Macro-Perspectives on Rigidity and Risk in Global Input Sourcing

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December 2, 2020

As trade barriers have fallen over the past several decades, US firms have increased their usage of imported inputs in production. This rise in the global sourcing of inputs has lowered production costs and enhanced US competitiveness. At the same time, there is widespread concern that dependence on foreign inputs exposes firms to heightened risk. This concern is well founded: the Great Trade Collapse in 2008-2009, the Japan Tōhoku earthquake/tsunami, the US-China Trade War, and the recent COVID shock all generated international supply disruptions, which reverberated through the global production network.

While the potential importance of these shocks is obvious, these events have outpaced the development of models needed to analyze them. In this proposal, we articulate a new framework for analyzing the consequences of supply chain disruptions on the macro-economy. A key piece of the framework is a precise notion of rigidity in supply chains; We assume firms undertake sunk cost investments in order to import inputs. This assumption builds on existing approaches to modeling exporter dynamics, but it flips the emphasis from exporting to importing. Further, we develop an approach to sunk costs that is tractable in high dimensional macroeconomic models, including models that feature production (input-output) networks. The payoff to developing this model is that we are able to use the model to ask and answer new questions about the risks inherent in global sourcing.

We describe the background and objectives for the project in Section 1. We then sketch out the key model mechanism in Section 2, and we discuss how it captures some essential features of global input sourcing. In Section 3, we describe how we plan to embed this mechanism into extended models. The first extension embeds the mechanism in a multisector context, with input-output linkages across sectors. This extension allows us to examine how foreign sector-level shocks interact with rigidity in global sourcing and propagate through the domestic economy. The second extension focuses on a multi-country setting, in which domestic producers make decisions about the country sources for their foreign inputs. This extension allows us to characterize the optimal global sourcing portfolio and examine how adjustment in it shapes responses to risk shocks. In both settings, we will seek to develop a better understanding of the degree of substitutability in input sourcing and the risk/return tradeoff that producers face in making global input sourcing decisions, as well as the aggregate consequences of those decisions.

1 Background and Objectives

Over the past decade, there has been significant progress in the macroeconomic analysis of production networks, which has improved our understanding of how shocks propagate throughout the economy [Acemoglu et al. (2012); Baqaee and Fahri (2019); Carvalho and Tahbaz-Salehi (2019)]. Nonetheless, existing models are ill-equipped to address important issues raised by recent shocks.

For one, anecdotes from recent episodes point to supply chain rigidity – lack of ability to substitute across suppliers in the short run – as a fundamental problem. For example, when General Motors could not source an electronic controller from its supplier in Japan following the Tōhoku event, it was unable to flexibly switch to alternative suppliers and instead shut down production [Bunkley (2011)]. In contrast, existing models allow agents are able to flexibly re-optimize their sourcing decisions on a period-by-period basis.[1] The **first objective** of our project is to build realistic inflexibility and sluggish adjustment into the global sourcing of inputs.

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[1] To be more precise, existing models allow technological substitution possibilities to be limited – i.e., production functions may feature low elasticities of substitution among inputs. However, they do not capture the more general idea that input sourcing decisions are difficult to adjust for non-technological reasons. For example, the problem for General Motors was not only that the electronic controller was an essential input (in technology sense), but that it was unable to switch suppliers. This inability to switch suppliers is consistent with the existence of frictions that make input supply relationships a type of investment for the firm. This aspect is missing in existing models.

Closely related to this first concern, existing models are not well-suited to studying questions about supply chain risk: how risk shocks reverberate through supply chains, how firms manage supply chain risks, or how increased global sourcing has changed the overall riskiness of the economy. One reason is that the assumed flexibility in input sourcing in existing models makes risk considerations largely irrelevant for firm sourcing decisions. To capture the role of risk in shaping input sourcing decisions, one needs to conceptualize the sourcing decision as a dynamic problem, where firms are making input sourcing choices that depend on expectations of the future. A **second objective** of our project is to better capture the dynamic nature of input sourcing decisions, which opens the door to analyzing the impact of risk shocks and firm strategies to manage risk.

This second objective then sets the stage for the **third objective**: to analyze how both first and second moment shocks are transmitted through the production network. In existing models, it is conventional to analyze first-order approximations to the model in the vicinity of a non-stochastic steady state. This convention is well-suited to study the implications of first moment shocks – e.g., to trace out the effects of a change in the level of import tariffs. Nonetheless, recent events are characterized not only by changes in levels (first moments), but also significant changes in risk. For example, the Trump trade war disrupted firms global sourcing strategies because it was unpredictable – in the sense that the variance of possible outcomes increased.[2] The COVID shock shares similar features. Thus, we seek to develop a model in which we can simulate the impact of both temporary and permanent shocks to the risk environment, as well as quantify changes in risk due to permanent changes in trade (e.g., due to changes in tariffs) that alter the economy's steady state. In turn, this model will also allow us to study how government policy could be used to facilitate adjustment or mitigate aggregate risk.

2 Illustrating the Model Mechanism

In this section, we describe the essential elements we employ to model foreign sourcing decisions. We focus here on a stylized one sector setting, with a continuum of ex ante homogeneous firms and single foreign source of inputs. We describe extensions that include multiple sectors, multiple source countries, or firm heterogeneity below. Each Home firm (indexed by i) produces a differentiated good, using the production function:

$$Y_t(i) = Z_t \left(L_t(i)^{(\sigma-1)/\sigma} + M_t(i)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, \tag{1}$$

where $M_t(i)$ is a composite of intermediate goods used by firm i. The composition of the composite input depends on whether the firm chooses to source its inputs solely from domestic suppliers, or also from abroad. Therefore, we write the composite input as a conditional function:

$$M_t(i) = \begin{cases} \left((1-\kappa)^{1/\eta} M_{Ht}(i)^{(\eta-1)/\eta} + \kappa^{1/\eta} M_{Ft}(i)^{(\eta-1)/\eta}\right)^{\eta/(\eta-1)} & \text{if foreign sourcing,} \\ M_{Ht}(i) & \text{otherwise.} \end{cases} \tag{2}$$

Here $M_{Ht}(i)$ is the quantity of a bundle of domestic inputs purchased by the firm, while $M_{Ft}(i)$ is the quantity of a bundle of foreign inputs purchased by the firm. Each of these are CES composites of all domestic and foreign varieties.

We assume that firms must undertake a sunk investment in order to source inputs from abroad. This assumption draws on a large international trade literature, in which fixed costs are used to explain heterogeneous participation in trade [Melitz and Redding (2014); Bernard et al. (2018)]. More recently, this same basic approach has been adopted in the firm-to-firm networks literature to model the matching process between domestic buyers and suppliers [Lim (2018); Bernard et al. (2019)]. We assume these costs are paid by firms that choose to engage in global sourcing, as in Antràs, Fort and Tintelnot (2017).[3] Further, like the

[2] Models that do study the impacts of trade policy uncertainty or risk attributable to sunk investments have typically adopted a "real options" approach [Fillat and Garetto (2015); Handley and Limão (2017)]. This is analogous to Bloom (2009) in the open economy. While tractable in low dimensional environments, the exact solution techniques required to solve these models are technically infeasible in high dimensional, general equilibrium models.

[3] Antràs, Fort and Tintelnot (2017) focus on a static model, with fixed costs, as do Bernard et al. (2018) in their model of firms that engage simultaneously in importing and exporting. Hoang (2020) extends the Antràs et al. approach to allow for sunk investments in input sourcing and estimates the model using moment inequalities for Chinese chemical producers.

literature on export dynamics [Alessandria, Arkolakis and Ruhl (2020)], we assume these import costs are sunk, which generates an interesting dynamic decision for the firm. Examples of these costs would include search costs to to find compatible suppliers, costs to modify the production process to use foreign inputs, costs incurred to communicate technical specifications to suppliers, and so on.

A firm that seeks to start importing foreign inputs invests Home labor to establish new supply relationships. This investment has a stochastic payoff: if a firm invests q_t units of labor, the firm is able to import inputs next period with probability $\rho(q_t)$, where $\rho'(\cdot) > 0$. The optimal investment decision for the firm trades off the expected gains from offshoring against the labor cost of investment. The expected gains are equal to the increase in the value of the firm from being able to source foreign inputs, and thus lower the marginal production cost of the firm. These capital gains are given by $V^F_{t+1} - V_{t+1}$, where V^F_{t+1} is the value of the firm if it sources inputs from abroad and V_{t+1} is the value of the firm otherwise. Optimal choice of q_t is then pinned down as follows:

$$W_t = \rho'(q_t) E_t \left[\Lambda_{t,t+1} \left(V^F_{t+1} - V_{t+1} \right) \right], \tag{3}$$

where $\Lambda_{t,t+1}$ the stochastic discount factor used by the firm. Having successfully started to import foreign inputs, there is an exogenous time-varying probability δ_t that the firm's foreign relationships will be destroyed, in which case the firm reverts to domestic sourcing and must invest again to restart importing.

Whether a firm actually sources foreign inputs is a binary outcome. However, the probabilistic mapping between investment costs and successful outcomes means that we need not track individual sourcing decisions. Rather, we characterize aggregates by firm type. The stock of companies that source inputs from abroad, denoted by N_t, is a smooth state variable that evolves according to the following law of motion:

$$N_{t+1} = N_t(1 - \delta_t) + \rho_t(1 - N_t) \tag{4}$$

This equation resembles the capital accumulation equation in standard dynamic macro models. As such, the stock of importing firms (N_t) behaves like capital in our model. This formalization is reminiscent of Ghironi and Melitz (2005), who treat the aggregate stock of firms as a state variable. In contrast, we focus on sluggish adjustment in sourcing decisions.

By recognizing the sunk nature of investments in global sourcing, this framework provides a natural micro-foundation for the difficulty that companies face in responding to foreign shocks. On the one hand, firms will be unable to flexibly re-optimize their sourcing in response to shocks to foreign productivity, trade costs, etc. Further, we allow for a shock (via δ_t) that directly targets firm relationships, such that firms may be subject to temporarily higher than normal rates of destruction in their relationships with foreign suppliers. Firms will only be able to rebuild their sourcing networks slowly in response to these shocks. These aspects of the model both touch on the **first objective** described in Section 1. Further, Equation (3) makes clear the intrinsically dynamic nature of investments in foreign input sourcing, which captures the **second objective**. Yet, the tractability of this dynamic framework is compatible with achieving the **third objective**, as we describe in the next section.

3 Embedding the Mechanism in Extended Models

We now turn to extensions of this basic framework, and related comparative statics exercises, that allow us to explore the propagation of global sourcing shocks through the domestic production network and firm sourcing strategies to manage them.

3.1 Multi-sector Model

The first extension embeds the baseline model into a multi-sector small open economy (SOE) framework with input-output linkages across sectors. This framework combines limited substitution (complementarity) in sectoral input use, as in Atalay (2017), with sunk cost dynamics in global sourcing. These two distinct forms of inflexibility will interact to govern the downstream propagation of foreign shocks, whereby downstream sectors may be vulnerable to disruption even if they are not directly engaged in global sourcing. Our expectation is that this interaction will amplify the macro-consequences of disruptions in global sourcing, though this is ultimately an empirical question on which there is little existing evidence. Further, this model

is a rich laboratory to study the propagation of second moment shocks through the production network, which have not previously been studied (to our knowledge).

Lastly, we can also study how long term reductions in trade costs alter the riskiness of production, by leading to increased foreign sourcing and thus increases in effective adjustment frictions. This final exercise speaks to policy-relevant questions: e.g., how policy might have contributed to increasing risk in the past, and where targeted reductions in global sourcing would lower aggregate risk in the economy the most.

3.2 Multi-country Model

The second extension re-focuses attention on how firms source inputs in a multi-country environment. To crystallize ideas, we again intend to focus on a SOE environment, in which Home firms can source particular inputs from one or more foreign partners.[4] Absent risk, firms have an incentive to concentrate input expenditure on low cost producers. However, risk management considerations will push them to source inputs from multiple countries in order to reduce the risks of supply chain disruption [Tomlin (2006)]. Thus, this model allows us to explore the interplay between risk and sourcing decisions: the extent to which risk reduces the likelihood of global sourcing, increases the number of foreign countries from which companies source, and how the international covariance structure of risk profiles affects the specific countries from which a company sources inputs.

Beyond these questions, we can also examine how sourcing decisions respond to shocks – as in, the extent to which supply chain disruptions can be mitigated by substitution across individual country sources. Because we will allow for country-specific sunk investments, our analysis will feature rich substitution dynamics across countries and time, with lower cross-country substitution in the short run than long run.

3.3 Data and Parameters

To study the quantitative properties of the model, we need a mix of standard macro and model-specific parameters. We also will use data from the BEA Input-Output Accounts and disaggregated Census trade data sources to capture sector and country input shipments.

Some model-specific parameters can be calibrated based on moments from firm-level data and related empirical estimates of import costs. For example, the average share of importing firms pins down the steady state share of firms engaged in global sourcing: N_0. Moments describing churn (exit/entry) of firms from importing inform steady-state values for δ_0 and ρ_0. Estimated values for fixed costs of importing then inform parameterization of the $\rho(\cdot)$ function that quantifies the sunk cost of importing.

Additionally, we need to calibrate the curvature of the $\rho(\cdot)$ function, which determines the time profile of short versus long run trade elasticities together with the stochastic shock process. For this, we will take advantage of natural experiments for which we have significant a priori information about the persistence of the shock. For example, Boehm, Flaaen and Pandalai-Nayar (2019) documents significant disruption in foreign input supply after the Tōhoku earthquake in Japan, which was known to be a one-time, temporary shock in input supplies. Alternatively, we could make use of tariff shocks, which often have ex ante identifiable temporary or permanent components depending on the instruments used, as in Boehm, Flaaen and Pandalai-Nayar (2019). In these cases, we can use the model structure and information on the dynamic evolution of endogenous variables such as the volume of imports, or the number of companies that source from that region (i.e., N_t), to identify structural model parameters.

4 Research Team

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[4] To be clear, the SOE assumption implies that foreign variables are treated as exogenous. For tractability, we intend to treat each foreign partner as independent of the other, abstracting from connections among them.

interdependence between countries. Graduate student support under the award will cover research assistance from an Economics PhD student at the University of Notre Dame.

References

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

Alessandria, George A., Costas Arkolakis, and Kim J. Ruhl. 2020. "Firm Dynamics and Trade." NBER Working Paper No. 27934.

Antràs, Pol, Teresa C. Fort, and Felix Tintelnot. 2017. "The Margins of Global Sourcing: Theory and Evidence from U.S. Firms." *American Economic Review*, 107(9): 2541–2564.

Atalay, Enghin. 2017. "How Important are Sectoral Shocks?" *American Economic Journal: Macroeconomics*, 9(4): 254–280.

Baqaee, David Rezza, and Emmanuel Fahri. 2019. "The Macroeconomic Impact of Microeconomic Shocks: Beyond Hulten's Theorem." *Econometrica*, 87(4): 1155–1203.

Bernard, Andrew B., J. Bradford Jensen, Stephen J. Redding, and Peter K. Schott. 2018. "Global Firms." *Journal of Economic Literature*, 56(2): 565–619.

Bernard, Andrew, Emmanuel Dhyne, Glenn Magerman, Kalina Manova, and Andreas Moxnes. 2019. "The Origins of Firm Heterogeneity: A Production Network Approach." NBER Working Paper No. 25441.

Bloom, Nicholas. 2009. "The Impact of Uncertainty Shocks." *Econometrica*, 77(3): 623–685.

Boehm, Christoph E., Aaron Flaaen, and Pandalai-Nayar. 2019. "Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tōhoku Earthquake." *The Review of Economics and Statistics*, 101(1): 60–75.

Bunkley, Nick. 2011. "Piecing Together a Supply Chain." *The New York Times*.

Carvalho, Vasco M., and Alireza Tahbaz-Salehi. 2019. "Production Networks: A Primer." *Annual Review of Economics*, 11: 635–663.

Fillat, Josè, and Stefania Garetto. 2015. "Risk, Returns, and Multinational Production." *The Quarterly Journal of Economics*, 130(4): 2027–2073.

Ghironi, Fabio, and Marc Melitz. 2005. "International Trade and Macroeconomic Dynamics with Heterogeneous Firms." *Quaterly Journal of Economics*, 120: 865–915.

Handley, Kyle, and Nuno Limão. 2017. "Policy Uncertainty, Trade, and Welfare: Theory and Evidence for China and the United States." *American Economic Review*, 107(9): 2731–2783.

Hoang, Trang. 2020. "The Dynamics of Global Sourcing." Unpublished Manuscript, Vanderbilt University.

Lim, Kevin. 2018. "Endogenous Production Networks and the Business Cycle." Unpublished Manuscript, University of Toronto.

Melitz, Marc J., and Stephen J. Redding. 2014. "Heterogeneous Firms and Trade." In *Handbook of International Economics*. . 4th ed., 1–54. Elsevier.

Tomlin, Brian. 2006. "On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks." *Management Science*, 52(5): 639–657.