Facilitating International Production Networks:

The Role of Trade Logistics

Abstract: Networked trade in parts and components is more sensitive to the importer's logistics performance than is final goods trade. The difference between the two trade semi-elasticities is over 45%, which is quantitatively important. We also find that logistics performance is particularly important for trade among developing countries in the Asia-Pacific region, which is where the emergence of production networks has been most pronounced. Logistics performance is also more important for South-South trade than for South-North trade. Our results suggest that developing country policymakers can support the development of international production networks by improving trade logistics performance.

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1 Introduction

The emergence of international production networks has been a notable feature of the global economy in recent years. This dynamic has been particularly marked in East Asia, where parts and components frequently cross borders a number of times before assembly into a final product is completed. Although a wide range of countries in Asia and elsewhere are now actively seeking greater integration into international production networks, relatively little is known about the kinds of policies that can promote the growth and development of cross-border production chains. This paper makes a first step towards filling that gap in the literature by focusing on one area—trade logistics—that we believe is likely to have a profound impact on the ability of firms to produce goods using network methods.

Trade logistics is a crucial part of the modern, globalized economy (Arvis et al. 2010). Better logistics performance enables firms to move goods across borders quickly, cheaply, and reliably. It helps reduce cost overheads by lowering inventory levels and making it possible to adopt “just-in-time” techniques. Networked production of goods such as consumer electronics relies particularly heavily on logistics to coordinate the production and distribution of large numbers of parts and components, and their final assembly into a finished product. Apple’s iPod, for example, contains over four hundred intermediate components sourced from domestic and overseas operators mostly in the Asia-Pacific region, for final assembly in Taiwan, China (Lo 2008). Such a business model can only be profitable if it is supported by high quality trade logistics. Similarly, the auto cable industry in Tunisia has substantial advantages such as geographical proximity to European customers and low wage rates, but its future expansion depends on the development of high quality logistics platforms that can reduce inventories and improve reliability and reactivity to customer requirements (World Bank, 2007).

Against this background, we use a gravity model to investigate the links between logistics performance and the growth of international production networks. By distinguishing in the data between trade in parts and components versus trade in final goods, we test the hypothesis that trade in parts and components—which we assume takes place largely within network structures—is more sensitive to improvements in logistics performance than is trade in final goods. We find substantial support for this hypothesis in the data, a conclusion which is robust to the use of a variety of estimation methods and samples. In line with the importance of networked production in the Asia-Pacific, we find that the association between trade and logistics performance is particularly strong in that region.

Our paper builds on and extends the existing literature in two ways. First, it adds a policy dimension to the analysis of international production networks. As the next section will show, the bulk of quantitative work in relation to parts and components trade has largely relied on descriptive methods, or on econometric modeling without explicit policy variables. The result is that we know something about the extent to which trade costs matter for the development of production networks, but very little about the particular types of trade costs—and thus policies—that matter most. Our paper addresses this gap in the literature by focusing on logistics, an important part of overall trade facilitation policies, which we show to be a key determinant of trade in parts and components. As such, our approach fits well with recent work on the determinants of trade costs, which has shown that logistics performance plays a fundamental role (Arvis et al., Forthcoming).

The second novelty of our paper is in relation to the trade facilitation literature. A number of papers have clearly demonstrated the potential of trade facilitation to help boost trade. Examples include Wilson et al. (2005), and, in the case of logistics as one type of trade facilitation, Behar et al (2011), Hoekman and Nicita (2010), and Portugal-Perez and Wilson (2008). All four papers, however, only consider the association between trade facilitation and total (aggregate) trade flows. There is as yet relatively little sector- or product-specific work on trade facilitation, which means that we have relatively little information as to which types of trade respond most strongly to improvements in trade facilitation.[1] What sectorally-disaggregated work there is tends to focus on broad categories rather than particular sectors that might be thought to be particularly sensitive to improvements in trade facilitation. Zaki (2010), for example, uses data disaggregated into 25 sectors to assess the effects of administrative burdens on bilateral trade. For the case of ASEAN, Shepherd and Wilson (2009) disaggregate trade flows into seven sectors using the one digit level of the Broad Economic Categories (BEC). In their analysis of transparency as one type of trade facilitation measure, Helble et al. (2009) split the data into trade in agriculture versus manufactures, and differentiated versus homogeneous goods. Other examples of exploiting these kinds of broad splits in the data include Persson (2010; homogeneous versus differentiated, and agriculture), and Portugal-Perez and Wilson (2010; fuels, ores and metals, manufactures, and textiles).

The two papers closest to ours in terms of sectoral disaggregation are Nordas et al. (2006) and Djankov et al. (2010). Both papers use Doing Business data on the time taken for export and import transactions as a measure of trade facilitation performance. Nordas et al. (2006) explicitly consider trade in intermediates, while Djankov et al. (2010) split the data between time-sensitive and time-insensitive products. The value added of our paper in relation to these two previous contributions comes from focusing on the distinction between final products and parts and components, which has not previously been examined in the literature. As we show in the next section, there are good theoretical reasons to believe that trade facilitation should have a particularly strong impact on parts and components trade. Our approach therefore expands on the level of sectoral analysis currently available in the trade facilitation literature.

The paper proceeds as follows. The next section reviews the theoretical and empirical literature on production networks, focusing on the role of trade costs and facilitation. Section 3 presents our dataset,

[1] A number of papers use disaggregated trade data, but do not examine in detail the possibility that the sensitivity of trade flows with respect to trade facilitation performance differs systematically across sectors. Examples include: Dennis and Shepherd (2010), and Shepherd (2010a).

discusses methodology, and provides some preliminary analysis based on graphical methods and descriptive statistics. Section 4 contains our model and estimation results, and Section 5 concludes with a number of policy implications that flow from our findings, as well as suggestions for further research.

2 Trade Costs, Trade Facilitation, and International Production Networks

As many authors note, vertical specialization has been at the center of the international organization of production in recent decades (Helpman, 2006). Trade costs and other barriers to trade have been greatly reduced. Lower transportation costs, better and cheaper access to communication technologies, and even the reduction of tariffs have allowed firms to relocate their supply chains and production processes across multiple countries. One of the most important issues in the literature on vertical specialization is the role of trade costs within global production networks (GPNs). Yi (2003) argues that intra-GPN trade should be more sensitive to changes in trade costs, since vertical specialization causes products to move across borders many times before reaching their final consumption location. The author proves that some of the main paradigms in international trade (increasing returns, and Armington) are unable to mimic the nonlinearities in trade growth after WWII, without resorting to extremely high elasticities. The author develops a two-country dynamic Ricardian model of vertical specialization that is able to account for the substantial increase in trade since the 1940s.

Evidence regarding the extent and impact of trade costs within GPNs is rather limited. One interesting exception is Hanson et al. (2004), which examines the role of trade costs in U.S. multinational firms' decision to export intermediate goods to their affiliates abroad for processing. Trade costs variables were obtained from the Feenstra (1996) dataset, based on the cost of insurance and freight, expressed as a percentage of the customs value of imports. The authors find that affiliate demand for imported inputs is higher in host countries with lower trade costs, among other things (wages, tax rates, etc), while exports by affiliates show similar correlation patterns.

On the other hand, Ma and Van Assche (2010) analyze the role of trade costs on intra-GPN trade using a comprehensive dataset on China's processing trade regime, enabling the authors to map the location of input production, the location of processing, and the location of consumption. Using a three-country industry-equilibrium model with heterogeneous firms from two advanced countries, the authors find that Chinese processed exports not only depend on *downstream trade costs* (export distance), but also on *upstream trade costs* (import distance), and the interaction of both. Unfortunately, trade logistics costs are only captured indirectly through the distance to the suppliers and customers of the firm, and then using oil prices.

Another approach to modeling GPNs employs Input-Output tables. These tables link the input with the output of an industry in different countries or domestically, as a customer and supplier of intermediate goods (Escaith et al., 2010). For instance, Hummels et al. (2001) use this methodology to compute the degree of vertical specialization for OECD countries, attributing 30 to 40 percent of exports (OECD and World) to vertical specialization. On the other hand, they develop a multi-stage production model, allowing higher specialization due to comparative advantage, and multiple trade costs as the different stages take place in different countries. Hence, the model predicts that small reductions in trade costs provide strong incentives for vertical specialization. However, the I-O approach does not come without setbacks, namely the need for improvement in the quality of data and the frequency with which the tables are updated.

Lastly, GPNs in recent years have been examined thoroughly from the perspective of outsourcing. However, the main focus in this case is somewhat different from the previous approaches, and so is its relevance for trade facilitation. In a nutshell, most of this body of knowledge has been focused on understanding the actual determinants, drivers, and mechanisms of fragmentation in production networks—and especially under what circumstances firms decide to outsource—whether motivated by strategic or cost-saving decisions (for a complete review of the literature on outsourcing, see Mankiw and Swagel, 2006; and Escaith et al., 2010).

A substantial portion of empirical work devoted to trade almost invariably suggests that reductions in logistics costs have a positive impact on aggregated trade flows (e.g., Hoekman and Nicita, 2010). Similarly, recent work on the determinants of trade costs has found that logistics performance plays an important role (Arvis et al., Forthcoming). However, the link between reduction of logistics costs and GPNs has been mostly neglected in applied research, except for a few cases discussed above. Logistics costs have not been captured in a straightforward manner in those cases, leaving open the question for further examination in the remainder of this paper.

3 Data and Methodology

3.1 Data

For full details of our data and sources, most of which are standard, see Table 1. Our trade data cover all countries and territories for which data are available in the UN-Comtrade database accessed via the World Bank's WITS server, namely 228 exporters and importers. Due to lack of availability of the logistics performance data and the lag with which comprehensive trade data become available, our dataset covers a single year only, namely 2007.

This section focuses on two novel aspects of our dataset. First, we rely on a parts and components product list based on Ando and Kimura (2005) and Obashi and Kimura (2010), which allows us isolate trade in parts and components from trade in final goods. According to the Harmonized System, manufactured goods range from Chapters HS28 to HS92. Hence, we include all relevant goods classified as part of general machinery (HS84), electric machinery (HS85), transport equipment (HS86-89), and precision machinery sectors (HS90-92). According to these authors, the distinction between intermediate goods and finished products is far from obvious, not only because of the level of aggregation in HS 6-digit information, "but because the HS classification is not designed on the basis of the functionality of goods". Hence components are only incorporated into this list if all the products within the code can be unambiguously considered as intermediate goods, not finished products. Hence, approximately 440 parts and components are built into a filter to isolate parts and components trade in aggregate trade flows. This filter is applied to bilateral trade flow data obtained from UN- Comtrade via WITS.

The other main source of information comes from the World Bank's Logistics Performance Index (LPI). The LPI is based on a worldwide survey of logistics service providers -namely freight forwarders and express carriers- who evaluate logistics "friendliness" (on a numeric scale, from 1 to 5) of countries with which they trade. This index is available for 155 countries, for the years 2007, 2010, and 2012 and is based on over 5,000 single country evaluations made by approximately 1,000 logistics professionals.[2] The final index is a weighted average of six main components, covering the following policy areas pertaining to logistics performance: efficiency of the clearance process, quality of infrastructure, ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments, and timeliness of shipments.[3] The LPI thus represents the most comprehensive source currently available on cross-country logistics performance, and Arvis et al. (2010) show that it is strongly correlated with economic outcome variables of interest, including trade performance. In particular, those authors provide graphical evidence suggesting that countries at higher levels of logistics

[2] We use LPI data for 2007 only due to the fact that many countries lag considerably in their provision of trade data.

[3] Scores in each of these areas can be influenced by governance and corruption issues in some countries. Similarly, logistics performance can influence corruption prevalence by making "speed money" payments more or less likely. For a detailed exploration of this subject, see Shepherd (2010b).

performance tend to specialize more strongly in the production of parts and components—an indication that is in line with the central conjecture of the present paper.

3.2 Preliminary Analysis

The remainder of the paper develops a fully specified econometric model and uses it to test the hypothesis parts and components trade is more sensitive to logistics performance than trade in final goods. Before moving to that context, however, it is useful to conduct some preliminary analysis based on graphical methods and descriptive statistics.

Figure 1 (sourced from Arvis et al. 2010) shows that there is a clear positive association between logistics performance and the share of parts and components in total exports. Countries with superior logistics performance tend to be relatively specialized in that sector. This finding is exactly what we would expect to see if our hypothesis is true, and logistics performance matters more for trade in parts and components than for trade in final goods.

Simple bivariate analysis of our dataset tells a similar story. The coefficient of correlation between exports (in logarithms) and logistics performance in the importing country is more than three times as strong for parts and components than for final goods (0.107 versus 0.033). Similarly, the fact that the line of best fit for parts and components in Figure 2 is steeper than that for final goods provides further preliminary evidence in favor of our contention. In fact, the slope coefficient for the parts and components line of best fit is over twice as large as that for final goods (0.526 versus 0.215). A given improvement in logistics performance would therefore seem to be associated with relatively larger trade gains in parts and components than in final goods.

It is important to stress that these results are descriptive only. They are based on correlations, and do not necessarily indicate the existence of a causal relationship. Moreover, they do not control for other intervening influences that might affect trade performance. In order to deal with these factors, we move in the next section to consider a fully-specified econometric model.

3.3 The Gravity Model

The gravity model is the standard framework for analyzing hypotheses similar to the one set out in this paper. We introduce some simple modifications into the benchmark gravity model by postulating that logistics performance impacts trade costs differently in different sectors—specifically in parts and components versus final goods. We start from the canonical, theory-consistent gravity model of Anderson and Van Wincoop (2003):

$$(1)\ \log(X_{ij}) = \log(E_j) + \log(Y_i) - \log(Y^w) + (1 - s)\log(t_{ij}) - (1 - s)\log(P_j) - (1 - s)\log(\Pi_i) + e_{ij}$$

where: X_{ij} is exports from country *i* to country *j* in sector *k*; E_j is expenditure in country *j*; Y_i is production in country *i*; Y^w is total (world) production; t_{ij} is bilateral trade costs; s is the intra-sectoral elasticity of substitution (between varieties within a sector); and e_{ij} is a random error term satisfying standard assumptions. The P_j and Π_i terms represent multilateral resistance, i.e. the fact that trade patterns are determined by the level of bilateral trade costs relative to trade costs elsewhere in the world. Inward multilateral resistance $(P_j)^{(1-s)} = \sum_{i=1}^{N}(\Pi_i)^{(s-1)} w_i \, (t_{ij})^{(1-s)}$ captures the dependence of economy *j*'s imports on trade costs across all suppliers. Outward multilateral resistance $(\Pi_i)^{(1-s)} = \sum_{i=1}^{N}(P_j)^{(s-1)} w_j \, (t_{ij})^{(1-s)}$ captures the dependence of economy *i*'s exports on trade costs across all destination markets. The *w* terms are weights equivalent to each economy's share in global output or expenditure.

To implement (1) empirically, we need to specify the trade costs function t_{ij} in terms of observables. Our approach follows the gravity modeling literature in using geographical distance as a proxy for transport costs, and dummy variables to account for countries that share a common border, language (as assessed on an ethnographic, rather than official, basis), or colonial past.[4] Our variables of primary interest are the importer and exporter LPI scores, as measures of overall logistics performance. To assess whether trade in parts and components is indeed more sensitive to logistics performance than trade in final goods, we estimate the gravity model separately for trade in final goods and trade in parts and components, and then compare coefficients across models. We therefore assume that trade costs take the following form:

$$(2)\ \log(t_{ij}) = b_1 LPI_i + b_2 LPI_j + b_3 \log(Distance_{ij}) + b_4 Contiguous_{ij} + b_5 Language_{ij} + b_6 Colony_{ij} + b_7 Colonizer_{ij}$$

Although it is possible to directly estimate (1) and (2) by nonlinear least squares, most empirical work using the Anderson and Van Wincoop (2003) model relies on fixed effects to control for production, expenditure, and multilateral resistance. Such an approach is problematic in the present case, however, because the exporter and importer logistics performance coefficients could not be separately identified—they would be perfectly collinear with the exporter and importer fixed effects. To deal with this problem, we follow Baier and Bergstrand (2009) who propose a first-order Taylor series approximation of the multilateral resistance terms:

$$(3a)\ \log \Pi_i^{(1-s\ \ )} \approx (s\ \ -1)\left[\sum w_j\ \ \log t_{ij} - \frac{1}{2}\sum\sum w_i\ \ w_j\ \ \log t_{ij}\right]$$

$$(3b)\ \log P_j^{(1-s\ \ )} \approx (s\ \ -1)\left[\sum w_i\ \ \log t_{ji} - \frac{1}{2}\sum\sum w_i\ \ w_j\ \ \log t_{ij}\right]$$

[4] For full details on the coding of these variables, see Mayer and Zignago (2011).

The gravity model given by equations (1) through (3b) can be estimated in a way that is consistent with theory, but without using fixed effects. Baier and Bergstrand (2009) show that estimation results obtained in this way are very close to those from nonlinear least squares or fixed effects estimation (without collinear variables), which supports the robustness of this methodology. All results presented in the next section are based on the Baier and Bergstrand (2009) transformation of the trade costs variables, which enables us to retain the importer- and exporter-specific LPI data as measures of logistics performance.

Although Baier and Bergstrand (2009) estimate their model using OLS, another branch of the gravity literature has recently proposed a variety of alternative econometric estimators that might be better suited to the empirical international trade context. Santos Silva and Tenreyro (2006) make a strong argument in favor of using the Poisson pseudo-maximum likelihood estimator as the gravity model workhorse. It has two main advantages over OLS. First, it is consistent under very weak assumptions—the data need not be distributed as Poisson, for example—and it is robust to a common type of heteroskedasticity that can result in biased estimates of parameters and standard errors under OLS. Second, the fact that Poisson is numerically equivalent to (weighted) nonlinear least squares run on a gravity model prior to log-linearization means that it is natural for the estimation sample to include observations where trade is equal to zero, i.e. a country pair does not engage in trade at all. Such observations are common in the bilateral trade matrix (Haveman and Hummels, 2004), but are dropped from OLS estimates because $\log(0)$ is undefined. For both of these reasons, we use Poisson to estimate the Baier and Bergstrand (2009) model, but present results from OLS and a variety of other estimators to show that our conclusions are robust.

4 Estimation Results and Interpretation

4.1 Baseline Results

Estimates for the baseline models appear in Table 43, with each column representing a sample based either on trade in final goods or trade in parts and components. Our objective is therefore to compare LPI coefficients between columns for a given estimator. Taking Poisson (columns 1 and 2) as the benchmark results, we find that standard gravity model variables have coefficients that are correctly signed, of appropriate magnitude, and at least 10% statistically significant. The only exception is the colony dummy, which carries an unexpected negative coefficient that is 5% statistically significant in the final goods regression. The models' overall explanatory power is relatively good, with an R2 approaching 30% in both cases.

Of course, our primary interest is in the coefficients on the logistics variables. The data show that logistics clearly matters for trade performance in general: the exporter and importer LPIs both have coefficients that are positive and 1% statistically significant in both the final goods and parts and components regressions. This result is in line with other findings in the trade literature using the LPI as an explanatory variable, such as Hoekman and Nicita (2010).

To see whether trade in parts and components is more sensitive to logistics performance than trade in final goods, we compare LPI coefficients between columns 1 and 2. The importer LPI coefficient is indeed larger in the parts and components model than in the final goods model. In quantitative terms, a half-point increase in the importer LPI is associated with a trade increase of around 24% for parts and components, but only 16% for final goods. The effect of importer logistics is thus about 50% stronger in the case of parts and components than in the case of final goods. By contrast, and contrary to our expectations, the exporter LPI coefficient is larger in the final goods equation than in the parts and components equation. A half-point increase in the exporter LPI is associated with a trade increase of around 35% in the case of final goods, and 28% in the case of parts and components. Despite being contrary to expectations, the result suggests that the difference in the exporter LPI effect is in any case much smaller than in the case of the importer LPI. One possible reason why there is little difference between exporter LPI coefficients is that export processes are relatively streamlined in most countries in order to facilitate exports of all types. By contrast, import processes are sometimes more cumbersome as a way of discriminating in fact, if not in law, against imports, particularly in an environment of declining tariffs. Factors like logistics performance might therefore be more distinctive for different types of goods in the import case. As we discuss below, this result is in any case subject to some degree of sensitivity according to the estimation methodology used. It would therefore be inappropriate to put too much weight on this initial resultfinding.

4.2 Results using Alternative Estimators

As noted above, there are good reasons for preferring Poisson as a workhorse gravity model estimator. However, the trade literature discloses a variety of alternative estimators that are commonly applied in the gravity model context, and it is important to ensure that our results are not overly reliant on the choice of Poisson. This section presents a range of alternative estimates based on different econometric models.

In columns 3 and 4 of Table 3, we present results using the gamma pseudo-maximum likelihood estimator, which is put forward as an alternative by Santos Silva and Tenreyro (2006). The main difference between the gamma and Poisson estimators is that they make different variance assumptions, with the former being more efficient if those assumptions hold more closely in the data. However, an undesirable aspect of the gamma estimator is that it tends to downweight large observations. This approach is problematic in the context of trade data because large observations are likely to be better measured, and thus have smaller variance, than small ones. Caution must therefore be exercised in interpreting the gamma results. However, one indication that an alternative variance assumption might be beneficial for these data is that the Park-type test proposed by Santos Silva and Tenreyro (2006, equation 13) rejects at the 1% level the null hypothesis that the Poisson pseudo-maximum likelihood variance assumption is appropriate (prob. = 0.000 for both models). Although the Poisson estimator remains consistent notwithstanding this result, there are possible efficiency gains to be had by using alternatives such as gamma.

In terms of the gravity model control variables, application of the gamma pseudo-maximum likelihood estimator produces results that largely accord with expectations. All control variables except the common colonizer dummy have coefficients that are correctly signed, and are statistically significant at the 10% level of better. The result on the importer LPI holds even more strongly in the case of the gamma estimator: the coefficient on the importer LPI score is nearly twice as large for parts and components as for final goods. Interestingly, results on the exporter LPI are also in line with expectations in this case, by contrast with the Poisson results. The parts and components coefficient for the exporter LPI is about 30% larger than the corresponding coefficient in the final goods regression. This finding serves to nuance the Poisson results, particularly in light of their possible inefficiency due to the model's problematic variance assumption. However, as previously noted, there are also difficulties with application of the gamma pseudo-maximum likelihood model to trade data, and we therefore continue to treat Poisson as the workhorse estimator for this paper.

In light of the continued use of the OLS estimator in the gravity literature, columns 1 and 2 of Table 4 present results using that method. The pattern of signs and significance of the coefficients of interest is the same as for the Poisson estimates. Again, the importer LPI coefficient is substantially larger for parts and components than for final goods, which partly confirms our hypothesis. OLS results are presented for comparative purposes only, however, since they suffer from two major defaults. First, observations for which trade is equal to zero cannot be included in the estimation sample, which reduces the sample size by about half relative to Poisson. Second, the Park-type test proposed by Santos Silva and Tenreyro (2006, equation 11) strongly rejects the adequacy of the OLS log-linearization of the gravity model (prob. = 0.000 in both models).

Another common gravity model estimator is the Heckman sample selection model (Helpman et al., 2008), which, unlike OLS, allows for the presence of zero entries in the bilateral trade matrix.[5] Results for the outcome (trade intensity) and selection (trade propensity) equations are in columns 3-6. We use Doing Business data on the time required to start a business (in logarithms) as the over-identifying variable, as in some of the regressions in Helpman et al. (2008). The estimated coefficients for the outcome equations are quite close to those from OLS, even though the Heckman model strongly rejects the null hypothesis of independence between the selection and outcome equations (prob. = 0.000 in both cases). All control variables have the expected signs and statistically significant coefficients. Again, the coefficient on the importer LPI variable is larger for parts and components than for final goods, which partly confirms our hypothesis.

Interestingly, the selection equations suggest that similar dynamics to those from the outcome equations may also be present in relation to trade propensity: exporter and importer logistics both have a positive and significant effect on trade propensity, as well as trade intensity, for final goods as well as parts and components. This result sits well with recent findings indicating that trade facilitation, of which logistics is a key part, can play an important role in expanding trade at the extensive, as well as intensive, margin (Dennis and Shepherd, 2011; and Shepherd, 2010). There is also evidence from the selection equations that importer logistics performance has a greater impact on trade propensity in the case of parts and components than in the case of final goods. This finding is in line with our hypothesis,

[5] We apply the standard Heckman estimator, but do not pursue the additional correction introduced by Helpman et al. (2008) to deal with firm heterogeneity.

but as for all other estimators except gamma, it applies only to the importer LPI, and not to the exporter LPI.

4.3 Results using Alternative Country Samples

In Tables 5 and 6, we retain the Poisson estimator as the baseline and exploit the possibility for variation across country groups to examine in greater detail the links between logistics performance and trade in production networks.

First (Table 5), we limit the estimation sample to countries in the World Bank's East Asia and Pacific (EAP) region. The reason for doing so is that production networking is widespread and particularly well developed in that region. We would therefore expect to see stronger evidence of the role that logistics can play when we limit consideration to the set of countries that are most actively engaged in this type of production and trade. In columns 1 and 2, we limit the sample to EAP exporters, but include all importers. In columns 2 and 3, we consider only EAP importers, but include all exporters. Due to the relatively small number of countries included in the sample, it is not possible to estimate a model based on intra-EAP trade flows only.

In both cases, we find continued strong evidence of the importance of logistics as a determinant intra-network trade relative to trade in final goods. For the sample with Asian countries as exporters and the rest of the world as importers, both the importer and exporter LPI scores have larger coefficients in the parts and components regression than in the final goods regression. This result thus confirms our hypothesis more strongly than many of the other models considered so far. For the reverse sample, with the rest of the world as exporters and Asian countries as importers, only the importer LPI score is stronger for parts and components than for final goods. Of particular interest is the finding that all LPI coefficients are stronger in the case of Asian trade than when the full sample is considered (cf., Table 3 columns 1-2). This is exactly in line with our expectations, given the important role that production networks play within the region, and provides even stronger evidence that logistics matters more for trade within production networks than for other types of trade.

Another potentially informative split in the data is between South-South and South-North trade. For definitional purposes, we take the “North” as including all high income countries (OECD members and others), while the “South” consists of all other countries (i.e., all World Bank low and middle income countries). Since there is a strong South-South element to the emergence of production networks—components are often produced in one developing country, while assembly takes place in another—we would expect to see some differences in the importance of trade logistics between South-South and South-North trade flows in this case.

Indeed, that is exactly what we find in the data. The coefficients on importer and exporter logistics performance in the South-South models (Table 6 columns 1-2) are stronger than in the baseline models using all countries (Table 3 columns 1-2). The importer LPI coefficient is much larger for trade in parts and components than for trade in final goods in the South-South regression, which is line with expectations; the exporter LPI coefficient, by contrast, is slightly weaker, which is contrary to expectations. These results suggest that South-South flows of parts and components are particularly sensitive to logistics performance on the import side. This finding is quite consistent with the expansion of developing country production networks that has been taking place over recent years.

These impressions are reinforced by the South-North models (Table 6 columns 3-4). The exporter logistics performance coefficients are again much stronger than in the baseline model. On the importer side, by contrast, the LPI only has a statistically significant coefficient in the case of parts and components trade. This finding again indicates that importer logistics performance is particularly important for intra-network trade, although the magnitude of the effect is smaller for South-North trade than it is for South-South trade.

5 Conclusion and Policy Implications

This paper has presented evidence that trade in parts and components within international production networks is more sensitive to logistics performance than is trade in final goods. The difference between the two effects is quantitatively significant: the semi-elasticity of trade with respect to importer logistics performance is over 45% larger for parts in components than for final goods in the baseline specification. In addition, trade in the Asia-Pacific region—which is where international production networks are most developed—is particularly sensitive to logistics performance. We also find evidence that South-South trade is more sensitive to logistics performance than other directions of trade. In the case of exporter logistics performance, results are much more mixed and depend to a large extent on the country sample used and the econometric estimator applied. We nonetheless find indications that in some cases at least, exporter logistics performance also matters more for trade in parts and components than for trade in final goods.

At least two important policy implications flow from our results. First, development of the logistics sector can obviously play a key role in promoting greater integration in international production networks. There is much that policymakers can do to assist that process. Building logistics competence is a many-faceted process, however, involving issues such as regulation of transport and related sectors, border procedures, infrastructure, and private sector development. Diagnostics exercises using the World Bank's LPI database are a logical place to start for policymakers interested in addressing the key bottlenecks in national logistics performance. Arvis et al. (2010) argue that countries that succeed in improving logistics performance generally do so by making changes in a number of areas, rather than taking a piecemeal approach. A supply chain is only as strong as its weakest link, so it is important for countries to ensure strong performance in all areas of logistics if they are to succeed in attracting increased involvement in international production networks.

Second, developing country policymakers should pay particular note to the importance of logistics performance in the context of South-South trade flows, particularly in parts and components. With some degree of global rebalancing possible in the future, South-South trade is likely to assume increased prominence as a driver of worldwide demand (Haddad and Shepherd, 2011). Barriers to further South-South economic integration—including those related to logistics performance—should therefore be a priority for policymakers going forward. Traditional trade policy barriers such as tariffs remain high for South-South trade, but it will be important for policymakers to address non-tariff measures as well. This paper, as well as other recent contributions to the literature discussed above, show that improving logistics and trade facilitation should be an important part of the policy mix.

In terms of future research, there is considerable scope for confirming and extending our results. First, estimation in a true panel data framework would make it possible to control for an additional array of country-specific factors using fixed effects. Such an approach is not currently feasible, however. The LPI is now available for three years—2007, 2010, and 2012—but the lag with which trade data become available, especially for developing countries, means that a true panel data approach will need to be left for later versions of the LPI.

Second, we have focused on trade in machinery parts and components and final goods as one example of the distinction between networked production and sales of finished products. Production networks also exist in other areas, however. Textiles and apparel is one example. Future work could examine whether our findings can be replicated in other networked production settings.

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Tables

Table 1: Data and sources.

Variable	Definition	Source
$Colony_{ij}$	Dummy variable equal to unity if countries i and j were once in a colonial relationship.	CEPII.
$Colonizer_{ij}$	Dummy variable equal to unity if countries i and j were colonized by the same power.	CEPII.
$Contiguous_{ij}$	Dummy variable equal to unity if countries i and j share a common land border, else zero.	CEPII.
$Distance_{ij}$	Geodesic distance between the main cities of country i and country j.	CEPII.
$Exports_{ij}$	Exports from country i to country j.	UN Comtrade via WITS.
GDP_i	GDP in country i.	World Development Indicators.
$Language_{ij}$	Dummy variable equal to unity if countries i and j share a common language, else zero.	CEPII.
LPI_i	Logistics Performance Index score for country i.	World Bank LPI database.

Note: All variables are for 2007.

Table 2: Summary statistics.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.	Corr. with Log Exports
$Colony_{ij}$	93744	0.010	0.099	0	1	0.0897
$Colonizer_{ij}$	93744	0.117	0.322	0	1	-0.0295
$Contiguous_{ij}$	93744	0.013	0.112	0	1	0.1459
$Distance_{ij}$	93744	8541.281	4687.455	10.479	19951.160	-0.1644
$Exports_{ij}^{k}$	103512	8366.421	190979.700	0	2.02E+07	n/a
GDP_i	82639	2.99e+11	1.17e+12	1.37e+08	1.37e+13	0.086
$Language_{ij}$	93744	0.170	0.375	0	1	0.012
LPI_i	67657	2.744	0.631	1.212	4.190	0.0703
$Parts^k$	103539	0.500	0.500	0	1	-0.3455

Note: $Exports_{ij}$ *contains 75,217 observations equal to zero.*

Table 3: Poisson, and gamma pseudo-maximum likelihood estimation results for final goods and parts and components separately.

	(1) Poisson Final	(2) Poisson Parts	(3) Gamma Final	(4) Gamma Parts
LPI (exp.)	**0.695***** **(0.000)**	**0.558***** **(0.000)**	**1.105***** **(0.000)**	**1.443***** **(0.000)**
LPI (imp.)	**0.327***** **(0.001)**	**0.479***** **(0.000)**	**0.664***** **(0.000)**	**1.241***** **(0.000)**
Log(distance)	-0.345*** (0.000)	-0.372*** (0.000)	-0.804*** (0.000)	-0.729*** (0.000)
Contiguous	0.667*** (0.002)	0.562** (0.041)	0.796*** (0.003)	0.585** (0.013)
Language	0.286* (0.076)	0.419** (0.027)	0.683*** (0.002)	0.535*** (0.009)
Colony	-0.464** (0.027)	-0.273 (0.302)	0.763** (0.018)	0.481* (0.056)
Colonizer	1.207** (0.016)	1.345** (0.011)	-0.002 (0.993)	-0.026 (0.932)
Log(GDP exp.)	0.866*** (0.000)	0.787*** (0.000)	0.980*** (0.000)	0.752*** (0.000)
Log(GDP imp.)	0.748*** (0.000)	0.682*** (0.000)	0.746*** (0.000)	0.669*** (0.000)
Constant	-33.028*** (0.000)	-31.756*** (0.000)	-34.902*** (0.000)	-32.606*** (0.000)
R2	0.296	0.283	0.159	0.144
Observations	20880	20880	20880	20880

*Note: The dependent variable in each case is exports. All trade costs variables are transformed as per Baier and Bergstrand (2009), as discussed in the main text. Estimation methods are indicated at the top of each column. Prob. values based on robust standard errors adjusted for clustering by country pair are in parentheses beneath the parameter estimates. Statistical significance is indicated by * (10%), ** (5%), and *** (1%).*

Table 4: OLS and Heckman estimation results for final goods and parts and components separately.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	Heckman		Heckman	
	Final	Parts	Final Outcome	Final Selection	Parts Outcome	Parts Selection
LPI (exp.)	**1.841***** **(0.000)**	**1.387***** **(0.000)**	**2.005***** **(0.000)**	**1.067***** **(0.000)**	**1.537***** **(0.000)**	**0.962***** **(0.000)**
LPI (imp.)	**0.365***** **(0.000)**	**0.466***** **(0.000)**	**0.452***** **(0.000)**	**0.720***** **(0.000)**	**0.568***** **(0.000)**	**0.758***** **(0.000)**
Log(distance)	-0.978*** (0.000)	-0.837*** (0.000)	-1.024*** (0.000)	-0.411*** (0.000)	-0.882*** (0.000)	-0.384*** (0.000)
Contiguous	1.063*** (0.000)	0.923*** (0.000)	1.027*** (0.000)	-0.133 (0.363)	0.872*** (0.000)	-0.206 (0.137)
Language	0.469*** (0.000)	0.359*** (0.000)	0.507*** (0.000)	0.294*** (0.000)	0.403*** (0.000)	0.236*** (0.000)
Colony	0.570*** (0.000)	0.590*** (0.000)	0.636*** (0.000)	0.876*** (0.000)	0.655*** (0.000)	0.776*** (0.000)
Colonizer	0.709*** (0.000)	0.600*** (0.000)	0.581*** (0.001)	-0.739*** (0.000)	0.377** (0.019)	-0.809*** (0.000)
Log(GDP exp.)	0.962*** (0.000)	0.740*** (0.000)	1.011*** (0.000)	0.305*** (0.000)	0.783*** (0.000)	0.273*** (0.000)
Log(GDP imp.)	0.625*** (0.000)	0.560*** (0.000)	0.661*** (0.000)	0.247*** (0.000)	0.594*** (0.000)	0.235*** (0.000)
Log(Doing Business)				-0.172*** (0.000)		-0.181*** (0.000)
Constant	-32.667*** (0.000)	-27.710*** (0.000)	-35.404*** (0.000)	-14.438*** (0.000)	-30.220*** (0.000)	-13.189*** (0.000)
R2	0.654	0.600	0.026		0.027	
Observations	9231	9952	20736	20736	20736	20736

*Note: The dependent variable in each case is exports. All trade costs variables are transformed as per Baier and Bergstrand (2009), as discussed in the main text. Estimation methods are indicated at the top of each column. Prob. values based on robust standard errors adjusted for clustering by country pair are in parentheses beneath the parameter estimates. Statistical significance is indicated by * (10%), ** (5%), and *** (1%).*

Table 5: Estimation results focusing on countries in the East Asia and Pacific region.

	(1)	(2)	(3)	(4)
	Poisson		Poisson	
Exporter sample:	Asia		All	
Importer sample:	All		Asia	
	Final	Parts	Final	Parts
LPI (exp.)	0.970**	1.165**	0.844***	0.562**
	(0.031)	(0.016)	(0.001)	(0.035)
LPI (imp.)	0.336*	0.541***	1.946***	2.355***
	(0.059)	(0.002)	(0.000)	(0.000)
Log(distance)	-0.689***	-0.884***	-1.423***	-1.550***
	(0.000)	(0.000)	(0.000)	(0.000)
Contiguous	0.535*	0.311	-1.126***	-1.481***
	(0.058)	(0.405)	(0.009)	(0.001)
Language	1.561***	1.830***	1.073***	1.287***
	(0.000)	(0.000)	(0.000)	(0.000)
Colony	-0.879**	-0.810**	0.076	0.532*
	(0.028)	(0.034)	(0.701)	(0.088)
Colonizer	0.056	-0.548	-0.632	-0.729
	(0.907)	(0.325)	(0.162)	(0.140)
Log(GDP exp.)	0.818***	0.589***	0.628***	0.561***
	(0.000)	(0.000)	(0.000)	(0.000)
Log(GDP imp.)	0.808***	0.719***	0.510***	0.518***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-30.385***	-24.292***	-16.309***	-16.502***
	(0.000)	(0.000)	(0.000)	(0.000)
R2	0.145	0.114	0.110	0.099
Observations	1728	1728	1728	1728

*Note: The dependent variable in each case is exports. All trade costs variables are transformed as per Baier and Bergstrand (2009), as discussed in the main text. Estimation methods are indicated at the top of each column. Prob. values based on robust standard errors adjusted for clustering by country pair are in parentheses beneath the parameter estimates. Statistical significance is indicated by * (10%), ** (5%), and *** (1%).*

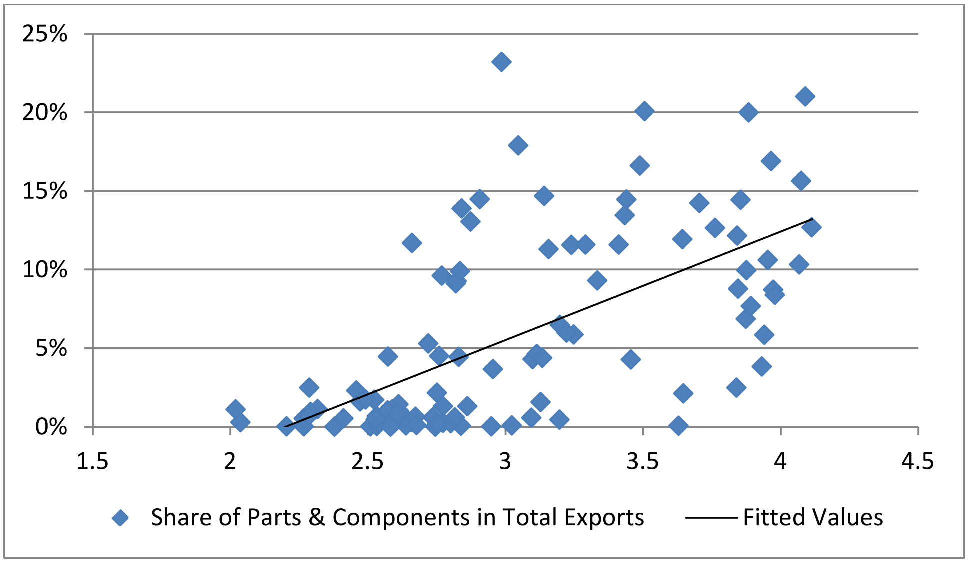
Table 6: Estimation results focusing on South-South and South-North trade.

	(1)	(2)	(3)	(4)
	Poisson		Poisson	
Exporter sample:	South		South	
Importer sample:	South		North	
	Final	Parts	Final	Parts
LPI (exp.)	2.159***	1.977***	3.036***	2.188***
	(0.000)	(0.001)	(0.000)	(0.000)
LPI (imp.)	0.494*	1.197***	0.139	0.812**
	(0.064)	(0.000)	(0.726)	(0.016)
Log(distance)	-1.074***	-1.226***	-0.715***	-0.817***
	(0.000)	(0.000)	(0.000)	(0.000)
Contiguous	-0.141	-0.688	1.885***	1.516***
	(0.716)	(0.192)	(0.000)	(0.000)
Language	0.577	0.785*	0.421	0.844***
	(0.130)	(0.098)	(0.299)	(0.004)
Colony	0.892*	0.550	-1.129**	-0.874**
	(0.089)	(0.354)	(0.014)	(0.024)
Colonizer	-1.347**	-1.682***	0.173	-0.503
	(0.034)	(0.003)	(0.765)	(0.373)
Log(GDP exp.)	1.027***	0.784***	1.139***	0.789***
	(0.000)	(0.000)	(0.000)	(0.000)
Log(GDP imp.)	0.873***	0.984***	0.855***	0.658***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-39.158***	-38.506***	-46.466***	-33.273***
	(0.000)	(0.000)	(0.000)	(0.000)
R2	0.155	0.128	0.109	0.098
Observations	11130	11130	4134	4134

*Note: The dependent variable in each case is exports. All trade costs variables are transformed as per Baier and Bergstrand (2009), as discussed in the main text. Estimation methods are indicated at the top of each column. Prob. values based on robust standard errors adjusted for clustering by country pair are in parentheses beneath the parameter estimates. Statistical significance is indicated by * (10%), ** (5%), and *** (1%).*

Figures

Figure 1: Logistics performance vs. trade in parts and components.



Source: Arvis et al. (2010).

Figure 2: Logistics performance vs. trade in final goods and trade in parts and components.