Networks and Trade*

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Abstract

Trade occurs between firms both across borders and within countries, and the vast majority of trade transactions includes at least one large firm with many trading partners. This paper reviews the literature on firm-to-firm connections in trade. A growing body of evidence coming from domestic and international transaction data has established empirical regularities which have inspired the development of new theories emphasizing firm heterogeneity among both buyers and suppliers in production networks. Theoretical work has considered both static and dynamic matching environments in a framework of many-to-many matching. The literature on trade and production networks is at an early stage, and there are a large number of unanswered empirical and theoretical questions.

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1 Introduction

The transformation of research in the field of international trade over the last few decades has been dramatic. The systematic digitization of customs forms has enabled researchers to dive deeply into the microeconomic underpinnings of international trade relationships. What once was a discipline of the aggregate exchange between countries across sectors has become increasingly focused on the firms that conduct trade and their heterogeneity, see Bernard et al. (2012) and Redding (2011). At the same time that trade research has shifted attention to the role of individual firms, the study of the economics of networks has grown rapidly, in conjunction with the emergence of big data on social and economic networks between firms and individuals (Graham, 2015 and Jackson, 2009). In spite of the importance of heterogeneous firms in the research in international trade, there has been, until recently, a surprising lack of attention to the fact that exporting and importing firms are embedded in a network of production and exchange across borders with many partners.

Firms are not islands. While the canonical models of production imagine anonymously supplied inputs being transformed into products sold to final consumers, almost all firms are connected to a network of firms. These connections are both to upstream suppliers of raw materials, components, and services as well as to downstream customers, both final demand and other firms. Research on this network feature of domestic and global production is just beginning and is the subject of this survey.

Trade is naturally a networked activity. International trade itself is comprised almost exclusively of transactions between firms, and research on exporters and importers shows that the vast majority of trade includes at least one large firm with many trading partners. Consumers are largely absent from trade across borders although technology is pushing that margin of trade as well.[1] Sellers, or exporters in the international context, sell potentially multiple products to multiple buyers in multiple destinations. Conversely importing firms potentially source multiple products from multiple sellers in multiple source countries. The well-documented skewness of activity across exporting and importing firms extends naturally to their foreign partnerships as well. Big exporters of a product to a particular destination typically have many buyers and a skewed distribution of sales across those buyers. In contrast a firm with low exports of the same product typically has a single customer in the market.

The recognition that a small number of firms have a disproportionate role in international trade both on the export side and on the import side has been the subject of several papers,

[1]The research on production networks and firm-to-firm connections naturally connects to a recent literature on the role of intermediation in trade, see Section 6.2. With few exceptions, the work on firm-to-firm connections has not distinguished between producers, pure intermediaries, or firms that both produce and intermediate.

see e.g. Antràs et al. (2017) and Bernard et al. (forthcominge). However, in all these papers, the foreign partners of the large firms, either suppliers or customers, are typically given no interesting economic features. Theoretical and empirical work has tended to focus either on the diversity and production decisions of exporting firms, or on the heterogeneity and sourcing decisions of importing firms, but has not considered them both at the same time.

The small but growing literature on firm networks in trade, both international and domestic, introduces "interesting" firms on both sides of the relationship. The advent of research on the network structure of production raises new questions about market structure, responses to shocks, returns to different factors such as skilled and unskilled labor, and the role of trade in increasing economic welfare. Early research on the buyer and seller margins of trade shows that the number of foreign partners is highly responsive to the traditional gravity forces of distance and market potential. In spite of the rapid decline in transport costs and tariffs, distance still attenuates aggregate trade flows, and the research on the networked nature of cross-border trade offers potential insights into these relationships. The research on firm-to-firm networks has the potential to enhance our understanding of the nature of information frictions and how policy might reduce those frictions and increase trade.

Building on the recent work on global supply chains, research on the formation and duration of supplier networks is addressing questions of how firms make upstream connections and how those connections affect the marginal cost of production. Related work is modeling the choice to perform tasks in-house or outside the firm and how firms find domestic or foreign suppliers.

A separate line of research considers the relationship between firm sales and the downstream set of customers. Research shows that large firms have more customers but do not sell more to each customer, rasing the question of how firms find and maintain their customer base as they grow. Research also shows that when the customer base is endogenous, then the responses to shocks to market demand, exchange rates or tariffs, will be different compared to the response in canonical models. Similarly, the possibility that firms on both sides of a transaction have market power introduces new and difficult questions about the change in market structure, prices, quantities and varieties as a result of trade liberalization. Reduced trade barriers may not result in the standard benefits of lower prices and increased varieties if firms endogenously change their contracting relationships.

The dynamics of these interactions, e.g. why connections survive and how they evolve over time, are just beginning to be considered in this emerging literature. Developing dynamic general equlibrium models of network formation and evolution can provide valuable insights into the short and long run responses to shocks. The research on trade and networks also links closely to the literature on granularity and shock propagation in macroeconomics.

A robust finding in this emerging literature is that the network structure matters for firm-level and aggregate outcomes. Simply put, who buys inputs from whom will determine firms' marginal costs and measured productivity along the supply chain. Various distortions in the supply chain may therefore lead firms to source from suboptimal suppliers, which will decrease aggregate productivity and real wages. In this literature, authors have identified variable trade costs and relationship-specific costs as one source of friction. The costs of switching suppliers may also lead firms to hold on to a given supplier for too long. Furthermore, the literature has shown that infrastructure improvements have a powerful effect on who and where firms source from, and that these improvements cause big changes in the network structure.

The remainder of this paper is structured as follows. We begin by reviewing some motivating empirical evidence in Section 2. We then present a general framework for firm-to-firm trade in Section 3 and then specific models and relevant empirical applications in Section 4. The evolution of relationships is discussed in Section 5, which includes full and partial information frameworks, considering both the role of search frictions and learning. There are several areas of research related to the developing work on exporter-importer connections in trade. Recent years have seen research on intermediaries in trade and the propagation of aggregate and idiosyncratic shocks. We briefly introduce the research in these areas and link it to our discussion of firm-to-firm connections in Section 6.

2 Networks: A New Perspective on International Trade

Aggregate trade is ultimately the sum of all transactions between importers and exporters so we begin by examining the role of buyers and sellers in aggregate trade flows. Aggregate exports from a specific country to destination j can be written as

$$x_j = f_j p_j b_j d_j \bar{x_j}$$

where f_j, p_j, and b_j are the number of exporters, products, and importers respectively, $d_j = o_j/(f_j p_j b_j)$, o_j is the number of exporter-product-buyer observations for which trade with country j is positive and $\bar{x_j} = x_j/o_j$ is average value per exporter-product-buyer. In a regression of the log of each component on the log of total exports to a given market, the coefficient represents the share of overall variation in trade accounted for by that respective margin.

Table 1: The Margins of Trade (2006).

	Sellers	Products	Buyers	Density	Intensive
Exports (log)	0.57[a]	0.53[a]	0.61[a]	-1.05[a]	0.32[a]
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
N	205	205	205	205	205
R^2	0.86	0.85	0.81	0.81	0.50

Note: Robust standard errors in parentheses. [a] p< 0.01, [b] p< 0.05, [c] p< 0.1.

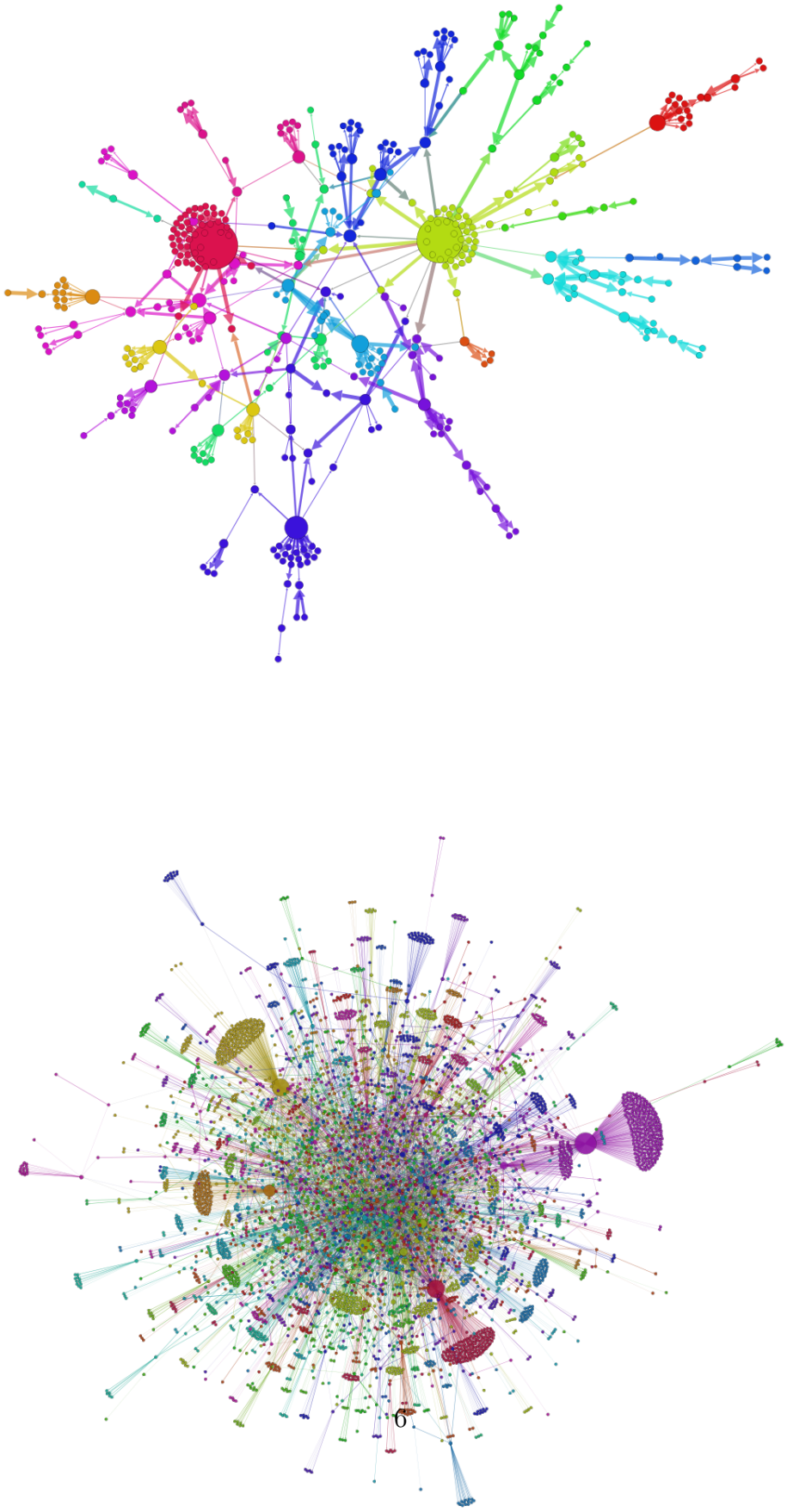
Source: Bernard et al. (Forthcominga).

Table 1, from Bernard et al. (Forthcominga), decomposes Norwegian aggregate exports to 205 destination countries. The results confirm and extend previous findings on the variation of the extensive and intensive margins of trade. While it has been shown in a variety of contexts that the number of exporting firms and exported products increase as total exports to a destination increase (columns one and two), these results show the comparable variation of the number of importing buyers in total exports (column three). In fact, the buyer margin is as large or larger than the firm or product margins. The variation of the buyer margin provides the initial motivation for examining individual trade links, their formation, characteristics and evolution.

It is also useful to visualize individual transactions in international trade. The top panel of Figure 1 shows all buyer-seller relationships between Norwegian exporters of a particular type of machines (HS product 847990) to buyers in the U.S. in 2006. Every node represents a firm, and the arrows show the direction of trade. The size of the node represents how many relationships a given firm has, while the size of the arrow shows the value of the transaction. The figure shows that most firms have few connections while a small number of firms have many connections, i.e. that the in-degree (number of suppliers) and out-degree (number of customers) are highly skewed. The bottom panel of Figure 1 shows all relationships between Norwegian exporters and U.S. buyers in 2006, in total 8,320 relationships, 1,298 sellers and 5,066 buyers. Here, of course, it is difficult to see the individual links, but nevertheless one observes the dominance of a few firms.

This pattern is a general finding across industries and countries. In the U.S. domestic market using data on public firms from Compustat, Atalay et al. (2011) find that the in-

Figure 1: Firm-to-Firm Trade. U.S. importers and Norwegian exporters, HS 847990, 2006.



degree (number of suppliers) distribution is highly skewed and similar results exist for Japan (Bernard et al., 2014) and Belgium (Dhyne et al., 2015).[2] The evidence from international trade data, measuring the number of importers per exporter and the number of exporters per importer are broadly similar, as shown for Ecuador, Uruguay, and Costa Rica by Carballo et al. (2013), Norway and Colombia by Bernard et al. (Forthcominga), and for France by Kramarz et al. (2016).

While a few firms are extremely well-connected on the buyer side, the seller side or both, it is not typically the case that their partners only have one connection. Table 2 decomposes total Norwegian exports into four mutually exclusive groups: trade from one-to-one matches, many-to-one, one-to-many and many-to-many. One-to-one matches represent 9.5 percent of all exporter-importer connections but account for only 4.6 percent of aggregate trade. Many-to-many matches, i.e. where both exporter and importer have multiple connections, make up almost two thirds of aggregate trade.[3] The dominance of many-to-many matching makes firm-to-firm relationships different than many other relationships that economists have analyzed empirically. For example, the assignment of workers to firms, or students to colleges, is typically (but not always) many-to-one. Our review of the literature will therefore start with models that feature many-to-many matching.

Table 2: Types of Matches, %.

	(1) One-to-one	(2) Many-to-one	(3) One-to-many	(4) Many-to-many
Share of value, %	4.6	26.9	4.9	63.6
Share of counts, %	9.5	40.1	11.0	39.4

Note: 2006 data. Column (1) refers to matches between exporters (E) and importers (I) where both have one connection in a market, column (2) refers to matches where the E has many connections and the I has one, columns (3) refers to matches where the E has one connection and the I has many, column (4) refers to matches where both E and I have many connections. The first row shows the trade value for each group relative to total trade. The second row shows the number of matches in the group relative to the total number of matches. Source: Bernard et al. (Forthcominga).

[2]These distributions are well approximated by a Pareto distribution, except in the tails where the Pareto over predicts the connectedness of central firms and the mass of firms that have low in-degrees.

[3]One might hypothesize that a substantial share of firms with multiple connections only have two links. The share of trade value from many-to-many links when excluding two-connection firms is almost 50 percent.

3 General Framework

In this section, we present a simple framework that clarifies some key concepts and questions that we will address in this article. Our starting point is a model where firms are heterogeneous in productivity or quality, as in Melitz (2003). Firms source inputs from one or more suppliers. Consequently, firms may sell to other firms, in addition to final demand. Consider the following production function of firm i:

$$y_i = \kappa z_i l_i^{\alpha} v_i^{1-\alpha},$$

where y_i is output, z_i is productivity, l_i is labor, α is the labor share and $\kappa > 0$ is a normalization constant.[4] v_i is a constant elasticity of substitution (CES) input bundle:

$$v_i = \left(\sum_{k \in \mathcal{S}_i} \left(\phi_{ki} \nu_{ki} \right)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)},$$

where ν_{ki} is the quantity purchased from firm k, $\mathcal{S}_i$ is the set of suppliers to firm i and $\sigma > 1$ is the elasticity of substitution across suppliers. ϕ_{ki} is a demand shifter that captures the idea that firms (and industries) may have very different production technologies, and that their purchases from a given supplier may vary greatly.[5] The corresponding input price index is $P_i^{1-\sigma} = \sum_{k \in \mathcal{S}_i} \left(p_{ki} / \phi_{ki} \right)^{1-\sigma}$, where p_{ki} is the price charged by supplier k to firm i. The marginal cost of the firm is then

$$c_i = \frac{w^{\alpha} P_i^{1-\alpha}}{z_i}, \tag{1}$$

where w is the common wage rate. Total sales by firm i is

$$\begin{aligned} s_i &= \sum_{j \in \mathcal{C}_i} s_{ij} + \mathcal{F}_i \\ &= \sum_{j \in \mathcal{C}_i} \left(\frac{\phi_{ij}}{p_{ij}} \right)^{\sigma-1} P_j^{\sigma-1} M_j + \mathcal{F}_i, \end{aligned} \tag{2}$$

[4] $\kappa = \alpha^{-\alpha} \left(1-\alpha\right)^{\alpha-1}$

[5] One might also use a two-tiered production function with different elasticities of substitution across suppliers within and between industries. We abstract from this here in order to keep the notation to a minimum.

where M_j is total intermediate purchases of firm j. $\mathcal{F}_i$ is sales going to final demand, which in equilibrium will be determined by a mixture of demand and supply side parameters.

This framework is flexible enough to capture salient features of observed networks. For example, firms in "upstream" industries such as oil production may have relatively few suppliers in the set $\mathcal{S}_i$ and sell mainly to other firms in the network (and relatively little to final demand $\mathcal{F}_i$). Firms in "downstream" industries such as retail may have many suppliers and sell mainly to final demand.[6]

This setup illustrates a number of important aspects of production networks. First, from equation (1) we see that the marginal cost of firm i depends on the marginal costs of i's suppliers, through the input price index P_i. A change in firm-level fundamentals such as productivity, z_k, will therefore affect marginal costs of all downstream firms that are using k as an input directly, or indirectly through higher-order linkages. For the same reason, the set of suppliers $\mathcal{S}_i$ will also matter for firms' costs. Domestic or international trade costs are likely to affect production costs because (i) they may change who you source from, i.e. the set $\mathcal{S}_i$ (the extensive margin), and (ii) they change the cost of sourcing from a particular supplier k through the price p_{ki} (the intensive margin). Firm-level and aggregate measured productivity will therefore depend on the level and structure of trade costs. Second, from equation (2) we observe that a firm's sales s_i are determined by both the set of customers $\mathcal{C}_i$ (the extensive margin), as well as how much is sold to each customer (the intensive margin), which will depend on the price charged p_{ij} and the customer's effective demand $(\phi_{ij}P_j)^{\sigma-1}M_j$. Again, trade costs are likely to affect both these margins. Therefore, the impact of e.g. tariffs on trade flows will depend on how $\mathcal{C}_i$ might change.

In the following sections, we will review various frameworks for understanding how firms find suppliers and customers, i.e. how the sets $\mathcal{S}_i$ and $\mathcal{C}_i$ are formed. We will also see how trade costs matter for the formation of the network, and we will study various firm-level and aggregate implications of the network structure.

4 Firm-to-firm Matching Models

A fundamental question in trade is how buyer-seller relationships are established. This section provides an overview of the literature that is based on static frameworks. To organize the presentation, we structure the section into two parts. First, we present papers with two types of firms: sellers and buyers. This gives rise to so-called bipartite networks because a seller might link to buyer, but a seller (buyer) cannot link to other sellers (buyers). While this first wave of research has provided useful insights, it is also limited because in observed

[6]We discuss intermediaries in trade in Section 6.2.

networks firms are typically sellers and buyers at the same time. The second subsection therefore presents new research where this constraint is removed.

4.1 Bipartite Networks

Bernard et al. (Forthcominga) develop a simple theory that explains buyer-seller links $\mathcal{S}_i$ and $\mathcal{C}_i$ and the volume of trade between firms and countries.The network is bipartite, so that one group of firms will have other firms as customers (the set $\mathcal{S}_i$ is empty and $\mathcal{C}_i$ is non-empty), while the other group of firms will have other firms as suppliers (the set $\mathcal{S}_i$ is non-empty and $\mathcal{C}_i$ is empty). The theory provides a buyer-seller micro-foundation for global trade flows. In this framework, both buyers and sellers are heterogeneous in productivity. High productivity can also be thought of as high quality at equal cost. Sellers, for example German exporters, can potentially meet and sell to all other firms, both within Germany and abroad. The model presumes full information about all agents in the market. However, it is costly to establish links to customers.[7] These relationship-specific costs can be thought of as expenses of establishing a good and trustworthy relationship, tweaking the product to the client's requirements, or negotiating the legal contract. Depending on the size of these costs, which do not vary with the value of trade between partners, it will not be profitable to sell to all potential customers. Instead, the German exporter will only sell to customers that demand more than a certain threshold quantity. An implication of this model is that lowering relationship-specific costs expands the number of customers in the set $\mathcal{C}_i$. In equilibrium, firms therefore get more suppliers, which leads to lower marginal costs in equation (1) above. The model therefore predicts that non-tariff barriers embodied in relation-specific costs (i.e., legal hurdles) can have a dampening effect on both aggregate trade and real wages.

Furthermore, a highly productive, or high quality, exporter will sell to more customers than a low productivity exporter because high efficiency corresponds to more sales to each potential customer. The marginal customer of a highly productive firm will be smaller (or less productive) than that of a low productive firm, because only the highly efficient firm finds it profitable to incur the fixed cost for that relationship. This mechanism gives rise to so-called *negative degree assortativity*: less connected sellers, i.e. firms with few customers, will, on average, link to more connected buyers. And conversely, very connected sellers will, on average, link to less connected buyers. Empirically there is strong support for this prediction from the model both in international trade relationships and in domestic production networks. Observed production networks, both within and across countries, are

[7]The costs are borne by the seller and not by the buyer. This assumption, along with the CES demand function as described in Section 3, ensures that buyers are always willing to accept new connections. In e.g. Antràs et al. (2017) and Bernard et al. (forthcomingb) the buyer bears the costs.

characterized by negative assortativity (Lim, 2017 using U.S. Compustat data, Bernard et al., 2014 for Japan, Bernard et al., 2017 for Belgium, and Bernard et al. (forthcomingd) for Colombian imports).[8] It is important to note that negative degree assortativity does not mean that well connected sellers only sell to poorly connected buyers. The most productive firms will sell to a wider range of buyers, from the most productive (best connected) down to the less productive (less connected). Low productivity sellers, however, will only be able to connect to a high productivity partner.

This feature of the international and domestic firm-to-firm production network is in stark contrast to the positive assortativity found in many social and economic networks based on individual connections. One example is the network of friends on Facebook: if you are popular on Facebook, then on average your friends are also popular and, in fact, are more popular than you. If you have few friends on Facebook, then your average friend is typically also unpopular.[9] Negative assortativity had typically only been observed in technical networks, such as the network of servers on the internet (Jackson and Rogers, 2007). In this sense, the production network has features that make it distinct from many other matching environments. It is both dominated by many-to-many matches and there is, on average, a productive, well connected firm on one side of almost every transaction.[10]

In the model, the distribution of customers per firm inherits the shape of the underlying productivity distribution, which is assumed to follow a Pareto (power law) distribution. The theory predicts that a few firms will have a large number of customers while most firms will have few, consistent with the empirical evidence. Finally, the model predicts a particular type of invariance property: the distribution of sales across a firm's buyers is independent of how many buyers she has. For example, median sales, across all buyers for a firm with 10 customers is equal to median sales for a firm with 1000 customers. This is a very strong prediction: big firms are large because they have more customers (extensive margin), not because they sell more to those customers (intensive margin).[11] Perhaps surprisingly, the Norwegian export data offer empirical support for this prediction. Sales to customers at the 10th, 50th and 90th percentiles do not vary with the number of customers of the exporter in the market. Bernard et al. (2017) find the same invariance property in the Belgian domestic

[8]Serrano and Boguna (2003) find negative assortativity holds at the country level, the partners of well-connected countries are, on average, less well connected themselves.

[9]Network formation models where individuals meet friends of friends can explain positive assortativity as observed in social networks (Jackson and Rogers, 2007).

[10]Blum et al. (2010, 2012) were early contributions that observed the importance of large firms in pairwise relationships in international trade.

[11]A high productivity firm sells more than a low productivity firm to the same customer. However, the high productivity firm connects to more customers, and those marginal customers are smaller. The two forces cancel out so that the distribution of sales across buyers, within a firm, is identical for all firms.

production network, highlighting the importance of the extensive margin of firm-to-firm connections.

An important question is whether the move to examining ever more detailed data on trade transactions gives us new insights about the welfare gains from trade. In Bernard et al. (Forthcominga) the gains are similar to the class of models analyzed by Arkolakis et al. (2012). Hence, the change in real income in moving from the current equilibrium to autarky depends on only two sufficient statistics: (i) the share of expenditure on domestic goods and (ii) an elasticity of imports with respect to variable trade costs. However, the buyer-seller focus shows that high relationship-specific costs dampen trade flows and therefore reduce real incomes for consumers. The reason is simple: higher relation-specific costs mean fewer links between firms. This translates to higher production costs in a world where firms benefit from having many suppliers. One way to think about this is that the firm is not able to fully take advantage of specialization in production when it has few suppliers. Higher production costs then translate into higher consumer prices and therefore lower real wages for consumers.

High relationship-specific costs therefore cause lower aggregate output and welfare. The exact nature of these relationship-specific costs is not well understood. They may encompass items as varied as the level of communications technology in the two countries, the similarity of languages, and the density of activity across space. They may be associated with the characteristics such as the degree of trust between agents in two economies. Greater trust may make it easier and less costly to establish relationships, for example, potentially lowering costs associated with contract negotiations. Identifying the sources of relationship-specific costs is an important and promising research area where we currently have limited empirical knowledge.

Another important implication of the buyer-seller focus is related to the impact of tariffs. In classic trade theory, a tariff might help the import competing sector because they will then enjoy higher output prices and less competition from abroad. In Bernard et al. (Forthcominga), instead, a tariff is bad for domestic firms because they typically use imported intermediate inputs. Tariffs therefore raise production costs for importing firms, and the higher the share of imported inputs, the higher the increase in costs will be. In addition, firms would want to drop their marginal suppliers, because those relationships are no longer profitable. This is not just a theoretical possibility: as mentioned above, a large share of global trade is in intermediate inputs, meaning that tariffs can be bad news even for import competing sectors.[12] It is well known in the literature that when trade consists of cross-border supply chains, then tariffs have adverse impacts on import-intensive firms. The new insight here is that tariffs have two effects: First, the direct effect of increased prices from

[12]The magnitude of this effect will depend on the level of tariffs in downstream and upstream industries.

existing foreign suppliers, and, second, the indirect effect of losing suppliers.

Bernard and Dhingra (2016) consider the effects of tariff liberalization in the context of firm-to-firm matching and the US-Colombia free trade agreement. They show that trade liberalization increases the incentive to engage in joint contracts, thus raising the profits of these exporters and importers at the expense of consumer welfare. Using matched importer-exporter data from Colombian import transactions, they show that US exporters that started to enjoy duty-free access were more likely to increase their average price, decrease their quantity exported and reduce the number of import partners in the Colombian market.

Bernard et al. (Forthcominga) provides a framework for thinking about relationships between firms in international trade and associated efficiency and welfare gains. It is empirically challenging to identify such mechanisms because firms with high productivity naturally choose to have more, and perhaps better, suppliers. Causality therefore goes both ways - from relationships to productivity and the reverse. Bernard et al. (forthcomingb) estimate the impact of more and/or better suppliers $\mathcal{S}_i$ on sales and productivity by exploiting a quasi-natural experiment.[13] Instead of looking at firm-to-firm trade across countries, they analyze relationships within a country. A new high-speed train (Shinkansen) was introduced in Japan in 2004 in the southern island of Kyushu. The train dramatically lowered travel time in the southern part of Japan; between the major cities on the route, Hakata and Yatsushiro, travel time fell from 135 to 35 minutes. An interesting feature of the Shinkansen trains is that they only carry people and not cargo. This means that the natural experiment only lowered the cost of moving individuals, whereas shipping costs remained constant.

The paper tests two main hypotheses: first, whether the high-speed train made it easier for firms to find and link to new suppliers or customers along the new train line; second, whether the high-speed train facilitated more efficient collaboration with suppliers located along the new train line. The presumption is that lower travel time made it easier to find and interact with suppliers, e.g. by monitoring their production. Both hypotheses rely on the premise that face-to-face (F2F) communication is more effective than other forms of communication such as telephone, email or video conferences. Research from the management literature gives some support to this idea (Warkentin et al., 1997; Hightower and Sayeed, 1995, 1996; Maznevski and Chudoba, 2000).

The authors have annual balance sheet data before and after the introduction of the high-speed train as well all firm-to-firm relationships in Japan in two cross-sections. They use a triple differences approach, exploiting (i) changes before and after the new train, (ii) the

[13] A related question is whether an exogenous change in connections also trigger new relationships. A recent paper by Furusawa et al. (2017) estimate the impact of offshoring, i.e. international outsourcing, on the likelihood of using domestic suppliers. They find that upon offshoring, firms are less likely to drop domestic suppliers.

geolocation of a firm, in particular whether it is located close by a new train station or not and (iii) the input intensity of the industry the firm belongs to. Input intensity is important because theory suggests that input intensive industries are expected to benefit more than other industries in response to the shock. The reason is simply that high input intensity means that the price of intermediate inputs is relatively more important in production costs. Any change in the price index due to the infrastructure shock will therefore translate into larger changes in marginal costs, prices and output. The third difference is also important to rule out alternative mechanisms (such as endogeneity of the location of new train stations and various demand side and commuting mechanisms). The results from the study are striking. Firms that were located close to a new station connected to suppliers in more locations in Japan compared to other firms, and they increased their share of suppliers located close to a new station. These same firms also grew faster both in terms of output and labor productivity compared to the control group, suggesting that marginal costs in equation (1) decreased because of changes in the set $\mathcal{S}_i$.

The results strengthen the hypothesis that firm-to-firm trade yields measured productivity gains for the economy as a whole. Moreover, the results suggest that the infrastructure shock gives rise to more firm-to-firm trade and specialization across firms. Hence, it seems to be a story of comparative advantage, but not across industries and countries as in classic trade theory, but instead across firms within a country. An implication of this research is that economic integration within a country can be as important as integration across countries. Other studies have found that within-country trade costs are significant. For example, Atkin and Donaldson (2015) find that a doubling of distance between buyer and seller increases transport costs by four to five times more in Ethiopia and Nigeria than in the U.S. This suggests that there is significant scope to improve gains from both domestic and international trade in many countries.

An early contribution in the empirical literature on firm-to-firm connections is Blum et al. (2012). Using data on firm-to-firm trade between Chile and Colombia, they document a set of stylized facts and develop a simple trade model. The empirical findings mirror the ones described above. First, both firm-level exports and imports are characterized by extreme concentration. Second, in most exporter-importer pairs, at least one of the parties is a large international trader. Third, the in-degree and out-degree distributions are also very skewed. The starting point of their model is Melitz (2003), with fixed costs associated with selling to each consumer in foreign markets. It is assumed that the fixed costs are larger for small firms than large firms. Instead of selling directly to the consumer, exporters may instead export through an intermediary. If the intermediation cost is not too large, it may be cheaper for small exporters to use intermediaries instead of selling directly. This setup gives rise

to a simple sorting pattern: small exporters will match with one importer (the intermediary), whereas large exporters will match with many importers (final consumers). Moreover, these importers will buy small amounts while the intermediary importers will purchase large amounts. Finally, the model gives rise to a flavor of negative degree assortativity described above: In their model, low out-degree exporters will match with high in-degree importers and high out-degree exporters will match with low in-degree importers. Low in-degree importers and exporters will not match. However, their model fails to capture the presence of matches between large exporters and large importers, which are commonly observed in the data and dominate aggregate trade flows.

The papers above rely on some sort of friction that limits the number of matches taking place in the economy. Benguria (2015) develops a model where gathering information about the quality of a buyer is costly, so an exporter will not always end up with the best possible match. Trade liberalization can potentially increase the quality of matches because firms will search more actively. In the model, an exporter can only sell to a customer via a foreign distributor. The exporter therefore engages in two activities: production and searching for distributors. There is heterogeneity in productivity among exporters and distributors, and ideally the exporter would like to match with the most productive distributor. However, buyer productivity is unobserved, and the exporter must incur a cost each time she wants to observe the productivity of a randomly sampled distributor. A firm that searches many times will meet more potential buyers and will on average will find a higher productivity distributor compared to a firm that only searches once. Naturally, more productive exporters will search more and therefore find better distributors, leading to positive assortative matching on the intensive margin, i.e. highly productive exporters match with highly productive importers. Using the same logic, lower variable trade costs will lead to greater search intensity and exporters will match to better importers than before. A limitation of the model is that exporters are matching with only one importer. In the data, we typically see small firms only connecting to one customer, whereas large exporters match with many. The author tests these predictions using data on firm-to-firm trade between U.S. exporters and Colombian importers, and exploiting the U.S.-Colombia Free Trade Agreement which greatly improved market access among U.S. firms. Search intensity is not observed in the data, so instead the author checks whether lower Colombian import tariffs induced U.S. exporters to switch to new and more productive importers, providing evidence which is consistent with the predictions of the model. This suggests that opening up to trade may lead to efficiency gains because it enhances buyer-seller match quality.

In related research, Sugita et al. (2014) analyze one-to-one matches between Mexican exporters and U.S. importers, and also find evidence for positive assortativity on the intensive

margin. They develop a theory combining a Becker (1973) model of the marriage market and a Melitz (2003) trade model. In their framework, exporters and importers are heterogeneous in productivity. Consider the case when the cross-derivative of the joint production function of a firm-pair is positive, i.e. there are complementarities between the exporter and importer. In a stable matching equilibrium that features pair-wise stability, i.e. that both seller and buyer find an optimal partner, then matching will feature positive assortativity on the intensive margin. Sugita et al. (2014) test for positive assortativity using Mexican firm-to-firm trade data. Specifically, they exploit the phase-out of the Multi-Fibre Agreement which resulted in massive entry of Chinese exporters in the U.S. market. According to their model, Mexican exporters should re-match with new, less productive U.S. importers, i.e. partner downgrading. The authors find evidence for this mechanism, but a limitation of the theory and empirics is the exclusive focus on one-to-one matches. A promising area of future research is to build richer matching frameworks with many-to-many matching.

4.2 Full Networks

The theory described above only deals with one step in the production network, i.e. between buyer and seller but not between the buyer's buyer or the seller's seller, and so on. Eaton et al. (2015) develop a theory for the full production network with many countries, with the aim of analyzing the impact of outsourcing, i.e. using an external supplier instead of in-house labor, on the labor market. Each firm produces a good by combining various tasks according to a Cobb-Douglas production function. Tasks can be produced within the firm or purchased in the market. From the firm's perspective, labor and the available intermediate inputs are perfect substitutes for producing a task. Sellers randomly meet potential buyers, and low-cost sellers are more attractive than others and therefore meet more potential buyers. Buyers optimally choose whether they want to produce a task themselves or outsource to the lowest-cost supplier. The firm can therefore have zero, one or many suppliers. The firm can also have one or many customers depending on whether she is chosen as a supplier among potential customers. The probability that a given task is outsourced depends on a range of model parameters. For example, higher relative home wages and better foreign technology increase the probability that a given task is outsourced. Interestingly, even though the basic production technology is Cobb-Douglas across tasks, the overall labor share in production costs is not constant and will depend on wages and other factors.

Using this framework, one can solve for the aggregate equilibrium in the production of intermediates, given wages, and then solve for the labor market equilibrium to determine wages. The authors illustrate the mechanics of the model in a simple counterfactual exercise.

They assume that labor is composed of non-production and production workers and that non-production workers cannot be outsourced. Trade liberalization will increase the fraction of tasks that are outsourced because lower trade costs make it more likely to find a good match abroad. An interesting theoretical possibility is that trade liberalization can cause a fall in real wages among production workers and a rise in real wages among non-production workers. The intuition is simple: non-production workers will benefit from cheaper goods, while tasks produced by production workers are now more likely to be outsourced to a cheap foreign supplier. Labor market clearing therefore requires the wage of production workers to fall. This research therefore suggests that the network structure can potentially affect the skill premium in the economy.

Oberfield (forthcoming) provides a theory of the formation of the production network in order to analyze the role of network structure on aggregate productivity. Each firm randomly meets potential suppliers. For each potential supplier, the firm has a Cobb-Douglas production function using labor and intermediate inputs, along with a match-specific productivity parameter. Hence, in contrast to the paper above, labor and inputs are not perfect substitutes. Match productivity is random across all firm pairs. After a meeting, the firm chooses to match with the optimal supplier. The decision depends on supplier's price along with the match-specific productivity component. Hence, the firm may not always choose the lowest cost supplier if the idiosyncratic match component is poor. The firm may also be unlucky and not meet anyone. In this model, intermediate inputs are required in production, so firms with no suppliers will exit the market.

The number of potential suppliers a firm meets follows a Poisson distribution, and for each meeting, the identity of the supplier is random and uniformly drawn from all firms in the economy. In this framework, a firm will only have one supplier. However, in equilibrium a firm can have many customers. The reason is that the firm can be discovered by other customers, and many of them may choose to use the firm as a supplier. In equilibrium, the distribution of customers asymptotically follows a power law distribution. In other words, a few dominant firms with a large number of customers, so-called superstars, will emerge in equilibrium. The reason is that a slight cost advantage relative to other firms will make the firm attractive as a supplier. Hence, low cost firms that happen to meet many potential customers will win over a large fraction of those potential customers and obtain many actual customers. This is consistent with the empirical regularities discussed above: Observed production networks have a small share of firms with many customers and a large share of firms with very few customers. In Oberfield's model, the skewness of the customer distribution will depend on the wage share in the industry. Superstars will be bigger if the wage share is low, because then cost differences between potential suppliers will be relatively

more important (and the match-specific component relatively less important). More firms will then choose the superstar as a supplier, as it is the cheapest option. This, in turn, has consequences for aggregate productivity. A low wage share raises aggregate productivity because high productivity firms become more dominant in the supply chain. As in the research above, a powerful conclusion and insight is that the network structure matters for aggregate productivity. A limitation of Oberfield (forthcoming) is that the model describes a closed economy and there is no notion of trade frictions. A promising area of research involves extending the model to an open economy and modeling geography explicitly.

5 Dynamics and Information Frictions

The frameworks described above are static - they are silent on the evolution of the production network over time. In this section, we describe recent important contributions that also have a dynamic component. We structure this section into three parts. First, we review papers with no uncertainty about the economic environment and where all agents observe all other firms in the market. Second, we review papers where firms need to actively search in order to find potential matches. Finally, we look at papers where firms may also learn about their own attractiveness in other markets, or about the quality of potential partners, through repeated interactions with other firms.

5.1 Full Information

Lim (2017) introduces simple dynamics in the production network. The static model is similar to the setup in Section 3 and model of Bernard et al. (Forthcominga) described above, but it is extended in various ways. First, firms are buyers and sellers simultaneously, and the author can characterize the full static market equilibrium of the production network (conditional on the realization of the network structure). Second, the author develops simple dynamics and network formation. As above, there are relationship-specific fixed costs, so only a subset of matches is profitable. Sellers actively target potential customers, whereas the customers themselves are completely passive (due to CES preferences, customers always value access to new varieties). More productive firms will form more links both upstream and downstream. They will form more outward links (to customers) because their sales volumes are higher to more potential customers, so that more matches are profitable. They will form more inward links (to suppliers) because they generate higher demand for intermediate inputs and therefore more suppliers are willing to pay the fixed cost of matching to them. The fixed costs vary randomly over time and across all firm pairs, but firms cannot add or

drop connections every period. Instead, there is randomness in when the firm can add/drop connections, a so-called Calvo-fairy. This is mainly a modeling trick, but one can think of this a reduced-form way of introducing persistence in relationships, for example that firms cannot immediately enter or cancel a contract. When the Calvo-fairy arrives, the firm will consider all possible future revenue and costs before establishing or dropping a link. Firms therefore have rational expectations about the future. An immediate implication is that relationships that are profitable today may not be activated because the match is not profitable enough in the long run. And conversely, currently unprofitable relationships may be activated because they are profitable enough in the long run. The Calvo-fairy assumption enables Lim to characterize the dynamic market equilibrium of this economy in a relatively straightforward way. Lim's work therefore provides a useful framework that can be used for quantitative work.[14] After calibrating the model, the author finds that the propagation of firm-level shocks may be very different when there is endogenous adjustment of the production network.

Monarch (2016) develops a dynamic discrete choice framework to model importer decisions of exporter choice, with the aim of estimating the magnitude of costs associated with switching from one supplier to the next. In contrast to Lim (2017), the model is partial equilibrium and only one step in the production network is considered (i.e., the network is bipartite). Moreover, buyers can only have one supplier, whereas suppliers can potentially have many customers. Buyers observe prices and qualities of all potential suppliers, and pick the optimal one based on the expectation about future profits for a potential match. Exporters are passive and are willing to sell to any buyer. Suppliers' prices are subject to random shocks every period. Buyers know the distribution of these shocks but not the future realizations of them. The buyer's problem of finding the optimal supplier becomes dynamic because there is a switching cost associated with replacing one supplier with a different one. One can think of these switching costs as long/term trading contracts. Just as with sunk costs, switching costs naturally leads to persistence in relationships: even if the supplier's price increases, the relationship may persist if the expectation is that the price will revert back relatively soon. However, if the relationship deteriorates substantially, the buyer will opt for a "divorce" and find an alternative partner.

The author estimates the model by maximum likelihood using data on manufacturing imports by U.S. buyers from Chinese exporters over the period 2002-2008. The data source is the Longitudinal Foreign Trade and Transaction Database (LFTTD), which is collected by U.S. Customs and Border Protection and maintained by the U.S. Census Bureau.As

[14]In a recent working paper, Tintelnot et al. (2017) offer a complementary domestic network formation model and study how international trade affects firm efficiency and real wages.

mentioned above, sunk costs and switching costs lead to persistence in relationships. This is strongly supported by the U.S data. In the dataset, the overall survival rate, i.e. the share of importers using the same supplier year-to-year, is almost fifty percent. A major empirical challenge is that while persistence is consistent with switching costs, it is also consistent with the hypothesis that relationships are optimal, i.e. that there is no alternative supplier around that would be a better match. This is a version of an identification problem that has been analyzed in the sunk costs literature for many years (see e.g. Moxnes, 2010). It is therefore of first order importance to control for observed and unobserved covariates that determine match survival, such as quality and/or productivity of suppliers and buyers.

Structural estimation of the model reveals that switching costs are quantitatively important. Consider two identical suppliers, one that is the current partner and another that is not. The results suggest that the buyer would require much lower prices from the outsider in order to make her indifferent between the two suppliers. A broader implication is that aggregate import prices are inflated. In a counterfactual, the author shows that cutting switching costs by half would lower the U.S.-China import price index by 15 percent.

5.2 Search Frictions

In spite of the rich structure and analytical elegance in Lim (2017), it lacks a geographical dimension. It is therefore not well suited to study international trade or spatial questions within the boundaries of a country. Chaney (2014) introduces international trade and geography in a simple network model. Firms randomly meet customers in two different ways. First, the firm meets customers based on the headquarter location of the firm. For example, it may be more likely to find a customer in its domestic market compared to in Japan. Second, the firm meets customers based on the location of its existing customers. For example, if it already met a customer in Japan, then search can originate from Japan, making it more likely to find new customers in Japan or near Japan. The central idea is therefore that existing connections lower the cost of finding new connections, in the spirit of Jackson and Rogers (2007). The existing foreign network can provide more information about local market conditions, the preferences of consumers there, and so on. Firms that are lucky and meet many foreign clients therefore have a big advantage compared to non-exporting firms. As a consequence, superstar firms will also emerge in Chaney's model: the lucky few that get many connections will grow even more, while the large majority of firms will be small and only serve the home market. In the model, there are no transportation costs in the traditional sense. However, as in e.g. Allen (2014) and Startz (2016), information does not flow freely. The network is important because it helps reduce those informational barriers

between firms. A limitation of the model is that firms are only selling to consumers, so firms are not using other firms as suppliers. The model is therefore not well suited to study heterogeneity on the supply side. Moreover, the growth in the customer base $\mathcal{C}_i$ is entirely driven by a stochastic process, so firm-level fundamentals such as productivity do not play a role.

An empirical implication of Chaney (2014) is that firms' geographic expansion abroad is history dependent. A firm exporting to Germany, for example, will have a higher likelihood of exporting to France or Poland the next period, compared to Argentina. There is empirical support for this, see e.g. Morales et al. (2014) or the empirical evidence in Chaney's paper.

While most of the literature has focused on one-sided search, i.e. that either the seller or the buyer actively searches for a partner while the other firm sits idle, Eaton et al. (2016) make progress by allowing both seller and buyer to search.[15] International trade takes place between producers (exporters) and retailers (importers). Exporters can match to many importers and importers can match to many exporters (many-to-many matching). The likelihood that a firm finds a partner depends on various factors: the intensity of search; market tightness; and the existing connections of the firm. This last feature of the model helps generate "fat-tailed" in-degree and out-degree distributions, which is pervasive in the data. Search costs are assumed to be positive and convex in search intensity pinning down search intensities for buyers and sellers. While firms choose how much to search, meetings are assumed to be random. Hence, the baseline model does not feature assortative matching on the intensive margin, but the authors show in an appendix an extension of the model with this feature. The authors calibrate the model using Colombian customs data with information about Colombian importers and foreign exporters in the footwear industry. A key takeaway from the calibrated model is that search costs are large and that reducing them leads to substantial welfare gains. In the model, welfare gains come from an increase in the number of varieties available to final consumers, and in addition the fact that varieties become more spread out across retailers.

5.3 Learning

In Eaton et al. (2014), information about possible partners abroad is limited, so that exporters and importers must engage in costly search to establish new business partnerships. In addition, the firm can learn from interactions with other firms. Specifically, when they find a match, they receive a noisy signal about the attractiveness of their product in that

[15] Krolikowski and McCallum (2016) model search frictions with heterogeneous exporters and identical importers. Search frictions induce selection into exporting, alter the gains from trade and result in a lower than optimal number of searching firms.

market. The firm then updates her belief about the scope for exporting profits in a Bayesian manner, and then adjusts her search intensity accordingly. In other words, firms learn about their attractiveness over time. Firms that happen to be popular among buyers will search more intensively, while unpopular sellers will search less.

Search costs are increasing and convex in search intensity. Interviews conducted with Colombian exporters revealed that search costs were related to the following top three activities: maintaining a foreign sales office; paying the exports promotion office to organize visits with prospective clients abroad, and sending their sales representatives to those visits; sending sales representatives abroad to visit potential clients on their own. The model also allows for search costs to depend on the firm's current stock of customers, perhaps because a large customer base increases the seller's visibility in the marketplace.

When a firm searches more intensively, it will encounter more potential buyers. Search is random, so the seller cannot direct search towards certain types of buyers. After meeting potential buyers, only a fraction θ is willing to do business with her. This fraction θ represents the attractiveness of the firm, and it is this magnitude the firm aims to learn about. In every period, the belief about θ is updated according to the actual realization of new relative to potential customers. In their model, sellers are heterogeneous because they differ in productivity as well as in attractiveness θ. There is also heterogeneity in demand, as each potential match is associated with a time-varying idiosyncratic demand shifter across buyer-seller relationships. Given a match, the seller will evaluate the profitability of the relationship. It may be negative because the seller needs to incur a fixed cost to keep the match alive. If so, the seller will exit the relationship. There is also a constant exogenous hazard rate that a match will terminate.

The authors calibrate the model using U.S. data on manufacturing imports by buyers in the U.S. from Colombian exporters over the period 1992-2999. The data source is identical to the one used in Monarch (2016) described above. The results indicate search costs up to over $50,000 for an expected yield of one potential customer per year. Moreover, those costs are significantly reduced when firms already have clients abroad, suggesting that network effects are important. Learning is also quantitatively important, in the sense that sellers quickly adjust their search intensity when potential matches are more or less successful than anticipated.

A related type of information friction is that firms cannot completely observe the quality or productivity of a potential partner. While Eaton et al. (2014) focused on how exporters are learning about their attractiveness among customers, Monarch and Schmidt-Eisenlohr (2016) analyze how importers are learning about the reliability of their suppliers. There are two types of suppliers in their model, firms that want to shirk and exert no effort

(myopic firms) and firms that comply. The type of the supplier is not directly observed by the importer, because local contract enforcement means that myopic firms may be forced to comply. Being forced to comply occurs with a fixed probability. In every period of a relationship, the importer observes whether the supplier exerts effort or not (a noisy signal), and if the relationship is a successful one, then the importer becomes more certain that the supplier is reliable. If the exporter shirks, then the relationship ends immediately. A limitation of the framework is that the relationship formation and destruction is not modeled, i.e. observed relationships are taken as exogenous.

What are the economic consequences of this type of mechanism? First, the volume of trade between buyer and seller increases over time. This occurs because expected costs, and therefore output prices, decrease when the buyer is more certain that the supplier is reliable (the delivery probability increases). Lower prices, in turn, generate more sales and higher intermediate input demand. Second, the survival probability of a relationship increases with age, because unreliable suppliers will typically reveal themselves early on. Third, countries with good contract enforcement, or inherently reliable suppliers, will on average have longer-lived relationships (under plausible parameter values). The authors calibrate the model to detailed panel data on U.S. importer relationships, using the U.S. LFTTD data. An important finding is that learning, i.e. accumulating knowledge about suppliers, leads to substantially higher aggregate trade than in a situation without learning. The authors illustrate this by resetting relationships, i.e. wiping out all knowledge about suppliers. This leads to a substantial decline in overall imports and it takes several years before imports move back to the initial steady-state.

Rauch (1999) was an early contribution to the literature on information frictions and trade. He introduced the idea that information frictions might dampen trade and that the customer- or supplier network might help reduce those frictions. In his empirical work, he grouped products in two categories - differentiated and homogeneous products. He then showed that geographic proximity was much more prevalent for differentiated compared to homogeneous products, consistent with the idea that geographic proximity might reduce those informational asymmetries more for products that are more complex. In later work, Rauch and Trindade (2002) showed that ethnic Chinese networks contribute to more bilateral trade, and that the effect is stronger for trade in differentiated products. The authors showed that the product of ethnic Chinese in the export and import countries is positively correlated with bilateral trade between those countries. Again, this suggests that social networks might dampen information frictions between buyers and sellers. This early empirical work is supportive of such an hypothesis, but at the same time it is difficult to completely rule out competing hypothesis. The new generation of datasets on networks and trade makes this a

promising future research agenda.

6 Related Emerging Areas

Before concluding, we briefly review research closely related to the literature on trade and networks.

6.1 Shock Propagation

A central question in macroeconomics is how shocks propagate throughout the economy and how the network structure affects aggregate volatility. Acemoglu et al. (2012) show that idiosyncratic shocks to certain sectors can have aggregate consequences under certain configurations of the input-output structure of the economy. In particular, shocks in a sector can propagate to the rest of the economy if that sector is a supplier to a disproportionally large number of other sectors (first-order interconnections), or if that sector is indirectly supplying many other sectors (higher-order interconnections). di Giovanni et al. (2014) and Magerman et al. (2016) take this insight to the firm-level and quantify to what extent shocks to individual firms generate aggregate volatility, and to what extent the network structure is causing it, using French and Belgian data respectively. Empirical evidence from exogenous shocks also points to sizable supply chain distortions at the firm level. For example, Carvalho et al. (2016) and Boehm et al. (2016) use the Japanese Tohoku earthquake in 2011, while Barrot and Sauvagnat (2016) use U.S. natural disasters over a 30-year period, to identify idiosyncratic shocks to firms and their propagation through the supply chain. In related research, Heise (2016) examines propagation in old versus new relationships. He finds that, perhaps surprisingly, prices adjust more freely in old relationships compared to new ones. He then builds a model based on risk sharing to rationalize the empirical findings.

6.2 Intermediaries

The research on production networks and firm-to-firm connections naturally connects to a recent literature on the role of intermediation in trade. Early theoretical work, e.g. Rauch and Watson (2004) and Petropoulou (2011), models trade as an outcome of search and networks. Antràs and Costinot (2011) add frictions to a search model of farmers and intermediaries. Recent papers take a more technological perspective based on models of heterogeneous firms, e.g. Ahn et al. (2011), Akerman (forthcoming), and Felbermayr and Jung (2011). In these papers, exporting entails both fixed and variable costs and the intermediation technology allows wholesalers to lower the per-product fixed costs and exploit economies of scope in

exporting. The common prediction of these models is that producing firms sort into different export channels according to their productivity. As in Blum et al. (2011), these models predict a pattern of firm-to-firm matching where larger intermediaries match with small producers either within countries or across borders. Using Belgian data, Bernard et al. (forthcomingc) show that two thirds of the products exported by manufacturers are not produced by the firm, suggesting an important role for large firms intermediating exports for smaller producers. However, in spite of the advances in the work on intermediation, we have little direct evidence on the connectivity and partners of intermediaries, making this an important topic for further research.

7 Conclusions

This paper has provided a brief review of the small but flourishing literature on trade and networks. A data revolution has taken place during the last few years, where detailed information about firm relationships within and across borders is becoming available for more and more countries. Only a few years ago, economists knew next to nothing about the input-output structure of the economy at the firm level. The availability of new data has enabled researchers to analyze completely new questions as well as to get better answers to old ones. In the years ahead, we expect a continuing boom in research on trade and networks as well related areas analyzing production networks (e.g., empirical IO, macroeconomics and labor).

A range of related and important research questions are omitted or only briefly discussed in this article. Perhaps the most important one is how the network structure affect the propagation of shocks in the economy, and how shocks transmit from one firm to the next in a global (or local) value chain. Another related question is how information itself can spread throughout the nodes of the production network. We have also allocated little space to the related literature on intermediated trade.

The research so far shows that networks are important to understand the growth of firms at the micro level and of countries at the aggregate level. Information frictions and (the lack of) trust affect firm-to-firm links which again affect measured productivity growth. More research on what drives these frictions will inform policy and can help policymakers improve resource allocation and economic growth.

References

Acemoglu, Daron, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-

Salehi, "The Network Origins of Aggregate Fluctuations," *Econometrica*, 2012, *80(5)*, 1977–2016.

Ahn, J., Amit K. Khandelwal, and Shangjin Wei, "The role of intermediaries in facilitating trade," *Journal of International Economics*, 2011, *84(1)* (15706), 73–85.

Akerman, Anders, "A theory on the role of wholesalers in International trade based on economies of scope," *Canadian Journal of Economics*, forthcoming.

Allen, Treb, "Information Frictions in Trade," *Econometrica*, 2014, *82* (6), 2041–2083.

Antràs, Pol and Arnaud Costinot, "Intermediated Trade," *The Quarterly Journal of Economics*, 2011, *126* (3), 1319–1374.

Antràs, Pol, Teresa C Fort, and Felix Tintelnot, "The Margins of Global Sourcing: Theory and Evidence from U.S. Firms," *American Economic Review*, 2017, *107* (9), 2514–64.

Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare, "New trade models, same old gains?," *American Economic Review*, 2012, *102* (1), 94–130.

Atalay, Enghin, Ali Hortacsu, James Roberts, and Chad Syverson, "Network Structure of Production," *Proceeding of the National Academy of Science*, 2011, *108(13)*, 5199–5202.

Atkin, David and Dave Donaldson, "Who's Getting Globalized? The Size and Implications of Intra-national Trade Costs," 2015.

Barrot, Jean-Noël and Julien Sauvagnat, "Input specificity and the propagation of idiosyncratic shocks in production networks," *The Quarterly Journal of Economics*, 2016, *131* (3).

Benguria, Felipe, "The Matching and Sorting of Exporting and Importing Firms: Theory and Evidence," Technical Report 2015.

Bernard, Andrew B. and Swati Dhingra, "Importers, Exporters and the Division of the Gains from Trade," Working Paper, NBER 2016.

_ , Andreas Moxnes, and Karen Helene Ulltveit-Moe, "Two-sided Heterogeneity and Trade," *Review of Economics and Statistics*, Forthcoming.

_ , _ , and Yukiko Saito, "Geography and Firm Performance in the Japanese Production Network," Technical Report 14-E-034, RIETI 2014.

_ , _ , **and** _ , "Production Networks, Geography and Firm Performance," *Journal of Political Economy*, forthcoming.

_ , **Emily J. Blanchard, Ilke Van Beveren, and Hylke Vandenbussche**, "Carry-Along Trade," *Review of Economic Studies*, forthcoming.

_ , **Emmanuel Dhyne, Glenn Magerman, Kalina Manova, and Andreas Moxnes**, "The Origins of Firm Heterogeneity: A Production Network Approach," Technical Report 2017.

_ , **Esther Ann Boler, and Swati Dhingra**, "Firm-to-Firm Connections in Colombian Imports," in Lili Yan Ing and Miaojie Yu, eds., *World Trade Evolution*, forthcoming.

_ , **J. Bradford Jensen, Stephen J. Redding, and Peter K. Schott**, "The Empirics of Firm Heterogeneity and International Trade," *Annual Review of Economics*, 2012, *4*, 283–313.

_ , _ , _ , **and** _ , "Global Firms," *Journal of Economic Literature*, forthcoming.

Blum, Bernardo S., Sebastian Claro, and Ig Horstmann, "Intermediation and the nature of trade costs: theory and evidence," Unpublished, Rotman School of Management 2011.

_ , _ , **and Ignatius Horstmann**, "Facts and figures on intermediated trade," *The American Economic Review*, 2010, *100* (2), 419–423.

_ , _ , **and Ignatius J. Horstmann**, "Import Intermediaries and Trade Costs: Theory and Evidence," mimeo, University of Toronto 2012.

Boehm, C., Aaron Flaaen, and Nitya Pandalai-Nayar, "Input linkages and the transmission of shocks: Firm-level evidence from the 2011 tohoku earthquake.," Technical Report 2016.

Carballo, Jeronimo, Gianmarco I.P. Ottaviano, and Christian Volpe Martincus, "The Buyer Margins of Firms' Exports," CEPR Discussion Paper 9584 2013.

Carvalho, Vasco M., Makoto Nirei, and Yukiko U. Saito, "Supply Chain Disruptions: Evidence from Great East Japan Earthquake," Working Paper 2016.

Chaney, Thomas, "The Network Structure of International Trade," *American Economic Review*, 2014, *104 (11)*, 3600–3634.

Dhyne, Emmanuel, Glenn Magerman, and Stela Rubínová, "The Belgian production network 2002-2012," Working Paper Research 288, National Bank of Beligum 2015.

di Giovanni, Julian, Andrei A. Levchenko, and Isabelle Mejean, "Firms, Destinations, and Aggregate Fluctuations," *Econometrica*, 2014, *82* (4), 1303–1340.

Eaton, Jonathan, David Jinkins, James Tybout, and Daniel Xu, "Two-sided Search in International Markets," 2016. Mimeo, Penn State.

_ , Marcela Eslava, David Jinkins, C. J. Krizan, and James Tybout, "A Search and Learning Model of Export Dynamics," working paper 2014.

_ , Samuel Kortum, and Francis Kramarz, "Firm-to-Firm Trade: Imports, Exports, and the Labor Market," 2015.

Felbermayr, Gabriel and Benjamin Jung, "Trade Intermediation and the Organization of Exporters," *Review of International Economics*, 09 2011, *19* (4), 634–648.

Furusawa, Taiji, Tomohiko Inui, Keiko Ito, and Heiwai Tang, "Global Sourcing and Domestic Production Networks," 2017.

Graham, Bryan S., "Methods of Identification in Social Networks," *Annual Review of Economics*, 2015, *7*, 465–485.

Heise, Sebastian, "Firm-to-Firm Relationships and Price Rigidity: Theory and Evidence," 2016. Federal Reserve Bank of New York.

Hightower, R. T. and L. Sayeed, "The impact of computer mediated communication systems on biased group discussion.," *Computers in Human Behavior*, 1995, *11* (1).

Hightower, R.T. and L. Sayeed, "Effects of communication mode and prediscussion information distribution characteristics on information exchange in groups," *Information Systems Research*, 1996, *7* (4).

Jackson, Matthew O., "Networks and Economic Behaviour," *Annual Review of Economics*, 2009, *1*, 489–511.

_ and Brian W. Rogers, "Meeting Strangers and Friends of Friends: How Random Are Social Networks?," *American Economic Review*, 2007, *97* (3), 890–915.

Kramarz, Francois, Julien Martin, and Isabelle Mejean, "Volatility in the Small and in the Large: The Lack of Diversification in International Trade," Discussion Paper 11534, CEPR 2016.

Krolikowski, Pawel M. and Andrew H. McCallum, "Goods-market Frictions and International Trade," Working Paper 16-35, Federal Reserve Bank of Cleveland 2016.

Lim, Kevin, "Firm-to-firm Trade in Sticky Production Networks," 2017.

Magerman, Glenn, Karolien De Bruyne, Emmanuel Dhyne, and Jan Van Hove, "Heterogeneous Firms and the Micro Origins of Aggregate Fluctuations," Technical Report, KU Leuven 2016.

Maznevski, Martha L. and Katherine M. Chudoba, "Bridging Space Over Time: Global Virtual Team Dynamics and Effectiveness," *Organization Science*, 2000, *11* (5), 473–492.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 2003, *71* (6), 1695–1725.

Monarch, Ryan, ""It's Not You, It's Me": Breakups in U.S.-China Trade Relationships," 2016.

_ **and Tim Schmidt-Eisenlohr**, "Learning and the Value of Trade Relationships," 2016.

Morales, Eduardo, Gloria Sheu, and Andrés Zahler, "Gravity and extended gravity: Using moment inequalities to estimate a model of export entry," Technical Report, National Bureau of Economic Research Working Paper 2014.

Moxnes, Andreas, "Are Sunk Costs in Exporting Country Specific?," *Canadian Journal of Economics*, 2010, *43* (2).

Oberfield, Ezra, "A Theory of Input-Output Architecture," *Econometrica*, forthcoming.

Petropoulou, Dimitra, "Information costs, networks and intermediation in international trade," Globalization and Monetary Policy Institute Working Paper 76, Federal Reserve Bank of Dallas 2011.

Rauch, James E., "Networks versus markets in international trade," *Journal of International Economics*, June 1999, *48(1)*, 7–35.

_ **and Joel Watson**, "Network Intermediaries in International Trade," *Journal of Economics & Management Strategy*, 2004, *13(1)*, 69–93.

_ **and Vitor Trindade**, "Ethnic Chinese Networks in International Trade," *Review of Economics and Statistics*, February 2002, *84(1)*, 116–130.

Redding, Stephen J., "Theories of Heterogeneous Firms and Trade," *Annual Review of Economics*, 2011, *3*, 77–105.

Serrano, Ma Angeles and Marian Boguna, "Topology of the World Trade Web," *The Accounting Review*, 2003, *68* (1).

Startz, Meredith, "The value of face-to-face: Search and contracting problems in Nigerian trade," 2016.

Sugita, Yoichi, Kensuke Teshima, and Enrique Siera, "Assortative Matching of Exporters and Importers," 2014.

Tintelnot, Felix, Ayumu Ken Kikkawa, Magne Mogstad, and Emmanuel Dhyne, "Trade and Domestic Production Networks," 2017.

Warkentin, Merrill E., Lutfus Sayeed, and Ross Hightower, "Virtual Teams versus Face-to-Face Teams: An Exploratory Study of a Web-based Conference System," *Decision Sciences*, 1997, *28* (4).