Intra-industry trade: A Krugman-Ricardo model and data

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Abstract

This paper develops a many-good, many-country model of international trade which combines Ricardian comparative advantage and increasing returns to scale. It is shown how the gains from trade depend on relative country sizes, trade cost, and the technological similarity between countries. Trade consists of both inter- and intra-industry trade. The Grubel-Lloyd index of intra-industry trade is positively related to own country size and the number of exported sectors, and is negatively related to average partner country size, the number of imported sectors, and the trade cost. The empirical evidence supports most of these predictions, and fits the model better for OECD than for non-OECD countries.

JEL Classification: F11, F12, F14.
Keywords: Increasing returns to scale; Comparative advantage; intra-industry trade.

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1 Introduction

As the international trading system becomes more complex, new theories have been developed to explain trade patterns between countries. Traditional trade theories focus on comparative advantage, in terms of technological differences in the Ricardian model, or factor endowment differences in the Heckscher-Ohlin and specific factors models. More recently, new trade theories have emphasised imperfect competition and increasing returns to scale, such as the Krugman (1980) model, and heterogeneity across firms as in Melitz (2003).

There is an important literature which combines aspects of various international trade theories, providing a more unified picture of the reasons for international trade. For instance, Helpman and Krugman (1985) combine Heckscher-Ohlin factor endowments with Spence-Dixit-Stiglitz imperfect competition to show the pattern of trade that emerges when both traditional and new trade theories are combined. Davis (1995) combines Heckscher-Ohlin factor endowments with Ricardian comparative advantage to show how intra-industry trade can arise in the absence of imperfect competition. More recently, Bernard et al (2007) combine a Melitz (2003) model of monopolistic competition with heterogeneous firms with Heckscher-Ohlin factor endowments to show how firm heterogeneity interacts with country characteristics in international trade. The present paper contributes to this literature, by combining Ricardian comparative advantage with imperfect competition.

To be precise, this paper develops a multi-sector, multi-country model of international trade, based on both traditional and new trade theories. It combines Ricardian technological differences across countries, and monopolistic competition of the Krugman (1980) variety, and builds upon the comparative advantage model developed by Ruffin (2009). Also related to the present paper is the Ricardian model with a continuum of goods as developed by Dornbusch et al (1977), and the extension to many countries developed by Eaton and Kortum (2002). It differs from Ricci's (1997) combination of Ricardian comparative advantage and monopolistic competition in having many sectors and countries. Chung (2007) allows for differences across countries in the fixed and marginal costs of production in a model of international trade under monopolistic competition. Shelburne (2002) develops a multi-country version of the monopolistic competition model. More closely related to the present paper is Kikuchi et al (2008), who develop a many-sector, two-country model of international trade with Ricardian comparative advantage and monopolistic competition. By introducing many countries and trade costs, the present paper generates additional results on the pattern of trade relative to Kikuchi et al (2008).

On the empirical side, there is a vast literature documenting and analysing the determinants of intra-industry trade. This literature has been surveyed by Greenaway and Milner (1987, 2005) and Greenaway and Torstensson (1997). Grubel and Lloyd (1975) was the first major study of the phenomenon. Much of the earlier empirical work was exploratory in nature, for instance Balassa and Bauwens (1987). More recent work has mainly been based on the theoretical approach of Helpman and Krugman (1985). Helpman (1987) was the first of these, and was followed by Hummels and Levinsohn (1995), Kim and Oh (2001), Debeare (2005), Cieslik (2005), and Kamata (2010). These papers are based on the model without trade costs. Bergstrand (1990) and Bergstrand and Egger (2006) formally introduce trade costs into the model and develop theoretically-founded empirical predictions on the relationship between intra-industry trade and trade costs. Compared to the recent literature, the present paper develops a new model of intra-industry trade which generates new empirical predictions, which we take to the data.

Section 2 sets out the model. We derive two main theoretical results. First, we show in Section 3 that the gain from trade arises from both traditional and new sources: from specialisation in the sectors in which a country has a comparative advantage in, and increasing numbers of goods available for consumption[2]. The second main theoretical result, which we show in Section 4, is that international trade consists of both inter-industry and intra-industry trade. Intra-industry trade arises because more than one country has a comparative advantage in each sector; if only one country has a comparative advantage in each sector, then all trade would be inter-industry. We show how the various parameters of the model affect the Grubel-Lloyd (GL) index of intra-industry trade. In particular, own country size and the number of exported sectors are positively related to the GL index, while average partner country size, the number of imported sectors and transport costs are negatively related to the GL index.

[2] In this paper, as will be made clear below, the economy consists of many sectors, and each sector consists of many goods.

Section 5 documents the data used in the empirical analysis. In Section 6 we show that the empirical evidence is mostly consistent with what the theoretical model predicts about the determinants of the GL index. The Grubel-Lloyd index is found to be positively related to the number of exported sectors and negatively related to the number of imported sectors. Trade costs as measured by distance between trading partners and average tariffs are negatively related to the GL index. The variables based on the model explain a larger fraction of the GL index for OECD countries than for non-OECD countries. Section 7 provides some brief conclusions.

2 Autarkic equilibrium

There are T countries, $t = 1, \ldots, T$ and S sectors, $s = 1, \ldots, S$. Each country has L_t units of labour, which is perfectly mobile across sectors but perfectly immobile across countries; L_t may differ across countries. Define $L_W = \sum_t L_t$ as the world supply of labour, so that $\overline{L_W} = L_W/T$ is the average country size.

The representative consumer's utility is a Cobb-Douglas function:

$$U = \prod_{s=1}^{S} C_s^{\frac{1}{S}} \tag{1}$$

Each sector consists of many goods, so that consumption in each sector C_s is a constant-elasticity-of-substitution (CES) sub-utility function defined over $g = 1, \ldots, G$ goods:

$$C_s = \sum_{g=1}^{G} c_{gs}^{\rho} \tag{2}$$

Where $0 < \rho < 1$, and c_{gs} is the consumption of good g in sector s. Technological advantage is synonymous with comparative advantage in this paper; we favour the latter term in the remainder of the paper. Each country t has a comparative advantage in $rL_t < S$ sectors[3]. Each sector has the same number of countries which have a comparative advantage in it. Hence there will be rL_W/S countries with a comparative advantage in each sector. Assume that $rL_W > S$; that is, the number of sectors which countries have a comparative advantage in, exceeds the total number of sectors. This ensures that at least one country has a comparative advantage in each sector.

[3] Note that if this is true for any country t, it must also be true for the average country, so $r\overline{L_W} < S$.

Each good g is produced under increasing returns to scale and monopolistic competition as in Krugman (1980). All firms in the same sector in a country share the same cost function – there is no firm heterogeneity of the Melitz (2003) type. Labour is the only factor of production, and is freely mobile across sectors and goods but not across countries. The labour used in country t in producing a good g in sector s is given by:

$$l_{gs} = a + bq_{gs} \qquad \text{for} \qquad s \notin rL_t \tag{3}$$

$$l_{gs} = \alpha\left(a + bq_{gs}\right) \qquad \text{for} \qquad s \in rL_t \tag{4}$$

where q_{gs} is the output of good g in sector s, and $\alpha < 1$ reflects the comparative advantage of country t in sectors rL_t, in the form of lower cost of production. Assume full employment, and free entry and exit of firms so that profits are zero in equilibrium. Since in equilibrium all firms in sector s will charge the same price and produce the same output, the total labour used in each sector is simply the number of goods in each sector times the labour used in each good: $L_s = n_s l_{gs}$. Then the solution to the model gives (see Krugman (1980) for details):

$$p_s = \frac{wb}{\rho} \qquad q_{gs} = \left(\frac{a}{b}\right)\left(\frac{\rho}{1-\rho}\right) \qquad n_s = \frac{(1-\rho)L_s}{a} \qquad \text{for} \qquad s \notin rL_t \tag{5}$$

$$p_s = \frac{\alpha wb}{\rho} \qquad q_{gs} = \left(\frac{a}{b}\right)\left(\frac{\rho}{1-\rho}\right) \qquad n_s = \frac{(1-\rho)L_s}{\alpha a} \qquad \text{for} \qquad s \in rL_t \tag{6}$$

Where w is the wage rate, p_s is the price of each good g in sector s, and n_s is the endogenously-determined number of goods in each sector. Hence there are lower prices and a larger number of goods in the sectors with a comparative advantage as compared to the other sectors (assuming the labour used in each sector is the same).

In autarky, each country must produce all sectors, and given the Cobb-Douglas utility and free movement of labour across sectors, will devote $L_s = L_t/S$ labour to each sector. Consumption equals output and is identical across sectors: $c_{gsA} = q_{gs}$. Let n_1 be the number of goods in each comparative advantage sector, and n_2 be the number of goods in each non-comparative advantage sector. Then,

$$n_1 = \frac{(1-\rho)L_t}{S\alpha a} \qquad \text{and} \qquad n_2 = \frac{(1-\rho)L_t}{Sa} \tag{7}$$

Because all goods in each sector are symmetric, we have:

$$\begin{aligned} C_s^A &= \sum_{g=1}^{G} c_{gsA}^{\rho} = n_s c_{gsA}^{\rho} \\ &= n_1 c_{gsA}^{\rho} = \frac{(1-\rho)L_t}{S\alpha a}\left(\frac{a}{b}\frac{\rho}{1-\rho}\right)^{\rho} \qquad \text{for} \qquad s \in rL_t \\ &= n_2 c_{gsA}^{\rho} = \frac{(1-\rho)L_t}{Sa}\left(\frac{a}{b}\frac{\rho}{1-\rho}\right)^{\rho} \qquad \text{for} \qquad s \notin rL_t \end{aligned}$$

Hence, utility under autarky is:

$$U^A = \left(n_1 c_{gsA}^{\rho}\right)^{\frac{rL_t}{S}} \left(n_2 c_{gsA}^{\rho}\right)^{\frac{S-rL_T}{S}} = c_{gsA}^{\rho}(n_1)^{\frac{rL_t}{S}}(n_2)^{\frac{S-rL_T}{S}} = \left[\frac{(1-\rho)L_t}{Sa}\left(\frac{a}{b}\frac{\rho}{1-\rho}\right)^{\rho}\right]\left[\frac{1}{\alpha}\right]^{\frac{rL_t}{S}} \tag{8}$$

3 The gains from trade

When international trade is allowed, each country will specialise in and export the rL_t sectors in which it has a comparative advantage, and will import the other $S - rL_t$ sectors from the other countries[4]. This implies that larger countries produce a more diversified range of sectors than small countries, which is in accord with the empirical findings of Hummels and Klenow (2005). In addition, because there are many goods in each sector, and there are rL_W/S countries which have a comparative advantage in each sector, a country will also import goods from the sectors in which it has a comparative advantage. That is, trade will be both inter- and intra-industry in nature.

In the jargon of the new trade literature, when trade is liberalised, new firms enter the sectors where a country has comparative advantage and produce a larger number of goods in these sectors, while firms in the other sectors exit. Therefore, all the labour in each country is used in the rL_t sectors in which it has a comparative advantage. It is well-known that there is indeterminacy in production in the Ricardian model (see for example Eaton and Kortum (2012)). To simplify the analysis, we make the fairly strong assumption that labour is equally divided between the country's comparative advantage sectors when international trade is allowed. As we will see later on, this assumption enables us to make a clear prediction about the relationship between the parameters of the model and the pattern of trade between countries, so it is an empirical issue whether this is an appropriate assumption to make.

Suppose that international trade occurs in the presence of iceberg trade costs[5] such that for every unit of a good exported, $\tau < 1$ units arrive at the destination country; $1 - \tau$ is therefore the trade cost. For simplicity let τ be identical across countries. Assume that the trade cost is always small enough so that all countries always find it beneficial to engage in

[4] Will countries always specialise in free trade? Yes, provided there are gains from trade. Specialisation in a country's comparative advantage sectors results in the largest number of goods in the world economy, thus maximises welfare of all countries.

[5] Despite dramatic reductions in formal trade barriers such as tariffs in recent decades, the total cost of international trade remains high; see Anderson and van Wincoop (2004) for a discussion.

international trade. It can be shown that the number of goods produced in each sector does not depend on the trade cost. Then, for a producer in a comparative advantage sector of a country, letting an asterisk denote values for consumers in other countries, the equilibrium prices and quantities are (analogously to equations (5) and (6) above):

$$p_g = \frac{wb}{\theta} \qquad c_{gsFT} = \frac{a}{b}\frac{\rho}{1-\rho}\frac{L_t}{L_W} \tag{9}$$

$$p_g^* = \frac{p_g}{\tau} = \frac{wb}{\tau\theta} \qquad c_{gsFT}^* = c_{gsFT}\tau^{\frac{1}{1-\rho}} = \frac{a}{b}\frac{\rho}{1-\rho}\frac{L_t}{L_W}\tau^{\frac{1}{1-\rho}} \tag{10}$$

$$n_s^{FT} = \frac{1-\rho}{r\alpha a} \qquad n_{sW}^{FT} = \frac{(1-\rho)L_W}{\alpha a S} \tag{11}$$

Where n_{sW}^{FT} is the number of goods produced in the world in that sector. Hence, for sectors where a country does *not* have a comparative advantage in, total consumption is:

$$C_{S\notin rL_t} = n_{sW}^{FT}\left(c_{gsFT}^*\right)^{\rho} = n_{sW}^{FT}\left(c_{gsFT}\right)^{\rho}\tau^{\frac{\rho}{1-\rho}} \tag{12}$$

For sectors where a country has a comparative advantage in, this is equal to consumption of goods produced domestically plus consumption of goods produced in the rest of the world:

$$C_{S\in rL_t} = n_s^{FT}\left(c_{gsFT}\right)^{\rho} + (n_{sW}^{FT} - n_s^{FT})\left(c_{gsFT}\right)^{\rho}\tau^{\frac{\rho}{1-\rho}} \tag{13}$$

$$= \left[n_s^{FT} + (n_{sW}^{FT} - n_s^{FT})\tau^{\frac{\rho}{1-\rho}}\right]\left(c_{gsFT}\right)^{\rho} \tag{14}$$

Hence utility when international trade is allowed is:

$$U^{FT} = \left(c_{gsFT}\right)^{\rho}\left[n_s^{FT} + (n_{sW}^{FT} - n_s^{FT})\tau^{\frac{\rho}{1-\rho}}\right]^{\frac{rL_t}{S}}\left[n_{sW}^{FT}\tau^{\frac{\rho}{1-\rho}}\right]^{\frac{S-rL_t}{S}} \tag{15}$$

Define the gains from trade as the ratio between free trade and autarkic utility. The gains from trade are:

$$\text{Gain} = \frac{U^{FT}}{U^A} = \left(\frac{L_t}{L_W}\right)^{\rho-1}\left(\frac{\tau^{\frac{\rho}{1-\rho}}}{\alpha}\right)^{\frac{S-rL_t}{S}}\left[\tau^{\frac{\rho}{1-\rho}} + \left(1-\tau^{\frac{\rho}{1-\rho}}\right)\frac{S}{rL_W}\right]^{\frac{rL_t}{S}} \tag{16}$$

Gains from trade arise if $U^{FT}/U^A > 1$. This clearly depends on the trade cost τ, so equation (16) also implicitly defines the minimum value of τ (the maximum value of the trade cost) for which countries will trade and gain from trade.

It can be shown that:

$$\frac{d\text{Gain}}{d(L_t/L_W)} < 0, \qquad \frac{d\text{Gain}}{dS} > 0, \qquad \frac{d\text{Gain}}{dr} < 0, \tag{17a}$$

$$\frac{d\text{Gain}}{d\alpha} < 0, \qquad \frac{d\text{Gain}}{d\tau} > 0, \qquad \frac{d\text{Gain}}{d\rho} < 0 \tag{17b}$$

That is, the gains from trade increase as the relative size of the country L_t/L_W decreases, the number of sectors S increases, the number of sectors each country has a comparative advantage in r decreases, α decreases (that is, the degree of comparative advantage *increases*), τ increases (the trade cost *falls*), and the love-for-variety parameter ρ decreases (the lower the elasticity of substitution between goods). These results are similar to those obtained in other models. In particular, smaller countries gain more than larger countries and trade costs reduce the gain from trade, while the greater the difference between countries (the smaller is r or α), the greater the gain (see Ethier (2009)).

4 Trade patterns

In free trade, each country is specialised in the rL_t sectors in which it has a technological advantage. Assume that trade is balanced, and that a country devotes $1/r$ labour to each of its comparative advantage sectors. Since preferences are homothetic and goods produced in different countries are imperfect substitutes, in equilibrium each country will export the following fraction of its output in each of these rL_t sectors (hence also its total output):

$$\text{Exports} = \frac{(L_W - L_t)\tau^{\frac{1}{1-\rho}}}{L_t + (L_W - L_t)\tau^{\frac{1}{1-\rho}}} \tag{18}$$

Hence exports as a share of GDP decreases the larger is the country relative to the rest of the world, and the lower the trade cost.

International trade consists of both inter-industry and intra-industry trade. Because rL_W/S countries are assumed to have a comparative advantage in any one sector, these countries will export different goods within that sector to each other. A country's imports in its comparative advantage sectors are:

$$\text{Imports} = \frac{L_t\tau^{\frac{1}{1-\rho}}\left(\frac{rL_W}{S}-1\right)}{L_t^* + (L_W - L_t^*)\tau^{\frac{1}{1-\rho}}} \tag{19}$$

Where L_t^* is the average labour force in the other countries that specialise in these sectors. Hence the aggregate Grubel-Lloyd (GL) index of intra-industry trade of a country across all sectors will be:

$$\text{GL} = \left(1 - \frac{|\text{Exports}-\text{Imports}|}{\text{Exports}+\text{Imports}}\right)\left(\frac{rL_t}{S}\right) = \left\{1 - \frac{\left|\frac{(L_W - L_t)\tau^{\frac{1}{1-\rho}}}{L_t + (L_W - L_t)\tau^{\frac{1}{1-\rho}}} - \frac{L_t\tau^{\frac{1}{1-\rho}}\left(\frac{rL_W}{S}-1\right)}{L_t^* + (L_W - L_t^*)\tau^{\frac{1}{1-\rho}}}\right|}{\frac{(L_W - L_t)\tau^{\frac{1}{1-\rho}}}{L_t + (L_W - L_t)\tau^{\frac{1}{1-\rho}}} + \frac{L_t\tau^{\frac{1}{1-\rho}}\left(\frac{rL_W}{S}-1\right)}{L_t^* + (L_W - L_t^*)\tau^{\frac{1}{1-\rho}}}}\right\}\left(\frac{rL_t}{S}\right) \tag{20}$$

Where the last term on the right-hand-side is the share of sectors the country has a comparative advantage in (hence produces when international trade is allowed); this simple expression arises because all sectors are the same size[6]. It can be shown that:

$$\frac{dGL}{dL_t} > 0, \qquad \frac{dGL}{dL_t^*} < 0, \qquad \frac{dGL}{dL_W} > 0, \qquad \frac{dGL}{dr} > 0, \qquad \frac{dGL}{dS} < 0, \tag{21a}$$

$$\frac{dGL}{d\tau} < 0, \qquad \frac{dGL}{d\rho} > 0, \qquad \text{if} \qquad L_t > L_t^* \tag{21b}$$

$$\frac{dGL}{d\tau} > 0, \qquad \frac{dGL}{d\rho} < 0 \qquad \text{if} \qquad L_t < L_t^* \tag{21c}$$

The GL index increases the larger is the country, the smaller the other countries which have a comparative advantage in the same sectors, the larger the size of the world economy, the larger the number of sectors the country has a comparative advantage in, and the smaller the total number of sectors. The impact of the trade cost and the elasticity of substitution between goods depend on the size of the country relative to that of other countries which have a comparative advantage in the same sectors. If the country is larger than these other countries, then lower values of τ (higher trade costs) or higher values of ρ (the elasticity of substitution) imply higher values of the GL index, whereas the opposite is the case if the country is smaller than the other countries which have a comparative advantage in the same sectors. Empirically, because most countries' main trading partner is a large country such as the US or China, only four countries have $L_t > L_t^*$: the US, China, Japan and Germany. Hence for almost every country in the world, the model predicts that trade costs and the elasticity of substitution between goods will both be negatively related to the GL index. The result on trade costs is particularly important, since we have shown that in a very standard model without forward and backward linkages (for instance, Yi (2003)), trade costs reduce the share of intra-industry trade in total trade.

Comparing the model's predictions on the determinants of the GL index with the predictions of the Helpman (1987) model, in Helpmans' model the share of intra-industry trade depends on the similarity in per capita GDP or relative endowments, and on the dispersion of per capita income. Kim and Oh (2001) show that the share of intra-industry trade also depends on relative country sizes and total country pair size, while Cieslik (2005) shows that the model predicts that the sum of the capital-labour ratios is also a determinant of the share of intra-industry trade. Bergstrand (1990) shows that trade costs influence the share of intra-industry

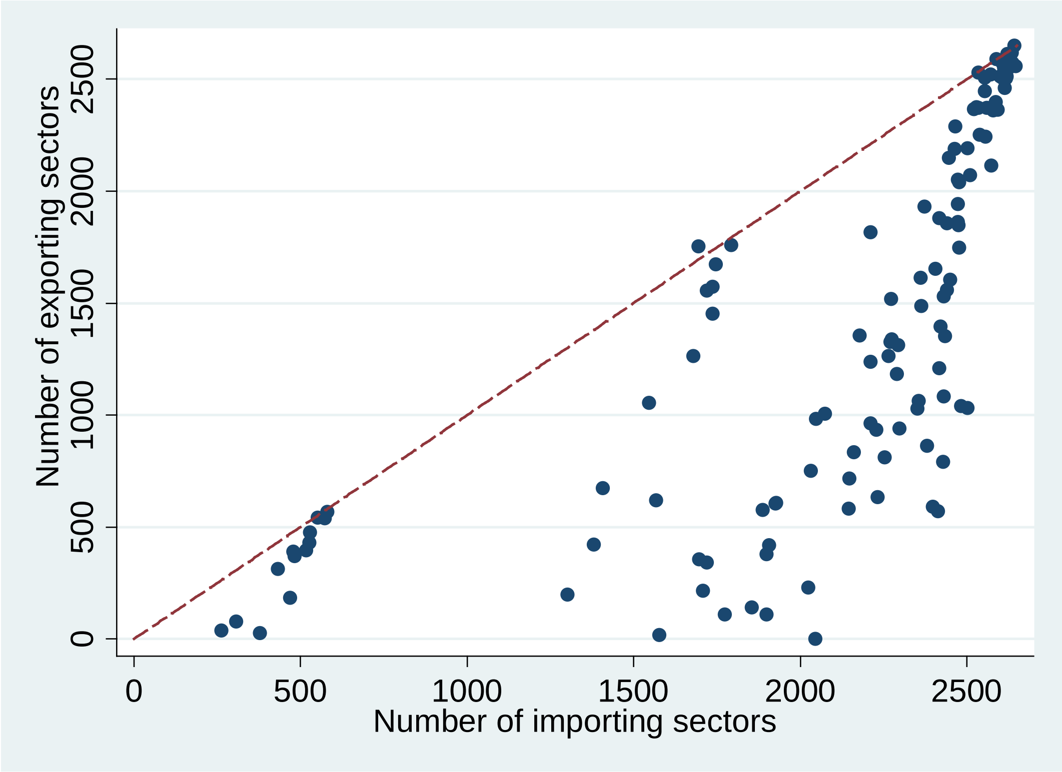
[6] It is also possible to derive the GL index for each sector; we do not pursue this line of inquiry in the present paper.

trade. Therefore the main difference between our model and this previous work is that our model predicts a relationship between the number of sectors exported and imported and the GL index. In the empirical sections we will investigate whether this is an important determinant of the GL index.

5 Data and methods

We make use of 2010 data from the UN Comtrade database. The year 2010 was chosen because it is a recent year in which international trade flows were not severely affected by the global financial crisis of 2008-09 or the Euro debt crisis of 2011-12. Data on additional variables was obtained from other sources which will be discussed below. Combining the UN Comtrade data with data from these other sources results in a total of 118 countries in the empirical analysis.

Figure 1: The number of exporting and importing sectors: UN Comtrade data, 5-digit SITC, 2010.



One of the key assumptions of the theoretical model is that a country has a comparative advantage in a subset of the available sectors. As discussed above, if each country has a comparative advantage in only one sector, then it would be completely specialised in this sector. On the other hand, if all countries have the same technology in all sectors, countries would simultaneously export and import all sectors so that the number of sectors exported is the same as the number imported, as each country would produce different goods within each sector. Figure 1 shows the number of 5-digit SITC Revision 4 sectors (a total of 2652 sectors) exported and imported by all the countries in the database, where each dot represents a country, and the dashed line represents equal numbers of exporting and importing sectors. The correlation coefficient between the two series is 0.7247. Almost all countries are below the 45-degree line (the exception is India), indicating that countries export fewer sectors than they import. Hanson (2012) also documents this specialisation in exports across countries. A similar figure can be drawn for different levels of aggregation – in general, the more aggregated the data, the higher the correlation between the number of sectors exported and imported, as we would expect: at the 4-, 3-, 2- and 1-digit levels the correlation between number of sectors exported and imported is 0.7298, 0.7979, 0.8415, and 0.8781, respectively.

The key empirical prediction of the model as summarised in equations (20) and (21), is that the Grubel-Lloyd (GL) index of intra-industry trade is positively related to a country's size, the size of the world economy, and the number of sectors it exports, and is negatively related to the number of sectors a country imports and the average size of its trading partners. In addition, trade costs are negatively related to the GL index if the country is smaller than its trading partners on average, but the opposite relationship holds if the country is larger than its trading partners. Hence we estimate the following equation using OLS:

$$GL_i = \beta_0 + \beta_1 N_{Export} + \beta_2 N_{Import} + \beta_3 \ln GDP_i + \beta_4 \ln \overline{GDP_{j\neq i}} + \beta_5 TC + \beta_6 D + \beta_7 TC \times D + \epsilon_i \tag{22}$$

Previous empirical work such as Hummels and Levinsohn (1995) and Debaere (2005) have used a limited dependent variable estimator since the GL index is bounded between zero and one (a logistic transformation in the case of Hummels and Levinsohn, and a Tobit estimator in the case of Debaere). We do not use such an estimator here, since we work with the aggregate GL index as compared with the bilateral GL index used in Hummels and Levinsohn (1995) and Debaere (2005). Where previous work has encountered instances where the empirical bilateral GL index is equal to zero, we document no cases of the aggregate GL index being equal to zero in our sample.

We proxy country size by its GDP measured in constant US dollars, obtained from the World Development Indicators of the World Bank. We use two proxies for trade cost: the average applied tariff on manufactured goods imposed by a country's trading partners also obtained from the World Development Indicators, and the average distance of a country from its trading partners, measured by the great circle distance between the most important cities in each country, obtained from the GeoDist database compiled by Mayer and Zignago (2011) and available at the CEPII (Centre D'Etudes Prospectives Et D'Informations Internationales) website. The trade cost and partner GDP variables are weighted by the share of trade with each trading partner. D is a dummy that takes a value equal to 1 when a country's GDP is larger than the average of its trading partners' GDP. We interact D with both measures of trade cost to capture the different relationship between trade cost and the GL index depending on relative country sizes. Note also that we do not include a measure of World GDP in equation (22) since we only use data from one time period.

6 Empirical results

The results of estimating equation (22) are reported in Table 1. Column (1) uses average distance from trading partners as the proxy for trade costs. As predicted by the model, the number of exported sectors is positively related to the GL index, while the number of imported sectors is negatively related to the GL index. The coefficients are highly statistically significant, and hold across the different specifications in the rest of Table 1. Reporter country GDP is positively related to the GL index while average trading partner GDP is negatively related to the GL index across all specifications. These are as predicted by the model, although this time the coefficients are often not significant at conventional levels. Average distance from trading partners is negatively associated with the GL index; countries which are further away from their trading partners are less likely to engage in intra-industry trade. This is consistent with the model if countries are smaller on average than their trading partners.

Column (2) of Table 1 replaces average distance from trading partners with the average tariff imposed by a country's trading partners as a measure of trade cost. This has a negative albeit insignificant coefficient. Column (3) includes both average distance and average tariffs; the negative and significant coefficient on average distance from trading partners remains, but the average trading partner tariff is now positive (but still insignificant).

Columns (4) to (6) of Table 1 interact the trade cost measures with a dummy for whether the country is larger than its trading partners on average, as suggested by equations (20) and (21). As noted above, only four countries have $D = 1$: the US, China, Japan and Germany. In column (4), the dummy variable has a positive and significant coefficient, indicating that the four countries that are larger than their trading partners have a higher GL index, while the interaction with average distance is negative but not significant. Similar results are obtained in column (5) when distance is replaced by average partner tariffs. However, when both measures of trade cost are included in column (6), the interaction between the dummy and distance from trading partner is negative and significant, suggesting that countries that are larger than their trading partners have an even larger decline in the GL index the further they are from their trading partners on average. On the other hand, the interaction between the dummy and average trading partner tariff is positive and significant, suggesting the opposite interpretation. These seemingly contradictory results are probably due to the fact that there are only four countries for which $D = 1$, so that any relationships obtained are likely to depend more on the idiosyncratic features of these four countries than on any general trend[7].

Overall the results of Table 1 provide strong evidence in support of the predictive powers of the model. All the coefficients are of the expected sign, and significantly so in the case of the number of sectors imported and exported, and trade costs. In addition, the R-squared of the regression is relatively high – above 0.6 in all specifications.

[7] We have also estimated the first three columns of Table 1 excluding the four countries for which $D = 1$; the results are very similar to those reported.

Table 1: The determinants of the Grubel-Lloyd index.

	(1)	(2)	(3)	(4)	(5)	(6)
Imported sectors	-0.010	-0.011	-0.011	-0.011	-0.011	-0.011
	(0.003)***	(0.003)***	(0.002)***	(0.003)***	(0.003)***	(0.003)***
Exported sectors	0.021	0.022	0.021	0.021	0.022	0.021
	(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Reporter GDP	1.299	0.983	1.292	1.194	0.914	1.244
	(0.756)*	(0.734)	(0.746)*	(0.830)	(0.850)	(0.831)
Average partner GDP	-0.828	-3.012	-0.800	-0.774	-2.971	-0.604
	(1.602)	(1.822)	(1.627)	(1.616)	(1.867)	(1.647)
Average distance from trading partners	-2.182		-2.557	-2.144		-2.504
	(0.601)***		(0.644)***	(0.604)***		(0.648)***
Average partner tariff		-1.173	1.252		-1.152	1.116
		(1.061)	(1.138)		(1.079)	(1.152)
D				0.175	0.102	-0.267
				(0.104)*	(0.350)	(0.116)**
D × Average distance from trading partners				-0.026		-0.115
				(0.022)		(0.021)***
D × Average partner tariff					-0.025	0.269
					(0.091)	(0.062)***
Constant	19.989	83.245	16.686	20.736	83.516	13.614
	(41.422)	(47.473)*	(41.454)	(41.799)	(47.989)*	(41.823)
R^2	0.67	0.62	0.68	0.67	0.62	0.68
N	118	118	118	118	118	118

Notes: *** significant at 1%; ** significant at 5%; * significant at 10%. Estimation method is OLS. Figures in parentheses are heteroskedastic-robust standard errors. D is a dummy equal to 1 if Reporter GDP > Average partner GDP.

A key contribution of Hummels and Levinsohn (1995) is to perform the empirical analysis on OECD and non-OECD countries separately. This is based on the idea that the model of intra-industry trade may be expected to fit OECD countries better than non-OECD countries, because OECD countries specialise in differentiated manufactured goods whereas non-OECD countries specialise in non-differentiated goods. We can perform the same division with our data; our sample consists of 34 OECD countries and 84 non-OECD countries. That OECD countries engage in more intra-industry trade than non-OECD countries is corroborated in our data; at the 5-digit level, the average GL index for OECD countries is 0.46, while it is 0.17 for non-OECD countries.

Table 2 reports the results of estimating equation (22) for OECD and non-OECD countries separately. We focus on the analogues to columns (1) to (3) in Table 1. The table does indeed suggest that the model fits OECD countries better than non-OECD countries. The R-squared of the regressions are much higher for OECD countries: between 0.6 and 0.7 compared to between 0.4 and 0.5 for non-OECD countries. For both OECD and non-OECD countries, the number of exported sectors is positively and significantly related to the GL index, while the number of imported sectors is negatively and significantly related to the GL index. Neither reporter nor average partner GDP has any significant effect in either group of countries, although OECD countries have coefficient signs that are in accord with the theoretical model whereas non-OECD countries do not. However, trade costs have no significant impact on the GL index for non-OECD countries. For OECD countries, trade costs as measured either by distance from trading partners or trading partner tariffs are negatively and significantly related to the GL index when these measures are included separately in the regression. When both measures of trade costs are included together, only distance from trading partners have a negative and significant effect on the GL index.

The data also shows that the average GL Index increases the more aggregated is the data. The average GL Index at the 5-digit level of aggregation is 0.25, while at the 4-digit level it is 0.29, at the 3-digit level it is 0.34, and the 2-digit level it is 0.40, and at the 1-digit level it is 0.53. That is, to some extent the degree of intra-industry trade is an artefact of industrial aggregation; a similar point has been made by Greenaway and Milner (1983) and Bhagwati and Davis (1999).

Table 2: Dividing the sample into OECD and non-OECD countries.

	OECD countries			Non-OECD countries		
	(1)	(2)	(3)	(4)	(5)	(6)
Imported sectors	-0.032	-0.036	-0.032	-0.010	-0.010	-0.010
	(0.011)***	(0.010)***	(0.011)***	(0.003)***	(0.003)***	(0.003)***
Exported sectors	0.039	0.041	0.040	0.019	0.019	0.020
	(0.012)***	(0.011)***	(0.012)***	(0.003)***	(0.003)***	(0.003)***
Reporter GDP	1.620	1.932	1.663	-0.123	-0.378	-0.117
	(1.195)	(1.638)	(1.252)	(0.892)	(0.772)	(0.881)
Average partner GDP	-0.815	-5.022	-0.947	-0.955	-1.806	-0.972
	(4.336)	(4.936)	(4.326)	(1.596)	(1.899)	(1.620)
Average distance from	-3.120		-2.970	-0.984		-1.369
trading partners	(0.487)***		(0.789)***	(0.833)		(0.930)
Average partner tariff		-9.255	-0.667		0.198	1.150
		(2.583)***	(3.317)		(1.053)	(1.181)
Constant	27.143	158.181	31.586	49.535	74.388	47.585
	(114.354)	(128.266)	(112.987)	(44.602)	(51.877)	(44.013)
R^2	0.71	0.65	0.71	0.46	0.45	0.47
N	34	34	34	84	84	84

Notes: *** significant at 1%; ** significant at 5%; * significant at 10%. Estimation method is OLS. Figures in parentheses are heteroskedastic-robust standard errors. D is a dummy equal to 1 if Reporter GDP > Average partner GDP.

7 Conclusions

As more countries join the global trading system, and as more goods are traded and consumed, more models of international trade are developed, to help us understand the pattern of and the gains from international trade. This paper presents a model of international trade with many goods and many countries which combines Ricardian comparative advantage, monopolistic competition, and transport costs. Two main theoretical results are obtained. First, the gains from trade are shown to be larger for smaller countries, and smaller the higher is the trade cost and the more similar are countries to each other. Second, the trade pattern that emerges in the model is both inter- and intra-industry in nature. The model yields a prediction linking the share of intra-industry trade as measured by the Grubel-Lloyd index to the number of sectors exported and imported by the country, the size of the country and the average size of its trading partners, and the trade cost. These predictions are broadly consistent with a cross-section of countries using 2010 data from the UN Comtrade database. In addition, OECD countries fit the model better than non-OECD countries, as would be expected if OECD countries specialise in differentiated goods while non-OECD countries specialise in non-differentiated goods. The simple structure of the theoretical model presented in this paper of course prevents it from fully capturing all the complexities of international trade patterns.

The theoretical model yields new predictions on the determinants of the Grubel-Lloyd index compared to the Helpman (1987) model; in particular, the role of the number of sectors traded. In principle it would be possible to compare the performance of the two models; here we have refrained from doing so, taking the line advocated by Leamer and Levinsohn (1995) to "estimate, don't test" the model. Hence this possibility is left to future work.

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