Trade Costs and International Production Networks:
Lessons from the Asia-Pacific Experience

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Abstract: The emergence of transnational production networks has been one of the main drivers in determining the organization of the world economy over recent years. In particular in the Asia-Pacific region a large number of developing countries succeeded in integrating into transnational production networks and thereby enhancing their export performance. In this paper, we use a gravity model to provide preliminary empirical evidence as to the impacts of trade costs, technology, and contract enforceability on the emergence of these networks.

Keywords: Production Networks, Fragmentation, Trade Costs, Trade Facilitation

JEL Codes: F 13, F 14, F 15, F 23, O 24, R 30

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2 The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the view of the World Bank, its Executive Directors, or the countries they represent.
I. Introduction

One of the defining trends of the recent development of the global economy has been the emergence of transnational production networks. Transnational production networks (TPN) can be defined as spreading the production of intermediate or final goods across several countries. TPN can be organized within a single firm (vertically integrated) or involve different companies. In both cases, the fragmentation of production requires a sophisticated organization.

The organization of TPN was made possible, among others, through technological breakthrough, such as new inventory management techniques and just-in-time methods. Today, sophisticated computer technology allows controlling the production process instantly, despite the fact that production in different location and/or countries is involved. The fast build-up of TPN was further enhanced by various policy measures. A number of government provided special incentives for foreign direct investment. Today, export processing zones can be found in almost all countries in South East Asia.

Another important policy choice was to push forward with trade liberalization. Over the last two decades almost all countries in the Asia-Pacific region have lowered their tariffs and reduced their non-tariff barriers. Trade liberalization took place on the multilateral as well as regional level. One aspect of trade liberalization concerns trade facilitation, which will be the focus of this paper. Trade facilitation efforts aim at enhancing the movements of goods and services across national borders. The objective is to achieve the most time- and cost-effective flow of goods and services.

The role of trade facilitation and other complementary policy measures in the construction of TPN has not yet been studied in a systematic way. Research so far has focused on the question how trade facilitation in general can help to enhance international trade. For example, Djankov et al. (2006) found that an additional day’s delay at export reduces trade by 1%. Nordas et al. (2006) including 140 exporters and 3 importers in their sample confirm that the impact of time on trade is negative and significant, and is particularly strong in the case of intermediate goods. Kimura et al. (2005) use also the distinction between intermediate and final goods and analyze parts and components trade
in Europe and East Asia. Their results indicate that parts and components appear to be more sensitive to distance-related trade costs than do their corresponding final products.

The study that is closest to this paper is a short working paper by Umemoto (2005). He applies a gravity model to APEC trade in machinery parts, and augments the model with a summary indicator of trade facilitation. He uses this indicator as a proxy for production network quality and finds that it has a positive impact on trade. One shortcoming of this study is that it only analyzes in detail the machinery sector. Despite this focus it does not specify which parts and components of machinery were actually included in the sample. Furthermore, it only takes one broad indicator of trade facilitation thereby making it difficult to draw concrete policy conclusions.

As Umemoto’s (2005) work suggests, there is an important role for policy-makers in terms of facilitating the types of transactions upon which TPN are based. A favorable policy environment can be expected to foster not only the extent of trade taking place within transnational production networks, but also the emergence and success of such networks on a regional basis. This is true both of direct measures, such as lower trade costs, and also indirect ones such as improved information and communications technology and stronger contract enforceability.

The goal of this paper is to provide a preliminary assessment of the impact of such measures on the growth of transnational production networks involving developing country firms. In particular, we are interested in drawing lessons from the positive experiences that developing countries in some regions (e.g., East Asia) have had with such networks in terms of trade expansion and technology upgrading. Participating in transnational networks can be key for developing countries in order to reap the full benefits of integrating into the global economy.

This paper tries to find answers to the following research questions:

- How can measures to reduce trade costs, improve technology, and strengthen contract enforceability enhance integration into transnational production networks?
- Which measures have been particular successful in promoting participation in transnational production networks?
In terms of the existing literature, the value added of the present paper is two-fold. First, we include a broader range of policy indicators than in previous studies. We use new data on the costs of importing and exporting from the World Bank’s *Doing Business* report, in addition to more common measures such as tariffs and international distance. Second, this paper emphasizes the potential for different policy impacts on final versus intermediate goods. This focus is novel and allows us to dissect the trend towards transnational production networks as well as to derive policy recommendations for developing countries in the Asia Pacific.

The paper is constructed as follows. The first section offers a conceptual framework of how to think about networks, and production networks in particular. It tries to analyze what role policy measures can play in favoring the organization of transnational production networks. In the second section, we briefly summarize major trends in international fragmentation of production. Our focus is on the East-Asia Pacific region, for which we retrace in detail the development of networks in the electronics industry. In the analytical part, we construct a gravity model of international trade in final goods and intermediate goods in the Asia-Pacific region. Section 5 concludes, and discusses some possible directions for future research in this area.

II. The Theory of Networks and their Application to Transnational Organization of Production and Trade Facilitation

2.1 The Nature of Networks

A network can be defined as a set of more than two interconnected nodes. The field of economics typically studies networks among market participants such as consumers, firms or institutions. Networks are established in order to provide or to exchange goods, services, and/or information among members of the network. The architecture of networks can be very different ranging from a simple star network, where a central node
connects all other nodes, to very complex structures. If the network flows run mainly in one direction (such as broadcasting), the networks are called one-way networks, otherwise two-way networks.

The connection of nodes requires compatibility, which means that nodes are combinable to exchange the demanded goods, services, and/or information. Compatibility is especially important in two-way networks where the flows are exchanged in both directions. However, compatibility is inherent only in few cases; for the majority of cases compatibility can only be achieved if the market participants adhere to common standards (Economides, 1996). Common standards lower transaction costs and enable interoperability. Furthermore, they facilitate the building-up of new connections between nodes and therefore help boost the size of the network.

Compatibility is not the only requirement for the smooth functioning of networks. An often neglected aspect in network theory is the costs related to the flows between nodes. The exchange of information, goods, or services always requires energy of all possible kinds to overcome the distance between nodes. For example, in a distribution network for retailers, goods need to be shipped from one or several centers to local retailers. Another example is a broadcasting network, for which physical infrastructure needs to be build up.

Both examples illustrate two different kinds of costs related to the flows within a network. Flows in a distribution network are mainly caused by the actual shipment. Mainly labor and physical capital are used to deliver goods. We call this type of costs variable network costs since they are caused by the movement of goods or services between nodes. In some type of networks, variable flow costs can constitute only a marginal part of the overall costs. For example, in the case of a broadcasting network the most important cost share is to set up and maintain the network. We therefore denominate this type of costs fixed network costs.

The size of networks is often constraint by both types of costs. The value of the network must always be higher than the fixed and variable network costs. As network costs become excessively high, the network reaches its limits and nodes remain unconnected. One might imagine the case of a telecommunication network for a scarcely populated
area. The costs to set-up and to run the network may outweigh the possible revenues generated by connecting the area to an existing network.

Network costs can be determined by various factors. As the previous example shows, geographical circumstances can play a role. Furthermore, the technology available to market participants can also be decisive when building up networks. For example, using satellites to broadcast TV revolutionized the network for TV stations. Among other factors that influence the outcome are market regulations. If a firm enjoys a position of monopoly, its incentives to construct are very different than in the case of perfect competition. Institutions can also be important, since the formation of networks is often dependent on the ability of the various participants to contract with each other in an environment containing appropriate enforcement mechanisms.

Thinking about these principles helps us develop a clearer understanding of the interrelationship between trade costs and the emergence of TPN. In the context of TPN, the nodes of the network are typically defined as the countries. Amongst them, we observe a trading relationship which can be considered as the link between the nodes. A network of production requires compatibility among components. Finally, TPN only emerge if the network costs are low enough. The main purpose of this paper is to study in detail the nexus between network costs and TPN. The next section provides more details about the emergence of TPN in the Asia Pacific.

2.2. From National to Transnational Production Networks

The concept of production networks is not new. Already in the early stages of industrialization production networks were observed. However, the extent to which production networks were used was limited and they were generally located within one country. It was only over the last three decades that transnational production became of salient feature of the organization of the global economic activity. This section provides first of all a definition of the term ‘production network’. It then traces briefly the expansion of production from the national to the transnational level. We argue that standards and the reduction of network costs have been the main drivers of this step towards internationalization.
We define a production network as follows: The organization of the production of a final product is split into two or more separate production stages which are undertaken in different locations. This definition implies that a network is set up with the objective to achieve the most efficient organization of production. For reasons which we will explore later the production of the final product is not undertaken in one location, but spread over two or more locations.

Production networks can be organized within the boundary of a single firm or take place between different firms. Traditionally, production networks were built within the boundaries of a single firm and business research therefore focused on the most efficient network structure within this set-up. However, starting in the 70s, firms began to reorganize their production and to extend production networks outside a single firm. One major reason for the reorganization of production were several antitrust suits which broke large agglomerations, such as AT&T in the USA, into pieces. In order to achieve economies of scope, several firms decided to produce complementary intermediate goods in joint operations (Economides, 1996). Continuing this trend, more and more firms, which were previously vertically integrated, started to separate their activities and focused just on one core business field.

The computer industry provides a prime example of this trend, as described by Gangnes and van Assche (2004) as well as van Assche (2007). Prior to the 1980s, all leading computer companies designed and manufactured their products in-house. This also implied that each company had to develop their own operating system, which then rendered the interoperability between systems and components of other companies very difficult.

With the arrival of the personal computer in the early 1980s, computer manufacturers started to build computers with standardized modules which allowed them to easily develop different machines for different applications. Once the compatibility standards between modules were set, it became possible to rely on outside suppliers for the production of the modules. Computer companies realized that it was cheaper to source their components from outside firms and to focus only on certain activities. Another advantage of outsourcing production to contract manufacturers is that it gives firms greater flexibility in the volume of their production. On short notice they are able to
adjust the production volume upward or downward without having to invest in sophisticated automated manufacturing equipment.

As a result of this process of allocating certain production stages outside the firm, the firms’ structure in the computer industry changed from being vertically integrated to being horizontally specialized. In today’s computer market we find Dell and Gateway as examples for firms which specialize on the design and marketing of computer. They have outsourced the assembly to contractors, such as Solectron or Flextronics. The latter firms use components of companies that focus on certain components, such as Intel and AMD the leading companies in the microprocessor market.

**Figure 1: Organization of Production Networks Within and Across Firms**

Figure 1 illustrates this change in the organization graphically. The boundaries of firms are depicted through continued lines, whereas the production stages are separated by dotted lines. In the Figure to the left one observes three companies which produce in three different locations. The production of the final products takes place in a single location within the boundary of a single firm. The right graph shows how the computer industry is set up today. The boundaries of firms are not horizontal, which means that they focus on a particular stage of production and are present in different locations. The concentration on one stage in the production process requires the integration into
production networks. The dotted lines show how these networks are spanned now vertically.³

As Figure 1 demonstrates, this shift in the organization of production not only affected the industry structure within countries. As the factor intensities of production differ from production stage to production stage, production became increasingly fragmented internationally. Sourcing components internationally has allowed firms to benefit from the different cost advantages of countries. The fragmentation of production across countries was not always based on relative cost differences between countries. For example, lead firms in the electronics industry firms asked their contractors to follow their strategy of internationalizing their activities (Ando and Kimura, 2006). As a consequence, contract manufacturers which wanted to stay competitive chose to go abroad. A prominent example is the electronics contract manufacturer Solectron which expanded the number of location from one in Silicon Valley to nearly fifty facilities worldwide within ten years (Sturgeon, 2002). Whereas investing abroad required a sophisticated management of flows within the firm, it also allowed increasing productivity and penetrating new markets.

Overall, we can observe that the main drivers behind this trend of spreading production stages over different locations have been twofold. First, many industries started to base their production on components which were combinable to produce different final products. This change in the design of production allowed the outsourcing of production stages. Firms started to specialize in certain production stages and hence relied on networks to coordinate the production process. The second decisive change has been the reduction in network costs. Variable as well as fixed network costs have come down allowing firms to spread their activities over different locations against the background of a stable set of contract enforcement institutions. The focus of this paper is on the extent to

³ A word of caution here might be in order. The trend towards splitting activities across firms might not continue in the future. Over the last years, the new development has been that large contractors offer more and more services in addition to the assembly process. These services span from services prior to production, such as circuit-board layout or testing, to back-end services, such as final packaging and after-sales services (Sturgeon, 2002). The boundaries of the firms are constantly shifting. However, more important to our study, the fragmentation of production across countries seems to persist.
which trade-related network costs have been reduced, thereby favoring the emergence of transnational production networks.

Existing economic models of international production sharing provide a framework for analyzing firms’ decisions on the location of production and on the boundaries of the firm (ref.). One stream of the literature focuses on the question of output generated by splitting the production process into sub-processes or fragments which are separated in space (e.g. Jones and Kierzkowski, 1990, 2001; Deardorff, 2001a, 2001b; Grossmann and Rossi-Hansberg, 2006). The authors mainly study how the fragmentation affects trade flows, welfare, and factor prices.

Another part of this literature analyses the problem from the perspective of a firm’s organizational choice (e.g. McLaren, 2000; Grossman and Helpman, 2002, 2004, 2005; Antràs, 2003; Marin and Verdier 2003a, 2003b; Antràs and Helpman, 2004; and Antràs, Garicano and Rossi-Hansberg, 2006). These contributions focus on the question whether a firm will choose to be vertically integrated or to buy customized components from an arms-length supplier located domestically or abroad. They also try to see the implication on the hierarchical organization of a firm.

Empirical work has tried to confirm the respective predictions and analyzed in further detail the nature of TPN. Kimura (2006) collects eighteen facts about the nature of transnational production and distribution networks in East Asia. Most important to our study, he finds that wage differentials still play a crucial role for multinational firms when taking location decisions. However, other factors seem to gain prominence, such as infrastructure services. Furthermore, he presents evidence that the costs for connecting production sites in different countries have fallen. According to the author, the firms present in the region have developed highly sophisticated production systems, such as just-in-time or supply chain management. Finally, he argues that the stronger presence of production networks compared to other regions, such as the EU, is related to the efforts by government to attract foreign direct investment. Our study will especially look at the

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4 The empirical literature on production networks in East Asia is rich. The most recent contributions are Ando (2006), Ando and Kimura (2007), and Kimura et al. (2007).
effect of trade facilitation measures on the successful integration into regional production networks.

Despite this rich literature on fragmentation and TPN, very little work has been done so far in studying the interrelationship between reductions in network costs and the development of TPN. Measures to reduce network costs due to trade frictions may have played a crucial role in this process. In the following section we describe in more detail the possible mechanisms that could be at work.

2.3. The Role of Trade Costs in TPN

From an analytical point of view, the most important defining feature of the rise of TPNs is increased prevalence of trade in parts and components. These are associated with production fragmentation, since intermediate inputs are manufactured in one or more countries and then shipped to another for final assembly. A first investigation of the role of trade cost reductions in driving the emergence of TPN can therefore usefully focus on the incidence of trade costs on parts and components trade as compared with final goods. The conceptual framework for this research is that reductions in trade costs are likely to bring about increases in parts and components trade through two mechanisms. Firstly, existing flows will be increased due to a simple cost reduction effect. We should therefore observe an effect on the intensive margin. Secondly, new trade flows will be made possible by changes in firm organization brought about as falling costs make it rational to move some stages of the production process overseas (extensive margin). The recent theoretical literature on international production sharing provides support for that proposition. (Helpman, 2006, provides a comprehensive review of that literature.) It is therefore to be expected that trade in parts and components will be more responsive to policy measures that reduce trade costs than will be trade in finished products.

We can use these two conjectures on how trade costs interplay with the emergence of transnational production networks to derive two main working hypotheses. First, trade in parts and components is more responsive to changes in trade costs than trade in final goods. A change in trade costs is supposed to produce a strong effect on the intensive as well as extensive margin of trade in parts and component. The main mechanism behind
this hypotheses stems from the flexibility on the supply side on how to set up the production chain.
The second working hypothesis is that policy measures that reduce fixed network costs for firms also lead to an increase in trade. As explained above, new nodes may be set-up and become part of the network if the expected gains outweigh the present fixed costs to install the node. As we will see later in greater detail, we approximate the presence of fixed costs with data on contract enforceability.
Finally, it is important to outline the possible benefits for developing countries in reducing trade costs. Their participation in global production networks is potentially beneficial since it increases their trade integration and provides opportunities for technological and organizational spillovers to occur. Both outcomes are requisite for economic growth in developing countries. In summary, trade facilitation measures that effectively reduce trade related costs can be expected to produce important development gains.

III. The East Asia Experience

3.1. Facts about TPN in the East-Asia Pacific Region

Until the 1980s a typical north-south trade pattern dominated trade in East Asia. Less developed countries specialized mainly in natural-resource based or highly labor intensive exports, whereas developed countries focused on capital (physical and human) intensive products (Kimura, 2006). At the beginning of the 1990s, intra-industry trade became increasingly important as less developed countries entered into the production of manufacturing products. The growing intra-industry trade in East Asia was predominantly vertical in its nature, as Fukuo et al. (2003) and Ando (2005) show using detailed unit value data. Overall, we observe an increasing trend towards intra-industry trade in the region since the beginning of the 1990s.

5 Kimura (2006) provides a comprehensive and at the same time concise overview of the recent developments in the production and distribution networks in East Asia.
6 Recent work by the World Bank on parts and components trade has largely been devoted to the issue of identifying such trade in aggregate trade statistics, and charting the main trends underlying its evolution in
International fragmentation of production processes, and hence the development of transnational production networks, has been particularly strong in East Asia. Some authors even find that the cross-border production sharing in East Asia is higher than between US and Mexico or between Western Europe and Central/Eastern Europe (Kimura, 2006; Kimura et al. 2007).

This co-evolution has been accompanied by a rapid increase in the extent of international production. Electronics firms headquartered in developed countries have moved the production and assembly of labor-intensive electronics components to developing countries, primarily in East Asia, to take advantage of low wages. This has gradually turned East Asia into a global electronics manufacturing platform, spurring employment and economic growth. East Asia’s share of world electronics production rose from 6 percent in 1985 to 26 percent in 2000.

The focus of this paper is therefore on the growth of TPN in the electronics industry. Since we do not have detailed data on how the flows of goods and services with TPN networks, we use trade data in intermediate and final goods as a proxy for network trade. As we will see later in greater detail, we distinguish between parts and components for the electronics and three final product groups.

3.2. The Electronics Industry TPN in the East-Asia Pacific Region

Using the SITC trade classification one can identify different industry networks. For example, Kaminski and Ng (2005) distinguish between four different networks: automotive goods; office machinery; telecommunications and recording equipment; and furniture. We limit our study to the electronics network which comprises electronic parts and components and three final product groups: electronic office equipment, electronic IT goods, and consumer electronics. For full details of the product definitions we use, see the Appendix.

With total trade volume in final goods of USD 382 billion (2005), and of over USD 650 billion in parts and components, the electronics network is by far the largest network in different regions. The main references are Yeats (1998), Ng and Yeats (1999) and Kaminski and Ng (2005, 2006).
the East-Asia region. The network of the automotive industry (as identified by Kaminiski and Ng, 2005) is around only one ninth of size measured in total trade flows (USD 158 billion in 2005). We have also calculated the volume of network for textile and clothing products (intermediate as well as final products). With a total trade volume of over USD 52 billion, the textile network is even smaller.

Apart from their relatively smaller size, both industries show particularities which can not easily be controlled for. The automotive market in final goods is dominated in East-Asia by a small number of companies. Location decisions might be driven factors unrelated to the subject of our study. The textile and clothing sector has long been distorted by the Multi-fiber Arrangement. In the process of phasing out this Arrangement under the Agreement on Textiles and Clothing, major restructuring in the sector took place. Again, this reorganization is not related to our study. It is worthwhile noting that the textile industry seems to be consolidating in a few countries, particularly in China. Even though several other countries maintain sizable shares in the export of textile parts, China nearly doubles its share from 22% to 39% from 1988 to 2005. China has also rapidly increased its share in the export market for final textile goods, growing from less than 30% in 1988 to nearly 70% in 2005.

**Figure 2: Development of the Asian-Pacific Electronics Network (1988-2005)**

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7 A definition of this network is available from the authors upon request.
Trade in electronics goods has grown rapidly in the region under consideration over the time period studied, as Figure 2 illustrates. Trade in final goods grew more than six-fold, whereas trade in parts and components grew more than eight-fold. This strong growth was sustained through the whole period except for a small dip in 1998 and a large contraction in 2001 with the contraction in the trade of parts and components outpacing that of final products. We see a pronounced upward trend in the percentage of total trade accounted for by trade in electronics parts and components. Between 1988 and 2005, trade in parts and components increased from 55% to nearly 64% of the total. This evidence seems to indicate fragmentation of the electronics industry in which more firms are outsourcing the manufacturing of parts and components to neighboring countries.

Another way to analyze the extent to which production stages are split over the region is to study the market shares of countries in the total market for parts and components as well as for final products. If fragmentation is taking place, then we probably will see that more and more countries are participating actively in the value chain of production. This trend would then be reflected by an increasing number of countries present on the market for parts and components or final goods.

In order to test this conjecture we gather the data on the market shares for parts and components in the electronics industry. Figure 3 and Figure 4 compare these market shares for the starting and end points of our sample, namely 1988 and 2005. For the year 1988 we observe that the market was largely dominated by the USA, which imported over 40% of all parts and components in the electronics industry. Five countries, namely Singapore, Hong Kong (China), Canada, Korea, and Japan had market shares between 5% and 10%. We see a great deal of fragmentation as the distribution of electronics parts imports and exports becomes more evenly spread through the region. Japan was initially the biggest exporter of final electronics goods to the region, with over 40% of the export market. However, Japan was eventually overtaken by China, who, in 2005, represented over 40% of such exports (up from under 5% in 1988).

Figure 3: Shares of Imports in Electronic Parts and Component by Country in 1988
Looking at the same graph in the year 2005 the market shares are much more evenly distributed among several countries. The USA sees its share shrink to about 14% whereas China emerges as the new regional leader with a share of around 21%. In the year 2005, we count two additional countries with a market share of over 5%, thus indicating a more equal distribution among countries.

Overall, comparing the evolution of trade flows in parts and components versus final products, we observe that an increasing number of intermediate electronic goods become
traded which is a first clear indication for the emergence of new production networks across the region.

IV. Data, Methodology, and Results

Drawing on the above analysis, the remainder of the paper tests the following three hypotheses empirically:

1. Trade in parts and components is more sensitive to trade costs than is trade in final goods;
2. Trade in parts and components is more sensitive to development of information and communication technologies than is trade in final goods; and
3. Trade in parts and components is more sensitive to contract enforceability than is trade in final goods.

The first two hypotheses are more related to the concept of flexible network cost, whereas the last one tries to capture fixed network costs. This section describes the dataset we use, and its sources. We then discuss estimation methodology using the gravity model, before presenting preliminary results for the electronics network in the Asia Pacific.

4.1. Data

As already discussed, a major stumbling block for empirical work on the determinants of production networking lies in the difficulty of identifying trade flows that take place within such networks. To facilitate our exploratory work in this paper, we focus on the electrical goods network identified above. Using SITC2 trade data for 19 countries in the Asia Pacific region, we collect bilateral data on trade in final goods and parts and
components within the electrical goods network. We obtain these data from the COMTRADE database, accessed through WITS. Since some of our independent variables are only available for 2005, we proceed in a purely cross-sectional framework. We measure trade costs along three dimensions. First, we use international distance as a proxy for transport costs. These data are sourced from the CEPII distance dataset (Mayer and Zignago, 2006), as are dummy variables for countries that share a common border, language, and colonizer. All of these variables are commonly included in gravity model formulations. Second, we measure direct trade policy measures using effectively applied tariff data from the TRAINS database, accessed through WITS. To aggregate up from the product line level, we take the simple average. In addition to these two common measures of trade costs, we include new data from the World Bank’s Doing Business report on the costs of exporting and importing. These data measure the total official cost for exporting or importing a standardized cargo of goods, excluding international transport charges and tariffs. The types of costs captured include document preparation, inland transport (i.e., from the factory to the port), administrative costs related to customs clearance, technical controls, and inspections, and ports and terminal handling charges. The data are collected from local freight forwarders, shipping lines, customs brokers, and port officials, based on a standard set of assumptions. These assumptions include that the cargo travels in a 20ft container, is valued at $20,000, and does not require any special phytosanitary, environmental, or safety standards beyond what is required internationally. (For full details of the data and methodology, see www.doingbusiness.org.)

As discussed above, the ability to fragment the production process across borders relies crucially on modern information and communications technologies. We therefore also include a proxy for technology development in our independent variable set. We use the Global Competitiveness Report’s perception indicator of the quality of competition in the ISP sector for this purpose.  

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8 The countries we examine are: Australia, Brunei, Cambodia, Canada, China, Hong Kong (China), Indonesia, Japan, Republic of Korea, Malaysia, Mongolia, New Zealand, Philippines, Russian Federation, Singapore, Taiwan (China), Thailand, United States, and Vietnam.  
9 An alternative would be to follow the approach of Freund and Weinhold (2004) and use the number of internet hosts in the exporting and importing countries. We will include this as a robustness check in future versions of this paper.
Finally, we use the *World Governance Indicators’* rule of law series as a proxy for contract enforceability. While the concept of the rule of law is clearly much broader than this one aspect, we would argue that it is nonetheless likely to be correlated with the dimension we are trying to measure, namely contract enforceability. Ranjan and Lee (2007) use this series as one of their indicators of contract enforceability.

### 4.2. Methodology

Anderson and Van Wincoop (2003, 2004) provide a microeconomic basis for the commonly used gravity model of international trade. They show that one type of theory-consistent gravity model takes the following form:

\[
\log(X_{ij}^k) = \log(E_j^k) + \log(Y_i^k) - \log(Y^k) + (1-\sigma_k)\log(t_{ij}^k) - (1-\sigma_k)\log(P_j^k) - (1-\sigma_k)\log(\Pi_i^k) + \varepsilon_{ij}^k \tag{1}
\]

where: $X_{ij}^k = \text{exports from country } i \text{ to country } j \text{ in sector } k$; $Y_i^k = \text{output of country } i \text{ in sector } k$; $E_j^k = \text{expenditure of country } j \text{ in sector } k$; $Y^k = \text{aggregate (world) output in sector } k$; $\sigma_k = \text{elasticity of substitution in sector } k$; $t_{ij}^k = \text{trade costs facing exports from country } i \text{ to country } j \text{ in sector } k$; $\omega_i^k = \text{country } i \text{'s output share in sector } k$; $\omega_j^k = \text{country } j \text{'s expenditure share in sector } k$; and $\varepsilon_{ij}^k = \text{random error term, satisfying the usual assumptions}$. Inward resistance $\left(P_j^k \right)^{-\sigma_k} = \sum_{i=1}^{N} \Pi_i^k \omega_i^k \left(t_{ij}^k \right)^{-\sigma_k}$ captures the fact that $j$’s imports from $i$ depend on trade costs across all suppliers. Outward resistance $\left(\Pi_i^k \right)^{-\sigma_k} = \sum_{j=1}^{N} P_j^k \omega_j^k \left(t_{ij}^k \right)^{-\sigma_k}$, by contrast, captures the dependence of exports from $i$ to $j$ on trade costs across all importers.

Before implementing the model in an empirical setting, we need to specify bilateral trade costs $t_{ij}^k$ in terms of observables. As is standard in the literature, we include bilateral tariffs ($\tau_{ij}^k$), international distance as a proxy for transport costs ($\text{dist}_{ij}$), and dummy variables for a common border ($\text{contig}_{ij}$), official language ($\text{comlang}_{ij}$), and colonizer ($\text{comcol}_{ij}$). To examine the impact of trade facilitation, we use *Doing Business* data to
construct a measure for the total costs of exporting and importing within a particular bilateral link \((cost_{ij})\). As a proxy for IT development, we use a perception measure of the quality of competition in the ISP sector, taken from the *Global Competitiveness Report* \((isp_{ij})\). It is averaged across the exporting and importing countries. To proxy contract enforceability, we use the rule of law measure from the *World Governance Indicators* database, taking the simple average across the importing and exporting countries \((rol_{ij})\).

Thus, trade costs are specified as:

\[
\log(t^k_{ij}) = \beta_1 \log(cost_{ij}) + \beta_2 \log(1 + \tau^k_{ij}) + \beta_3 \log(dist_{ij}) + \beta_4 contig_{ij} + 
\]

... + \beta_5 comlang_{ij} + \beta_6 comcol_{ij} + \beta_7 isp_{ij} + \beta_8 rol_{ij} \quad (2)

While Anderson and Van Wincoop (2003) show that it is possible to use nonlinear methods to estimate the structural parameters of (1) and (2) directly, by far the more common approach is to account for the multilateral resistance terms \(P^k_i\) and \(\Pi^k_j\) using fixed effects. To avoid having to estimate an unduly large number of parameters, we simplify this approach by including fixed effects only in the importer, exporter, and sector dimensions. Combining (1) and (2) and dropping variables that are collinear with the fixed effects gives the reduced form (3) that we use for estimation:

\[
\log(X^k_{ij}) = \sum_{i=1}^I \delta_i + \sum_{j=1}^J \delta_j + \sum_{k=1}^K \delta_k + \alpha_1 \log(cost_{ij}) + \alpha_2 \log(1 + \tau^k_{ij}) + \alpha_3 \log(dist_{ij}) + \alpha_4 contig_{ij} + 
\]

... + \alpha_5 comlang + \alpha_6 comcol + \alpha_7 isp_{ij} + \alpha_8 rol_{ij} + \epsilon^k_{ij} \quad (3)

Following Santos Silva and Tenreyro (2006), we estimate (3) using the Poisson QML estimator. As those authors point out, estimation by Poisson has the advantage of not dropping observations with zero bilateral trade from the dataset, as would be the case under OLS.

### 4.3. Estimation Results

We estimate (3) for the electrical goods sector. Our strategy is to estimate the model separately for trade in final goods and trade in parts and components, and to compare coefficients across models in order to gauge the relative sensitivity of parts and components trade to trade cost changes. Given the relatively small number of countries
in our sample, we treat the results as preliminary at this stage. In the next section, we discuss possible extensions and robustness checks. Table 1 contains our results. All core trade cost variables, i.e. distance, tariffs, and export/import costs, carry the expected negative signs and are generally statistically significant at the 10% level. The common border dummy variable is also statistically significant and has the expected sign, whereas common language has an unexpected negative sign and is statistically significant in the final goods regressions only. The sign on the common colonizer dummy is also negative (contrary to expectations), but is not statistically significant in any formulation.

Table 1: Estimation results.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Final</th>
<th>PC</th>
<th>Final</th>
<th>PC</th>
<th>Final</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln_cost</td>
<td>-2.497***</td>
<td>-0.646</td>
<td>-2.238**</td>
<td>-0.510</td>
<td>-3.054***</td>
<td>-0.342</td>
</tr>
<tr>
<td></td>
<td>[0.899]</td>
<td>[1.234]</td>
<td>[0.873]</td>
<td>[1.208]</td>
<td>[0.957]</td>
<td>[1.221]</td>
</tr>
<tr>
<td>ln_tariff</td>
<td>-4.548***</td>
<td>-3.504*</td>
<td>-4.544***</td>
<td>-3.505*</td>
<td>-4.557***</td>
<td>-3.515*</td>
</tr>
<tr>
<td></td>
<td>[1.472]</td>
<td>[2.027]</td>
<td>[1.473]</td>
<td>[2.027]</td>
<td>[1.476]</td>
<td>[2.026]</td>
</tr>
<tr>
<td>ln_dist</td>
<td>-0.375***</td>
<td>-0.416***</td>
<td>-0.360***</td>
<td>-0.403***</td>
<td>-0.382***</td>
<td>-0.410***</td>
</tr>
<tr>
<td></td>
<td>[0.061]</td>
<td>[0.074]</td>
<td>[0.065]</td>
<td>[0.076]</td>
<td>[0.063]</td>
<td>[0.072]</td>
</tr>
<tr>
<td>contig</td>
<td>0.643***</td>
<td>0.396**</td>
<td>0.679***</td>
<td>0.415**</td>
<td>0.620***</td>
<td>0.402**</td>
</tr>
<tr>
<td></td>
<td>[0.157]</td>
<td>[0.195]</td>
<td>[0.172]</td>
<td>[0.196]</td>
<td>[0.164]</td>
<td>[0.196]</td>
</tr>
<tr>
<td>comlang</td>
<td>-0.541***</td>
<td>0.082</td>
<td>-0.509***</td>
<td>0.125</td>
<td>-0.592***</td>
<td>0.096</td>
</tr>
<tr>
<td></td>
<td>[0.183]</td>
<td>[0.207]</td>
<td>[0.186]</td>
<td>[0.207]</td>
<td>[0.186]</td>
<td>[0.202]</td>
</tr>
<tr>
<td>comcol</td>
<td>-0.113</td>
<td>-0.14</td>
<td>-0.112</td>
<td>-0.155</td>
<td>-0.119</td>
<td>-0.122</td>
</tr>
<tr>
<td></td>
<td>[0.298]</td>
<td>[0.322]</td>
<td>[0.304]</td>
<td>[0.324]</td>
<td>[0.285]</td>
<td>[0.324]</td>
</tr>
<tr>
<td>ln_isp</td>
<td>5.536</td>
<td>11.779</td>
<td>[7.650]</td>
<td>[7.806]</td>
<td>-3.826</td>
<td>2.843</td>
</tr>
<tr>
<td></td>
<td>[7.650]</td>
<td>[7.806]</td>
<td>[2.927]</td>
<td>[3.145]</td>
<td>5040</td>
<td>5040</td>
</tr>
</tbody>
</table>

Observations: 9660, 5040
Importer Fixed Effects: Yes, Yes
Exporter Fixed Effects: Yes, Yes
Sector Fixed Effects: Yes, Yes

Robust standard errors corrected for clustering by country pair are in brackets.

In line with expectations, we find that the coefficient on distance is slightly larger in absolute value terms for parts and components than for final goods: a 1% decrease in distance is associated with an increase in trade value of 0.36-0.38% for final goods, and 0.40-0.42% for parts and components. This is a relatively small difference, and cannot at this stage be necessarily ascribed to the sorts of mechanisms discussed above. Further
work will be required to examine this finding in greater detail, and in particular to assess its statistical significance and robustness.

For the other trade cost variables (tariffs and import/export costs), results are contrary to expectations in the sense that the estimated coefficients are larger in absolute value for final goods trade than for parts and components. Thus, a 1% fall in import/export costs is associated with a trade increase of 2.2-3.1% for final goods, but only 0.3-0.6% for parts and components. Moreover, the estimated coefficients for import/export costs are statistically insignificant for parts and components trade, but are 5% significant for final goods. For tariffs, the estimated magnitudes are quite close for final products and parts and components: a 1% reduction in the power of the tariff is associated with a 4.5-4.6% increase in final goods trade, and a 3.5% increase in parts and components trade. Tariffs enter the final goods equation at the 1% level of significance, but are only 10% significant in the case of parts and components.

Our results suggest that both contract enforceability and information technology costs impact parts and components trade more strongly than trade in final goods. In the case of information technology, a 1% improvement in our ISP competition index is associated with a 5% increase in trade in final goods, and an 11% increase in parts and components trade. For rule of law, a 1% improvement is associated with a 2.8% increase in parts and components trade. However, this variable carries an unexpected negative sign in relation to final goods trade. While these results are suggestive, they should not be taken too literally due to the lack of statistical significance of these coefficients for both final goods and parts and components.

Taking these results together, we conclude that the data appear to provide only limited support for the three hypotheses we are testing. Although distance related trade costs would appear to impact trade in parts and components slightly more strongly than trade in final goods, the opposite is true for import/export costs and tariffs. While ISP competition and rule of law both appear to impact trade in parts and components more strongly than trade in final goods, it is difficult to draw any strong conclusions due to the lack of statistical significance of the estimated coefficients.
V. Conclusion

This paper has provided preliminary empirical evidence as to the extent of trade that takes place through production networks in the Asia Pacific region, as well as its determinants. We have shown that in the case of the electronic goods sector, recent trade growth has been considerably more rapid for parts and components than for final goods. To the extent that parts and components trade can be used as a proxy for within-network production fragmentation, this suggests that the role of TPNs has become considerably more important in the Asia Pacific region over recent years.

In terms of the determinants of this observed growth in TPN trade, our results are suggestive of a number of results that should be explored in greater depth in future work. First, we find some limited evidence that distance related trade costs impact parts and components flows more strongly than final goods flows. This finding would be consistent with increased sensitivity of network trade to trade costs. However, we also find results for tariffs and export/import costs that would not support such an interpretation.

Second, we also find limited evidence that network trade is more sensitive to communication and information technology, as well as contract enforceability, than is trade in final goods. However, our results are suggestive only, since the estimated parameters for these variables are not statistically significant.

Future work could usefully explore these suggestive results in greater depth, in an effort to better ascertain the extent of any differences there might be between trade in parts and components and trade in final goods. An important part of this effort would be an expansion of the dataset to include a larger number of countries. This would introduce greater variability into our independent variables, and thereby hopefully produce more precise parameter estimates. It would also be desirable to address the issue of endogeneity in our various cost measures, by identifying appropriate instruments for these variables. Given the important role that foreign investment plays in the establishment of transnational production networks, it may also be appropriate to investigate the role of national investment climates in this regard. Since there is as yet relatively little empirical work on the policy determinants associated with the rise of TPNs, we expect that future research in this area will be particularly fruitful.
VII. References


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Kimura, Fukunari, Yuya Takahashi and Kazunobu Hayakawa, 2005, “Fragmentation and Parts and Components Trade: Comparison Between East Asia and Europe”, Faculty of Economics, Keio University, mimeo.


VIII. Appendix

8.1. *Electronics Industry Network (Office Electronics, IT Electronics, and Consumer Electronics)*

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>759.1</td>
<td>Parts, nes of and access. for machines of headings 7511 or 7518</td>
</tr>
<tr>
<td>759.9</td>
<td>Parts, nes of and access. for machines of headings 7512 and 752</td>
</tr>
<tr>
<td>764.9</td>
<td>Parts, nes of and accessories for apparatus falling in heading 76</td>
</tr>
<tr>
<td>771.1</td>
<td>Transformers, electrical</td>
</tr>
<tr>
<td>771.2</td>
<td>Other electric power machinery, parts, nes</td>
</tr>
<tr>
<td>772.1</td>
<td>Switches, relays, fuses, etc; switchboards and control panels, nes</td>
</tr>
<tr>
<td>772.2</td>
<td>Printed circuits, and parts thereof, nes</td>
</tr>
<tr>
<td>772.3</td>
<td>Fixed, variable resistors, other than heating resistors, parts, nes</td>
</tr>
<tr>
<td>773.1</td>
<td>Insulated electric wire, cable, bars, etc</td>
</tr>
<tr>
<td>773.2</td>
<td>Electrical insulating equipment</td>
</tr>
<tr>
<td>775.79</td>
<td>Parts, nes of the electro-domestic equipment of heading 7757</td>
</tr>
</tbody>
</table>
775.87 Non-carbon electric heating resistors
775.89 Parts, nes of the electro-thermic appliances

776.1 Television picture tubes, cathode ray
776.2 Other electronic valves and tubes
776.3 Diodes, transistors, photocells, etc
776.4 Electronic microcircuits
776.8 Crystals, and parts, nes of electronic components of heading 776
778.1 Batteries and electric accumulators, and parts thereof, nes
778.2 Electric filament lamps and discharge lamps; arc-lamps
778.3 Automotive electrical equipment; and parts thereof, nes
778.4 Electro-mechanical hand tools, and parts thereof, nes
778.8 Other electrical machinery and equipment, nes
874.9 Parts, nes, and accessories of headings 873, 8743, 87454 or 8748

FPO 751.1 Typewriters; cheque-writing machines
751.2 Calculating, accounting, cash registers, ticketing, etc, machines
751.8 Office machines, nes
752.1 Analogue and hybrid data processing machines
752.2 Complete digital data processing machines
752.3 Complete digital central processing units; digital processors
752.4 Digital central storage units, separately consigned
752.5 Peripheral units, including control and adapting units
752.8 Off-line data processing equipment, nes

FPT 761.1 Television receivers, colour
761.2 Television receivers, monochrome
762.1 Radio receivers for motor-vehicles
762.2 Portable radio receivers
762.8 Other radio receivers
763.1 Gramophones and record players, electric
763.8 Other sound recording and reproducer, nes; video recorders
764.1 Electrical line telephonic and telegraphic apparatus
764.2 Microphones; loud-speakers; audio-frequency electric amplifiers
764.3 Television, radio-broadcasting; transmitters, etc
764.8 Telecommunications equipment, nes

FPE 774.1 Electro-medical equipment
774.2 X-ray apparatus and equipment; accessories; and parts, nes
775.1 Household laundry equipment, nes
775.2 Domestic refrigerators and freezers
775.3 Domestic dishwashing machines
775.4 Electric shavers and hair clippers, parts thereof, nes
775.71 Domestic electric vacuum cleaners and floor polishers
775.72 Domestic electric room fans and vented hoods
775.73 Domestic electric food grinders and mixers, etc
775.78 Other domestic electric appliances, nes
775.81 Electric water heaters
775.82 Electric soil and space heaters
775.83 Electric hair dressing apparatus
775.84 Electric smoothing irons
775.85 Electric blankets
775.86 Electro-thermic domestic appliances, nes
871.0 Optical instruments and apparatus
872.0 Medical instruments and appliances, nes
873.1 Gas, liquid and electricity supply or production meters; etc
873.2 Counting devices non-electrical; stroboscopes
874.1 Surveying, navigational, compasses, etc, instruments, nonelectrical
874.2 Drawing, marking-out and mathematical calculating instrum., etc
874.3 Gas, liquid control instruments and apparatus, non-electrical
874.4 Nonmechanical or electrical instruments for physical, etc, analysis
874.5 Measuring, controlling and scientific instruments, nes
874.8 Electrical measuring, controlling, etc, instruments, apparatus, nes