or foreign suppliers. The costs of ordering products and levels of uncertainty will differ by the product's source, mode of transportation, and storability. Firms will differ in their size and inventory management capabilities, specifically their holding costs, ability to forecast demand, and ordering costs.

Using moments of the U.S. data, we will estimate the model's parameters for many industries, which will **provide measures of the industry's ability to manage supply-chain risk through inventories and alternative transportation modes.** A key part of the estimation is allowing for transportation "congestion" effects that raise transport prices during global disruptions. These effects are likely to be negligible for idiosyncratic disturbances but are important sources of risk when many industries are attempting to substitute transportation modes.

The proposed research is part of a larger research agenda using general equilibrium models to quantify the impact of supply disruptions and governments' responses to them. A general equilibrium model is necessary to evaluate the macroeconomic implications of these supply disturbances since it will allow us to endogenize movements in interest rates, demand, and exchange rates. Importantly, it allows us to evaluate the costs from aggregate fluctuations induced by expanding supply chains globally. These models will allow us to evaluate optimal government responses—which may be not to respond at all.

3 Research team

The co-principal investigators are **George Alessandria** (University of Rochester and National Bureau of Economic Research) and **Kim J. Ruhl** (University of Wisconsin – Madison and National Bureau of Economic Research). The principal investigators are ideally suited to this research topic, having published extensively on the effects of firm-level and aggregate uncertainty in the open economy. They have several influential theoretical and empirical papers on the determinants of firm-level market access investments, inventory management, and uncertainty in the open economy. They have studied these topics in both partial and general equilibrium models and recently wrote, along with Costas Arkolakis (Yale University), a comprehensive review article on firm dynamics and uncertainty in international markets (Alessandria et al., 2021).

Funding from this proposal will fund graduate student research assistants. There are several Ph.D. students at the University of Rochester and Wisconsin who are working on topics related to this proposal. Their involvement in the project will be a valuable training opportunity.

4 Conflict of interest statements

We have no conflicts of interest.

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