Trade Costs and Intra-Industry Trade

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Abstract

Formal economic modeling of intra-industry trade essentially began with Krugman (1979, 1980, 1981), Lancaster (1980), and Helpman (1981). Helpman (1987) is generally credited with the first econometric "test" of these theories of intra-industry trade, with subsequent notable contributions from Hummels and Levinsohn (1995) and Debaere (2004). However, all these theories and empirical models ignore transportation – or, more broadly, trade costs. Yet, as Anderson and van Wincoop (2004) suggest, trade costs are quite large. This paper extends work by Bergstrand (1990) that addressed intra-industry trade in the explicit presence of trade costs. In the context of a Helpman-Krugman cum trade costs model, we derive four empirically testable hypotheses regarding intra-industry trade and trade costs. These hypotheses are investigated empirically using a cross-section of bilateral OECD Grubel-Lloyd indexes. The results are strongly in accordance with the hypotheses, indicating the importance of a more rigorous and systematic treatment of trade costs in the intra-industry trade literature.

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By

Jeffrey H. Bergstrand and Peter Egger

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I. Introduction

> *Trade costs have economically sensible magnitudes and patterns across countries and regions and across goods, suggesting useful hypotheses for deeper understanding* (Anderson and van Wincoop, 2004, p. 1).

Grubel and Lloyd (1975) created an industry in the international trade literature. Their systematic empirical investigation of trade flows yielded the seminal observation that the bulk of international trade – certainly among industrialized nations – was *intra-industry*, not inter-industry. This was a startling observation for international trade economists whose prevailing theories of international trade at that time – the Ricardian and Heckscher-Ohlin theories – could only explain *inter-industry* trade. These facts motivated several insightful trade theorists to combine the industrial organization and international trade literatures to offer formal theories of intra-industry trade. Notably, Krugman (1979, 1980, 1981), Lancaster (1980), and Helpman (1981) are generally cited as the most influential papers in this regard. Helpman and Krugman (1985) is a seminal book synthesizing and enhancing this theory.

Of course, the absence of a formal theoretical foundation for intra-industry trade (IIT) certainly did not prevent empirical trade economists from estimating econometric models of the determinants of intra-industry trade prior to 1980. However, Helpman (1987) is generally cited as providing the first "testable" hypotheses of intra-industry trade based upon an explicit general equilibrium model. Among other papers, several seminal articles have re-evaluated Helpman's empirical propositions in the context of formal theories, including Hummels and Levinsohn (1995), Evenett and Keller (2002), and Debaere (2004).

However, each of the papers just noted have evaluated intra-industry trade in the context of a model with *zero trade costs*. As Anderson and van Wincoop (2004) remind us convincingly, trade costs are *large* – and matter. Even the large empirical literature on determinants of intra-industry trade lacking formal theoretical foundations found fairly systematically that distance significantly reduces intra-industry trade, economically and statistically. However, while the international trade literature (especially, work using the gravity equation) has provided convincing rationales for the negative relationship between distance – as a proxy for "trade costs" – and the volume of trade, there is not yet a well accepted rationale for why distance should have a strong negative empirical correlation with the *share* of intra-industry trade, especially after accounting for countries with common land borders (i.e., "cross-hauling"). One paper that did try to address theoretically and empirically the importance of transport costs in the context of a two-sector model of Heckscher-Ohlin inter-industry and Helpman-Krugman intra-industry trade is Bergstrand (1990).

The purpose of the present paper is to advance some new theoretical and empirical insights into the relationship between intra-industry trade and trade costs. Anderson and van Wincoop (2004) is an excellent survey of international trade costs, and among other goals discusses in particular the relationship between trade costs and the volume of trade. Our paper is aimed at enhancing our knowledge of the relationship between trade costs and the *share* of intra-industry trade. We also address indirectly an important issue raised in Davis (1998) on the relationship between absolute trade costs vs. relative trade costs (between two industries' products) for international trade and the "home-market effect."

In this paper, we enhance the standard two-country, two-good, two-factor Helpman-Krugman model to incorporate explicit transport costs for both the differentiated and homogeneous products. In the presence of positive transport costs, analytical solutions can only be obtained by focusing the analysis on a limited (and often unrealistic) set of parameter domains. Consequently, we provide numerical solutions to the nonlinear relationships between trade costs and Grubel-Lloyd intra-industry trade indexes (GLI). Specifically, we motivate four "testable" hypotheses. First, an increase in trade costs associated with only differentiated goods should reduce both the volume of intra-industry trade in differentiated goods *and* the *share* of such intra-industry trade in overall trade. Second, a *proportional* increase in trade costs (across both sectors) will tend to reduce the overall G-L index as well. Third, the presence of explicit trade costs introduces nonlinearities into the model that can influence potentially the sensitivities of relationships among trade costs and the share of intra-industry trade to economic size and relative factor proportions. We rely upon numerical solutions from a computable general equilibrium (CGE) version of our theoretical model to show, for instance, that the effect of a proportional increase in trade costs is sensitive to the *level* of differences in relative factor endowments. Fourth, we show also that the marginal effect of an increase in only differentiated goods trade costs is also sensitive to relative factor endowment differences. Finally, we investigate these four hypotheses empirically using a large cross-section of bilateral G-L indexes. The results confirm our theoretical hypotheses.

The remainder of the paper is as follows. Section 2 outlines the theoretical model and the four empirically testable hypotheses. Section 3 discusses our database. Section 4 presents the main empirical results. Section 5 presents the results of a sensitivity analysis. The last section concludes.

II. **Theoretical Issues**

A. The Model

To illustrate the role of trade costs for intra-industry trade, consider a two-country, two-sector, two-factor model à la Helpman and Krugman (1985). One of the two sectors produces a Dixit and Stiglitz (1977) constant-elasticity-of-substitution (CES) type differentiated good (X), and the other sector produces a homogeneous good (Y). We assume fixed endowments of two factors, capital (K) and labor (L), in each of two countries (i,j). In country i's differentiated sector, n_i firms engage in (large-numbers-case) monopolistic competition. Each firm faces a demand x_{ii} in the domestic market and x_{ij} in the foreign market. These demands are given by:

$$x_{ii} = p_{Xi}^{-\varepsilon} P_{Xi}^{-1} \alpha E_i ; \quad x_{ij} = p_{Xi}^{-\varepsilon} t_X^{1-\varepsilon} P_{Xj}^{-1} \alpha E_j , \tag{1}$$

where p_{Xi} is the price of each differentiated variety in country i, α is the expenditure share on differentiated goods (hence, consumers spend a share of 1-α on the homogeneous good), $E_i=w_iL_i+r_iK_i$ is total income of labor and capital (w and r denote the respective factor rewards), P_{Xi} is the CES price index given by:

$$P_i = n_i p_{Xi}^{1-\varepsilon} + n_j \left(t_X p_{Xj}\right)^{1-\varepsilon} , \tag{2}$$

and ε denotes the elasticity of substitution between varieties. We assume iceberg-type transport costs in both sectors (see Samuelson, 1952). We consider non-zero and different transport costs in both sectors. Assume t_X-1 (t_Y-1) units of each differentiated variety (of the homogeneous good) "melt" during transportation of goods to foreign consumers. In this regard, our approach differs from several previous analyses of the Helpman-Krugman model, where it has been typically assumed that $t_X = t_Y = 1$ (Helpman, 1987, Hummels and Levinsohn, 1995; Evenett and Keller, 2002; Debaere, 2004). However, Davis (1998) studies the role of transport costs for the home-bias and focuses on two specific configurations of t_X and t_Y, namely $t_X = t_Y \neq 1$ and $t_X \neq 1$ but $t_Y = 1$.

An assumption of factor market clearing guarantees:

$$\begin{aligned} L_i &= a_{LX} n_i (x_{ii} + x_{ij}) + a_{LY} (Y_{ii} + t_Y Y_{ij}) + a_{Ln} n_i \\ K_i &= a_{KX} n_i (x_{ii} + x_{ij}) + a_{KY} (Y_{ii} + t_Y Y_{ij}) + a_{Kn} n_i . \end{aligned} \tag{3}$$

We will make a few plausible assumptions regarding technology to simplify the analysis. First, we assume firm setup is capital intensive relative to production of goods. Second, we assume that production of the differentiated good is capital intensive relative to that of the homogeneous good. This is guaranteed formally by

$$\frac{a_{Kn}}{a_{Ln}} > \frac{a_{KX}}{a_{LX}} > \frac{a_{KY}}{a_{LY}} . \tag{4}$$

We ensure the latter inequality by assuming $a_{KY} = 0$. Further, we assume a world-wide identical Leontief technology, which rules out the possibility of factor intensity reversals. For convenience, we express X in terms of *produced* units and Y in *consumed* units.

An assumption of free entry and exit guarantees zero profits in the differentiated goods sector:

$$(p_{Xi} - c_{Xi})(x_{ii} + x_{ij}) = a_{Ln} w_i + a_{Kn} r_i \tag{5}$$

where c_{Xi} denotes marginal costs (average variable costs) in the X-sector. Large-number monopolistic competition leads to a constant mark-up over marginal costs, so that we can write the pricing conditions applying to both sectors as

$$p_{Xi} = c_{Xi} \frac{\varepsilon}{\varepsilon - 1}; \quad p_{Yi} = c_{Yi} = w_i . \tag{6}$$

Choosing the price of Y in market i as the numéraire then implies $w_i = 1$.

The volume of trade in this model is given by

$$VT = p_{Xi} n_i x_{ij} + p_{Xj} n_j x_{ji} + t_Y \left| p_{Yj} Y_{ij} - Y_{ji} \right| , \tag{7}$$

and the "trade overlap" (Finger, 1975) expressed as a share of the trade volume – hence, the G-L index – is

$$GLI = \frac{2 \min\{ p_{Xi} n_i x_{ij}, p_{Xj} n_j x_{ji} \}}{p_{Xi} n_i x_{ij} + p_{Xj} n_j x_{ji} + t_Y \left| p_{Yj} Y_{ij} - Y_{ji} \right|} = 1 - \frac{\left| p_{Xi} n_i x_{ij} - p_{Xj} n_j x_{ji} \right|}{p_{Xi} n_i x_{ij} + p_{Xj} n_j x_{ji} + t_Y \left| p_{Yj} Y_{ij} - Y_{ji} \right|} . \tag{8}$$

We are interested in the comparative static results of the G-L index with respect to t_X and t_Y in particular. A comparative static analysis in models of monopolistic competition is generally messy, and analytical results can only be obtained by focusing on certain (often unrealistic) parameter domains. In our case, for instance, choosing $\varepsilon = 0$ would allow such an analysis. To avoid this dilemma, we will provide some numerical solutions later.

B. Changes in Relative Trade Costs and Intra-Industry Trade

In this section, we consider the relationship between a change in trade costs in the differentiated goods sector (holding constant trade costs for the homogeneous good) and the theoretical impact on our overall index of intra-industry trade, *GLI*. We consider an increase in the (gross) trade-cost factor in industry X, $\Delta t_X > 0$. A rise in good X's trade costs will make imports of X by each country more expensive, lowering import demand and the value of both countries' trade flows in X. Using the first equality in eq. (8), this tends to lower both the numerator and denominator in (8). However, in general equilibrium, and with asymmetric economic sizes and relative factor endowments, the full impact of a rise in t_X is unclear.

1. Economic Intuition

To analyze the impact, we make a few assumptions. Assume that the two countries are equal in economic size (real GDP), but country i (j) is relatively abundant in capital (labor), the factor used relatively intensively to produce X (Y). Consequently, country i (j) is the net exporter of X (Y); both countries export X, but only j exports Y.[1] Given that country i is the net exporter of X and produces a larger share of X in the world, a rise in t_X causes the relative price of X to consumers in country j (the net importer of X) to rise dramatically, reducing real income in country j. Due to the "love of variety" for X, the bulk of X consumed in j is imported. This reduction in j's real income is equivalent economically to a loss of factor endowments, which should raise factor prices in country j. However, the price of labor in j (w_j) cannot rise. First, the price of labor in i (w_i) is the numeraire; consequently, given the model's structure, $p_{Yi} = 1$. Consequently, in country j, the wage rate is unchanged; since profit maximization ensures the wage rate equals the producer price of homogeneous good Y in country j, and the latter is linked (adjusted for Y's trade cost factor) to the price of good Y in i (the numeraire, $p_{Yi} = w_i$), w_j is unchanged.

So the prices of capital in both countries (r_i, r_j) bear the brunt of adjustment. The implied scarcity of capital in j drives up its price (r_j). However, since i is the net exporter of X, the fall in demand for X leads to an excess supply of capital, and the price of capital in i (r_i) actually falls. On net, the relative wage-rental ratio in country i rises *relative to* the

[1] We assume a sufficiently large relative factor endowment difference to yield this outcome.

relative wage-rental ratio in j, causing the relative price of X to Y in i to fall *relative to* that in j. The widening of relative prices in the two countries increases industry specialization, diminishing the overall share of intra-industry trade (*GLI*).

2. Edgeworth Box Approach

In light of the 2x2x2 dimensions of our model, we can illustrate relationships between trade costs, real GDPs, relative factor endowments, and G-L indexes using a traditional Edgeworth box. Figure 1 provides an illustration.

> Figure 1 HERE <

In this figure, we depict an iso-GDP-share line, which reflects the same share of world (real) GDP corresponding to a given set of values for transport costs. Assume that the solid iso-GDP-share line is associated with $t_X = t_Y$ and with equally sized countries. With non-zero trade costs ($t_X = t_Y > 1$), the solid iso-GDP-share line is kinked (in contrast to a world within the factor-price-equalization set with zero trade costs). The reason is that, at the southeast end of the line, country i is relatively labor abundant and will be the sole producer and exporter of homogeneous good Y, while producing and exporting a small amount of differentiated good X. As country i's K-L ratio increases for a given real GDP, at some point near the diagonal (depending upon the values of t_X and t_Y), incomplete specialization in production of Y results; this creates the initial kink in the line moving northwest. At an even higher K-L ratio for country i (just above the diagonal), country i will produce none of good Y and will specialize in the production and export of its differentiated varieties of X; this is the second kink in the line moving northwest.

Figure 1 also illustrates two solid iso-Grubel-Lloyd-Index (iso-GLI) lines associated with two alternative relative factor endowments for the two countries. At point A, for example, countries have identical GDPs but different relative factor endowments. The G-L index is less than unity; analogously, for point B.

We now consider the effects of changes in transport costs on these loci. Consider an increase in trade costs in good X. This increase causes country i's iso-GDP-share line to tilt as indicated. If good Y uses labor relatively intensively in production, with an increase in t_X the original (solid) iso-GDP-share line is now associated with a lower relative real income in j compared with i.

More importantly, Figure 1 illustrates the effect on the iso-GLI line. The solid line reflects a constant G-L index level at various K-L ratios for country i assuming that $t_X = t_Y > 1$. As discussed above, the fall in the relative price of good X to good Y in country i relative to country j implies that industry specialization will increase for the two countries, lowering the overall share of intra-industry trade. Figure 1 illustrates that, in the northwest quadrant, the iso-GLI line shifts to the right. That is, the original (solid) iso-GLI line is now associated with a lower level of GLI.

3. Numerical Simulations

Because of extensive nonlinearities in the model, we will find it useful to create a computable general equilibrium (CGE) version of our model. This will enable us to generate expected theoretical relationships more closely related to the econometric model. For instance, it is well known in this class of (Helpman-Krugman-type) models that the share of intra-industry trade will increase the larger (and more similar) in economic size are two countries. As just shown, in general equilibrium trade cost changes affect both *GLI* and economic sizes. In the empirical model to follow, the inclusion in regressions of GDPs as well as trade costs implies that the estimated relationship between trade costs and *GLI* is *holding constant* variation in GDPs. We would like to know theoretically the effect of trade costs on *GLI* holding GDPs constant. However, we can use the CGE version of our model to generate a theoretical relationship between trade costs and *GLI* holding constant relative economic sizes.

We now describe the methodology for the CGE model. First, we reallocate capital so that country i holds between 50 percent and 99.95 percent of the world capital endowment, and we reallocate labor to ensure that this country holds between 0.05 percent and 50 percent of the world labor endowment. Hence, we focus in the simulations on the northwest quadrant of the factor box in Figure 1, where country i is capital abundant. Second, we choose an extremely fine grid and compute 100^2=10,000 equilibria. Third, we choose a particular value of country i's share of world GDP (in our case, 54 percent) and select all factor endowment configurations out of the 10,000 which (approximately) "produce" this (endogenous) share of world GDP; hence, our simulated relationship between trade costs and *GLI* will hold constant relative GDPs.

However, the effects of trade cost changes on *GLI* will be sensitive to the values of parameters. In the context of our model, the parameters are the Leontief input requirements (*a*'s), the share of expenditures devoted to the differentiated good, capital requirements for firm setups, and countries' factor endowments. In the remainder of the paper, we demonstrate theoretically (using the CGE model) and later empirically (using regression analysis) the effect of changes in each sector's transport cost factor on the aggregate *GLI* index for the country pair *and* the sensitivity of this effect to relative factor endowments. It will be useful to define the absolute difference in the logs of relative factor endowments by $DRLFAC = \left| \ln \frac{K_i}{L_i} - \ln \frac{K_j}{L_j} \right|$.

We now demonstrate theoretically (using the CGE model) the relationships between trade costs and intra-industry trade. We will display a *GLI-DRLFAC* locus for four different values of transport costs, always holding the chosen share of world GDP constant, as we do in the empirical analysis of *GLI* later, where GDP size and similarity enter as determinants. In Figure 2, we focus in particular on a range of relative factor endowment differences (*DRLFAC*) that is empirically plausible and where countries are imperfectly specialized (so that *GLI* > 0). In particular, the relationships shown will hold for a range of the ratio of relative factor endowments for two countries from unity (identical relative factor endowments) to one country having five times the K/L ratio of the other, which represents the OECD countries. To produce the figure, we basically leave the "bird's eye view" of Figure 1 but rather look at the GLI associated with a specific level of relative GDP at different configurations of t_X and t_Y. Specifically, we assume a conventional value for the elasticity of substitution among manufactures ($\varepsilon = 6$; see Anderson and van Wincoop, 2004) and base our insights on numerical solutions of the model.[2]

> Figure 2 HERE <

With this background, we consider the effect of the rise in trade costs in sector X. Figure 2 illustrates four lines. We are concerned here with only two: the line representing the relationship between *GLI* and *DRLFAC* for trade costs of ($t_X = 1.1$, $t_Y = 1.1$) and the line for trade costs of ($t_X = 1.3$, $t_Y = 1.1$). As discussed in section 2B above, our first hypothesis is that a rise in t_X will lower the overall share of intra-industry trade. The line for ($t_X = 1.3$, $t_Y = 1.1$) is lower relative to that for ($t_X = 1.1$, $t_Y = 1.1$), as expected.

[2] Concerning the input coefficients, we choose $a_{LX} = 0.6$, $a_{LY} = 1$, $a_{KX} = 0.8$, $a_{KY} = 0$, $a_{Ln} = 0$, $a_{Kn} = 1$. The expenditure share on differentiated goods is set at $\alpha = 0.8$. Further, we assume K = 60 and L = 100 for world endowments. In the initial equilibria, transport costs are set at $t_X = t_Y = 1.1$. To assess the impact of alternative transport costs, we choose a value of $t_X = 1.3$ and $t_Y = 1.3$ when indicated.

C. Proportional Changes in Trade Costs and Intra-Industry Trade

We now consider the theoretical effect of a proportional change in trade costs in both sectors on the *GLI* index for the country pair. Figure 2 illustrates that a rise in trade costs from ($t_X = 1.1$, $t_Y = 1.1$) to ($t_X = 1.3$, $t_Y = 1.3$) reduces the *GLI* index of intra-industry trade. Note that the shift downward of the locus is of less magnitude than the downward shift in the case of a rise in only X's trade costs.

The reason is the following. In this case, w_j falls dramatically because the cost of trading Y has risen sharply, lowering Y's price on the world market (excluding trade costs). Even though the price of capital falls in both countries, the relative factor prices in the two countries do not widen as much as in the previous case. Consequently, inter-industry specialization does not increase as much, and intra-industry trade does not decrease as much.

D. Changes in Relative Trade Costs and Relative Factor Endowments

The nonlinearities generated in the model by the introduction of trade costs likely make the effect of trade cost changes on the Grubel-Lloyd index of intra-industry trade sensitive to parameters, including initial levels of endowments. A priori, it is difficult to predict analytically *how* these nonlinearities will affect the impact of trade costs on *GLI* at different parameter levels; this is why we construct CGE models. We now use Figure 2 to guide us in understanding the varying sensitivity of the fall in *GLI* to the level of differences in relative factor endowments. Careful examination of Figure 2 reveals that the effect of a rise in relative trade costs in X on the reduction of the *GLI* index is greater the *larger* is the absolute difference of (log) relative factor endowments for the two countries. Since we know a rise in the relative trade cost of the differentiated good impacts the X sector disproportionately and leads to greater inter-industry specialization, this effect is exacerbated the wider is the initial level of inter-industry specialization due to a large difference in relative factor endowments. This is confirmed by the fact that – at the LHS of Figure 2 when relative factor endowments are nearly identical – *GLI* falls by about 0.15 (approximately, 20 percent) with a rise in t_X from 1.1 to 1.3, but *GLI* falls by about 0.20 (approximately, 30 percent) when one country's relative factor endowment is about five times that of the other.

E. Changes in Proportional Trade Costs and Relative Factor Endowments

Analogously, the effect of proportional trade cost changes across sectors on the Grubel-Lloyd index will be sensitive to the initial difference in relative factor endowments. We know from section C above that the *GLI* index falls less with a proportional increase in trade costs compared with a rise in only X's relative trade cost. However, in this case as well, relative factor prices change and widen, increasing inter-industry specialization. The wider the initial level of relative factor endowments (and, consequently, inter-industry specialization), the greater this increase in inter-industry specialization will have upon the overall level of intra-industry trade. Consequently, we would expect that a proportional change in trade costs would have a larger negative impact on *GLI* the larger is *DRLFAC* – the difference in relative factor endowments. Figure 2 confirms this clearly; the effect on *GLI* is much larger at high values of *DRLFAC* than at low values.

We now evaluate empirically these four hypotheses.

III. **Data**

Our data base consists of intra-industry trade share figures based on 3-digit bilateral trade data in Standard International Trade Classification Revision 2 as available from the OECD (International Trade by Commodity Statistics, 1990-2000). For each country pair in the sample[3], we weight the 3-digit based *GLI* figures to construct a single, aggregate *GLI* value. To eliminate the influence of outliers in the time dimension, we average the bilateral data across years.

Although our theoretical model addresses "trade cost" factors, in the spirit of Anderson and van Wincoop (2004), the actual measurement of such costs is extraordinarily difficult, as their paper emphasizes. For empirical purposes, we adopt a narrower definition of trade costs, in particular, transport costs. We define total bilateral transport costs according to the c.i.f./f.o.b. ratio. Using our data, we construct gross c.i.f./f.o.b. factors for all the country pairs in our sample for both homogeneous goods and differentiated goods.

We employ a narrow definition of homogeneous goods trade; we classify the 1-digit categories "0", "2", and "3" as homogeneous goods. We exclude beverages and tobacco

[3] Australia, Austria, Belgium, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, Ireland, Italy, Japan, Korea (Republic of), Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, USA.

(category "1") from this definition, since earlier research – not to mention our own colleagues – suggest considerable product differentiation within subcategories covering wine "11241", Whisky "11241", and beer "1123." Applying this definition, we end up with a share of homogeneous goods trade in total trade of 12 percent on average; see Table 1.

> Table 1 HERE <

All other data come from the World Bank's *World Development Indicators*. Specifically, we use real GDP (base year is 1995), labor force, and gross fixed capital formation. The latter are used to compute capital stocks according to the perpetual inventory method, assuming a depreciation rate of 13.3% as suggested in Leamer (1984).
Table 1 provides details on the median, mean, and standard deviation of all variables in use. We would like to highlight that trade costs of homogeneous goods are higher than those of differentiated goods by five percentage points on average, and this difference is significant at 1 percent according to a paired t-test.

IV. **Econometric Analysis**

In the econometric analysis, we estimate initially the following five specifications of cross-section regressions:

$$GLI_{ij} = \gamma_0 + \gamma_1 GDT_{ij} + \gamma_2 SIMI_{ij} + \gamma_3 DRLFAC_{ij} + \gamma_4[\ln(t_{Xij})-\ln(t_{Yij})] + \gamma_5 \ln(t_{Yij}) + u_{ij} \quad (9)$$

$$GLI_{ij} = \gamma_0 + \gamma_1 GDT_{ij} + \gamma_2 SIMI_{ij} + \gamma_3 DRLFAC_{ij} + \gamma_4[\ln(t_{Xij})-\ln(t_{Yij})] + \gamma_5 \ln(t_{Yij}) + \gamma_6 DRLFAC_{ij}\times[\ln(t_{Xij})-\ln(t_{Yij})] + \gamma_7 DRLFAC_{ij}\times\ln(t_{Yij}) + u_{ij} \quad (10)$$

$$GLI_{ij} = \gamma_0 + \gamma_1 GDT_{ij} + \gamma_2 SIMI_{ij} + \gamma_3 DRLFAC_{ij} + \gamma_5 \ln(t_{Yij}) + \gamma_6 DRLFAC_{ij}\times[\ln(t_{Xij})-\ln(t_{Yij})] + u_{ij} \quad (11)$$

$$GLI_{ij} = \gamma_0 + \gamma_1 GDT_{ij} + \gamma_2 SIMI_{ij} + \gamma_3 DRLFAC_{ij} + \gamma_4[\ln(t_{Xij})-\ln(t_{Yij})] + \gamma_7 DRLFAC_{ij}\times\ln(t_{Yij}) + u_{ij} \quad (12)$$

$$GLI_{ij} = \gamma_0 + \gamma_1 GDT_{ij} + \gamma_2 SIMI_{ij} + \gamma_3 DRLFAC_{ij} + \gamma_6 DRLFAC_{ij}\times[\ln(t_{Xij})-\ln(t_{Yij})] + \gamma_7 DRLFAC_{ij}\times\ln(t_{Yij}) + u_{ij} \quad (13)$$

where $GDT_{ij}=\ln(GDP_i+GDP_j)$, $SIMI_{ij}=(GDP_i \cdot GDP_j)/(GDP_i+GDP_j)^2$ is the chosen formulation of similarity in country size (see Helpman, 1987, and Bergstrand, 1990, for two alternative specifications), $DRLFAC_{ij}$ is defined in Section 2, and $\ln(t_{Xij})$ and $\ln(t_{Yij})$ are the logs of the c.i.f./f.o.b. bilateral transport costs of differentiated and homogeneous goods, respectively. Let u_{ij} be a classical error term. Note that any variation in $\ln(t_{Yij})$ is representing variation in *total* trade costs, as the inclusion of $[\ln(t_{Xij})-\ln(t_{Yij})]$ is holding constant *differences* in trade costs between sectors.

We take into account that *GLI* is a limited dependent variable. Accordingly, we use the logistically transformed index, defined as ln(GLI/[1-GLI]), in the regressions to ensure that the model prediction of *GLI* lies in the [0,1] interval (see also Bergstrand, 1983, 1990; Hummels and Levinsohn, 1995).

> Table 2 HERE <

Table 2 summarizes the results. First, we consider the coefficient estimates for the variables representing economic size, similarity, and relative factor endowment differences. The sum of the two countries' GDPs has the expected positive effect on *GLI* and the coefficient estimates are statistically significant. GDP similarity also has the expected positive relationship with *GLI*, although coefficient estimates generally lack statistical significance at conventional levels. Differences in relative factor endowments have the expected negative relationship with the share of intra-industry trade; coefficient estimates are statistically significant. Thus, in all five specifications, economic size, economic similarity, and relative factor endowment differences have the expected correlations with *GLI.*

In examining the empirical relationships between *GLI*, the transport cost variables, and the interaction terms, we consider each of the five specifications in turn. Model 1 considers first the effects of absolute and relative trade cost changes on *GLI* in the absence of interactions with relative factor endowment differences. In the presence of $\ln(t_{Yij})$, variation in $[\ln(t_{Xij})-\ln(t_{Yij})]$ represents changes in X's transport cost only. As expected based upon our theory, increases in the relative transport cost factor in X have a negative relationship with *GLI*. Also, as expected, increases in absolute transport costs $\ln(t_{Yij})$, holding variation in $[\ln(t_{Xij})-\ln(t_{Yij})]$ constant, decrease *GLI*. Thus, the coefficient estimates in Model 1 are remarkably consistent with the theoretical model.

In Model 2, we include as well two interaction terms between the transport cost variables and *DRLFAC*. As shown in Table 2, the coefficient estimate for $DRLFAC_{ij} \times \ln(t_{Yij})$ has the expected negative sign, but is not statistically significant. The coefficient estimate for $DRLFAC_{ij} \times [\ln(t_{Xij})-\ln(t_{Yij})]$ does not have the expected sign, but also is not statistically significant. The explanation for these interaction term coefficient results is collinearity among subsets of the regressors. In particular, $\ln(t_{Yij})$ and $DRLFAC_{ij} \times \ln(t_{Yij})$ are highly collinear (correlation coefficient of 0.71) and $[\ln(t_{Xij})-\ln(t_{Yij})]$ and $DRLFAC_{ij} \times [\ln(t_{Xij})-\ln(t_{Yij})]$ are highly collinear (correlation coefficient of 0.82).

To account for this collinearity, we also ran Models 3, 4 and 5, as shown above. In Model 3, we include the three core variables – GDT, SIMI, and DRLFAC – with only $\ln(t_{Yij})$ and $DRLFAC_{ij} \times [\ln(t_{Xij})-\ln(t_{Yij})]$, as the correlation coefficient between these two variables is only 0.29. As shown in Table 2, both variables – absolute transport costs and relative transport costs – have the expected negative coefficient estimates; these results are spared multicollinearity. Moreover, the interaction of $[\ln(t_{Xij})-\ln(t_{Yij})]$ with *DRLFAC* will still allow estimating the marginal impact of relative trade costs on the transformed *GLI* at various levels of relative factor endowment differences. These estimates will be summarized later.

In Model 4, we include the three core variables with only $[\ln(t_{Xij})-\ln(t_{Yij})]$ and $DRLFAC_{ij} \times \ln(t_{Yij})$. As shown in Table 2, both variables have the expected negative relationship with *GLI*. The interaction of $\ln(t_{Yij})$ with *DRLFAC* will allow estimating the marginal impact of absolute trade costs on the transformed *GLI* at various levels of relative factor endowment differences, holding constant relative trade costs.

For completeness, Model 5 includes the three core variables with only $DRLFAC_{ij} \times \ln(t_{Yij})$ and $DRLFAC_{ij} \times [\ln(t_{Xij})-\ln(t_{Yij})]$. Once again, both interaction terms have coefficient estimates with the expected negative signs. We will also be able to retrieve estimates of the marginal impacts at various levels of *DRLFAC*.

> Tables 3a and 3b HERE <

Tables 3a and 3b provide estimates of the marginal impacts of the two transport cost variables on the transformed GLI at various levels of relative factor endowment differences. Table 3a provides estimates for Models 3 and 4. As our theory illustrated in Figure 2 suggests, the negative marginal effects become larger (in absolute terms) with larger differences in relative factor endowments. The results in Table 3b for Model 5 confirm these results. The only difference of the estimated marginal effects from the theory is that the marginal effects for the trade cost difference variable are larger (in absolute terms) than those for the total trade cost variable. Careful examination of Figure 2 reveals that the line for (t_X=1.3, t_Y=1.1) lies systematically below that for (t_X=1.3, t_Y=1.3). While the estimated marginal effects are not statistically significant, we will find later in the sensitivity analysis that a slightly different specification reverses this outcome.

V. **Sensitivity Analysis**

We investigate the robustness of our findings in Models 1-5 in several respects; in several areas, we omit Model 2 simply for brevity and ease of presentation.

5.1 Measuring Economic Size and Similarity

The basic specification described above in equations (9)-(13) has one frequently used alternative. Both Helpman (1987) and Hummels and Levinsohn (1995) used max($lnGDP_i$, $lnGDP_j$) and min($lnGDP_i$, $lnGDP_j$) to represent economic size and similarity, rather than GDT and SIMI used earlier. This alternative specification is presented in Table 4.

> Table 4 HERE <

Table 4 shows that the basic results are largely insensitive to the change in specification. However, we notice one improvement. As Model 1 reveals, for example, the relative coefficient sizes (in absolute terms) for the transport cost difference variable and the absolute transport cost variable change. The change in relative coefficient sizes is revealed also in estimates of the marginal effects for the transport cost variables using the alternative specification shown in Tables 5a and 5b.

> Tables 5a and 5b HERE <

Tables 5a and 5b indicate that the estimated marginal effects for changes in relative transport costs are now larger in absolute terms than those for changes in absolute transport costs. This is consistent with the theoretical implications of the model, as shown in Figure 2.

For the remaining results in this paper, we analyze Models 1, 3, 4, and 5 only; we exclude Model 2 for brevity and convenience.

5.2 Treatment for Influential Observations

We conducted two sensitivity analyses to detect the possibility of our results being driven either by outliers or leverage points. For outliers, we follow Belsley, Kuh and Welsch (1980) and run OLS on all four models excluding observations with an absolute error term larger than two standard errors of the regression. For leverage observations, we run median regressions, cf., Greene (2000), to determine how sensitive the results are to influential observations. As shown in Table 6, the coefficient estimates for the relevant transport cost (or interaction) variables are largely the same as in Table 2. (All the results shown in Table 6 use the original specification with GDT and SIMI.)

We also considered the possible influence of the results being driven by the smallest country pair's observation or the largest country pair's observation. As Table 6 indicates, the coefficient estimates for the relevant variables were insensitive to the exclusion of either country pair.

5.3 Influential Observations for Particular Parameters

We follow Efron and Tibshirani (1993) and conduct a jackknife analysis to assess the maximum impact of cross-sectional observations on each transport cost (or interaction) variable's coefficient estimate. Specifically, we investigate the maximum positive and negative deviation from our original coefficient estimates in Table 2 as a result of excluding a single country-pair. In general, the results are robust. In every model, the maximum and minimum coefficient estimates are economically very close to the respective coefficient estimates reported in Table 2. For example, in Model 1, the coefficient estimate for $[\ln(t_{Xij})-\ln(t_{Yij})]$ is -0.223 in Table 2 whereas the minimum (maximum) coefficient estimate for this variable in Table 6 is -0.244 (-0.175). The coefficient estimate for $\ln(t_{Yij})$ is -0.334 in Table 2 whereas the minimum (maximum) coefficient estimate for this variable in Table 6 is -0.443 (-0.305). Thus, the results are robust to a jackknife analysis.

5.4 Trade-Imbalance-Adjusted GLI

As pointed out in earlier and more recent research, the use of bilateral trade-imbalance-adjusted *GLI* indices often is preferable over unadjusted ones; see Bergstrand, 1983; Greenaway and Milner, 1986; Egger, Egger, and Greenaway, 2004. Accordingly, we also estimated our five specifications employing trade-imbalance-adjusted *GLI* measures. We used bilateral aggregate OECD trade figures to compute adjusted GLI indices. There is no one widely-adopted method for "adjusting" G-L indexes. For convenience and in the interest of a sensitivity analysis, we adjusted the bilateral trade flows to reflect bilateral aggregate trade balance. As shown in the last line of Table 6, the results reported in Table 2 are generally robust to the alternative use of adjusted *GLI* indices.

VI. **Conclusions**

Anderson and van Wincoop (2004) have recently challenged international trade economists to lend *much more consideration* to the importance of "trade costs" in influencing the pattern of international trade as well as international price disparities. Their work suggests that the average implied markup attributable to the costs of international transaction may be approximately as high as *170 percent*! Despite this, international trade economists have devoted little attention to this important notion.

Researchers in the determinants of intra-industry trade have shared in under-emphasizing the importance and role of trade costs in influencing Grubel-Lloyd measures of such trade. This paper departs from earlier models of intra-industry trade – such as the work of Helpman, Krugman, Hummels and Levinsohn, and Evenett and Keller – by focusing theoretically and empirically on the nonlinear relationship between trade costs and the determinants of intra-industry trade. Because of nonlinear relationships between economic size, relative factor endowments, and trade costs, we developed a simple computable general equilibrium model to illustrate – under plausible parameter values – the influence of trade costs on Grubel-Lloyd measures of intra-industry trade (*GLI*). Our theoretical results suggest that the level of trade costs should negatively impact the *share* of intra-industry trade, that differences in trade costs between differentiated goods and homogeneous goods should affect *GLI*, and that the marginal effects of either of these variables on *GLI* are highly sensitive to the level of relative factor endowment differences.

In a large cross-section of bilateral intra-industry trade shares based on OECD data, we investigate these hypotheses empirically. The findings are strongly in support of our view. This illustrates how – as Anderson and van Wincoop (2004) suggest – a more realistic treatment of transport costs in our standard models of trade could help to put forward new and interesting hypotheses and could become a cornerstone for subsequent empirical research in international economics.

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Figure 1: Iso-GLI and Iso-GDP-Share Lines

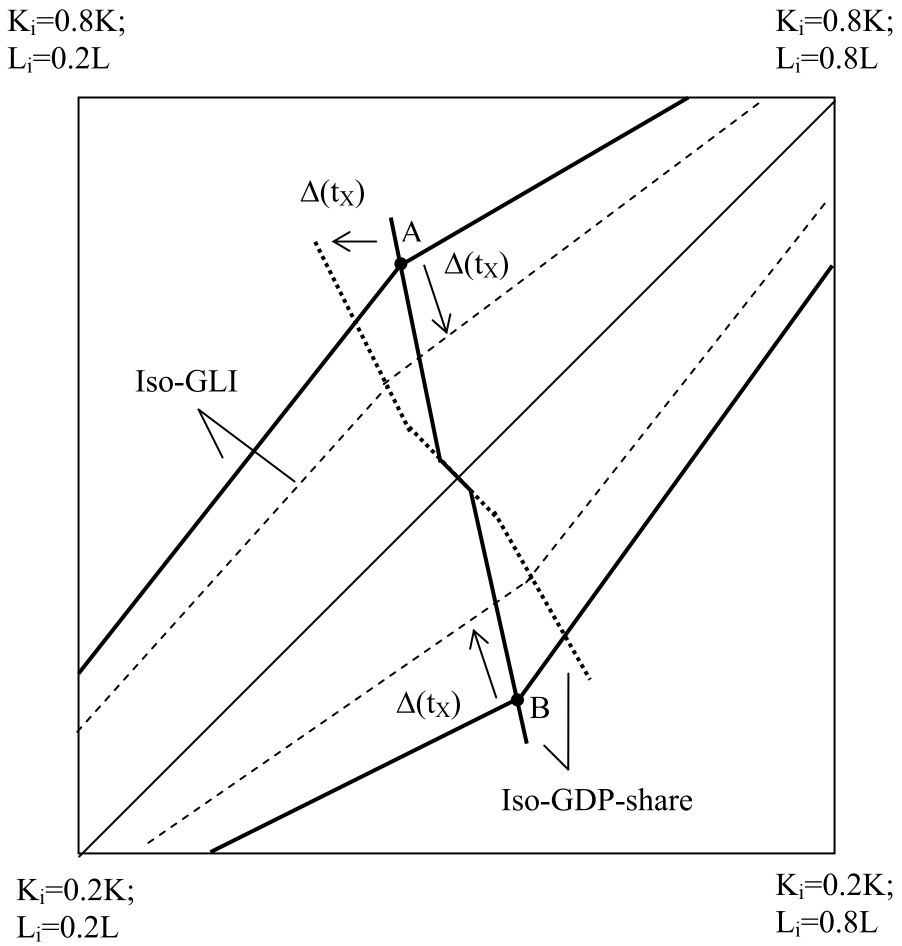

Figure 2: Factor endowment differences, transport costs and the Grubel-Lloyd index

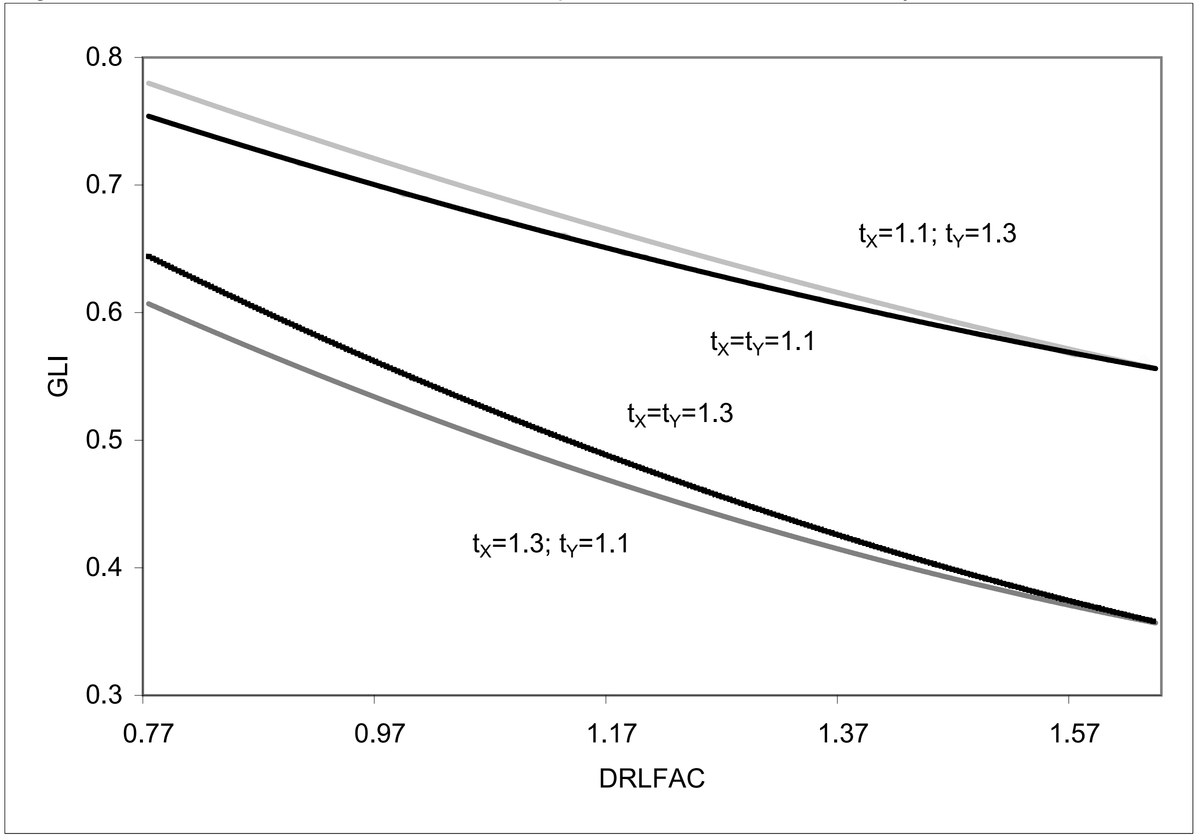

Table 1: Descriptive statistics (1990-2000 averages)

Variable	Median	Mean	Std. dev.
Grubel-Lloyd Index (GLI)	0.19	0.22	0.16
Log bilateral maximum real GDP (MAXG)	26.99	26.91	1.22
Log bilateral minimum real GDP (MING)	25.27	25.59	0.97
Log bilateral sum of real GDP (GDT)	27.27	27.27	1.06
Bilateral similarity index (SIMI; real GDP-based)	0.16	0.15	0.08
Absolute log difference in capital-labor ratios (DRLFAC)	0.64	0.95	0.89
1+bilateral differentiated goods trade costs (t_X)	1.09	1.15	0.38
1+bilateral homogeneous goods trade costs (t_Y)	1.17	1.20	0.35
Bilateral share of homogeneous goods	0.05	0.12	0.19

Table 2: Regression results

	Model 1	Model 2	Model 3	Model 4	Model 5
Log bilateral sum of GDP: GDT	0.286 ***	0.285 ***	0.293 ***	0.290 ***	0.298 ***
	0.041	0.042	0.041	0.041	0.042
Log similarity in GDP: SIMI	0.080	0.079	0.083	0.092 *	0.097 *
	0.054	0.054	0.054	0.054	0.054
Absolute log difference in bilateral labor ratios: DRLFAC	-0.362 ***	-0.354 ***	-0.363 ***	-0.347 ***	-0.350 ***
	0.042	0.044	0.043	0.044	0.044
Log difference in differentiated and homogeneous goods transport costs: $\ln(t_X)-\ln(t_Y)$	-0.223 ***	-0.354 **	-	-0.284 ***	-
	0.087	0.165	-	0.083	-
Log 1+bilateral homogeneous transport costs: $\ln(t_Y)$	-0.334 ***	-0.250 *	-0.393 ***	-	-
	0.101	0.148	0.096	-	-
Interaction term: $\text{DRLFAC}\times[\ln(t_X)-\ln(t_Y)]$	-	0.113	-0.107 *	-	-0.119 *
	-	0.121	0.062	-	0.064
Interaction term: $\text{DRLFAC}\times\ln(t_Y)$	-	-0.073	-	-0.175 **	-0.195 ***
	-	0.105	-	0.070	0.072
Constant	-8.753 ***	-8.721 ***	-8.928 ***	-8.832 ***	-9.023 ***
	1.064	1.074	1.066	1.074	1.078
Observations	810	810	810	810	810
Between R^2	0.16	0.16	0.15	0.15	0.15

The dependent variable is the logistic transformation of GLI. Figures below coefficients are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent.

Table 3a: Marginal effect of trade costs

	Trade cost difference Model 3	Total trade costs Model 4
Lowest decile of DRLFAC (0.124)	-0.013 *	-0.022 **
	0.008	0.009
Mean of DRLFAC (0.946)	-0.101 *	-0.166 **
	0.059	0.066
Highest decile of DRLFAC (2.157)	-0.231 *	-0.378 **
	0.135	0.151

The dependent variable is the logistic transformation of GLI. Marginal effects refer to the transformed GLI. Figures below marginal effects are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent.

Table 3b: Marginal effect of trade costs

	Trade cost difference	Total trade costs
	Model 5	
Lowest decile of DRLFAC (0.124)	-0.015 *	-0.024 ***
	0.008	0.009
Mean of DRLFAC (0.946)	-0.113 *	-0.184 ***
	0.061	0.068
Highest decile of DRLFAC (2.157)	-0.257 *	-0.421 ***
	0.139	0.155

The dependent variable is the logistic transformation of GLI. Marginal effects refer to the transformed GLI. Figures below marginal effects are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent.

Table 4: Alternative specification for economic size and similarity

	Model 1	Model 2	Model 3	Model 4	Model 5
Log maximum of exporter and importer GDP	0.253 ***	0.251 ***	0.265 ***	0.252 ***	0.263 ***
	0.040	0.040	0.040	0.040	0.041
Log minimum of exporter and importer GDP	-0.004	-0.003	0.000	0.000	0.005
	0.051	0.051	0.052	0.051	0.052
Absolute log difference in bilateral labor ratios: DRLFAC	-0.295 ***	-0.284 ***	-0.292 ***	-0.276 ***	-0.277 ***
	0.048	0.050	0.048	0.049	0.050
Log difference in differentiated and homogeneous goods transport costs: $\ln(t_X)-\ln(t_Y)$	-0.446 ***	-0.604 ***	-	-0.491 ***	-
	0.094	0.168	-	0.090	-
Log 1+bilateral homogeneous transport costs: $\ln(t_Y)$	-0.297 ***	-0.168	-0.414 ***	-	-
	0.112	0.162	0.107	-	-
Interaction term: DRLFAC$\times[\ln(t_X)-\ln(t_Y)]$	-	0.141	-0.228 ***	-	-0.241 ***
	-	0.124	0.069	-	0.071
Interaction term: DRLFAC$\times\ln(t_Y)$	-	-0.120	-	-0.180 **	-0.204 **
	-	0.116	-	0.079	0.082
Constant	-8.045 ***	-8.028 ***	-8.476 ***	-8.136 ***	-8.553 ***
	1.232	1.241	1.237	1.239	1.249
Observations	810	810	810	810	810
Between R^2	0.14	0.14	0.13	0.13	0.12

Figures below coefficients are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent.

Table 5a: Marginal effect of trade costs

	Trade cost difference Model 3 in Table 4	Total trade costs Model 4 in Table 4
Lowest decile of DRLFAC (0.124)	-0.028 ***	-0.022 **
	0.008	0.007
Mean of DRLFAC (0.946)	-0.215 ***	-0.170 **
	0.065	0.051
Highest decile of DRLFAC (2.157)	-0.491 ***	-0.389 **
	0.148	0.117

The dependent variable is the logistic transformation of GLI. Marginal effects refer to the transformed GLI. Figures below marginal effects are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent.

Table 5b: Marginal effect of trade costs

	Trade cost difference	Total trade costs
	Model 5 in Table 4	
Lowest decile of DRLFAC (0.124)	-0.030 ***	-0.025 **
	0.009	0.010
Mean of DRLFAC (0.946)	-0.228 ***	-0.193 **
	0.067	0.077
Highest decile of DRLFAC (2.157)	-0.519 ***	-0.441 **
	0.152	0.176

The dependent variable is the logistic transformation of GLI. Marginal effects refer to the transformed GLI. Figures below marginal effects are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent.

Table 6: Sensitivity analysis

	Model 1 - based		Model 3 - based		Model 4 - based		Model 5 - based	
	$\ln(t_X)$-$\ln(t_Y)$	$\ln(t_Y)$	$\ln(t_Y)$	RLFAC× ($\ln(t_X)$-$\ln(t_Y)$)	$\ln(t_X)$-$\ln(t_Y)$	RLFAC× $\ln(t_Y)$	RLFAC× $\ln(t_X)$-$\ln(t_Y)$	RLFAC× $\ln(t_Y)$
Influential observations:								
Excluding outliers[a)]	-0.108 *	-0.393 ***	-0.523 ***	-0.144 ***	-0.343 ***	-0.181 ***	-0.170 ***	-0.202 ***
	0.062	0.096	0.093	0.055	0.072	0.062	0.057	0.064
Median regression	-0.308 ***	-0.319 **	-0.464 ***	-0.183 *	-0.325 ***	-0.210 **	-0.189 **	-0.220 *
	0.093	0.162	0.174	0.101	0.084	0.098	0.112	0.133
Excluding smallest country-pair	-0.230 ***	-0.331 ***	-0.391 ***	-0.111 *	-0.290 ***	-0.173 **	-0.124 *	-0.193 ***
	0.087	0.101	0.096	0.063	0.083	0.070	0.065	0.072
Excluding largest country-pair	-0.225 ***	-0.336 ***	-0.394 ***	-0.111 *	-0.284 ***	-0.181 ***	-0.122 *	-0.201 ***
	0.087	0.101	0.096	0.063	0.083	0.070	0.064	0.072
Jackknife analysis:								
Jackknife analysis (minimum $\ln(t_X)$-$\ln(t_Y)$ coeff.)	-0.244 ***	-0.330 ***	-	-	-0.303 ***	-0.177 **	-	-
	0.087	0.100	-	-	0.083	0.070	-	-
Jackknife analysis (maximum $\ln(t_X)$-$\ln(t_Y)$ coeff.)	-0.175 *	-0.371 ***	-	-	-0.250 ***	-0.187 ***	-	-
	0.090	0.102	-	-	0.085	0.070	-	-
Jackknife analysis (minimum $\ln(t_Y)$ coeff.)	-0.197 **	-0.443 ***	-0.502 ***	-0.092 *	-	-	-	-
	0.087	0.110	0.105	0.046	-	-	-	-
Jackknife analysis (maximum $\ln(t_Y)$ coeff.)	-0.240 ***	-0.305 ***	-0.363 ***	-0.123 *	-	-	-	-
	0.088	0.103	0.099	0.064	-	-	-	-
Jackknife analysis (minimum RLFAC×[$\ln(t_X)$-$\ln(t_Y)$] coeff.)	-	-	-0.390 ***	-0.125 **	-	-	-0.139 **	-0.156 *
	-	-	0.096	0.062	-	-	0.069	0.088
Jackknife analysis (maximum RLFAC×[$\ln(t_X)$-$\ln(t_Y)$] coeff.)	-	-	-0.408 ***	-0.055	-	-	-0.070	-0.208 ***
	-	-	0.097	0.081	-	-	0.084	0.073
Jackknife analysis (minimum RLFAC×$\ln(t_Y)$ coeff.)	-	-	-	-	-0.286 ***	-0.195 **	-0.122 *	-0.215 ***
	-	-	-	-	0.082	0.070	0.064	0.072
Jackknife analysis (maximum RLFAC×$\ln(t_Y)$ coeff.)	-	-	-	-	-0.299 ***	-0.142 *	-0.139 **	-0.156 *
	-	-	-	-	0.085	0.082	0.069	0.088
Trade imbalance adjusted GLI:								
Trade imbalance adjusted GLI as LHS variable	-0.087 **	-0.497 ***	-0.542 ***	-0.051 **	-0.217 ***	-0.212 ***	-0.004	-0.275 ***
	0.044	0.102	0.097	0.028	0.092	0.077	0.009	0.087

Figures below coefficients are standard errors. Two-tailed t-tests: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent. - a) We follow Belsley et al. (1980) in defining outliers as observations with absolute residuals larger than two standard errors of the regression.