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Magnification Effect in International Production Networks: Evidence from Asia[§]

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Abstract: This study empirically examines the "magnification effect" proposed in Yi (2003, *Journal of Political Economy*). He demonstrated theoretically that, as the number of separable production stages increases, the magnitude of trade increases explosively through the reduction of trade costs. We investigate the existence of the magnification effect for intra-Asian trade in machinery industries. Specifically, we estimate a gravity equation for worldwide trade that includes tariffs and their interaction term with a dummy variable for intra-Asian trade. As a result, we found a significantly negative coefficient for this interaction term, especially in the electrical machinery industry, indicating that tariff reductions increase intra-Asian trade more greatly than other trade. These results are robust against endogeneity in tariffs and other confounding factors.

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1. Introduction

Since the 1990s, international production networks have developed in Asia. A traditional example of such networks is cross-border production sharing between the U.S. and Mexico in automobile production, which is characterized by back-and-forth intra-firm transactions between headquarters in the U.S. and their assembly plants in Maquila, Mexico. Since the 2000s, however, the production networks in Asia have attracted much attention from the public and academia, with Baldwin (2008) describing these networks as "Factory Asia." In particular, such production networks in Asia have developed in machinery industries, which are characterized by a large number of multi-layered vertical production/distribution processes. Asian firms, including Japanese, Korean, and Taiwanese firms, have

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a competitive edge in developing a subcontracting system, exploring modulation techniques, and constructing efficient vertical value chains (Kimura et al., 2007). Several studies have shown that international production networks in Asia are outstanding in terms of the magnitude of production and trade (e.g., Baldwin and Lopez-Gonzalez, 2015; Pomfret and Sourdin, 2018).

The literature suggests that tariffs play a role in the explosive growth in trade within international production networks, dubbed the "magnification effect" by Yi (2003). He demonstrated theoretically that, as the share of input costs in the total value of export products decreases, or the number of separable production stages increases, exports increase explosively through the reduction of trade costs. There are two forces behind this effect. First, multistage production reduces each stage's value-added but increases each exporter's burden in terms of tariff payment. As vertical specialization develops, the share of input cost in total production value rises, resulting in a decrease in the value added during the production of export products. Therefore, the tariff payment for exporting increases dramatically relative to the valued added because the tariff is imposed on the total production value rather than the value added. Such an increase in the tariff burden discourages producers to export, so exports become more sensitive to tariffs because the input cost share is higher. Second, because tariffs are imposed at each production stage, a tariff burden at one stage cascades to later stages. Thus, trade liberalization dramatically reduces the prices of imported products and increases trade.

Asian countries have reduced their tariffs on both a most favored nation (MFN) basis and a preference basis. In particular, the Association of South-East Asian Nations (ASEAN) has acted as the hub of a regional trade agreement (RTA) network in this region. ASEAN countries have eliminated tariffs for intra-ASEAN trade since 1993 in a gradual manner. Afterward, ASEAN expanded its RTA network with "plus-one countries," including Australia, China, India, Japan, Korea, and New Zealand, by concluding the so-called "ASEAN plus-one" RTAs. Bilateral RTAs between plus-one countries have also been successively implemented, including the China–New Zealand RTA (2008), Korea–India RTA (2010), Japan–India RTA (2011), Japan–Australia RTA (2015), and China–Korea RTA (2015). As a result, these tariff reductions contribute to the development of international production networks and, based on the magnification effect, increasing intra-Asian trade explosively.

This study aims to empirically examine whether tariff reductions have contributed to the growth of trade in Asia. Surprisingly, to our best knowledge, no empirical studies have investigated the existence of the magnification effect. Yi (2003) calibrated a model of vertical specialization and showed through simulation that the model can explain about half of the U.S. export growth from 1962 to 1999 and almost 100% of its export growth through vertical specialization. However, no empirical studies have examined the magnification effect in international production in Asia. One critical reason for the absence of such studies is that a ready-made database on worldwide tariffs had not been available until recently. Such a database is now provided by the World Integrated Trade Solution (WITS) and the Tariff Analysis Online facility provided by the World Trade Organization. The database includes information on various kinds of tariff regimes, including MFN and RTAs. By combining such tariff information with data on bilateral trade values in machinery industries, we estimate a gravity equation with a variable of applied tariffs. Our dataset includes bilateral trade among 169 countries between 1995 and 2017. We focus on trade in

machinery industries.

More specifically, our gravity equation includes not only the tariffs but also their interaction term with an Asia dummy that takes a value of one for intra-Asian trade. If multistage production develops more in intra-Asian trade, and thus the magnification effect is larger, we will find the larger tariff-elasticity in intra-Asian trade. We estimate this equation by the Poisson pseudo maximum likelihood (PPML) method and the instrumental variable (IV) method. The PPML allows us to include zero-valued trade in a natural way, while in the IV method, we address possible endogeneity issues in our tariff variables. As a result, we found a significantly negative coefficient for the interaction term between tariffs and the Asia dummy, indicating the magnification effect in intra-Asian trade. This result is robust against excluding outliers (e.g., China) and controlling for other factors that could produce the larger tariff elasticity in the interaction term.

A large number of studies have examined trade in international production networks/global supply chains. These studies investigated the duration or magnitude of trade in such networks. Baldwin and Taglioni (2014) derived a modified gravity equation that is suited to explaining trade where international supply chains are important. The early studies employed data on gross trade and applied trade in machinery parts and finished machinery products separately to the gravity equation.[1] More recent studies apply trade in value-added to the equation.[2] Some of these studies, such as Kimura et al. (2007) and Greaney and Kiyota (2020), have shown the significantly larger trade in machinery industries in Asian countries than in other countries. We aim to contribute to this literature by showing the significantly larger effect of tariffs in intra-Asian trade, that is, the magnification effect.

The rest of this paper is organized as follows. The next section provides an overview of the magnification effect and its mechanism. After providing our empirical framework in Section 3, we report our estimation results in Section 4. Lastly, Section 5 concludes this paper.

2. Magnification Effect

This section briefly provides theoretical background on the magnification effect, proposed by Yi (2003). Conventional trade models, including the standard Ricardian model and the monopolistic competition model, cannot explain why relatively small tariff reductions explosively increase international trade. A key feature of these models is that they do not consider multistage production and vertical specialization, which have developed in many countries. For instance, a producer in country *A* produces a good by using intermediate inputs produced in countries *A* and *B*. In this case, the value-added to the imported inputs is entirely generated in country *B*. A reduction of 1 percentage point in input tariffs decreases the trade costs of input exporters by 1 percentage point. A small tariff reduction

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[1] Examples of early studies include Athukorala and Yamashita (2006), Kimura et al. (2007), Hayakawa (2014), and Okubo et al. (2014).

[2] These later studies include Johnson and Noguera (2012), Aichele and Heiland (2018), Kaplan et al. (2018), and Greaney and Kiyota (2020).

cannot cause a large increase in trade unless the elasticity of substitution between inputs is unrealistically high.

Yi (2003) showed that multistage production magnifies the trade-increasing effect of a tariff reduction. He extended a continuum-good Ricardian model developed by Dornbusch et al. (1977) to a multistage production model. Also, based on Eaton and Kortum (2002), where each country's total factor productivity in producing a particular input is drawn from a distribution function, Yi (2010) and Connolly and Yi (2015) extended Yi (2003) to consider the home bias in trade and the growth effects of tariff reduction, respectively.

To explain the mechanism as simply as possible, we describe the magnification effect by using a two-country, three-stage example. Specifically, suppose that there are three stages of production in manufacturing a final good. We explain each stage in reverse order. The final good is non-tradable, and it is consumed domestically.[3] In stage 2 of the production process, each stage-2 input, indexed by $z \in [0,1]$, is produced using a stage-1 input and primary production factors (e.g., capital and labor) in either country A or country B. If stage-2 inputs are imported, the tariff, τ_2, is imposed. In stage 1, inputs used for stage-2 production are produced in either country A or B using only primary factors of production.[4] These stage-1 inputs are tradable, and a tariff, τ_1, is imposed if they are traded. In the words of Baldwin and Venables (2013), this vertical structure exhibits a "spider-and-snake" configuration. Namely, it has both a sequential production process (snakes) and assemblies of separate inputs in downward productions (spiders).

Let us consider imports of country A from country B. For simplicity, we assume the same situation as Connolly and Yi (2015), where country A always produces the stage-1 inputs used by Country B to produce stage-2 inputs. Country A also imports these stage-2 inputs from Country B. By this assumption, possible production patterns for the final-good production in country A is reduced to two patterns: AA and AB, where AB means that the stage-1 production is conducted in country A and the stage-2 production is undertaken in country B. Figure 1 illustrates the process of production. In the final-good production, the continuum of inputs produced in stage 2 is assembled without costs.

=== Figure 1 ===

By applying this setting to Yi (2010), we show country A's total import value of the stage-2 inputs as

$$X_{BA} = (1 - \tilde{z})(1 + \theta)I_A, \tag{1}$$

where θ is the share of the stage-1 inputs in the Cobb-Douglas type of production function for the stage-2 inputs and I_A is the income of country A. By the property of the Cobb-Douglas type function, θ

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corresponds to the share of stage-1 input costs to the total value of stage-2 inputs. $1 - \tilde{z}$ is the equilibrium share of the stage-2 inputs that are imported from country B, which is calculated as

$$1 - \tilde{z} = \frac{1}{1 + \{(1 + \tau_1)^\theta (1 + \tau_2)\}^{\frac{\nu}{1-\theta}}}, \tag{2}$$

where ν is the shape parameter of a Frechét probability distribution. As ν becomes larger, the productivity difference between countries becomes smaller.[5] Thus, a larger ν makes $1 - \tilde{z}$ more sensitive to tariff changes.

By substituting (2) into (1) and differentiating it with respect to τ_2, we arrive at the tariff elasticity of imports as follows:

$$\widehat{X_{BA}} = -\nu \tilde{z} \left(\frac{1}{1 - \theta}\right) \widehat{1 + \tau_2}. \tag{3}$$

The parameter θ is key for generating the magnification effect. If $\theta = 0$, there is no stage-1 production, and a reduction in the tariff does not greatly increase the imports unless ν is very large. A positive value for θ magnifies the trade-increasing effect of a tariff reduction. For instance, if $\theta = 1/2$, the share of the stage-1 inputs used in the production of the stage-2 inputs is 50%. The trade-increasing effect of a tariff reduction is twice larger than the effect without a multistage input production.

The intuitive explanation is as follows. Because the production of stage-2 inputs requires stage-1 inputs, the value-added share of the stage-2 production is $1 - \theta$. Because the stage-2 producers react to how a reduction in τ_2 affects the value-added on the stage-2 inputs, the effective burden of the stage-2 tariff is the nominal tariff divided by the value-added share of the stage-2 inputs, which is given by $\tau_2/(1 - \theta)$. Even though τ_2 is applied to the total values of the stage-2 inputs, the contribution of the values added in stage 2 is smaller than the total value. Therefore, the effective burden of tariff is $1/(1 - \theta)$ times larger than the case without multistage productions.

In addition, if we consider simultaneous reductions in tariffs at different stages, τ_1 and τ_2, the magnification effect of a tariff reduction becomes larger. Let $\tau \equiv \tau_1 = \tau_2$, then we arrive at the tariff elasticity of imports for stage-2 inputs as

$$\widehat{X_{BA}} = -\nu \tilde{z} \left(\frac{1 + \theta}{1 - \theta}\right) \widehat{1 + \tau}. \tag{4}$$

A tariff reduction in stage-1 inputs also lowers the input costs for the stage-2 production in country B. It contributes to increasing the fraction of the stage-2 inputs that country A imports from country B. If $\theta = 1/2$, the trade-increasing effect of a tariff reduction is three times higher than the case without the stage-1 production. This is because the tariff impedes the trade in each stage of production. An increase in the number of production stages implies that a larger number of production stages are affected by the tariff, resulting in enhancement of the magnification effect by the tariff reductions, as is suggested by Yi (2003, 2010).

Although we have examined the magnification effect of tariff reductions in input trade, we can

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[5] See Appendix A of Connolly and Yi (2015) for the derivation. Connolly and Yi (2015) only considered a simultaneous reduction of trade costs across stages. Here, we separate a tariff on the stage-2 inputs from a tariff on the stage-1 inputs.

apply the same mechanism to tariff reductions in the trade of final goods. Suppose that domestic consumers purchase and consume differentiated products, some of which are imported from foreign countries. In stage 2, each differentiated product is produced with the stage-1 input and the primary factors, where we use the same θ as the share of the stage-1 inputs in the stage-2 production. In stage 1, inputs used for the production of the differentiated goods in stage 2 are produced. By this re-interpretation of the stages, we can regard equation (3) as the tariff elasticity of imports of final products, where $1 - \tilde{z}$ is the share of differential products imported from the foreign country. Therefore, the magnification effect discussed here is applied to both input trade and output trade.

3. Empirical Framework

This section provides our empirical framework to investigate the effect of tariffs on trade. Specifically, our baseline equation is set to the following:

$$X_{ijt} = \exp\{\alpha \times \ln(1 + Tariff_{ijt}) + \beta \times RTA_{ijt} + \delta_{ij} + \delta_{it} + \delta_{jt}\} \cdot \epsilon_{ijt}. \quad (5)$$

X_{ijt} is export values in a given industry from countries i to j in year t. $Tariff_{ijt}$ represents applied tariff rates when exporting from countries i to j in year t. RTA_{ijt} takes a value of one if two countries belong to the same RTA and a value of zero otherwise. Notice that because tariff rates are directly controlled by $Tariff_{ijt}$, the coefficient for the RTA dummy indicates the effects of changes in non-tariff measures (NTMs) through RTAs. δ_{ij}, δ_{it}, and δ_{jt} are respectively the time-invariant country pair, time-variant exporter, and time-variant importer fixed effects. The time-invariant country pair characteristics include geographical distance, language similarity, and cultural similarity. This type of fixed effects also addresses the endogeneity issue of the RTA dummy variable (Baier and Bergstrand, 2007). Gross domestic product and multinational resistance (e.g., price index) are examples of time-variant exporter and importer characteristics (Feenstra, 2002). ϵ_{ijt} is a disturbance term.

We estimate this equation for trade in three machinery industries separately, including electrical machinery, transport equipment, and precision machinery, by two methods. The machinery industries used in the model are known to have international production networks that have developed in Asia. The first method used is the PPML method (Silva and Tenreyro, 2006). As Melitz (2003) suggested, trade values can be systematically zero. However, taking logarithms of trade values drops such observations from the estimation sample, leading to the elimination of potentially useful information and resulting in a sample selection bias. To overcome this issue, recent studies employ PPML, which enables us to naturally incorporate zero-valued exports. The other method is to estimate the logged version of equation (5) by the IV method. This estimation addresses the possible endogeneity issue but results in dropping zero-valued trade from the estimation sample. Thus, the two methods above are complementary in our analysis.[6]

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[6] In estimation, we use Stata commands of "HDFE" (i.e., "ppmlhdfe" and "ivreghdfe") to control for various fixed effects. To our knowledge, the command for the triple combination (HDFE, PPML, and IV) is not available.

It is expected that there is some source of endogeneity in our tariff variable. As specified above, we control for various fixed effects. These fixed effects reduce the possibility of failing to control for factors that can affect both tariffs and trade. However, there may be unobservable elements that cannot be controlled for by the set of fixed effects we employ. For example, when the government reduces tariffs, it may introduce NTMs instead, resulting in decreasing trade (e.g., Niu et al., 2018; Beverelli et al., 2019). Thus, the error term in equation (5) may be positively correlated with our tariff variable. In this case, the estimate of tariffs by the ordinary least square (OLS) method suffers from upward bias and is underestimated. The bias with a similar direction may also arise from reverse causality. For example, an increase in trade may induce the government to raise tariffs to protect domestic industries. In sum, the OLS estimates will suffer from the endogeneity bias.

As an instrument, we use applied tariff rates in non-machinery industries. Because the broad trade policy is determined at the national level, the trend of tariffs is likely to be correlated across industries. Namely, tariffs in non-machinery industries are likely to correlate with tariffs in machinery industries. In addition, changes in tariffs in non-machinery industries do not have direct impacts on machinery trade. This property of tariffs in non-machinery industries strengthens the validity of their exclusion restriction. One threat to the exclusion restriction is the existence of unobservable elements that affect both machinery trade and tariffs in non-machinery industries. As discussed above, our inclusion of fixed effects reduces the possibility of failing to control for such elements. However, there may be some time-variant country pair-specific factors that cannot be controlled for by our set of fixed effects. For example, NTMs introduced in conjunction with a tariff reduction in non-machinery industries may also affect machinery trade. The existence of such factors may violate the exclusion restriction of our instruments.

To investigate the magnification effect in Asian trade, we modify the baseline equation above. Specifically, we introduce the interaction term of tariffs with a dummy variable that takes a value of one for intra-Asian trade (*Asia*).

$$X_{ijt} = \exp\{\alpha_1 \times \ln(1 + Tariff_{ijt}) + \alpha_2 \times \ln(1 + Tariff_{ijt}) \times Asia_{ij} + \beta \times RTA_{ijt} + \delta_{ij} + \delta_{it} + \delta_{jt}\} \cdot \epsilon_{ijt}.$$
(6)

As mentioned in Section 1, ASEAN has established trade networks by concluding RTAs with six neighboring countries that are known as ASEAN-plus-one RTAs. Therefore, we define the Asian dummy based on these networks. Specifically, it takes a value of one for trade among the 16 Asian countries (i.e., the 10 ASEAN countries and six countries in ASEAN-plus-one RTAs—Australia, China, India, Japan, Korea, and New Zealand). When we estimate this equation by the IV method, we also use the interaction term between the Asian dummy and tariffs in non-machinery industries as an instrument.

For our model, the magnification effect in intra-Asian trade is demonstrated by a significantly negative coefficient for the interaction term between tariffs and the Asian dummy. Although international production networks have a network nature and cover multiple countries, we discussed the mechanism of the magnification effect based on the two-country setting in Section 2. The empirical specification above also examines bilateral trade, that is, trade between two countries. Our theoretical predictions suggest that we observe the magnification effect when the cost share of the stage-1 inputs in

producing the stage-2 inputs, θ, is larger. We suppose that the international production networks developed in Asia leads to higher θ in bilateral pairs in intra-Asian trade because such networks increase the extent to which the exports rely on the imported intermediate inputs. Thus, if a production network raises the cost share of inputs and creates the magnification effect within the network, the tariff elasticity will be outstandingly high in the trade among Asian countries.[7]

Our data sources are as follows. We obtain the trade data from the CEPII.[8] It is called "BACI" database and is an updated version of the data provided in Gaulier and Zignago (2010). The database offers disaggregated data on bilateral trade flows for more than 5000 products and 222 countries. Originally, the data are available at the six-digit level of the harmonized system (HS) nomenclature. We aggregate these trade data up to the industry-level to decrease the occurrence of zero-value trade.[9] The electrical machinery, transport equipment, and precision machinery industries are defined as HS codes 84-85, 86-89, and 90-92, respectively. Thus, our industry-level trade values, X_{ijt}, include both trade of intermediate inputs and that of final goods. As discussed in Section 2, the magnification effect arises in both input and output trade as long as their production has multiple stages, and countries import many varieties of these goods. We use the data reported in the HS1992 version to maximize the length of study years, which includes the period between 1995 and 2017 in the BACI database.

The sources of other variables are as follows. The RTA dummy variable is drawn from Egger and Larch (2008), updated to 2017.[10] The study RTAs include those under GATT Article XXIV and those based on the Enabling Clause. The RTA dummy takes the value of one if either type of RTAs is formed between two countries. We construct our tariff variables in the following manner. First, tariff line-level data on tariff rates are obtained from the WITS database. Second, at the tariff-line level, we identify the lowest tariff rates among all regimes, including not only MFN but also RTAs and a generalized system of preferences, available for each country pair. Last, we compute the simple average of tariff rates by industry. Because the data on tariffs are not necessarily available for all countries included in BACI database, our dataset for estimation includes trade among 169 countries (see Appendix). Our instrument is also computed as the simple average of tariffs among HS codes 1-83 and 93-97.

Before reporting our estimation results, we provide an overview of machinery trade and tariffs.

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[7] Furthermore, when considering the multiple-country setting, the export value from countries i to j may be affected by not only tariff rates in this flow but also their tariff rates with the third countries. For instance, if country j also imports the stage-2 inputs from a third country (country k), the export value from countries i to j would be smaller when the tariff rates imposed on the imports from country k becomes lower. In addition, if the producers of the stage-2 inputs in countries i and j use the stage-1 inputs imported from country k, the tariff rates imposed on the imports from country k affect the costs of producing the stage-2 inputs, and thereby change the export values of the stage-2 inputs from countries i to j. We assume that such effects of tariff rates with the third countries are captured by exporter-year and importer-year fixed effects.

[8] http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=37

[9] We restrict observations of country pair-year to those with positive values in total trade at a country pair-year-level. Thus, trade values by industries can be zero in some study pairs. Note that because the unit of trade values in the BACI database is 1,000 USD, "positive values" mean that more than 1,000 USD of trade is observed.

[10] The data are available in https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

Figure 2 depicts the share of intra-Asian trade out of total trade worldwide. All three machinery industries show a gradual rise over time. As of 2017, intra-Asian trade in electrical machinery, transport equipment, and precision machinery accounts for nearly 30%, around 20%, and nearly 10%, respectively, of total global trade. Namely, the presence of electrical machinery trade in Asia is a large share of global trade. Figure 3 depicts the trend of average tariffs in intra-Asian trade and the other trade. Notice that the latter trade includes trade between Asian countries and non-Asian countries. Although we can see a tentative hike in tariffs in intra-Asia in 1999[11], all tariffs show gradual decline over time. In particular, the reduction in tariffs on transport equipment in Asia is particularly large. As of 2017, in intra-Asia, the average tariff rates in machinery industries are only 2%-3%.

===   Figures 2 & 3   ===

4. Empirical Results

This section reports our estimation results. Based on the exercise in Egger and Tarlea (2015), we cluster standard errors by country pairs and years. We begin with the OLS estimation for comparison purposes. The results are shown in Table 1. The number of observations is different across industries because of the difference in the number of singleton observations. In columns (I)–(III), we introduce only tariffs. The coefficients for tariffs are significantly negative in all three industries. Their absolute magnitude is the largest in transport equipment and smallest in precision machinery. In transport equipment, for example, a 1% decrease in tariffs increases trade by 2%. The results of the logged version of equation (5), that is, the equation with tariffs and RTA dummy, are shown in columns (IV)–(VI). The coefficients for tariffs are again negatively estimated but not significant for precision machinery. The coefficients for RTA dummy are positively estimated but significant only in electrical machinery. Thus, for electrical machinery, the elimination of some NTMs by RTAs increases trade by 5% (=exp(0.048)−1).

===   Table 1   ===

Next, we estimate equation (5) by the PPML and IV methods. The PPML results are reported in columns (I)–(III) in Table 2. Due to the inclusion of zero-valued trade, the number of observations greatly increases. The coefficients for tariffs are again negatively estimated but not significant in transport equipment. The coefficient for RTA dummy turns out to be significantly negative in electrical machinery. The IV results are shown in columns (IV)–(VI). The test statistics for under-identification and weak identification show reasonably high values. The high value in the former test indicates that the rank condition is satisfied and that the equations are identified, while the high value in the latter test suggests that our IV estimates are unlikely to suffer from bias due to weak instruments. Compared with the OLS results, the absolute magnitude of the tariff coefficients rises. Thus, as discussed in the previous section,

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[11] In the original dataset, Thailand and Vietnam show a notable rise in tariffs in 1999.

the OLS estimates suffer from upward bias. The coefficients for tariffs are significantly negative in all three industries. As in the OLS results, the coefficients for RTA dummy are positively significant only in electrical machinery. In summary, except for electrical machinery, the impact of tariff reductions in our results are unstable and not robust.

=== Table 2 ===

We start to examine the magnification effect in intra-Asian trade. The estimation results of equation (6) by the PPML and the IV are presented in Table 3. The test statistics for under-identification and weak identification again show rather high values. The coefficients for tariffs are negatively estimated in all columns though they are not significant in columns (I) and (III). The interaction term with the Asia dummy has significantly negative coefficients in electrical machinery and precision machinery. Moreover, the absolute magnitude of the interaction term is much larger than that of the tariff variable. On the other hand, in transport equipment, the coefficient for the interaction term is significantly positive in the PPML result. Thus, these results may indicate the existence of a significant magnification effect in intra-Asian trade in electrical machinery and precision machinery. Its absence in transport equipment might be reasonable because this industry adopts the just-in-time production system and seeks a high share of local procurement compared with the other two machinery industries. The positive coefficient for the interaction term in transport equipment may indicate that such industry characteristics are more significant in Asian countries.

=== Table 3 ===

We conduct two kinds of robustness checks. First, we exclude China and Hong Kong from the estimation sample. Due to the large demand size and supply capacity, China and Hong Kong may act as outliers in the estimation. For instance, Arkolakis (2010) suggests that a country with larger market size attracts more entrants that engage in relatively small amounts of exports because of a lower market-penetration cost.[12] Then, it shows that trade liberalization increases exports of these firms more greatly. This factor may generate a large tariff elasticity in China and Hong Kong even if the magnification effect does not exist. Therefore, we again estimate our model by excluding China and Hong Kong. The results are shown in Table 4 and do not qualitatively change from the previous estimation, especially in the interaction term. Intra-Asian trade indicates a higher tariff elasticity than other trade in electrical machinery and precision machinery.

=== Table 4 ===

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[12] If firms use media such as internet, television, and newspapers, each advertisement reaches many people. In this case, marketing and advertising operations exhibit increasing returns to scale with respect to the number of consumers. Therefore, a larger market size corresponds to a lower market-penetration cost.

Second, we control for another factor that changes the trade-increasing effect of tariff reductions. If price elasticities of trade (i.e., trade elasticities) between Asian countries are larger than those in other regions, the tariff elasticity of intra-Asian trade tends to be larger even without the magnification effect.[13] Naturally, the trade elasticities are larger if price elasticities of demand are larger. Moreover, the trade elasticities in Asia would be larger if the market competition is tougher and the firms earn smaller revenues in Asia, as is indicated by Spearot (2013) and Bas et al. (2017). To control for the differences in the elasticities, we also introduce the interaction term of tariffs with importer's trade elasticities.[14] The estimation results are shown in Table 5 and indicate similar results as previous ones. While the interaction term with tariff elasticities has insignificant coefficients, the coefficients for that with the intra-Asian dummy are again significantly negative. In the IV estimation, we can also see the significantly negative coefficient for transport equipment.

===   Table 5   ===

5. Concluding Remarks

Over the last several decades, international production networks have developed in Asia. Theoretical studies have demonstrated that tariffs play a role in dramatically increasing trade in such production networks, known as the magnification effect. In this paper, we empirically examined whether intra-Asian trade enjoyed such a large increase due to tariff reduction. To this end, we estimated a gravity equation with tariffs and their interaction term with a dummy variable for intra-Asian trade against the worldwide trade in several machinery industries. As a result, we found a significantly negative coefficient for this interaction term, especially in the electrical machinery industry, indicating that tariff reductions increase intra-Asian trade more greatly than other trade. Yi (2003) suggests that welfare gains from trade liberalization in the multistage production model are substantially larger than those in the standard models. Therefore, our result indicates that intra-Asia trade liberalization in machinery industries largely benefits Asian countries.

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[13] Connolly and Yi (2015) suggest that the shape parameter v plays the same role as the elasticity of trade with respect to trade costs in the monopolistic competition model or the Armington model of trade. Therefore, we can regard v in equation (4) as the parameter that captures a part of the variances in the trade elasticities, other than the magnification effect, between the two countries.

[14] The data on trade elasticities at an HS three-digit level are obtained from Broda et al. (2017). We use the simple average in each industry.

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Table 1. Baseline estimation results by OLS

Industries	(I) Electrical	(II) Transport	(III) Precision	(IV) Electrical	(V) Transport	(VI) Precision
ln (1 + Tariff)	-1.168***	-2.043***	-0.807*	-1.084***	-1.982***	-0.761*
	[0.373]	[0.491]	[0.401]	[0.378]	[0.480]	[0.406]
RTA				0.048**	0.037	0.028
				[0.022]	[0.036]	[0.025]
Number of obs.	292,934	215,365	214,144	292,934	215,365	214,144

Notes: Estimation results by the OLS method. ***, **, and * indicate significance at the 1%, 5%, and 10 % levels, respectively. Standard errors reported in parentheses are clustered by country pairs and years. In all specifications, we control for country-pair fixed effects, exporter-year fixed effects, and importer-year fixed effects.

Table 2. PPML and IV results

Industries	(I) Electrical	(II) Transport	(III) Precision	(IV) Electrical	(V) Transport	(VI) Precision
ln (1 + Tariff)	-0.972**	-0.825	-0.06	-1.922***	-2.615***	-1.262**
	[0.489]	[0.640]	[0.816]	[0.474]	[0.516]	[0.472]
RTA	-0.092	0.074	0.081*	0.042*	0.03	0.023
	[0.058]	[0.050]	[0.044]	[0.021]	[0.036]	[0.025]
First stage						
ln (1 + Tariff) in others				0.673***	0.858***	0.812***
				[0.008]	[0.009]	[0.010]
Method	PPML	PPML	PPML	IV	IV	IV
Underidentification				21.6	21.9	21.4
Weak identification				6446.2	9763.7	6616.5
Number of obs.	388,501	355,134	345,219	292,934	215,365	214,144

Notes: Estimation results by the PPML or IV method. ***, **, and * indicate significance at the 1%, 5%, and 10 % levels, respectively. Standard errors reported in parentheses are clustered by country pairs and years. In all specifications, we control for country-pair fixed effects, exporter-year fixed effects, and importer-year fixed effects.

Table 3. Magnification effect

Industries	(I) Electrical	(II) Transport	(III) Precision	(IV) Electrical	(V) Transport	(VI) Precision
ln (1 + Tariff)	-0.525	-1.139*	0.136	-1.722***	-2.486***	-0.974*
	[0.480]	[0.668]	[0.789]	[0.473]	[0.523]	[0.476]
ln (1 + Tariff) * Asia	-3.061***	1.635*	-1.870**	-2.441**	-1.156	-3.193***
	[0.765]	[0.938]	[0.858]	[0.982]	[0.800]	[0.685]
RTA	-0.113*	0.076	0.077*	0.036*	0.026	0.017
	[0.058]	[0.049]	[0.044]	[0.021]	[0.036]	[0.025]
Method	PPML	PPML	PPML	IV	IV	IV
Underidentification				21.7	18.7	21.6
Weak identification				3005.1	1782.1	3253.0
Number of obs.	388,501	355,134	345,219	292,934	215,365	214,144

Notes: Estimation results by the PPML or IV method. ***, **, and * indicate significance at the 1%, 5%, and 10 % levels, respectively. Standard errors reported in parentheses are clustered by country pairs and years. In all specifications, we control for country-pair fixed effects, exporter-year fixed effects, and importer-year fixed effects.

Table 4. Magnification effect, excluding China and Hong Kong

| Industries	(I) Electrical	(II) Transport	(III) Precision	(IV) Electrical	(V) Transport	(VI) Precision
ln (1 + Tariff)	-0.978	-0.814	-2.617***	-2.019***	-2.800***	-1.127**
	[0.612]	[0.672]	[0.902]	[0.522]	[0.546]	[0.499]
ln (1 + Tariff) * Asia	-3.027***	1.654**	-1.883*	-2.747**	-0.902	-2.797***
	[0.877]	[0.777]	[1.108]	[1.224]	[1.122]	[0.935]
RTA	-0.051	0.092**	0.043	0.049**	0.041	0.027
	[0.037]	[0.043]	[0.042]	[0.022]	[0.038]	[0.025]
Method	PPML	PPML	PPML	IV	IV	IV
Underidentification				21.9	15.5	21.8
Weak identification				2431.6	554.7	2570.4
Number of obs.	374,651	342,247	331,702	280,365	205,547	203,324

Notes: Estimation results by the PPML or IV method. China and Hong Kong are excluded from both exporting and importing countries. ***, **, and * indicate significance at the 1%, 5%, and 10 % levels, respectively. Standard errors reported in parentheses are those clustered by country pairs and years. In all specifications, we control for country-pair fixed effects, exporter-year fixed effects, and importer-year fixed effects.

Table 5. Magnification effect, controlling for import demand elasticity

| Industries	(I) Electrical	(II) Transport	(III) Precision	(IV) Electrical	(V) Transport	(VI) Precision
ln (1 + Tariff)	-0.744	-1.530*	0.088	-0.143	-1.155	-0.703
	[0.660]	[0.808]	[1.141]	[0.956]	[0.704]	[0.616]
ln (1 + Tariff) * Asia	-3.016***	1.453	-1.469*	-2.585**	-2.981***	-4.060***
	[0.737]	[1.016]	[0.893]	[1.021]	[0.850]	[0.738]
ln (1 + Tariff) * Elasticity	0.041	0.027	0.044	-0.078	0.005	0.024
	[0.139]	[0.025]	[0.194]	[0.118]	[0.027]	[0.043]
RTA	-0.097	0.089	0.100**	0.032	0.025	-0.021
	[0.067]	[0.055]	[0.047]	[0.028]	[0.045]	[0.032]
Method	PPML	PPML	PPML	IV	IV	IV
Underidentification				19.5	20.3	20.3
Weak identification				511.2	2763.2	858.4
Number of obs.	207,016	189,931	188,718	159,775	116,515	121,816

Notes: Estimation results by the PPML or IV method. ***, **, and * indicate significance at the 1%, 5%, and 10 % levels, respectively. Standard errors reported in parentheses are clustered by country pairs and years. In all specifications, we control for country-pair fixed effects, exporter-year fixed effects, and importer-year fixed effects.
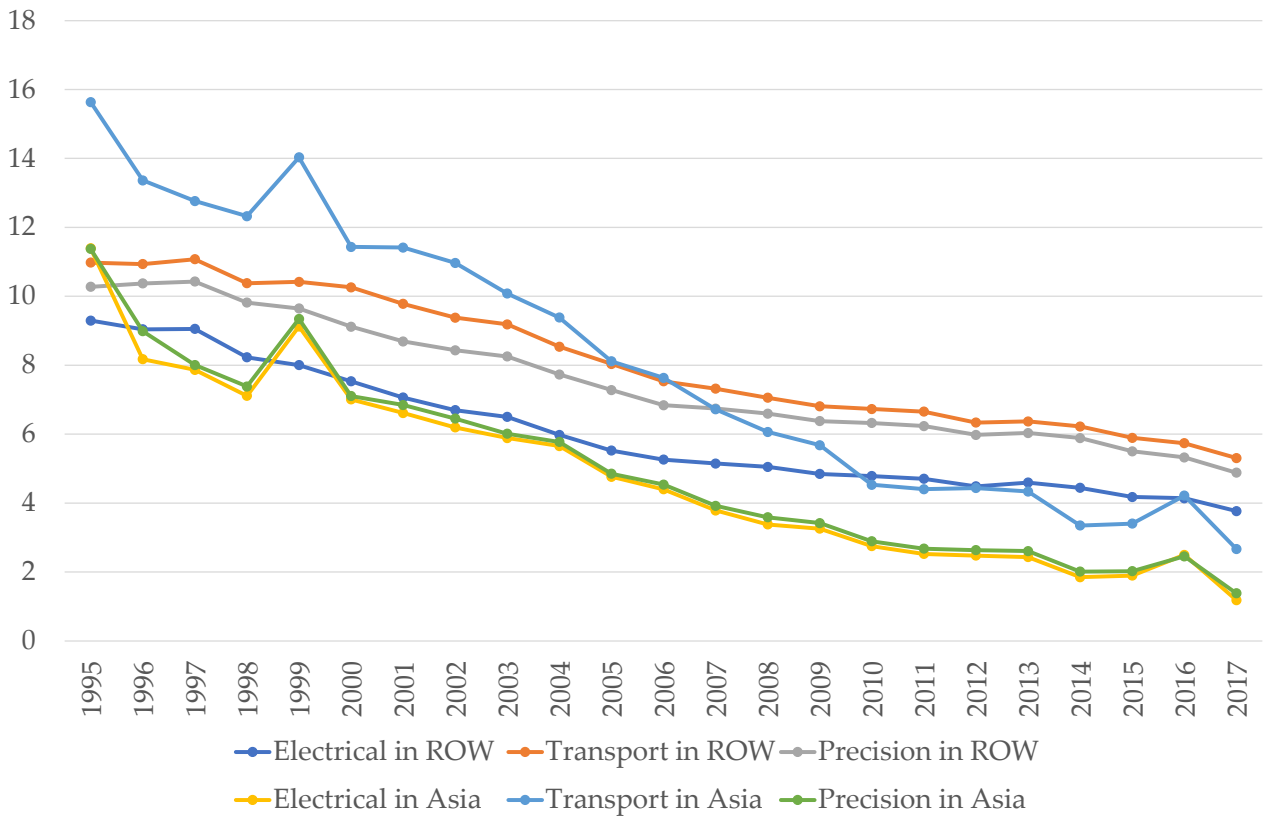
Figure 1. Stages of production
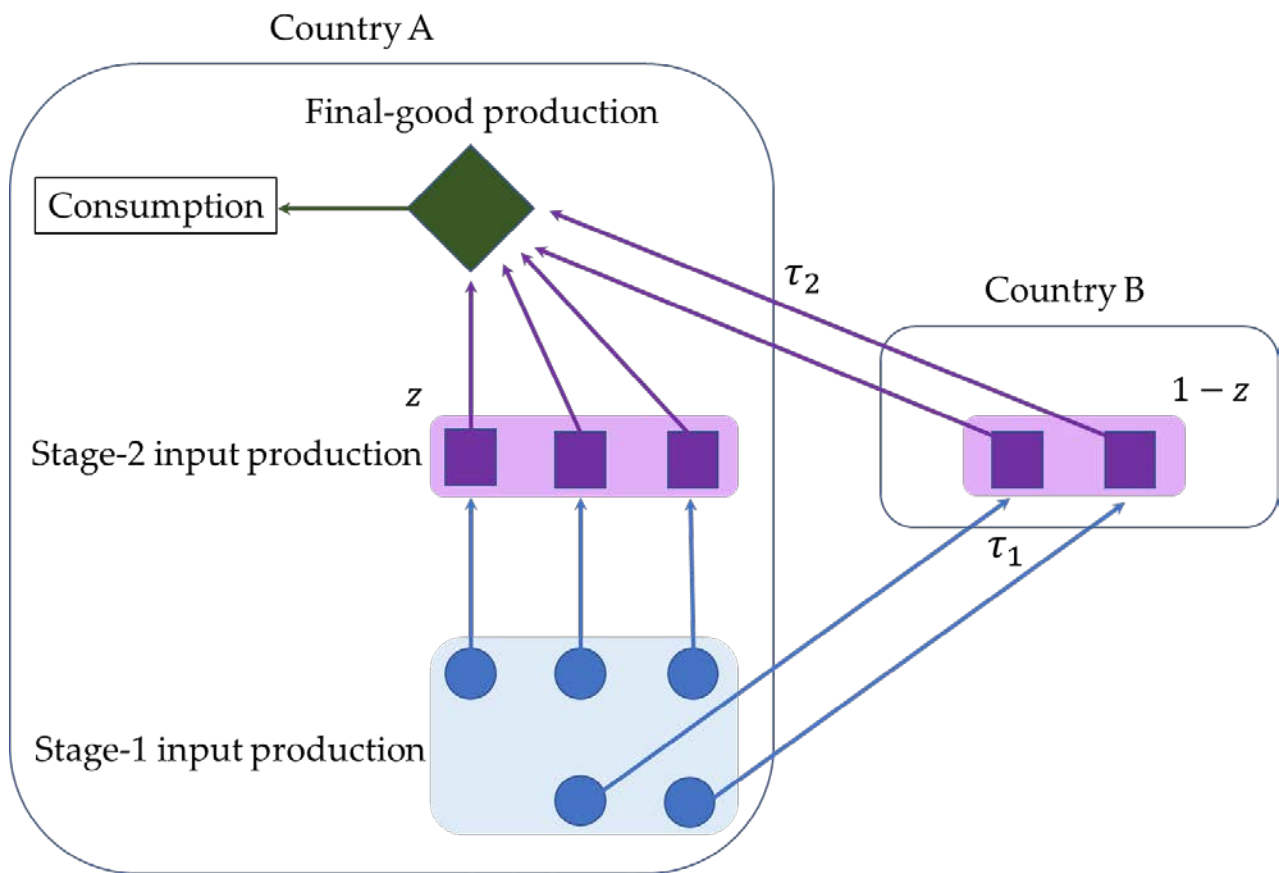
Note: Tariffs are applied if inputs are traded between countries.

Figure 2. Share of intra-Asian trade as a percentage of global trade (%)
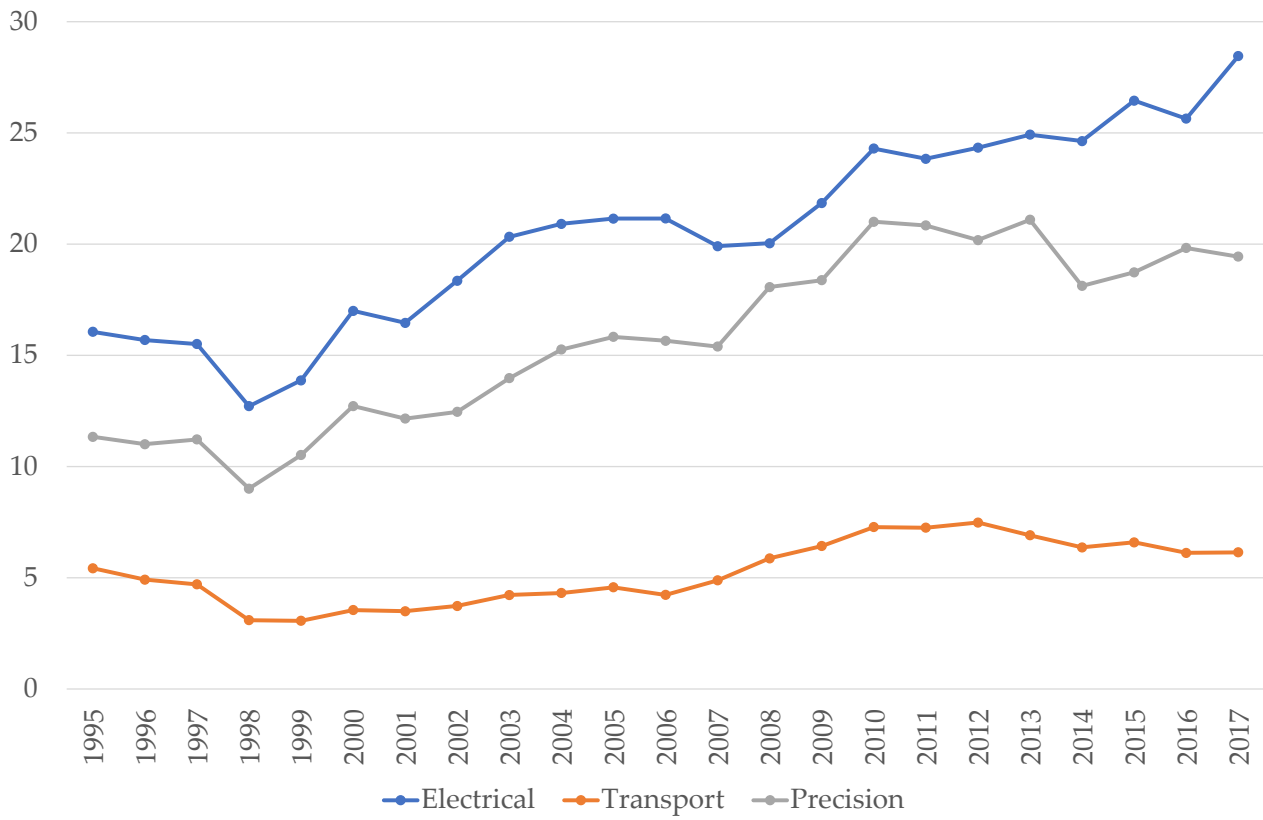
Source: BACI database.

Figure 3. Average tariffs (%)

Source: WITS.

Appendix. 169 Study Countries

AFG, AGO, ALB, ARE, ARG, ARM, AUS, AUT, AZE, BDI, BEL, BEN, BFA, BGD, BGR, BHR, BIH, BLR, BLZ, BMU, BOL, BRA, BRB, BRN, BTN, CAF, CAN, CHE, CHL, CHN, CIV, CMR, COG, COL, COM, CPV, CRI, CUB, CYP, CZE, DEU, DJI, DMA, DNK, DOM, DZA, ECU, EGY, ERI, ESP, EST, ETH, FIN, FJI, FRA, GAB, GBR, GEO, GHA, GIN, GMB, GNB, GNQ, GRC, GRD, GTM, GUY, HKG, HND, HRV, HTI, HUN, IDN, IND, IRL, IRN, ISL, ISR, ITA, JAM, JOR, JPN, KAZ, KEN, KGZ, KHM, KNA, KOR, KWT, LAO, LBN, LBY, LCA, LKA, LTU, LVA, MAC, MAR, MDA, MDG, MDV, MEX, MKD, MLI, MLT, MMR, MNG, MOZ, MRT, MSR, MUS, MWI, MYS, NER, NGA, NIC, NLD, NOR, NPL, NZL, OMN, PAK, PAN, PER, PHL, PLW, PNG, POL, PRT, PRY, PYF, QAT, RUS, RWA, SAU, SDN, SEN, SGP, SLB, SLV, SUR, SVK, SVN, SWE, SYC, SYR, TCD, TGO, THA, TJK, TKM, TON, TTO, TUN, TUR, TZA, UGA, UKR, URY, USA, UZB, VCT, VEN, VNM, VUT, YEM, ZAF, ZMB, ZWE