Revisiting the Revisited: An Alternative Test of the Monopolistic Competition Model of International Trade

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Abstract

This paper proposes an alternative test of the monopolistic competition model of international trade that has an implication for the relationship between the volume of trade and similarity among trading countries in the size of the economy. In the existing literature the model's implication has been tested for aggregate trade, which includes the sectors that are not characterized by product differentiation. In contrast, this paper focuses on trade of differentiated products that the monopolistic competition model directly aims to describe, and derives an equation predicting that the volume of trade *in the differentiated sectors* will be larger as the trading countries are more similar in GDP *and more symmetric in production structure*. This prediction is tested using disaggregated data on trade and manufacturing production, employing a non-linear estimation method to handle zero-trade observations.

The result shows that the predicted positive correlation between the volume of trade and the size similarity among countries is significant for both aggregate and differentiated sectors, regardless of whether the trade is among OECD or non-OECD countries. This result, contrary to Debaere's (2005) conclusion, brings us back to the puzzle presented by Hummels and Levinsohn (1995). Moreover, the proposed alternative approach in this paper demonstrates the following: (i) trade in the differentiated sectors among OECD countries is very well explained by the monopolistic competition model; however, (ii) for non-OECD countries, the predicted relationship between the volume of trade and the (adjusted) size similarity among countries is more pronounced in the *non*-differentiated sectors than in the differentiated sectors, which is counter to what the model suggests. The second point suggests that trade flows among non-rich countries may be driven or crucially influenced by some other mechanism than what is described by the monopolistic competition model.

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1. Introduction

New Trade Theory is characterized by a model of international trade with monopolistic competition among the varieties of differentiated products in an industry. This theory was originally motivated by the fact that a large part of international trade is intra-industry rather than inter-industry,[1, 2] a characteristic that neo-classical trade theory such as the Heckscher-Ohlin (H-O) Model or the Ricardian Model cannot explain. The monopolistic competition models of international trade, first presented in the works of Krugman (1979, 1980) and Helpman (1981), have been widely employed and applied in numerous studies of international trade.

This type of model has implications for the volume of trade; in particular, as Helpman and Krugman (1985, Chapter 8) have demonstrated, the volume of trade among a group of countries, as a share in the total income of the country group, will be larger as the sizes the economies of individual countries in the group are more similar to each other. In other words, if two regions have the same total sizes of their economies and consist of the same number of countries, the region in which countries are more equal in GDP will trade more within that region.

Although this theoretical implication is clear-cut and has an empirically testable form, only a few studies have directly examined this implication empirically. Helpman (1987) employed time-series data on 14 OECD countries and graphically showed the positive relationship between the volume of trade among the countries as a fraction of their total GDP and the similarity in their respective GDPs. Hummels and Levinsohn (1995) performed more formal empirical tests using panel data on bilateral trade flows between pairs of the same 14 OECD countries, as well as those of another 14 non-OECD countries. They expected that the data on

[1] The significance of intra-industry trade has been reported by, for example, Grubel and Lloyd (1975).
[2] On the other hand, it is debated in literature whether such intra-industry trade, or “trade overlap,” observed in the data is a matter of the aggregation of sectors or commodities. See Finger (1975).

trade between the OECD countries would fit the monopolistic competition model while it would not be the case for trade between the non-OECD countries, because the former was likely to be more intra-industry trade of horizontally differentiated products[3] that the theoretical model considers, while the latter did not seem to be characterized as such. Their results, however, showed that GDP similarity between two trading countries well explained the volume of bilateral trade between them, both for the OECD and non-OECD countries, which left a puzzle. Debaere (2005) re-examined the study by Hummels and Levinsohn, and claimed that their empirical approach may not have been able to properly assess the impact of the income similarity on bilateral trade, and this was why their results were puzzling. He thus presented a modified equation explaining the relationship between the volume of trade and GDP similarity between countries, and estimated it using updated data for the same set of OECD and non-OECD countries. From the estimation results he concluded that positive correlation between the volume of trade and size similarity among trading countries was significant only for the OECD countries but not for the non-OECD countries, and thus the puzzle was not present any more.[4]

These studies attempted to test the monopolistic competition model in the context of *aggregate* trade, which includes all types of traded goods. However, not all goods that are internationally traded are differentiated products, and the trade of those non-differentiated products may be driven by other mechanisms than the one that is described by the monopolistic competition model. In fact, to expand the tested implication—that the volume of trade will increase as trading economies become more equal in size—to the level of aggregate trade, they assumed that all industries were internally differentiated in terms of product varieties, or

[3] In literature two types of product differentiation are distinguished: horizontal product differentiation and vertical product differentiation. The former arises when products of a similar quality vary in certain characteristics, while the latter arises when products differ in quality. The product differentiation discussed in the current paper is horizontal differentiation, which the monopolistic competition model considers.
[4] The appendix reviews the work by Hummels & Levinsohn (1995) and by Debaere (2005).

alternatively that perfect specialization of production took place in every sector. These assumptions are very restrictive and thus may not be realistic.

In this paper, I propose an alternative empirical approach to testing the implication of the monopolistic competition model for the volume of trade among countries. The key is to focus on the trade of differentiated products. I review the model and derive the equation for the volume of bilateral trade of differentiated products without imposing such restrictive assumptions as those mentioned above. The derived alternative equation suggests that the simple GDP similarity between trading economies does not predict the volume of bilateral trade of differentiated products. The equation, however, implies that the volume of bilateral trade of differentiated products, as a share in the domestic production of these products in the two trading countries, will be proportional to the two countries' GDP similarity *adjusted for how symmetric the countries are in their production structure*. In other words, the volume of trade of differentiated products between two countries will be larger as the countries are more similar in GDP, as well as in the share of the differentiated sectors in GDP.

This implication must be tested with data on trade and production in the sectors of differentiated products. Therefore, in addition to data on aggregate trade and GDP such as those used in the previous studies, I employ disaggregated data on trade and production in manufacturing industries for a range of countries. I also use the information on product characteristics classified by Rauch (1999) to define the "differentiated sectors." Furthermore, to handle zero-trade observations in the data, I apply non-linear estimation methods in addition to the benchmark OLS estimation of log-linear forms of the volume-of-trade equations.

The empirical analysis, especially the result of the estimation with a non-linear method that handles zero-trade observations, shows that the tested implication of the monopolistic competition model—that the volume of bilateral trade per production will be larger as two trading countries are more similar in GDP and more symmetric in production structure—is supported by the data for both OECD and non-OECD countries, not only for the differentiated-sector trade but also for aggregate trade. Therefore, in terms of the relationship between the volume of trade and the size similarity, we go back to Hummels and Levinsohn's puzzle, contrary to Debaere's conclusion. However, using a unique approach that separates trade of differentiated products from aggregate trade, this paper also demonstrates two other things: (i) bilateral trade flows among OECD countries, especially in the sectors of differentiated products, are well explained by the monopolistic competition model; but (ii) trade flows among non-OECD countries are not equally well-explained by the model. This finding suggests that there should be some other mechanism that makes trade patterns among lower-income countries different from those among rich countries.

This study offers some insight for a series of empirical studies on the gravity equation, to which the monopolistic competition model provides a theoretical basis. Most studies have estimated the gravity equation for aggregate trade. For example, Feenstra, Markusen and Rose (2001), Evenett and Keller (2002), and Haveman and Hummels (2004) use the gravity equation for aggregate trade to test which theory of international trade is the most likely to explain the actual trade flows, following Deardorff (1998) pointing out that multiple trade theories can derive the gravity equation. The point of Feenstra et al. is the existence of a home-market effect that may distinguish the monopolistic competition model from others, while Evenett and Keller, as well as Haveman and Hummels, focus on the elasticity of national income with respect to the volume of trade, which will be smaller than unity if specialization in production is incomplete. However, aggregate trade involves the trade of various products, some of which the monopolistic competition model fits well, but others may be characterized by product homogeneity and incomplete specialization; thus all trade should not be explained by a single model in a unified manner.[5] In contrast, Harrigan (1994) and Jensen (2000) have estimated the gravity equation at the sectoral level using data on trade and production in manufacturing industries.[6] They, however, do not explicitly consider differences in product characteristics (differentiated versus homogeneous) across manufacturing industries, to which this paper pays careful attention.[7]

The remainder of this paper is organized as follows. The next section derives the equation explaining the volume of trade in the differentiated sectors, and discusses its implication in comparison with the equation for aggregate trade that has been used in the existing literature. The section presenting the empirical approaches follows. The data employed for the empirical analysis are described in section four. The results of the analysis are presented and discussed in the fifth section, which is followed by the concluding section.

2. Monopolistic Competition Model and Volume of Trade

In this section, to account for the volume of trade I derive two formulas from the monopolistic competition model of international trade introduced by Helpman and Krugman (1985, Chapters 6-8). This model is characterized as follows: (i) some sectors have a number of product varieties (I hereinafter call these sectors "differentiated sectors"); (ii) each of the product

[5] Feenstra, Markusen and Rose also divide trade into three categories according to Rauch (1999) to estimate their gravity equation, but the explanatory variables are for the aggregate; i.e., GDPs of exporter and importer countries.
[6] Harrigan introduces a variety of proxies for scale economies in his equation to see whether the home-market effect would be significant, which would indicate a monopolistic competition rather than Armington preference for national varieties. Jensen's interest is in the size of the estimated elasticity of volume of imports to the importer's income.
[7] Other empirical work such as Anderson and van Wincoop (2003) carefully derives a structural gravity-type equation from a generalized monopolistic competition model, but due to the unobservability of variables, their attention is limited to a certain factor such as distance or trade cost. Lai and Zhu (2004), on the other hand, have made an extended effort to measure as many variables as possible to estimate their structural and generalized volume-of-trade equation with data.

varieties in a differentiated sector is produced monopolistically competitively by a single firm; and (iii) consumers throughout the world have identical preferences that are characterized by a two-tier utility function: the upper-tier utility is homothetic, and the sub-utility over product varieties within a sector takes a CES functional form.

Here I consider an equilibrium of frictionless trade so that the price of each good or horizontally differentiated product is equal throughout the world. In this free-trade equilibrium, every product *in the differentiated sectors* produced in each country will be divided among all consumers worldwide, according to their share of world income. The volume of exports from one country to another is thus expressed as follows:

$$EX_i^j = \sum_{s \in D} y_j p_s Q_{s,i} + \sum_{s \in H} EX_{s,i}^j \,, \qquad (1)$$

where D: group of the differentiated sectors;
H: group of homogeneous sectors;
i, j: scripts for countries ($i \neq j$);
$EX_{s,i}^j$: exports from Country i to Country j in Sector s;
$Q_{s,i}$: Country i's production in Sector s;
p_s: equilibrium price of (differentiated) products in Sector s
y_j: Country j's GDP share in the world (= Y_j/Y_w)

Note that the volume of trade between a specific pair of countries in the sectors of homogeneous products (or "homogeneous sectors"), $EX_{s,i}^j$ for $s \in H$, is indeterminate. That is, although a country will export a homogeneous product when the amount of the product that the country domestically produces is greater than the amount it consumes, how much of the country's product will be exported to which country(ies) cannot be determined because, in the free-trade equilibrium, importing countries will be indifferent about from which country(ies) they import the homogeneous product to supply their domestic demand.

Aggregate volume of trade

The version of the formula for the *aggregate* volume of trade, which has been employed in studies such as Helpman (1987), Hummels and Levinsohn (1995), and Debaere (2005), further assumes the following:

(A1) Each country in the world is also completely specialized in production in the homogeneous sectors. That is, every homogeneous product is produced by no more than one country. Under this assumption, any product produced by a sole producer country (i.e., a sole exporter) will be imported by all other countries, and how much each country imports will be determined according to the country's share of world income. Therefore, no indeterminacy will be left for the quantities of bilateral trade, and the volume of exports in both homogeneous and differentiated sectors from Country *i* to Country *j* is expressed as follows:

$$EX_i^j = \sum_{s \in D,H} y_j p_s Q_{s,i} \ .$$

(A2) Products in any sector are tradable, i.e., there exist no non-traded sectors.[8] Under this assumption, the aggregate value of a country's production over the sectors equals its income, or GDP. That is;

$$\sum_{s \in D,H} p_s Q_{s,i} = Y_i ;$$

$$EX_i^j = y_j Y_i$$

where Y_i is GDP of Country *i*.

Therefore, following Helpman (1987), the *aggregate* bilateral trade volume between Countries *i* and *j* is expressed as follows:

[8] This assumption (A2) can be replaced with the following weaker assumption to derive Equation (2A) below. (A2'): Every country has an equal share of non-traded sectors in its GDP.

$$VT_{ij} \equiv EX_i^j + EX_j^i = y_j Y_i + y_i Y_j = 2Y_i Y_j / Y_w = y_{ij} \cdot 2(Y_i Y_j / Y_{ij})$$

$$\Leftrightarrow VT_{ij} / Y_{ij} = y_{ij}[1 - (Y_i / Y_{ij})^2 - (Y_j / Y_{ij})^2]$$

where $Y_{ij} = Y_i + Y_j$: Country *i-j* pair's total GDP

$y_{ij} = Y_{ij}/Y_w$: Country *i-j* pair's share of world GDP

The term in the square brackets on the right-hand side of the second equation indicates the similarity of GDPs, or the similarity of the sizes of the economy, of two trading countries. This term takes a greater value as the size of the two countries become more equal, and takes the maximum value of 0.5 when the two countries are exactly equal in GDP; i.e., $Y_i/Y_{ij} = Y_j/Y_{ij} = 1/2$.[9] Using this index of size similarity,[10] the equation is expressed as follows:

$$VT_{ij} / Y_{ij} = y_{ij} \cdot sim_{ij}, \tag{2A}$$

where $sim_{ij} = [1 - (Y_i / Y_{ij})^2 - (Y_j / Y_{ij})^2]$.

This Equation (2A) implies that the volume of *aggregate* bilateral trade, as a share in the total income (GDP) of the two trading countries, will be greater as their respective national incomes are more similar.

Volume of Trade in the Differentiated Sectors

The two assumptions A1 and A2 are very restrictive. Since Equation (2A) can be derived only with these restrictive assumptions, its validity should be limited accordingly. However, by focusing our attention on the differentiated sectors, it is possible to derive an alternative formula that can explain the volume of trade in such sectors in a similar way but without imposing these assumptions. Since countries are considered to be completely specialized in production of unique

[9] Note that $Y_j/Y_{ij} = 1 - Y_i/Y_{ij}$. In theory, this index takes the minimum value of zero when two countries are completely dissimilar in GDP; i.e., $Y_i/Y_{ij} = 0$ and $Y_j/Y_{ij} = 1$, or vice versa.

[10] Helpman (1987), as well as Hummels & Levinsohn (1995), calls this term the "dispersion" index, while Debaere (2005) names it the "similarity" index. I follow the latter since this index being larger means two countries being more similar in income.

varieties in the differentiated sectors, by taking the first term of Equation (1), export from Country *i* to Country *j* in the differentiated sectors is described as follows:

$$EX_i^{j,D} = \sum_{s\in D} y_j p_s Q_{s,i} = y_j X_i^D ,$$

where $EX_i^{j,D}$: export in the differentiated sectors from Country *i* to Country *j*

X_i^D: *value* of Country *i*'s domestic production in the differentiated sectors:

$$X_i^D \equiv \sum_{s\in D} p_s Q_{s,i} .$$

Therefore, the volume of trade *in the differentiated sectors* between Countries *i* and *j* is expressed as follows:

$$VT_{ij}^D = EX_i^{j,D} + EX_j^{i,D} = y_j X_i^D + y_i X_j^D = y_{ij}\{(Y_j/Y_{ij})\cdot X_i^D + (Y_i/Y_{ij})\cdot X_j^D\}$$

$$\Leftrightarrow \frac{VT_{ij}^D}{X_{ij}^D} = y_{ij}\left(1 - \frac{X_i^D}{X_{ij}^D}\cdot\frac{Y_i}{Y_{ij}} - \frac{X_j^D}{X_{ij}^D}\cdot\frac{Y_j}{Y_{ij}}\right) = y_{ij}\left[1 - \left(\frac{X_i^D/Y_i}{X_{ij}^D/Y_{ij}}\right)\cdot\left(\frac{Y_i}{Y_{ij}}\right)^2 - \left(\frac{X_j^D/Y_j}{X_{ij}^D/Y_j}\right)\cdot\left(\frac{Y_j}{Y_{ij}}\right)^2\right],$$

where VT_{ij}^D: volume of trade in differentiated sectors between Countries *i* and *j*

X_{ij}^D: Countries *i* and *j*'s total domestic production in the differentiated sectors ($X_{ij}^D \equiv X_i^D + X_j^D$).

The term in the square brackets in this equation is similar to the size similarity index in Equation (2A) for aggregate trade, but this term depends not only on two countries' relative income sizes but also on the sizes of production in the differentiated sectors of the countries (X_i^D, X_j^D). The GDP share term for each country ($(Y_i/Y_{ij})^2$ or $(Y_j/Y_{ij})^2$) is "weighted" by the term $(X_i^D/Y_i)/(X_{ij}^D/Y_{ij}^D)$, and this "weight" term indicates how large the share of the differentiated sectors in GDP is in each country, relative to the overall GDP share of the differentiated sectors in the two countries. In other words, this term indicates GDP similarity between two countries *adjusted for how symmetric the two countries are in their production structure*. This term takes a larger value as two countries are more similar in the size of their economies *and* more symmetric in production structure. I thus call this term the *production structure-adjusted size* (or *GDP*) *similarity*, and re-write the equation as follows:

$$VT_{ij}^D / X_{ij}^D = y_{ij} \cdot sim_{ij}^* \qquad (2D)$$

$$\text{where} \quad sim_{ij}^{*} = \left[1 - \left(\frac{X_i^D / Y_i}{X_{ij}^D / Y_{ij}} \right) \cdot \left(\frac{Y_i}{Y_{ij}} \right)^2 - \left(\frac{X_j^D / Y_j}{X_{ij}^D / Y_{ij}} \right) \cdot \left(\frac{Y_j}{Y_{ij}} \right)^2 \right].$$

Equation (2D) implies that the volume of bilateral trade *in the differentiated sectors*, as a share in the two countries' *total production* in those sectors, is predicted by the size similarity between the two trading countries *adjusted for how symmetric their production structures are*. That is, two countries will trade more in the differentiated sectors as the two countries are more similar in GDP and more symmetric in production.

Discussion on Production Structure-adjusted Size Similarity

As mentioned above, the volume of bilateral trade in the differentiated sectors, as a share in the two countries' domestic production in those sectors, is proportional to the similarity in size between the countries that is adjusted for the symmetry of the country pair's production structure. This adjusted index of GDP similarity takes a larger value as two trading countries are more similar in GDP and more symmetric in production structure. This is true in general, i.e., for more common cases in which a country with larger GDP is a larger producer in the differentiated sectors than the other country.[11] However, this index is in fact even greater for less common cases in which a country with *smaller* GDP is a larger producer in the differentiated sectors;[12] i.e., the two countries are dissimilar or asymmetric in an extreme manner.[13, 14] This is because, according to the monopolistic competition model of trade, a trade flow between countries will be larger when the exporter has larger production and the importer has larger income. Therefore,

[11] For instance, one country has 70% of two countries' total GDP and 60% of their differentiated-sector production.
[12] For example, one country has 30% of two countries' total GDP and 80% of their differentiated-sector production.
[13] In fact, in such a case the adjusted similarity index takes a value over 0.5 and up to 1, compared to the case in which two countries are perfectly similar and symmetric ($sim^* = 0.5$).
[14] In the data used in the current study, the number of such uncommon cases for the OECD countries is 228 out of the total 3,630 observations; and 2,144 out of 14,565 for the non-OECD countries. See Section 4 for the detailed description of the data.

having the sizes of GDP and sectoral production adjusted (or normalized), the trade flow in the sector will be larger when one country imports the whole domestic production of the other country (for a hypothetical case in which one country has 100% of a country pair's GDP but no production in the considered sector, while the other country has zero income but 100% of the country pair's production in that sector), rather than when two countries exchange a half of their respective production (for another hypothetical case in which two countries are exactly equal in both GDP and sectoral production).

3. Empirical Approaches to Estimate Volume-of-Trade Equations

In this section, I describe empirical specifications to estimate the volume-of-trade equations derived in the preceding section, to test how well bilateral trade is explained by the size similarity of two trading economies. Each approach is taken to estimate both Equation (2A) for aggregate trade and Equation (2D) for trade in the differentiated sectors. The results of the estimation from each approach, which is presented in the fifth section, are compared to examine how the proposed alternative model for the differentiated-sector trade differs from the conventional model for aggregate trade.

OLS Estimation of Log-linearized Form

As a benchmark, I first estimate the volume-of-trade equations in a log-linearized form by the OLS. Recalling Equations (2A) and (2D), but also considering other potential factors that may affect bilateral trade flows:[15]

$$VT_{ijt} / Y_{ijt} = sim_{ijt}^{\beta_1} \cdot y_{ijt}^{\beta_2} \cdot \mu_{ij} \cdot \varepsilon_{ijt} \tag{2A'}$$

[15] Since panel data are used for the estimation, here and in the rest of this paper, variables in the equations are expressed with script *t* to denote a time period.

$$VT^D_{ijt} / X^D_{ijt} = {sim^*_{ijt}}^{\beta_1} \cdot {y_{ijt}}^{\beta_2} \cdot \mu_{ij} \cdot \varepsilon_{ijt} \quad \text{(2D')}$$

Although the underlying monopolistic competition model explains a core mechanism determining the volume of trade as Equations (2A) and (2D) suggest (with both β_1 and β_2 equaling one), real trade flows may be affected by other factors. For example, the literature on the gravity equation suggests that bilateral trade flows will be affected by geographic factors such as distance, border sharing, and commonness of language. The term μ_{ij} is included in the equations to capture these factors that are specific to country pairs, as well as other unobserved potential country pair-specific (but time-invariant) factors affecting bilateral trade flows. The last term ε_{ijt} captures idiosyncratic disturbances to recorded trade flows or measurement errors in data, which are assumed to be log-normally distributed. Taking the logarithm of both sides of the two equations (2A') and (2D') yields the following linearized equations:

$$\log(VT_{ijt} / Y_{ijt}) = \beta_1 \cdot \log(sim_{ijt}) + \beta_2 \cdot \log(y_{ijt}) + \mu_{ij} + \varepsilon_{ijt} \quad \text{(3A)}$$

$$\log(VT^D_{ijt} / X^D_{ijt}) = \beta_1 \cdot \log(sim^*_{ijt}) + \beta_2 \cdot \log(y_{ijt}) + \mu_{ij} + \varepsilon_{ijt} \quad \text{(3D)}$$

Equation (3A) for the volume of aggregate bilateral trade is the same as the main empirical specification that is employed by Debaere (2005).[16] Equation (3D), which is designed to account for the volume of bilateral trade *in the differentiated sectors*, is an alternative empirical approach that this paper proposes. Both equations are estimated by OLS regression with country pair-specific dummies (μ_{ij}). Year-specific dummies are also included for the estimation in order to capture any trend in or shocks to trade flows that are common for all countries in the world.

[16] See Appendix for more details of the empirical approach of Debaere (2005), as well as Hummels and Levinsohn (1995).

Equations (3A) and (3D) are estimated separately for the samples of OECD and non-OECD countries.[17] This is to examine whether trade among OECD countries and trade among non-OECD countries are equally well explained by the volume-of-trade equations, following the studies by Hummels and Levinsohn (1995) and Debaere (2005). These studies separated a group of OECD countries from that of non-OECD countries for estimation, based on the understanding that intra-industry trade of differentiated products, which the monopolistic competition model primarily aims to explain, is dominant in trade among OECD countries, while trade among non-OECD countries should not be mainly characterized by horizontal product differentiation. Their expectation was thus that the aggregate version of the volume-of-trade equation (3A) would describe bilateral trade well for OECD countries but not for non-OECD countries. Although Hummels and Levinsohn found a result that was counter to this expectation (i.e., the data support the model for both country groups), Debaere's re-examination found empirical support for the model only for OECD countries, as initially expected. In contrast, the current study focuses on trade of differentiated products, which the monopolistic competition model aims to explain for any country group. Therefore, it is expected that the proposed equation (3D) for the differentiated-sector trade should explain both trade among OECD countries and trade among non-OECD countries equally well, while the conventional equation (3A) for aggregate trade would not.

An empirical issue here in estimating Equations (3A) and (3D) is the treatment of zero-trade observations. A considerable number of country pairs in both OECD and non-OECD groups have no bilateral trade in the differentiated sectors in certain years. In the data used in this study, observations with no differentiated-sector trade are less than one percent of all the observations in the OECD sample, while such zero-trade observations comprise more than 60%

[17] See the next section for the list of the countries included in each sample.

in the non-OECD sample.[18] For the estimation of the log-linear equations, these zero-valued observations bring the problem of undefined logarithmic values in the left-hand side. To handle this problem, for the benchmark estimation I (i) omit such zero-trade observations and use only observations with positive differentiated-sector trade; but also (ii) include these zero-trade observations for estimation by replacing zero with a very small positive number.[19, 20]

Non-linear Model for Zero-trade Observations: Poisson Quasi-maximum Likelihood Estimation:

Although replacing zero with a small positive number has been a convention in estimating a logarithmic form, it is not ideal. It is more desirable if there exists an other appropriate alternative estimation method that can treat zero in the value of trade as it is. Hummels and Levinsohn (1995) estimated (by the OLS) their volume-of-trade equation in a level form, instead of a logarithmic form, for their non-OECD sample to avoid omitting zero-trade observations. Debaere (2005) also employed similar level specifications[21] and estimated the equations by the Tobit method to keep zero-trade observations in his non-OECD data. The cost of using such level forms of the equation was that (i) they had to give up estimating separately the impact of the two variables of interest, the country pair's size similarity and the country pair's share of the world GDP; or (ii) as in one of Debaere's two level specifications, for separate estimation of the effects of the two variables they had to abandon the strict consistency of a

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[18] The details of the data are described in the next section.

[19] Debaere (2005) also applies a similar procedure to handle zero-trade observations in estimating his log-linear model.

[20] This number must be at least smaller than the minimum non-zero value of trade in the used data. The minimum value of the bilateral trade per production (VT^D_{ijt}/X^D_{ijt}) in the data is 9.4e-9, and I thus chose 10^{-9} (1.0e-9) for the positive small number replacing zero.

[21] The level forms of the volume-of-trade equation in the two studies are not the same. Hummels and Levinsohn (1995) used the value of (aggregate) trade (VT_{ij}) as the dependent variable, while Debaere (2005) employed the volume of aggregate trade as the share in GDP (VT_{ij}/Y_{ij}). Hummels and Levinsohn's approach thus left the term of the country pair's GDP (Y_{ij}) in the right-hand side of the equation, about which Debaere argued in terms of its relevance for assessing the impact of the size similarity between trading countries.

regression equation with the theoretical monopolistic competition model. (See Appendix for further details of the empirical approaches of Hummels and Levinsohn (1995) and Debaere (2005).)

In the current paper, I employ an alternative method to handle zero-trade observations, which can both maintain the structural consistency of the regression equation with the theoretical model and separately estimate the impacts of the two variables of interest. The alternative is the (fixed-effect) Poisson quasi-maximum likelihood (PQML) estimation. The Poisson regression is usually applied for count data, but it is also applicable to non-negative continuous variables. Hausman, Hall and Griliches (1984) developed the conditional fixed-effect PQML method in the panel data context, which has been shown by Wooldridge (1999) to be consistent and robust across distributional assumptions when the conditional mean of the dependent variable is an exponential-class function of the linear combination of regressors.[22] The PQML method has also been applied to the estimation of the gravity equation by Silva and Tenreyro (2006) for cross-sectional data and by Westerlund and Wilhelmsson (2006) for panel data. These studies have shown by simulation that with zero-trade observations the PQML method has the advantage of smaller potential estimation bias compared to the OLS estimation of a logarithmic form of the equation. I thus employ the PQML method and estimate the following form of the volume-of-trade equations:

$$VT_{ijt} / Y_{ijt} = sim_{ijt}^{\beta_1} \cdot y_{ijt}^{\beta_2} \cdot \mu_{ij} + \varepsilon_{ijt}$$

$$\Leftrightarrow VT_{ijt} / Y_{ijt} = \exp[\beta_1 \cdot \log(sim_{ijt}) + \beta_2 \cdot \log(y_{ijt}) + \mu_{ij}] + \varepsilon_{ijt} \qquad \text{(4A)}$$

[22] That is, $E[y|\mathbf{x}] = \alpha \cdot \exp(\mathbf{x\beta})$ where y is the dependent variable, $\mathbf{x}$ is the vector of regressors, $\boldsymbol{\beta}$ is the vector of coefficients, and α is a scalar.

$$VT_{ijt}^{D} / X_{ijt}^{D} = sim_{ijt}^{*\ \beta_1} \cdot y_{ijt}^{\ \beta_2} \cdot \mu_{ij} + \varepsilon_{ijt}$$

$$\Leftrightarrow VT_{ijt}^{D} / X_{ijt}^{D} = \exp[\beta_1 \cdot \log(sim_{ijt}^{*}) + \beta_2 \cdot \log(y_{ijt}) + \mu_{ij}] + \varepsilon_{ijt} \qquad (4D)$$

The main difference from the benchmark log-linear form (3A) or (3D) is that in the above form the stochastic error term ε_{ijt} is additive, instead of multiplicative as in Equations (2A') and (2D').

Tobit Estimation of Log-linearized Form

For the purpose of robustness check of the OLS estimation of the log-linear form, I also apply the Tobit regression to estimate the volume-of-trade equations. Even for the Tobit estimation, zero-trade observations in the data bring the issue of the undefined logarithm of zero in principle. However, in the specific data used in the current study,[23] bilateral trade is recorded in thousands of U.S. dollars, and thus no (or zero) value is recorded when the value of bilateral trade is less than \$500 (rounded to zero thousands). Using this feature of the employed data, I apply the Tobit estimation to the following log-linear specification, which is slightly different from Equations (3A) and (3D):

$$\log(VT_{ijt}) = \log(Y_{ijt}) + \beta_1 \cdot \log(sim_{ijt}) + \beta_2 \cdot \log(y_{ijt}) + \mu_{ij} + \varepsilon_{ijt} \qquad (5A)$$

$\log(VT_{ijt}) = \log(VT_{ijt}^{*})$ if $VT_{ijt}^{*} > 0.5$ (\$500)

$\log(VT_{ijt}) = \log(0.5)$ if $VT_{ijt}^{*} \leq 0.5$ (\$500)

$$\log(VT_{ijt}^{D}) = \log(X_{ijt}^{D}) + \beta_1 \cdot \log(sim_{ijt}^{*}) + \beta_2 \cdot \log(y_{ijt}) + \mu_{ij} + \varepsilon_{ijt} \qquad (5D)$$

$\log(VT_{ijt}^{D}) = \log(VT_{ijt}^{D*})$ if $VT_{ijt}^{D*} > 0.5$ (\$500)

$\log(VT_{ijt}^{D}) = \log(0.5)$ if $VT_{ijt}^{D*} \leq 0.5$ (\$500)

[23] The details of the employed trade data are described in the next section.

where VT_{ijt} or VT_{ijt}^{D} is the observed or recorded value of bilateral trade in the data, while VT_{ijt}^{*} or VT_{ijt}^{D*} is the underlying actual trade value.[24] The following two things should be noted for this estimation approach. First, a country pair's total production (X^{D}_{ijt} in the differentiated-sector equation or Y_{ijt} in the aggregate equation) is now moved from the denominator of the left-hand side to the right-hand side of the equation. The variable is thus included as one of the regressors, but the coefficient for this variable is restricted to be one for estimation. Secondly, all the zero values for bilateral trade in the data are replaced with $500 or 0.5 in thousands of dollars.

4. The Data

To estimate Equations (3A) and (3D) through (5A) and (5D) presented in the previous section, data on trade, GDP, and industrial production have been collected for various countries.

The data on bilateral trade are from the NBER-Statistics Canada Trade Data compiled by Feenstra, Lipsey, and Bowen (1997) for the period 1970-1992, and the UCD-Statistics Canada Trade Data that is compiled by Feenstra (2000) to supplement for the period up to 1997. The dataset contains trade flows between each pair of countries. Goods in the trade flows are classified according to the four-digit Standard International Trade Classification (SITC, Revision 2). The value of each trade flow is recorded in thousands of nominal U.S. dollars.

The data on GDP measured in current U.S. dollars are from the World Development Indicators (World Bank, 2005). Both GDP of each country and the world total GDP have been collected to compute the world income (GDP) share of each country pair (y_{ij}).[25]

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[24] It should be noted that the unconditional fixed-effect Tobit model will generally be biased due to the problem of incidental parameters (Hsiao, 2003; pp.48-9, 243).

[25] Note that the world GDP (Y_w) in this study also counts GDP of countries that are not included in the sample, and thus is greater than the sum of GDP of the 89 sample countries.

The data on industrial production are from the United Nation's Industrial Statistics Database (INDSTAT3; UNIDO, 2003), which contains the annual data on manufacturing production in countries for the years of 1960-2000. Manufacturing industries are classified according to the three-digit International Standard Industrial Classification (ISIC, Revision 2). The data on gross output in nominal U.S. dollars are used.

The data for the current study cover 89 countries for the years 1970 through 1997. These countries all have population above one million as of the year 1997. The countries are divided into two groups, OECD countries and non-OECD countries, according to the actual OECD membership as of the year 1973.[26] As a result, the data include 20 countries (190 bilateral pairs) in the OECD group and 69 countries (1,808 pairs[27]) in the non-OECD group. Table 1 lists the countries and years included in the data for each group. The bilateral trade flows between the OECD countries represent 33.8% of the world total flows on average over the period 1970-1997 (with an annual share ranging 0.3% through 62.0%); and the flows between the non-OECD countries represent 1.0% on average over the period (with an annual share ranging 0.5% through 1.5%). The panel data are kept unbalanced to retain as many observations in the data as possible.[28]

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[26] 1973 is the year in which New Zealand joined the OECD. New Zealand was the newest member until Mexico joined in 1994.

[27] The number of country pairs in the data is less than ${}_{69}C_2 = 2{,}346$. This is because the 69 countries include countries that appear in the data as one of a country pair in any year(s), while some country pairs have no years for which production or GDP data are available for both countries. For instance, the data for Mexico are available only for 1994-97 while the data for Hong Kong are available only for 1973-90. As a result, bilateral trade between these two countries is not included in the data for any year.

[28] I cannot make the panel balanced for the entire 190 + 1,808 country pairs for the 28 years due to the lack of data for one or more variables for some countries in some years.

Industry/commodity classifications for the production data and trade data

Since the trade data and the production data are based on different classification schemes, mapping one classification onto the other is required to merge the two datasets using a common classification.[29] In the production data 28 manufacturing industries are classified according to the three-digit ISIC, while in the trade data goods are classified into over a thousand categories according to the four-digit SITC. The mapping thus requires condensing the four-digit SITC (Revision 2) into the three-digit ISIC (Revision 2). I have mapped the trade data onto the three-digit ISIC using the concordance information sourced from the OECD, which is available on Jon Haveman's Industry Concordances web page (http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/TradeConcordances.html).[30]

Next, to separate the differentiated sectors from other (non-differentiated) sectors, I follow Rauch (1999), which classifies the four-digit SITC commodities into three categories based on the degree of product differentiation: goods traded on an organized exchange (homogeneous goods), reference priced goods, and differentiated goods. Although the production data, which are classified according to ISIC, cannot be simply mapped onto Rauch's three categories, there are ten three-digit ISIC manufacturing industries whose corresponding four-digit SITC categories are all classified as Rauch's differentiated goods. These industries are: 322 (wearing apparel), 324 (footwear), 332 (furniture), 355 (rubber products), 356 (plastic products), 361 (pottery, china, and earthenware), 362 (glass and products), 382 (non-electric machinery), 384 (transport equipment), and 385 (professional and scientific equipment). I

[29] While the ISIC for the production data is based on industrial activities, the SITC for the trade data is based on commodity characteristics. Since the two classifications are based on different principles, the mapping cannot necessarily be one-to-one.

[30] The original mapping is from the five-digit SITC to the three-digit ISIC. However, since the trade data have only the detail of the four-digit classification, I disregarded the details of the five-digit SITC in the original concordance.

therefore group these 10 three-digit industries as representative of the differentiated sectors, and accordingly compute bilateral trade and production in these differentiated sectors for each country pair for each year. These 10 differentiated manufacturing industries comprise 31.2% of the world aggregate trade on average, with the share in each year ranging from 24.3 to 37.0% during the period of 1970-1997.[31] These shares in the total trade flows among the 89 sample countries are: 41% on average with annual shares ranging 33 through 49% for the OECD countries; and 13% on average with annual shares ranging 9 through 21% for the non-OECD countries.

Zero-trade Observations

In the OECD group, while all country pairs have positive bilateral trade flows in all the 28 years, 28 out of 3,630 observations (for 190 country pairs for 28 years) have zero trade in the differentiated sectors. In the non-OECD group, 4,551 out of 14,565 observations (for 1,808 country pairs for 28 years) have no trade flows, and additional 2,798 observations have zero flows in the differentiated sectors.

Figures 1-A through 2-D plot bilateral trade per production vs the size similarity index with a trend line fitted by locally weighted regression (Lowess[32]). Figures 1-A and 1-D are for the OECD countries, and 2-A and 2-D are for the non-OECD countries. The left panels (Figures 1-A and 2-A) plot the value of aggregate trade per GDP against the index of GDP similarity between two countries (*sim_{ijt}*). The right panels (Figures 1-D and 2-D) plot the value of trade per production in the differentiated sectors against the index of production structure-adjusted GDP

[31] Note that the differentiated-sector industries are selected only from manufacturing industries.
[32] Locally weighted scatterplot smoothing. The smoothing parameter (or bandwidth) is 0.8 for the trend line in these figures.

similarity (sim^*_{ijt}). All the variables are in logarithms and mean-differenced, which correspond to the benchmark OLS estimation with dummies. The vertical and horizontal lines indicate zeros, which are the means of the mean-differenced variables. While the trend line exhibits some positive slope on all the figures, the positive relationship between the two variables does not seem to be very clear except for Figure 1-A for aggregate trade between the OECD countries.

5. Empirical Results

OLS Estimation of Log-linear Form

The results of the benchmark OLS estimation of the log-linear form of the volume-of-trade equations are presented in Tables 2 and 3. In each table, the second through fourth columns show the results for the OECD countries, and the fifth through seventh columns show the results for the non-OECD countries. For each country group, one column shows the result of the estimation of Equation (3A) for aggregate trade, and one column shows the result of the estimation of Equation (3D) for the differentiated-sector trade. For the purpose of comparison, the sectoral equation (3D) is also estimated for a group of three-digit ISIC manufacturing industries that are not included in the differentiated sector.[33] The estimation result for these "non-differentiated" sectors (indicated as "ND") is shown in another column for each country group.

The lower part of the tables shows the results of the tests, in the p-values, of the hypotheses that (i) the coefficient for the index of size similarity equals one; (ii) the coefficient for a country pair's world GDP share equals one; and (iii) these two coefficients are jointly equal

[33] The "non-differentiated" sector group consists of the following 17 three-digit ISIC industries: 311 (food products), 313 (beverages), 314 (tobacco), 321 (textiles), 323 (leather products), 331 (wood products), 341 (paper and products), 342 (printing and publishing), 351 (industrial chemicals), 352 (other chemicals), 353 (petroleum refineries), 354 (miscellaneous petroleum and coal products), 369 (other non-metallic mineral products), 371 (iron and steel), 372 (non-ferrous metals), 381 (fabricated metal products), and 383 (electric machinery). The miscellaneous category 390 is excluded from both differentiated and non-differentiated groups.

to one. These hypotheses are what the monopolistic competition model suggests when international trade is frictionless. It should be noted, however, that in reality various kinds of trade friction exist, and not all of them may be controlled for by country-pair specific dummies in the estimation. Having such trade friction, the coefficient estimates may be different from (smaller than) one even though the estimation suggests a positive and significant relationship between the volume of trade and the respective determinants.

Table 2 shows the result of the OLS estimation using observations with positive trade values but excluding zero-trade cases. In the following, to focus on the tested prediction on the relationship between the volume of bilateral trade per production and the size similarity between trading countries, I put my main focus on the estimate of the coefficient for the similarity index (β_1).[34] The result indicates that among the OECD countries the positive relationship between the volume of trade per production and the size similarity index is significant for both aggregate and differentiated-sector trade. This relationship is also positive for trade in non-differentiated sectors but less significant. In addition, the size of the coefficient estimate is the largest for the differentiated sectors ($\hat{\beta}_1$ = .858), it is smallest for the non-differentiated sectors ($\hat{\beta}_1$ = .312), and the case for aggregate trade falls in between ($\hat{\beta}_1$ = .422). The difference between the estimate for the differentiated-sector case and those for the other two cases is significant.[35] On the other hand, for the non-OECD countries, the coefficient is estimated to be positive and significant (at the 1% level) for all the three cases; but the difference in the value of the estimate is not significant across the cases.[36]

[34] The estimates of the coefficient for the countries' world GDP share (β_2) are discussed in a later subsection.
[35] The hypothesis that $\hat{\beta}_1$ is the same between the aggregate case and the differentiated-sector case is rejected at the 5% level of significance.
[36] The p-value of the test of $\hat{\beta}_1$ being equal between the differentiated-sector case (with the largest value) and the non-differentiated-sector case (with the smallest value) is 0.30.

The same equations (3A) and (3D) (, as well as (3ND)) are also estimated by OLS using all the observations with zero-trade values being replaced with a small positive number (10^{-9}). The result is shown in Table 3.[37] For the OECD countries, the overall result is the same as the previous case, except that now the estimate for the non-differentiated sector is not significant even at the 10% level. However, for the non-OECD countries, the coefficient estimate is insignificant for all the three cases.[38] The point estimate for differentiated-sector trade is larger than that in the other two cases, but the difference is not significant.[39] In other words, for the non-OECD countries, the OLS estimation of the log-linear form of the volume-of-trade equation gives a different picture depending on whether zero-trade observations are excluded or included.

Alternative Estimation of the Log-linear Form: Tobit

The Tobit estimation of the log-linear equations is also performed to see the robustness of the result when both zero- and nonzero-trade observations are included. Equations (5A) and (5D) are estimated for aggregate and differentiated-sector trade, respectively. As in the OLS estimation, Equation (5D) is also estimated for non-differentiated sectors (ND). The result is shown in Table 4. The overall picture is similar to Table 3 for the OLS estimation having zero-trade observations included, but the coefficient estimate $\hat{\beta}_1$ increases its significance in the differentiated-sector equation (5D) for both country groups. In particular, for the non-OECD countries the estimate is weakly significant (at the 10% level) in (5D) while it is insignificant in

[37] It should be noted that the result is somewhat sensitive to the choice of the small positive number for zero-trade values, except for the case of aggregate trade between the OECD countries. In particular, when a much smaller number (such as 10^{-18} or smaller) is applied, the estimate of coefficient for the similarity index (β_1) is insignificant (or its p-value exceeds 10%) for the differentiated-sector equation even for the OECD countries. On the other hand, for the non-OECD countries the result for the differentiated sectors does not qualitatively change in terms of the signs and significance of the estimates of two coefficients (β_1 and β_2).
[38] Note that the result for aggregate trade is consistent with Debaere's (2005).
[39] The p-value of the test of $\hat{\beta}_1$ being equal between the differentiated-sector case (with the largest value) and the non-differentiated-sector case (with the smallest value) is 0.22.

other two equations (5A) and (5ND).[40] This result indicates that the separation of the differentiated sectors in estimating the volume-of-trade equation, which the current paper proposes, gives evidence of the prediction of the monopolistic competition model more clearly than the conventional aggregate trade approach does.

Poisson Quasi-maximum Likelihood (PQML) Estimation

The above three estimation methods do not treat the zero value in the trade data as it is. On the other hand, the proposed estimation of Equations (4A) and (4D) by the Poisson quasi-maximum likelihood (PQML) procedure can treat zeros in observations as they are. Table 5 presents the result of the PQML estimation. Equation (4D) is also estimated for the non-differentiated sectors (ND).

The result for the OECD countries is consistent with the estimation results by the previous three methods, while the estimated coefficient for the similarity index is significant at the 1% level not only in the aggregate and differentiated-sector equations but also in the non-differentiated-sector equation. In other words, the estimation shows that among the OECD countries the positive correlation between the volume of trade per production and the adjusted size similarity is indicated even in the non-differentiated sectors. However, this may be because these non-differentiated sectors comprise manufacturing industries. These industries are excluded from the "pure" differentiated sectors, but that does not mean that products in these industries are all homogeneous. A more important thing in the estimation result is that the size of the estimated coefficient is the largest for the differentiated-sector trade, the median for the aggregate trade, and the smallest for the non-differentiated sectors. The coefficient estimate in

[40] However, the difference in the estimate across the three cases is not significant for the non-OECD countries. On the other hand, for the OECD countries, the estimate in the differentiated-sector equation is significantly larger than that in the other two cases at the 1% significance level.

the differentiated-sector equation is significantly larger than the estimate in the other two equations.[41]

For the non-OECD countries, the coefficient estimate is also significant in all the three equations (4A), (4D) and (4ND), at least at the 5% level. However, the estimate for the differentiated sector is the smallest and least significant,[42] which is counter to the expectation from the theory. In other words, the result of the PQML estimation implies that, among the non-OECD countries, the positive correlation between the volume of trade per production and the size similarity between countries is more striking as international trade contains more *non*-differentiated products.

Comparison of Four Approaches to Estimation

The above four estimation approaches give consistent results for the OECD countries, but for the non-OECD countries they provide different results from each other. To see which method describes the data, especially for the non-OECD countries, better than the others, I use the Akaike Information Criteria (AIC)[43] for the four estimation specifications. The AIC measures the goodness of fit of an empirical model, and a model with a lower AIC value is preferred to that with a higher AIC value. Table 6 compares the value of the AIC of each estimated model for the two country groups and the three versions (A, D, and ND). For any country group and any version, the estimated model by the PQML has the lowest AIC value, the OLS with only positive-trade observations gives the next lowest, the Tobit gives the third, and the estimated model by the OLS including (value-replaced) zero-trade observations has the highest AIC value.

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[41] The difference is significant at the 10% level between (4D) and (4A), and at the 5% level between (4D) and (4ND).
[42] However, the difference of the estimate between (4D) and the other two equations is not significant (the p-value is 0.15).
[43] Akaike (1974).

This comparison indicates that, for any case, the equation estimated by the PQML describes the data the best.

Summary and Discussion

As described above, the result for the OECD countries is consistent across the four estimation approaches. The estimated coefficient for the size similarity index is positive and significant not only in the differentiated-sector-trade equation but also in the aggregate-trade equation. The estimate for the differentiated sectors, however, is significantly larger than that in the other cases, and is also close to one.[44] On the other hand, the estimation for the non-differentiated sectors gives a smaller and less significant coefficient estimate than the other two cases, implying that the monopolistic competition model does not describe trade in the non-differentiated sectors as well as it does trade in the differentiated sectors. Therefore, this study, by separating differentiated (and non-differentiated) sectors from aggregate trade in estimation, clearly demonstrates that the positive correlation between the volume of trade among OECD countries and size similarity among the countries, which has been found in the previous studies, is driven by such correlation in trade of the differentiated products, as the monopolistic competition model suggests.

On the other hand, for the non-OECD countries, the results are mixed in the four approaches. Some methods estimate the coefficient for the similarity index being insignificant even in the differentiated-sector equation, but other methods estimate the coefficient being significant even for the non-differentiated sectors. However, the estimation by the PQML, which has econometric advantages (small potential estimation bias with zero-valued data) and better

[44] The p-value of the test of the hypothesis that the coefficient equals zero ranges from 0.38 through 0.85 across the four estimation procedures.

describes the data with a lower AIC value than the other three approaches, shows that the coefficient for the size similarity index is significant regardless of whether the traded sectors are differentiated or not. This result brings us back to Hummels and Levinsohn's puzzle; and also implies that Debaere's finding may be due to his way of handling zero-trade observations in estimation. Moreover, the current study deepens the puzzle. That is, the estimation indicates that for the non-OECD countries the correlation between the volume of trade and the size similarity between trading economies is weaker in the differentiated sectors than in the less differentiated sectors, while the correlation should be driven by product differentiation if the monopolistic competition model applies. The current study thus implies that some different mechanism from horizontal product differentiation may underlie the observed relationship between the volume of trade and the size similarity among these lower-income countries.

World GDP Share of Trading Countries

So far the analysis has been focused on the significance of the size similarity of two trading economies, which is one of the two determinants of the volume of trade per production in the model. In this subsection, I briefly discuss the estimation results for the other determinant: the GDP of two trading countries as a share in the world GDP (or, more simply, the country pair's world GDP share, s_{ij}). According to the monopolistic competition model, two countries' world GDP share should also be positively correlated with the volume of bilateral trade as a share in the countries' total production.

The results of the estimation from the four different approaches are as shown in Tables 2 through 5. For the OECD countries, the coefficient for the world GDP share (β_2) is insignificant in any estimation for any country group and trading sector. This result suggests that among rich countries how large trading countries are in the world may not be very important for the volume of trade per production. Exceptions, however are the estimates in the differentiated- and non-differentiated-sector equations, (4D) and (4ND), estimated by the PQML. In these cases the coefficient is estimated to be positive and significant. In particular, for the differentiated sectors the estimate is fairly large (but smaller than one) and very significant (at the 1% level). This should be additional evidence that the monopolistic competition model explains the flows of trade in differentiated sectors among rich countries. On the other hand, for the non-OECD countries, the result varies across estimations. However, in the estimation by the PQML and the log-linear OLS without zero-trade observations that give the two lowest AIC values, the coefficient is positive and significant for all sectors. This result implies that trading countries' world income share plays an important role in determining the volume of trade among non-rich countries. This finding is consistent with the study by Jensen (2000) that estimates equations for bilateral one-way trade (import or export) derived from the monopolistic competition model. He has also found that the importer's income (GDP) is not significant for trade between rich countries but significant for trade between middle-income or poor countries.[45]

Robustness Check: Alternative Groupings of Differentiated Sectors

Finally, for the purpose of checking the robustness of the estimation results, I re-estimate the volume-of-trade equations by varying criteria for selection of the group of the differentiated (and non-differentiated) sectors. The first alternative is to include in the differentiated sectors the three-digit ISIC industries in which corresponding Rauch's "differentiated" four-digit SITC

[45] However, Jensen re-estimated the coefficient by replacing country pair-specific dummies with direct measures of barriers to trade such as bilateral distance and the importing country's tariff. As a result, he found that the importer's income is rather insignificant when the importing country is poor than when the importer is a rich country, which was counter to his initial finding.

goods share more than 90% of the world trade value throughout the period of 1970-1997. This grouping adds the following three industries as differentiated sectors to the 10 industries in the benchmark grouping: 323 (leather products), 342 (printing and publishing), 383 (electric machinery). The second alternative is to include the three-digit ISIC industries that include none of Rauch's four-digit SITC goods "traded in an organized market," or homogeneous goods. The grouping further adds to the first alternative the following five industries: 313 (beverages), 352 (other chemicals), 354 (miscellaneous petroleum and coal products), 369 (other non-metallic mineral products), and 371 (iron and steel). Table 7 compares the benchmark and these two alternative groupings of the differentiated sectors by showing which three-digit ISIC manufacturing industries are included. Note that these two alternative groupings of the differentiated sectors cover broader sets of industries than the benchmark, and the second grouping includes more industries than the first.

The results of estimation by the respective four methods are presented in Tables 8.1 through 8.4 for the first alternative differentiated-sector grouping, and in Tables 9.1 through 9.4 for the second alternative grouping. The estimation results for both alternative groupings do not differ from the results of the estimation for the benchmark differentiated-sector grouping that are shown in Tables 2 through 5; and they thus confirm that the estimation results are robust across groupings of (non-)differentiated sectors.

It should also be noted that, for the OECD countries, the estimated coefficient for the size similarity is smaller in the differentiated-sector equation (D), and so is it in the non-differentiated-sector equation (ND), for the grouping with a broader range of industries (i.e., the first alternative compared to the benchmark; and the second alternative compared to the first). This finding for the OECD countries is consistent with what the model suggests, since the correlation between the volume of trade and the (adjusted) size similarity is less clear as the sectors consist of less differentiated or more homogeneous industries, in which the monopolistic competition model does not primarily aim to describe the trade. However, for the non-OECD countries, the coefficient estimate in the non-differentiated-sector equation (ND) is *larger* for a non-differentiated-sector grouping that covers *less* differentiated industries. This implies that for lower-income countries the correlation between the trade volume and the size similarity among trading economies is greater as the traded sectors are more homogeneous, which is counter to the theoretical expectation. Varying the grouping of sectors in estimation thus underlines the puzzle in the results for non-rich countries.

6. Conclusion

This paper proposes an alternative approach to testing the monopolistic competition model of international trade. The monopolistic competition model, in which the main driving force of international trade is horizontal product differentiation, suggests that the volume of trade will be larger as trading countries are more similar in the size of the economy. In the preceding studies such as Hummels and Levinsohn (1995) and Debaere (2005), this implication of the model has been tested for the relationship between aggregate trade and GDP similarity among countries, while aggregate trade includes sectors that are not characterized by product differentiation.

In contrast to the existing literature, this paper focuses on trade of differentiated products that the monopolistic competition model directly aims to describe. The paper derives the equation for the volume of trade of differentiated products under less restrictive assumptions than those required to derive the aggregate-trade equation. The derived equation predicts that the volume of trade *in the differentiated sectors* will be larger as the trading countries are more similar in GDP *and more symmetric in production structure*. This prediction is tested using the disaggregated data on trade and manufacturing production for various countries, in which industries are classified into the differentiated and non-differentiated sectors using the information on the degree of product differentiation provided by Rauch (1999). The test employs not only the conventional OLS regression for the log-linearized form of the equation but also the non-linear estimation methods such as PQML to handle zero-trade cases in the data.

The result shows that the predicted positive correlation between the volume of trade and the size similarity among countries is significant for both aggregate and differentiated sectors, regardless of whether the trade is among the OECD or non-OECD countries. This result, contrary to Debaere's conclusion, brings us back to the puzzle presented by Hummels and Levinsohn. Moreover, the proposed alternative approach in this paper reveals the following. First, for OECD countries the relationship between trade and the size similarity is shown more evidently by separating the differentiated sectors from aggregate trade, indicating that the monopolistic competition model explains very well trade in the differentiated sectors among OECD countries. Secondly, however, for non-OECD countries the predicted relationship between the volume of trade and the size similarity among countries is more pronounced in the *non*-differentiated sectors than in the differentiated sectors, which is counter to what is suggested by the model. The second point implies that trade flows among non-rich countries may be driven or crucially influenced by some other mechanism than what is described by the monopolistic competition model.

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Appendix

This appendix is to review empirical approaches of the two preceding studies; Hummels and Levinsohn (1995) and Debaere (2005). Both studies estimated some versions of the equation for the volume of aggregate bilateral trade, which are derived from the monopolistic competition model based on the two assumptions A1 and A2 described in the second section of this paper. The derivation of the equation is left to the section.

Hummels and Levinsohn (1995)

Hummels and Levinsohn estimated the following forms:[i]

for OECD countries: $$\log(VT_{ijt}) = \beta \cdot \log(Y_{ijt} \cdot sim_{ijt}) + \mu_{ij} + \varepsilon_{ijt} \qquad (*)$$

for non-OECD countries: $$VT_{ijt} = \beta \cdot (Y_{ijt} \cdot sim_{ijt}) + \eta_{ij} + \varepsilon_{ijt} \qquad (**)$$

where $sim_{ij} = [1-(Y_i / Y_{ij})^2 - (Y_j / Y_{ij})^2]$.

Some points should be noted, in terms of differences from the equation applied in the current paper. First, they used the (logarithm of) the volume of aggregate trade itself as the dependent variable, rather than the volume of trade per GDP as in Equation (3A) in this paper. A country pair's GDP, which appears as the denominator on the left-hand side in Equation (3A), was put on the right-hand side as the product term with the size similarity index in their forms. Secondly, they accordingly estimated only one coefficient for the product term of GDP and the similarity index[ii]; but did not estimate the impacts of the two factors separately. Thirdly, they assumed, as Helpman (1987) did, that the world income share of a pair of two countries would not change (at least much) across years, so that the term for the world income share (y_{ij}) was considered to be

[i] Notations are not the same as those used in the original paper.

[ii] Imposing the restriction that the coefficients for the two elements are the same is not a problem by itself, since the model suggests that the both elements are strictly proportional to the volume of trade. However, Debaere claims an econometric problem in this approach, as described later.

time-invariant and thus merged into the country pair-specific dummies η_{ij} in their equation for the OECD countries. (In the equation for the non-OECD, the time-invariant income share term was absorbed into the slope coefficient β.) They estimated the equation in the log-linear form (*) for the OECD countries but in the *level* form (**) for the non-OECD countries to keep observations with zero trade ($VT_{ijt} = 0$) in their estimation. They used balanced panel data on bilateral aggregate trade among 14 OECD countries in 1962-1983 to estimate Equation (*), and data for 14 non-OECD countries in 1962-1977 to estimate Equation (**).They applied the pooled OLS, random-effect OLS, and fixed-effect OLS regressions to both equations. In any case, they obtained an estimate for the coefficient β that was positive and significant for both country groups.

Debaere (2005)

Debaere started with a claim that the result of Hummels and Levinsohn, which was counter to the expectation for non-OECD countries, may have been driven by a high correlation between the volume of trade and GDP of country pairs rather than a correlation between trade and the size similarity of trading economies. He argued that, although the size similarity would not at all relate to, and thus be totally independent of, the volume of bilateral trade, the coefficient estimate for the product term of GDP and the similarity index ($Y_{ijt} \cdot sim_{ijt}$) would be significant if GDP (Y_{ijt}) is highly correlated to the volume of trade. This is in fact highly likely since in general the absolute volume of trade of large countries is greater than that of small countries.[iii] Therefore, he used regression equations whose dependent variable was the volume of

[iii] However, it should be noted that Hummels and Levinsohn seem to have noticed this issue by themselves. In fact, as they mentioned in their paper (Hummels and Levinsohn, 1995; pp.808, footnote 14), they also estimated an equation separating the term for income size or GDP (Y_{ijt}) from the similarity index, from which they concluded that the impact of the similarity index was still significant.

bilateral aggregate trade as the share in GDP of the country pair. His benchmark is the estimation of the log-linear equation, which was the same as Equation (3A) in this paper, by the OLS with country pair-specific and year-specific dummies. For zero-trade observations in his non-OECD data, he applies a similar “replacement method” to the one that is used in the current paper.[iv]

In addition to his benchmark log-linear form, he estimated the following two level forms of the equation for the volume of aggregate trade per GDP:

$$VT_{ijt} / Y_{ijt} = \beta \cdot (y_{ijt} \cdot sim_{ijt}) + \mu_{ij} + \varepsilon_{ijt}$$

$$VT_{ijt} / Y_{ijt} = \beta_1 \cdot sim_{ijt} + \beta_2 \cdot y_{ijt} + \mu_{ij} + \varepsilon_{ijt}$$

These equations were estimated by the OLS for OECD countries, and by the Tobit regression for non-OECD countries. (The regressions also included year-specific dummies.) For the estimation, he constructed balanced panel data on bilateral (aggregate) trade and GDP for 14 OECD countries and 12 non-OECD countries for the period of 1970 through 1989. The results of the OLS estimation of his benchmark log-linear equation led him to conclude that the monopolistic competition model was supported for OECD countries but not for non-OECD countries, as he expected (and Hummels and Levinsohn also expected initially).[v]

Countries in the Data

The table below lists countries that Hummels and Levinsohn selected for each of their OECD and non-OECD groups. The 14 countries in their OECD data are the same as those originally chosen by Helpman (1987). Debaere selected exactly the same sets of OECD and non-OECD countries as those in Hummels and Levinsohn’s study, except that he excluded Congo and Cote

[iv] See the third section of this paper.
[v] Although Debaere claimed that the results of his other estimations showed support for this conclusion, the evidence does not seem to be very clear but mixed.

d'Ivoire from the non-OECD group due to the unavailability of the data for these countries.[vi] Note that the data in the current study cover a broader range of countries for both OECD and non-OECD groups (see Table 1).

OECD countries (14)		Non-OECD countries (14*)	
Austria	Italy	Brazil	Nigeria
Belgium	Japan	Cameroon	Norway
Canada	Netherlands	Columbia	Pakistan
Germany	Sweden	Congo*	Peru
Denmark	Switzerland	Cote d'Ivoire*	Philippines
France	United Kingdom	Greece	Paraguay
Ireland	United States	South Korea	Thailand

Note: Countries marked with asterisk (*) are not included in the data used by Debaere (2005).

[vi] Hummels and Levinsohn, as well as Debaere, included Greece and Norway in their *non*-OECD group, while these two countries have been the original OECD members since 1961. In contrast, both countries are included in the OECD group for the current study.

Table 1: List of Countries and Years in Data

OECD (20 Countries)*		Non-OECD (69 Countries)			
Country	Years	Country	Years	Country	Years
Australia	1970-92	Albania	1993, 96	Morocco	1976
Austria	1970-97	United Arab Emirates	1977-78, 81	Moldova	1990-92
Belgium	1970-84	Argentina	1984-90, 93-96	Madagascar	1970-77
Canada	1970-94	Armenia	1994-97	Mexico	1994-97
Germany (West)	1971-84	Azerbaijan	1990-94	Macedonia	1990-96
Denmark	1970-91	Benin	1974-81	Mongolia	1993
Spain	1970-92	Bangladesh	1970-92, 95	Mozambique	1986-87, 91
Finland	1970-94	Bolivia	1981, 96, 97	Malawi	1970-75, 79-85
France	1970-79	Chile	1970-97	Malaysia	1970-97
United Kingdom	1970-92, 94, 95	Colombia	1970-97	Nigeria	1981-85, 91-96
Greece	1970-97	Costa Rica	1970-83, 91-97	Nicaragua	1970-85
Italy	1970-91	Dominican Republic	1970-84	Nepal	1997
Japan	1970-97	Algeria	1970-80	Oman	1994-97
Netherlands	1970-80	Ecuador	1970-97	Pakistan	1970-91
Norway	1970-91	Egypt	1970-96	Panama	1970-79, 92-95, 97
New Zealand	1970-89	Ethiopia	1981-96	Peru	1982-92, 94-96
Portugal	1970-89, 93-95	Gabon	1980-82, 91-95	Philippines	1970-97
Sweden	1970-97	Ghana	1970-87	Poland	1989-97
Turkey	1970-95	Gambia	1975-82	Russia	1993-97
United States	1970-95	Guatemala	1971-88, 91-95, 97	Saudi Arabia	1989
		Hong Kong	1973-90	Sudan	1972, 76
		Honduras	1971-75, 81-96	Senegal	1974-84, 89-90, 95, 97
		Croatia	1990-92	El Salvador	1970-85, 95-97
		Hungary	1970-97	Syria	1971-1979
		Indonesia	1994-96	Thailand	19774, 75, 77, 79, 82,
		India	1970-97		84, 88, 89, 91, 93, 94
		Iran	1974-77, 79-90, 93	Tunisia	1970-81
		Iraq	1970-77	Tanzania	90-91
		Israel	1970-89	Uganda	1971, 89
		Jordan	1971, 74-97	Uruguay	1971-86, 91-97
		Kyrgyz Republic	1994	Venezuela	1970-97
		Korea (South)	1970-96	Serbia & Montenegro	1994-97
		Kuwait	1970-97	South Africa	1970, 72-86, 96
		Liberia	1984	Zambia	1970-75, 80-82
		Sri Lanka	1970-74, 79-85. 96, 97	Zimbabwe	1970-86, 96

* The OECD countries are grouped according to the OECD membership as of Year 1973.

Table 2: Result of OLS Estimation, with Positive-Trade Observations

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.422***	0.858***	0.312*	0.577***	0.675***	0.562***
(s.e.)	(0.133)	(0.201)	(0.175)	(0.150)	(0.148)	(0.150)
[p-value]	[0.002]	[0.000]	[0.076]	[0.000]	[0.000]	[0.000]
log(world GDP share)	-0.163	0.284	-0.069	0.586***	0.514***	0.736***
(s.e.)	(0.163)	(0.270)	(0.195)	(0.147)	(0.159)	(0.137)
[p-value]	[0.318]	[0.293]	[0.724]	[0.000]	[0.001]	[0.000]
R-square	0.01	0.12	0.05	0.02	0.03	0.03
# observations	3,617	3,617	3,628	7,216	7,216	9,040
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.000	0.481	0.000	0.005	0.028	0.004
coef. for income share = 1	0.000	0.009	0.000	0.005	0.002	0.054
coef. for similarity = coef. for i-share =1	0.000	0.011	0.000	0.006	0.007	0.011

Notes: All variables are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. Observations with zero trade in differentiated sectors are ***excluded*** from the regression. Country pair-specific and year-specific dummies are included in the regression. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 322, 324, 332, 355, 356, 361, 362, 382, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 323, 331, 341, 342, 351, 352, 353, 354, 369, 371, 372, 381, and 383.

Table 3: Result of OLS Estimation, with All Observations

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.397***	0.793***	0.195	0.062	0.246	0.012
(s.e.)	(0.138)	(0.235)	(0.226)	(0.242)	(0.202)	(0.230)
[p-value]	[0.004]	[0.001]	[0.389]	[0.796]	[0.224]	[0.960]
log(world GDP share)	-0.155	0.281	-0.105	0.000	0.733***	0.314
(s.e.)	(0.169)	(0.305)	(0.219)	(0.254)	(0.225)	(0.240)
[p-value]	[0.361]	[0.358]	[0.632]	[0.999]	[0.001]	[0.192]
R-square	0.01	0.09	0.02	0.00	0.07	0.03
# observations	3,630	3,630	3,630	14,565	14,565	14,565
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.000	0.379	0.001	0.000	0.000	0.000
coef. for income share = 1	0.000	0.020	0.000	0.000	0.236	0.004
coef. for similarity = coef. for i-share =1	0.000	0.033	0.000	0.000	0.001	0.000

Notes: All variables are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. Observations with zero trade in differentiated sectors are included in the regression. Country pair-specific and year-specific dummies are included in the regression. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 322, 324, 332, 355, 356, 361, 362, 382, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 323, 331, 341, 342, 351, 352, 353, 354, 369, 371, 372, 381, and 383.

Table 4: Result of Tobit Estimation

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.397***	1.03***	0.287**	0.070	0.484*	0.265
(s.e.)	(0.133)	(0.171)	(0.142)	(0.269)	(0.261)	(0.274)
[p-value]	[0.003]	[0.000]	[0.044]	[0.794]	[0.063]	[0.334]
log(world GDP share)	-0.353	-0.517	-0.290	-0.784**	-0.068	-0.199
(s.e.)	(0.226)	(0.474)	(0.419)	(0.317)	(0.313)	(0.326)
[p-value]	[0.118]	[0.276]	[0.489]	[0.013]	[0.828]	[0.541]
R-square	0.81	0.63	0.77	0.31	0.37	0.31
# observations	3,630	3,630	3,630	14,565	14,565	14,565
(*Tests for Coefficient = 1: P-values*)	(censored obs.	(censored obs.	(censored obs.	(censored obs.	(censored obs.	(censored obs.
coef. for similarity = 1	0.000	0.851	0.000	0.001	0.048	0.007
coef. for income share = 1	0.000	0.001	0.002	0.000	0.001	0.000
coef. for similarity = coef. for i-share =1	0.000	0.002	0.000	0.000	0.001	0.000

Notes : All variables are in logarithm. Log of GDP (for the aggregate specification) or log of sectoral production (for the differentiated-sector specification) is included as a regressor, but the coeffient for the term is constrained to be 1. The OECD group includes 20 countries and the non-OECD sample includes 69 countries, both for years 1970-97. All observations are included, and left-censored at the value of ln($500). Country pair-specific and year-specific dummies are included in the regressions. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 322, 324, 332, 355, 356, 361, 362, 382, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 323, 331, 341, 342, 351, 352, 353, 354, 369, 371, 372, 381, and 383.

Table 5: Results of Poisson Quasi-maximum Likelihood (PQML) Estimation

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.628***	0.875***	0.497***	0.862***	0.434**	0.710***
(s.e.)	(0.120)	(0.149)	(0.140)	(0.311)	(0.194)	(0.182)
[p-value]	[0.000]	[0.000]	[0.000]	[0.006]	[0.025]	[0.000]
log(world GDP share)	0.102	0.583***	0.297**	0.652***	0.664***	0.527***
(s.e.)	(0.125)	(0.167)	(0.150)	(0.134)	(0.192)	(0.146)
[p-value]	[0.412]	[0.000]	[0.048]	[0.000]	[0.001]	[0.000]
# observations	3,630	3,630	3,630	12,329	10,218	11,869
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.002	0.399	0.000	0.657	0.004	0.111
coef. for income share = 1	0.000	0.013	0.000	0.009	0.080	0.001
coef. for similarity = coef. for i-share =1	0.000	0.034	0.000	0.026	0.008	0.005

Notes : The dependent variable is in level, while all the regressors are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. All observations are included. The conditional fixed-effect PQML estimation follows Hausman et al. (1984), including time-specific dummies. Observations for country pairs that have data for only one year or whose volume of trade is zero for the entire period (1970-97) are omitted for the estimation. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 322, 324, 332, 355, 356, 361, 362, 382, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 323, 331, 341, 342, 351, 352, 353, 354, 369, 371, 372, 381, and 383.

Table 6: Akaike Information Criteria (AIC) of Estimated Models

	OECD Countries			Non-OECD Countries		
	Volume-of-trade Equation for:			Volume-of-trade Equation for:		
Estimated Models	Aggregate (A)	Differentiated Sectors (D)	Non-diff'ed Sectors (ND)	Aggregate (A)	Differentiated Sectors (D)	Non-diff'ed Sectors (ND)
OLS (3): excluding zero-trade observations	806.60	4,434.27	1,620.14	19,985.79	22,575.58	29,521.20
OLS (3): including zero-trade observations	2,595.51	6,921.75	3,722.83	68,980.41	70,014.69	72,312.18
Tobit (5)	2,523.50	5,419.98	3,048.18	50,750.46	37,745.48	47,753.59
PQML (4)	134.10	198.73	148.90	99.50	126.52	123.00

Note: The number in the parenthese () following the name of estimation method indicates the equation number in the text.

Table 7: Alternative Groupings of Differentiated Sectors

ISIC	Industry	Benchmark Grouping	Alternative Grouping (1)	Alternative Grouping (2)
311	Food products			
313	Beverages			X
314	Tobacco			
321	Textiles			
322	Wearing apparel, except footwear	X	X	X
323	Leather products		X	X
324	Footwear, except rubber or plastic	X	X	X
331	Wood products, except furniture			
332	Furniture, except metal	X	X	X
341	Paper and products			
342	Printing and publishing		X	X
351	Industrial chemicals			
352	Other chemicals			X
353	Petroleum refineries			
354	Miscellaneous petroleum and coal products			X
355	Rubber products	X	X	X
356	Plastic products	X	X	X
361	Pottery, china, earthenware	X	X	X
362	Glass and products	X	X	X
369	Other non-metallic mineral products			X
371	Iron and steel			X
372	Non-ferrous metals			
381	Fabricated metal products			
382	Machinery, except electrical	X	X	X
383	Electric machinery		X	X
384	Transport equipment	X	X	X
385	Professional and scientific equipment	X	X	X
Number of manufacturing industries included in the differentiated sector group		10	13	18

Notes:

1. Manufacturing industries are classified according to the three-digit ISIC (Revision 2).
2. "X" indicates an industry included in the differentiated sector group for each grouping. The corresponding non-differentiated sector group comprises manufacturing industries that are not marked with "X."
3. The miscellaneous category ISIC 390 (other manufactured products) is excluded from the list.

Table 8.1: Result of OLS Estimation for Alternative Sector Grouping (1), with Positive-Trade Observations

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.423***	0.741***	0.571***	0.510***	0.592***	0.571***
(s.e.)	(0.133)	(0.206)	(0.157)	(0.149)	(0.147)	(0.157)
[p-value]	[0.002]	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]
log(world GDP share)	-0.166	0.217	0.663***	0.569***	0.578***	0.663***
(s.e.)	(0.164)	(0.274)	(0.141)	(0.147)	(0.149)	(0.141)
[p-value]	[0.312]	[0.429]	[0.000]	[0.000]	[0.000]	[0.000]
R-square	0.01	0.11	0.02	0.02	0.03	0.02
# observations	3,619	3,619	8,905	7,562	7,562	8,905
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.000	0.210	0.006	0.001	0.006	0.006
coef. for income share = 1	0.000	0.005	0.017	0.003	0.005	0.017
coef. for similarity = coef. for i-share =1	0.000	0.012	0.010	0.001	0.004	0.010

Notes : All variables are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97.
Observations with zero trade in differentiated sectors are ***excluded*** from the regression. Country pair-specific and year-specific dummies are included in the regression. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 322, 323, 324, 332, 342, 355, 356, 361, 362, 382, 383, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 331, 341, 351, 352, 353, 354, 369, 371, 372, and 381.

Table 8.2: Result of OLS Estimation for Alternative Sector Grouping (1), with All Observations

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.397***	0.680***	0.150	0.062	0.131	0.017
(s.e.)	(0.138)	(0.239)	(0.235)	(0.242)	(0.208)	(0.233)
[p-value]	[0.004]	[0.005]	[0.523]	[0.796]	[0.528]	[0.940]
log(world GDP share)	-0.155	0.223	-0.242	0.000	0.792***	0.237
(s.e.)	(0.169)	(0.309)	(0.225)	(0.254)	(0.223)	(0.241)
[p-value]	[0.361]	[0.471]	[0.284]	[0.999]	[0.000]	[0.326]
R-square	0.01	0.09	0.00	0.00	0.08	0.02
# observations	3,630	3,630	3,630	14,565	14,565	14,565
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.000	0.183	0.000	0.000	0.000	0.000
coef. for income share = 1	0.000	0.013	0.000	0.000	0.351	0.002
coef. for similarity = coef. for i-share =1	0.000	0.034	0.000	0.000	0.000	0.000

Notes : All variables are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97.
Observations with zero trade in differentiated sectors are included in the regression. Country pair-specific and year-specific dummies are included in the regression. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 322, 323, 324, 332, 342, 355, 356, 361, 362, 382, 383, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 331, 341, 351, 352, 353, 354, 369, 371, 372, and 381.

Table 8.3: Result of Tobit Estimation for Alternative Sector Grouping (1)

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.397***	0.960***	0.238*	0.070	0.421	0.239
(s.e.)	(0.133)	(0.176)	(0.138)	(0.269)	(0.258)	(0.282)
[p-value]	[0.003]	[0.000]	[0.085]	[0.794]	[0.103]	[0.396]
log(world GDP share)	-0.353	-0.830*	-0.370	-0.784**	-0.089	-0.213
(s.e.)	(0.226)	(0.486)	(0.374)	(0.317)	(0.298)	(0.325)
[p-value]	[0.118]	[0.088]	[0.323]	[0.013]	[0.766]	[0.513]
R-square	0.81	0.65	0.76	0.31	0.37	0.30
# observations	3,630	3,630	3,630	14,565	14,565	14,565
(*Tests for Coefficient = 1: P-values*)	(censored obs.	(censored obs.	(censored obs.	(censored obs.	(censored obs.	(censored obs.
coef. for similarity = 1	0.000	0.820	0.000	0.001	0.025	0.007
coef. for income share = 1	0.000	0.000	0.000	0.000	0.000	0.000
coef. for similarity = coef. for i-share =1	0.000	0.001	0.000	0.000	0.000	0.000

Notes: All variables are in logarithm. Log of GDP (for the aggregate specification) or log of sectoral production (for the differentiated-sector specification) is included as a regressor, but the coeffient for the term is constrained to be 1. The OECD group includes 20 countries and the non-OECD sample includes 69 countries, both for years 1970-97. All observations are included, and left-censored at the value of ln($500). Country pair-specific and year-specific dummies are included in the regressions. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively. The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.

Differentiated Sectors: 3-digit ISIC = 322, 323, 324, 332, 342, 355, 356, 361, 362, 382, 383, 384, and 385.

Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 331, 341, 351, 352, 353, 354, 369, 371, 372, and 381.

Table 8.4: Results of Poisson Quasi-maximum Likelihood (PQML) Estimation for Alternative Sector Grouping (1)

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.628***	0.843***	0.418***	0.862***	0.362*	0.722***
(s.e.)	(0.120)	(0.143)	(0.139)	(0.311)	(0.190)	(0.193)
[p-value]	[0.000]	[0.000]	[0.003]	[0.006]	[0.057]	[0.000]
log(world GDP share)	0.102	0.589***	0.201	0.652***	0.681***	0.466***
(s.e.)	(0.125)	(0.178)	(0.131)	(0.134)	(0.167)	(0.147)
[p-value]	[0.412]	[0.001]	[0.125]	[0.000]	[0.000]	[0.002]
# observations	3,630	3,630	3,630	12,329	10,478	11,824
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.002	0.271	0.000	0.657	0.001	0.149
coef. for income share = 1	0.000	0.021	0.000	0.009	0.057	0.000
coef. for similarity = coef. for i-share =1	0.000	0.064	0.000	0.026	0.001	0.001

Notes: The dependent variable is in level, while all the regressors are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. All observations are included. The conditional fixed-effect PQML estimation follows Hausman et al. (1984), including time-specific dummies. Observations for country pairs that have data for only one year or whose volume of trade is zero for the entire period (1970-97) are omitted for the estimation. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively. The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.

Differentiated Sectors: 3-digit ISIC = 322, 323, 324, 332, 342, 355, 356, 361, 362, 382, 383, 384, and 385.

Non-differentiated Sectors: 3-digit ISIC = 311, 313, 314, 321, 331, 341, 351, 352, 353, 354, 369, 371, 372, and 381.

Table 9.1: Result of OLS Estimation for Alternative Sector Grouping (2), with Positive-Trade Observations

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.424***	0.660***	0.263*	0.516***	0.576***	0.569***
(s.e.)	(0.133)	(0.204)	(0.153)	(0.147)	(0.160)	(0.157)
[p-value]	[0.002]	[0.001]	[0.087]	[0.000]	[0.000]	[0.000]
log(world GDP share)	-0.166	0.108	-0.034	0.548***	0.395**	0.785***
(s.e.)	(0.164)	(0.266)	(0.185)	(0.145)	(0.156)	(0.142)
[p-value]	[0.315]	[0.685]	[0.853]	[0.000]	[0.011]	[0.000]
R-square	0.01	0.07	0.05	0.03	0.05	0.02
# observations	3,622	3,622	3,628	7,960	7,960	8,642
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.000	0.097	0.000	0.001	0.008	0.006
coef. for income share = 1	0.000	0.001	0.000	0.002	0.000	0.131
coef. for similarity = coef. for i-share =1	0.000	0.003	0.000	0.001	0.000	0.022

Notes: All variables are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. Observations with zero trade in differentiated sectors are ***excluded*** from the regression. Country pair-specific and year-specific dummies are included in the regression. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 313, 322, 323, 324, 332, 342, 352, 354, 355, 356, 361, 362, 369, 371, 382, 383, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 314, 321, 331, 341, 351, 353, 372, and 381.

Table 9.2: Result of OLS Estimation for Alternative Sector Grouping (2), with All Observations

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.397***	0.572**	0.142	0.062	0.052	0.049
(s.e.)	(0.138)	(0.236)	(0.212)	(0.242)	(0.218)	(0.234)
[p-value]	[0.004]	[0.016]	[0.501]	[0.796]	[0.810]	[0.833]
log(world GDP share)	-0.155	0.081	-0.065	0.000	0.456**	0.492**
(s.e.)	(0.169)	(0.300)	(0.209)	(0.254)	(0.224)	(0.240)
[p-value]	[0.361]	[0.787]	[0.755]	[0.999]	[0.042]	[0.041]
R-square	0.01	0.05	0.02	0.00	0.05	0.04
# observations	3,630	3,630	3,630	14,565	14,565	14,565
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.000	0.071	0.000	0.000	0.000	0.000
coef. for income share = 1	0.000	0.003	0.000	0.000	0.015	0.035
coef. for similarity = coef. for i-share =1	0.000	0.008	0.000	0.000	0.000	0.000

Notes: All variables are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. Observations with zero trade in differentiated sectors are included in the regression. Country pair-specific and year-specific dummies are included in the regression. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.
Differentiated Sectors: 3-digit ISIC = 313, 322, 323, 324, 332, 342, 352, 354, 355, 356, 361, 362, 369, 371, 382, 383, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 314, 321, 331, 341, 351, 353, 372, and 381.

Table 9.3: Result of Tobit Estimation for Alternative Sector Grouping (2)

	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.397***	0.821***	0.214*	0.070	0.203	0.301
(s.e.)	(0.133)	(0.161)	(0.126)	(0.269)	(0.278)	(0.279)
[p-value]	[0.003]	[0.000]	[0.088]	[0.794]	[0.464]	[0.281]
log(world GDP share)	-0.353	-0.712	-0.142	-0.784**	-0.102	-0.064
(s.e.)	(0.226)	(0.488)	(0.317)	(0.317)	(0.314)	(0.324)
[p-value]	[0.118]	[0.144]	[0.655]	[0.013]	[0.745]	[0.843]
R-square	0.81	0.69	0.75	0.31	0.36	0.30
# observations	3,630	3,630	3,630	14,565	14,565	14,565
(*Tests for Coefficient = 1: P-values*)	(censored obs.	(censored obs.	(censored obs.	(censored obs.	(censored obs.	(censored obs.
coef. for similarity = 1	0.000	0.266	0.000	0.001	0.004	0.012
coef. for income share = 1	0.000	0.001	0.000	0.000	0.000	0.001
coef. for similarity = coef. for i-share =1	0.000	0.002	0.000	0.000	0.000	0.001

Notes : All variables are in logarithm. Log of GDP (for the aggregate specification) or log of sectoral production (for the differentiated-sector specification) is included as a regressor, but the coeffient for the term is constrained to be 1. The OECD group includes 20 countries and the non-OECD sample includes 69 countries, both for years 1970-97. All observations are included, and left-censored at the value of ln($500). Country pair-specific and year-specific dummies are included in the regressions. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.

Differentiated Sectors: 3-digit ISIC = 313, 322, 323, 324, 332, 342, 352, 354, 355, 356, 361, 362, 369, 371, 382, 383, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 314, 321, 331, 341, 351, 353, 372, and 381.

Table 9.4: Results of Poisson Quasi-maximum Likelihood (PQML) Estimation for Alternative Sector Grouping (2)

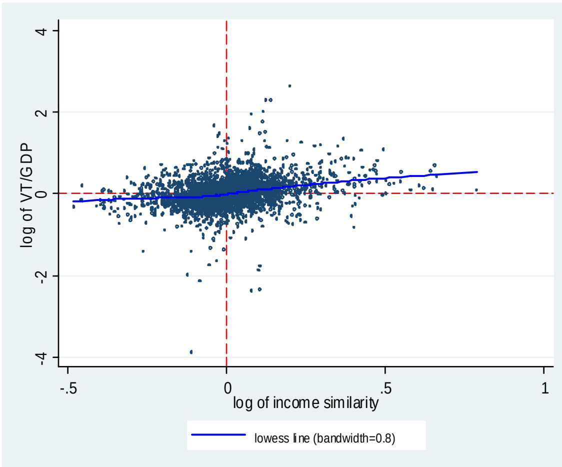
	OECD Countries			Non-OECD Countries		
Dependent Variable:	log(Volume of Trade Per Production)			log(Volume of Trade Per Production)		
	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)	Aggregate Eq. (3A)	Differentiated Eq. (3D)	Non-Diff'ed Eq. (3ND)
log(similarity)	0.628***	0.763***	0.403***	0.862***	0.469**	0.742***
(s.e.)	(0.120)	(0.138)	(0.134)	(0.311)	(0.194)	(0.191)
[p-value]	[0.000]	[0.000]	[0.003]	[0.006]	[0.015]	[0.000]
log(world GDP share)	0.102	0.536***	0.225*	0.652***	0.514**	0.585***
(s.e.)	(0.125)	(0.164)	(0.136)	(0.134)	(0.201)	(0.139)
[p-value]	[0.412]	[0.001]	[0.098]	[0.000]	[0.011]	[0.000]
# observations	3,630	3,630	3,630	12,329	10,831	11,659
(*Tests for Coefficient = 1: P-values*)						
coef. for similarity = 1	0.002	0.086	0.000	0.657	0.006	0.176
coef. for income share = 1	0.000	0.005	0.000	0.009	0.016	0.003
coef. for similarity = coef. for i-share =1	0.000	0.018	0.000	0.026	0.004	0.012

Notes : The dependent variable is in level, while all the regressors are in logarithm. The OECD group includes 20 countries and the non-OECD group includes 69 countries, both for years 1970-97. All observations are included. The conditional fixed-effect PQML estimation follows Hausman et al. (1984), including time-specific dummies. Observations for country pairs that have data for only one year or whose volume of trade is zero for the entire period (1970-97) are omitted for the estimation. Standard errors are clustered by country pair. ***, **, * indicate the significance levels at 1%, 5%, and 10%, respectively.
The lower parts of the table shows the results of the Wald test for the hypotheses of each coefficient equaling one and the two coefficients jointly equaling one, in p-values.

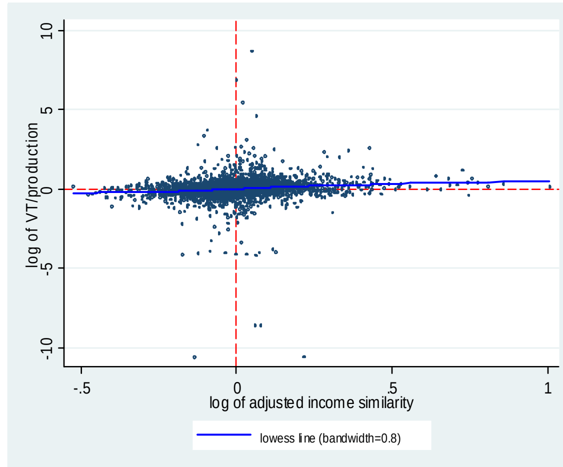
Differentiated Sectors: 3-digit ISIC = 313, 322, 323, 324, 332, 342, 352, 354, 355, 356, 361, 362, 369, 371, 382, 383, 384, and 385.
Non-differentiated Sectors: 3-digit ISIC = 311, 314, 321, 331, 341, 351, 353, 372, and 381.

Figures 1: Volume of Bilateral Trade per Production vs Size Similarity Index; for OECD Countries (in logarithm; mean-differenced)

1-A: Aggregate Trade

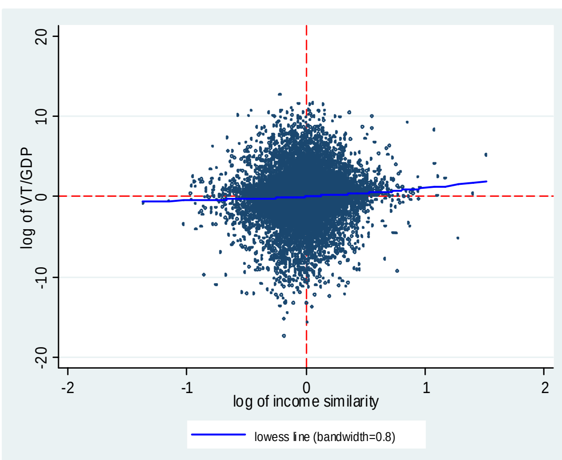


1-D: Differentiated-sector Trade

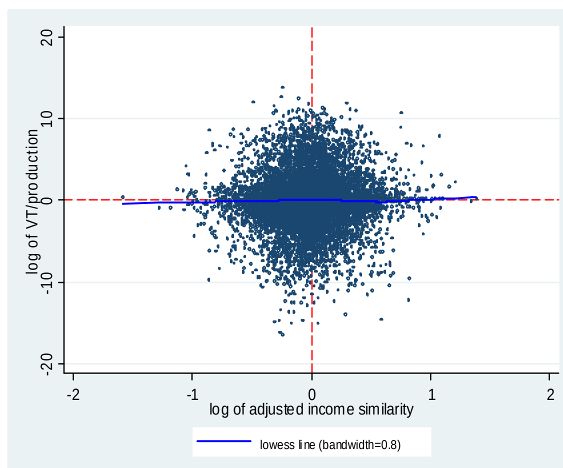


Figures 2: Volume of Bilateral Trade per Production vs Size Similarity Index; for Non-OECD Countries (in logarithm; mean-differenced)

2-A: Aggregate Trade



2-D: Differentiated-sector Trade



Note: The GDP similarity index (for 1-A and 2-A) or the production structure-adjusted size similarity index (for 1-D and 2-D) is on the horizontal axis, and the volume of bilateral trade as the share in GDP (for 1-A and 2-A) or production (for 1-D and 2-D) on the vertical. All the variables are in logarithm and mean-differenced (for the fixed-effect OLS). The vertical and horizontal lines indicate zero. The solid line in each figures is the trend lines fitted by locally weighted regression (Lowess) with the bandwidth = 0.8.