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

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May 2015

Abstract

This paper develops a model of international trade with a continuum of countries and sectors, which combines Ricardian comparative advantage and increasing returns to scale. Trade consists of both inter- and intra-industry trade. The model predicts that the trade-weighted Grubel-Lloyd index of intra-industry trade is positively related to the number of exported sectors, and is negatively related to the number of imported sectors. Empirical evidence from a panel of countries using the UN Comtrade database supports these predictions, and the model fits the data better for non-OECD than for OECD countries.

JEL Classification: F11, F12, F14.

Keywords: Increasing returns to scale; Comparative advantage; intra-industry trade.

* All data created during this research are openly available from the Lancaster University data archive at http://dx/doi.org/10.17635/lancaster/researchdata/33.

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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 the literature cited above. We develop a model of international trade with a continuum of countries and sectors, based on both traditional and new trade theories. We combine Ricardian technological differences across countries and monopolistic competition of the Krugman (1980) variety. In so doing, we provide an alternative to the Helpman and Krugman integration of traditional and new trade theories.

This alternative is important, as the empirical evidence (e.g. Harrigan (1997), Davis and Weinstein (2001)) shows that there is an important role for technological differences across countries in determining the structure of production.

The model generates new predictions for the determinants of the degree of intra-industry trade. The trade-weighted Grubel-Lloyd (TWGL) index of intra-industry trade is shown to depend positively on the number of sectors exported by a country, the country size and the total trading partner size, and negatively on the number of sectors imported. Whilst country size is not a new predictor of the TWGL index, the number of exported and imported sectors are, and we are interested in finding out whether these new predictors are empirically relevant. We therefore take these model predictions to data from the UN Comtrade database, making use of a panel of 172 countries from 1988 to 2013, and find that they are largely consistent with the data. In addition, the model's predictions fit the data better for non-OECD than for OECD countries. This suggests that the combination of technological differences and imperfect competition is more appropriate for the former countries, while the Helpman and Krugman combination of factor endowment differences and imperfect competition is more appropriate for the latter countries (see Hummels and Levinsohn (1995)).

On the theoretical side, this paper is related to models that extend the monopolistic competition model of trade in several ways. For instance, Ricci (1997) combines Ricardian comparative advantage and monopolistic competition in a two country, two sector model. 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 Helpman and Krugman (1985) model. The present paper innovates relative to this literature by adopting a many-country, many-sector framework, which more readily lends itself to empirical analysis.

There is of course a literature that includes models that have many goods and countries. For instance, Eaton and Kortum (2002) extend the Dornbusch et al (1977) Ricardian model with a continuum of goods to many countries. Kikuchi et al (2008) 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). Romalis (2004) combines the many-good Heckscher-Ohlin model developed by Dornbusch et al (1980) with trade costs and Krugman (1980) monopolistic competition. Chaney (2008) and Arkolakis et al (2008) extend the Melitz (2003) heterogeneous firms model to many countries. In these models, firms within each sector have different productivities, but all countries have the same technology. In contrast, our model has identical firms in each sector, but countries have comparative advantage in different sectors. Finally, Hsieh and Ossa (2011) develop a many-country, many-industry model of trade which combines Ricardian comparative advantage, Krugman (1980) imperfect competition, and Melitz (2003) firm heterogeneity. They use the model to analyse the effects on world incomes of productivity growth in China, whereas our focus in this paper is on intra-industry trade.

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 as discussed above, for which we find strong evidence in the data.

Section I sets out the model, while Section II discusses both the no-trade equilibrium and the open economy equilibrium. The main theoretical results are derived in Section III, where we show 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 trade-weighted Grubel-Lloyd (TWGL) index of intra-industry trade. In particular, own country size, total trading partner size and the number of exported sectors are positively related to the TWGL index, while the number of imported sectors is negatively related to the TWGL index.

Section IV documents the data and methods used in the empirical analysis. In addition to conventional panel data methods, we also control for the endogeneity of the number of exported and imported sectors using two-step GMM methods. In Section V we show that the empirical evidence is mostly consistent with what the theoretical model predicts about the determinants of the TWGL index, especially the two new predictors: the number of sectors exported and imported. The predictions of the model are more in line with the results for non-OECD countries than for OECD countries. Section VI provides some brief conclusions.

I. THE MODEL

There is a continuum of countries $z \in [0, Z]$, and a continuum of sectors $s \in [0, S]$. Labour is the only factor of production, and is perfectly mobile across sectors but perfectly immobile across countries. Each country has L_z units of labour. Define $L_W = \int_0^Z L_z \, dz$ as the world supply of labour, so that the average country size is $\overline{L_z} = L_W / Z$.

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

$$U = \int_0^S b_s \log(C_s) \, ds \tag{1}$$

Each sector consists of a continuum of varieties, so that consumption in each sector C_s is a constant-elasticity-of-substitution (CES) sub-utility function defined over $\omega \in [0, \Omega]$ varieties:

$$C_s = \int_0^\Omega c_\omega^\rho \, d\omega \qquad 0 < \rho < 1 \tag{2}$$

Each variety ω 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[1]. Divide sectors into those that a country has a comparative advantage in, S_1, and those that a country has a comparative disadvantage in, S_2. The labour used in country z in producing a variety ω in sector s is given by:

$$l_\omega = \gamma(f + c q_\omega) \qquad \text{for} \qquad s \in S_1 \tag{3}$$

$$l_\omega = f + c q_\omega \qquad \text{for} \qquad s \in S_2 \tag{4}$$

Where $S_1 + S_2 = S$, q_ω is the output of variety ω, and $\gamma < 1$ reflects the comparative advantage of country z in sectors S_1, in the form of lower cost of production. γ is assumed to be common across countries but may apply to different sectors in different countries. Technological advantage is synonymous with comparative advantage in this paper; we favour the latter term in the remainder of the paper.

We make two key assumptions on the comparative advantage sectors to simplify the analysis. First, the mass of comparative advantage sectors is proportional to the labour force in each country: $S_{1z} = \lambda L_z < S$, where λ is constant across countries. As a result, a larger country has a comparative advantage in more sectors than does a smaller country, but, as will be shown in Section III below, in the free trade equilibrium each country devotes the same amount of labour to each comparative advantage sector. By fixing the mass of comparative advantage sectors in a country, this assumption prevents agglomeration forces and the possibility of multiple equilibria in the presence of trade costs (see Krugman (1980), Fujita et al (1999)), so that labour specialisation is based only on comparative advantage. This enables us to obtain a relatively simple expression for the TWGL index later on.

The second key simplifying assumption is that each sector has the same mass of countries which have a comparative advantage in it. Hence there will be $\lambda L_W / S$ countries with a comparative advantage in each sector. Assume that $\lambda L_W > S$; that is, there is at least one country with a comparative advantage in each sector. These two assumptions impose a bound on the values of λ: $L_z < \frac{S}{\lambda} < L_W$. Similarly to the first assumption above, this assumption simplifies the analysis by making all sectors symmetric and eliminating the size of a sector from the analysis. Otherwise, a country may have a comparative advantage in sectors which many other countries also have a comparative advantage in, and this would influence the expression of the TWGL index.

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 mass of varieties in each sector times the labour used in each variety: $L_s = n_\omega l_\omega$. Then following the same steps as in Krugman (1980), the solution to the model gives:

$$p_1 = \frac{\gamma wc}{\rho} \qquad q_{\omega 1} = \left(\frac{f}{c}\right)\left(\frac{\rho}{1-\rho}\right) \qquad n_1 = \frac{(1-\rho)L_s}{\gamma f} \qquad \text{for} \qquad s \in S_1 \qquad (5)$$

$$p_2 = \frac{wc}{\rho} \qquad q_{\omega 2} = \left(\frac{f}{c}\right)\left(\frac{\rho}{1-\rho}\right) \qquad n_2 = \frac{(1-\rho)L_s}{f} \qquad \text{for} \qquad s \in S_2 \qquad (6)$$

Where w is the wage rate, p_1 is the price of each good ω in each sector in S_1, and n_1 is the endogenously-determined mass of varieties in each sector in S_1. Hence there are lower prices and a larger mass of varieties in the sectors with a comparative advantage as compared to the other sectors (assuming the labour used in each sector is the same), although output of each variety is the same across sectors.

II. AUTARKIC AND FREE TRADE EQUILIBRIA

First, we consider the case of autarky. In autarky, each country must produce all sectors, and given the Cobb-Douglas utility, free movement of labour across sectors and the fact that there are S sectors, will devote $L_s = L_z/S$ labour to each sector[2]. Then:

$$n_1 = \frac{(1-\rho)L_z}{S\gamma f} \qquad \text{and} \qquad n_2 = \frac{(1-\rho)L_z}{Sf} \qquad (7)$$

Total consumption equals output and is identical across varieties so individual consumption is $c_{\omega s}^A = q_{\omega s}/L_z$. Because all varieties in each sector are symmetric, we have:

$$C_s^A = \int_0^\Omega c_\omega^\rho \, d\omega = n_s (c_{\omega s}^A)^\rho$$

$$= n_1 (c_{\omega s}^A)^\rho = \frac{(1-\rho)L_z}{S\gamma f} \left(\frac{f}{c} \frac{\rho}{1-\rho} \frac{1}{L_z} \right)^\rho$$

$$= \frac{1}{S\gamma} \left[\frac{(1-\rho)L_z}{f} \right]^{1-\rho} \left(\frac{\rho}{c} \right)^\rho \qquad \text{for} \qquad s \in S_1 \qquad (8a)$$

$$= n_2 (c_{\omega s}^A)^\rho = \frac{(1-\rho)L_z}{Sf} \left(\frac{f}{c} \frac{\rho}{1-\rho} \frac{1}{L_z} \right)^\rho$$

$$= \frac{1}{S} \left[\frac{(1-\rho)L_z}{f} \right]^{1-\rho} \left(\frac{\rho}{c} \right)^\rho \qquad \text{for} \qquad s \in S_2 \qquad (8b)$$

Since the quantity of each variety is the same in each sector, while the mass of varieties is larger in the comparative advantage sectors S_1, each consumer's total consumption is larger in the comparative advantage sectors than in the comparative disadvantage sectors. It is possible to substitute these expressions for consumption in each sector into the utility function (1) to perform a welfare comparison between autarky and free trade. Since our focus in the empirical analysis is on trade patterns rather than welfare, we do not pursue this topic further.

Next, consider the case of international trade. Assume that there are no trade costs[3]. When free international trade is allowed, the free trade equilibrium is such that each country will specialise in and export the $S_1 = \lambda L_z$ sectors in which it has a comparative advantage, and import the other $S_2 = S - \lambda L_z$ sectors from the other countries. Specialisation in a country's comparative advantage sectors results in the largest mass of varieties in the world economy, and thus maximises the welfare of all countries. As a result, larger countries produce a more diversified range of sectors than small countries, which is in accord with the empirical findings in Hummels and Klenow (2005). In addition, because there are many varieties in each sector, and there are $\lambda L_W / S > 1$ countries which have a comparative advantage in each sector, a country will also import varieties from the sectors in which it has a comparative advantage. That is, trade will be both inter- and intra-industry in nature[4].

In the terminology of the new trade literature, when trade is liberalised, new firms enter the sectors where a country has comparative advantage and produce a larger mass of varieties in these sectors, while firms in the other sectors exit. Therefore, all the labour in each country is used in the $S_1 = \lambda L_z$ 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))[5]. 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. That is, $L_s = L_z/\lambda L_z = 1/\lambda$. 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.

Since we assume no trade cost, every country will export its comparative advantage sectors to every other country in the world. 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):

$$p_\omega = p_\omega^* = \frac{\gamma wc}{\rho} \qquad c_\omega^{FT} = (c_\omega^{FT})^* = \frac{f}{c}\frac{\rho}{1-\rho}\frac{1}{L_W} \tag{9}$$

$$n_s^{FT} = \frac{1-\rho}{\lambda\gamma f} \qquad n_{sW}^{FT} = n_s^{FT}\left(\frac{\lambda L_W}{S}\right) = \frac{(1-\rho)L_W}{\gamma f S} \tag{10}$$

Where n_{sW}^{FT} is the mass of varieties produced in the world in that sector. Since there are no trade costs, prices and consumption of domestic and foreign varieties are equalised. Therefore, each consumer's consumption in each sector is:

$$C_s^{FT} = n_{sW}^{FT}(c_\omega^{FT})^\rho = \frac{(1-\rho)L_W}{\gamma f S}\left(\frac{f}{c}\frac{\rho}{1-\rho}\frac{1}{L_W}\right)^\rho = \frac{1}{\gamma S}\left[\frac{(1-\rho)L_W}{f}\right]^{1-\rho}\left(\frac{\rho}{c}\right)^\rho \quad (11)$$

Comparing consumption under autarky (8a) and (8b) with consumption under free trade (11), the representative consumer consumes a smaller amount of each variety under free trade, but a larger mass of varieties, with the result that $C_s^{FT} > C_s^A$.

III. TRADE PATTERNS

With international trade, each country is specialised in the $S_1 = \lambda L_z$ sectors in which it has a technological advantage. Assume that trade is balanced, and that a country devotes $L_s = 1/\lambda$ labour to each of its comparative advantage sectors. Recall from equations (9) and (10) above that with international trade, if a sector is produced in a country, the output of each country in that sector is the same. As a result, the implication of the Krugman (1980) model that wages may differ if countries differ in size does not arise in this model, since in this model, a larger country simply has more sectors, not larger sectors as is the case in Krugman (1980). With zero profits in equilibrium and labour as the only factor of production, the value of output in each sector in each country is equal to the wage bill in that sector, $wL_s = w/\lambda$. Following the approach in Krugman (1980), the value of a country's exports in each sector are equal to the value of output in that sector (w/λ) times the demand from the rest of the world for the country's output $\big(w(L_W - L_z)(\lambda L_z/S)\big)$, divided by total world demand for the country's output $\big(wL_W(\lambda L_z/S)\big)$:

$$(\text{Exports})_{s\in S_1} = \left(\frac{w}{\lambda}\right)\left(\frac{L_W - L_z}{L_W}\right) \quad (12)$$

Exports in each sector depend on the size of the country relative to the rest of the world.

Because $\lambda L_W/S > 1$ countries are assumed to have a comparative advantage in any one sector, these countries will export different varieties within that sector to each other. The value of a country's imports in each of its comparative advantage sectors is equal to the value of output in that sector in each country (w/λ) times the country's share of world demand for the sector (L_z/L_W), times the mass of countries exporting that sector to the country in question $\left((\lambda L_W/S) - 1\right)$:

$$(\text{Imports})_{s\in S_1} = \left(\frac{w}{\lambda}\right)\left(\frac{L_z}{L_W}\right)\left(\frac{\lambda L_W}{S} - 1\right) \tag{13}$$

Where $\lambda L_W/S - 1$ is the mass of other countries which produce each sector in S_1. Define the Grubel-Lloyd (GL) index for country z in a sector s as:

$$\text{GL}_{\text{zs}} = \left(1 - \frac{|\text{Exports}_{\text{zs}} - \text{Imports}_{\text{zs}}|}{\text{Exports}_{\text{zs}} + \text{Imports}_{\text{zs}}}\right) \tag{14a}$$

$$= \left\{1 - \frac{\left|\frac{L_W - L_z}{L_W} - \frac{L_z(\lambda L_W - S)}{SL_W}\right|}{\frac{L_W - L_z}{L_W} + \frac{L_z(\lambda L_W - S)}{SL_W}}\right\} \qquad \text{for} \qquad s \in S_1 \tag{14b}$$

$$= 0 \qquad \text{for} \qquad s \in S_2 \tag{14c}$$

Hence the trade-weighted aggregate GL index of intra-industry trade of a country across all sectors will be:

$$\text{TWGL}_{\text{z}} = \int_0^S \left[GL_{zs} * \left(\frac{\text{Exports}_{\text{zs}} + \text{Imports}_{\text{zs}}}{\text{Exports}_{\text{z}} + \text{Imports}_{\text{z}}}\right)\right] ds \tag{15a}$$

$$= \left\{1 - \frac{\left|\frac{L_W - L_z}{L_W} - \frac{L_z(\lambda L_W - S)}{SL_W}\right|}{\frac{L_W - L_z}{L_W} + \frac{L_z(\lambda L_W - S)}{SL_W}}\right\}\left(\frac{\lambda L_z}{S}\right) \tag{15b}$$

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 we have assumed that all sectors are the same size. The GL index and the TWGL index are both bounded between 0 and 1; this is true for the TWGL index since we have assumed above that $\lambda L_z = S_1 < S$. In the empirical analysis we will work almost exclusively with the TWGL index, since it yields more interesting results than the GL index across sectors. A country has a positive GL index which is constant across the sectors in which it has a comparative advantage, while it will have a GL index equal to zero in the other sectors[6].

It can be shown that (see Appendix A for a derivation):

$$\frac{dTWGL_z}{dL_z} > 0, \qquad \frac{dTWGL_z}{dL_W} > 0, \tag{16a}$$

$$\frac{dTWGL_z}{d\lambda} > 0, \qquad \frac{dTWGL_z}{dS} < 0. \tag{16b}$$

The TWGL index increases the larger is the country, the larger the size of the world economy (or the size of its trading partners), or the larger the mass of sectors the country has a comparative advantage in, and the smaller the total mass of sectors (which is equal to the mass of sectors imported). These predictions will be taken to the data in the following sections.

Intuitively, the larger is the country (L_z), all else being equal, the larger the mass of sectors it will have a comparative advantage in, relative to the total mass of sectors S, hence the larger the fraction of trade that will be intra-industry in nature. A similar interpretation can be made for the parameter λ, which captures the mass of comparative advantage sectors a country has (given country size). For a given size of the country, the larger is the world economy (L_W), the larger the fraction of a country's output in each of its comparative advantage sectors is exported, and hence the larger the TWGL index. On the other hand, the larger is the total mass of sectors S, the smaller is a country's mass of comparative advantage sectors as a fraction of S, and hence the smaller the TWGL index.

Comparing the model's predictions on the determinants of the TWGL index with the predictions of the Helpman (1987) model, in Helpman's 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 trade. Therefore the main difference between our model and this previous work is that our model predicts a relationship between the mass of sectors exported and imported and the TWGL index. In the empirical sections we will investigate whether this new prediction of our model is an important determinant of the TWGL index.

IV. DATA AND METHODS

Our empirical analysis uses data from the UN Comtrade database. We make use of data at the 5-digit SITC Revision 3 level. Using a constant SITC revision for the analysis means that we avoid the changing definitions of goods associated with revisions of industrial classifications, and makes comparisons over time possible. Our sample thus consists of 172 countries from 1988 (the introduction of SITC Revision 3) to 2013, totalling 3,044 observations in an unbalanced panel. Data on additional variables was obtained from other sources which will be discussed below.

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 in Section III, 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 varieties within each sector. Figure 1 shows the number of 5-digit SITC sectors (a total of 2,814 sectors) exported and imported by all the countries in the database across all years, where each data point represents a country in a year, and the dashed line represents equal numbers of exporting and importing sectors. The correlation coefficient between the two series is 0.7710. Almost all countries are below the 45-degree line, indicating that most countries export fewer sectors than they import. This is also true of the average number of sectors exported and imported, which are 1,484 and 2,255 sectors respectively; see Table 1. Hanson (2012) also documents this specialisation in exports across countries. A similar figure can be drawn for different levels of aggregation. In general, we find that the more aggregated the data, the lower the correlation between the number of sectors exported and imported; at the 4-, 3-, 2- and 1-digit levels the correlation between number of sectors exported and imported is 0.6868, 0.6826, 0.6464, and 0.5349, respectively.

< Figure 1 here >

< Table 1 here >

The data shows that the average TWGL index increases the more aggregated is the data. From Table 1, the average TWGL index at the 5-digit level of aggregation is 0.23, while (in untabulated results) at the 4-digit level it is 0.27, at the 3-digit level it is 0.32, and the 2-digit level it is 0.38, and at the 1-digit level it is 0.51. 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 shows the countries with the largest and smallest values of the TWGL index at the 5-digit level, in 2010. While the countries with the largest values of the TWGL index are mostly developed countries and countries that are important entrepot countries which export and import large quantities of goods, the countries with the smallest values are mostly small, less-developed island countries that produce and export relatively few goods. This provides motivation for dividing the sample into OECD and non-OECD countries later in the empirical analysis.

< Table 2 here >

The key empirical prediction of the model as summarised in equations (16a) and (16b) is that the trade-weighted Grubel-Lloyd (TWGL) 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. Hence for country z in year t we estimate the following equation:

$$TWGL_{zt} = \beta_0 + \beta_1 N_{zt}^{Export} + \beta_2 N_{zt}^{Import} + \beta_3 \ln GDP_{zt} + \beta_4 \ln GDP_{jt} + \gamma_z + \delta_t + \epsilon_{zt} \quad (17)$$

Where GDP_{jt} is the total size of country z's trading partners j. We measure country size and total trading partner size[7] by GDP measured in constant US dollars, obtained from the World Development Indicators of the World Bank. Total trading partner GDP is weighted by the share of trade with each trading partner. γ_z and δ_t are country and time fixed effects. Table 3 reports the correlations between the variables used in estimating equation (17). The TWGL index is highly correlated with the number of sectors exported and imported, and reporter GDP. Similarly, the number of sectors exported and imported are highly correlated with reporter GDP. These are as would be predicted by the model. On the other hand, total trading partner GDP is not highly correlated with any of the other variables of interest.

< Table 3 here >

Previous empirical work such as Bergstrand (1990), Hummels and Levinsohn (1995), Debaere (2005), Bergstrand and Egger (2006) and Kamata (2010) 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, Bergstrand, and Bergstrand and Egger, a Tobit estimator in the case of Debaere, and a Poisson Quasi-maximum likelihood estimator in the case of Kamata). In this paper, we work with the TWGL index as compared with the bilateral GL index used in this other work. This is significant, since where previous work has encountered numerous instances where the empirical bilateral GL index is equal to zero, we document only 9 cases of the aggregate TWGL index being equal to zero in our sample. Hence we may not expect the Tobit censoring to have a large impact on the results. Nevertheless, we report the results using a Tobit estimator with a full set of country and year fixed effects, in addition to standard Fixed Effects estimates.

The number of sectors exported and imported are likely to be jointly determined with the TWGL index. Similarly, the identity of and hence size of the country's trading partners may well be jointly determined with the TWGL index. Since this potential endogeneity may invalidate conventional fixed effects estimates, we also perform a two-stage GMM estimate of equation (17). The GMM approach yields efficiency gains relative to two-stage least squares estimates. However, it is difficult to find appropriate instruments for the potentially endogenous variables. Therefore, we use as instruments the first and second lags of each of the endogenous variables, and report a set of test statistics on the validity of these instruments.

V. EMPIRICAL RESULTS

The results of estimating equation (17) are reported in Table 4. All regression results are reported with standard errors clustered by country, and all results reported include a full set of country and year fixed effects. Column (1) reports OLS/FE estimates, column (2) reports Tobit estimates, column (3) reports two-stage GMM estimates assuming the number of exported and imported sectors are endogenous, and column (4) reports two-stage GMM estimates assuming the number of exported and imported sectors and the total partner country size are all endogenous. What is striking is how similar are the results obtained using different estimation methods. As predicted by the model, in all four specifications in Table 4, the number of exported sectors is positively and significantly related to the TWGL index, while the number of imported sectors is negatively and significantly related to the TWGL index. However, neither the reporter country GDP nor the total trading partner GDP are significantly related to the TWGL index in any specification.

< Table 4 here >

Table 4 also reports a set of specification tests for the two GMM models. From the Hansen J test, we do not reject the null of overidentification, which indicates that the instruments are uncorrelated with the error term. The results of the Kleibergen and Paap underidentification and weak identification tests indicate that the excluded instruments are highly correlated with the endogenous regressors. This can also be seen from the F-statistics from the first stage regressions of the joint significance of the excluded instruments on the three endogenous variables, which are always highly significant. Taken together, these results lend support to the instruments chosen for the GMM estimates. However, comparing the GMM to the fixed effects results also indicates that the two sets of results are similar to each other. Overall, we interpret the results of Table 4 as providing fairly strong evidence in support of the predictive powers of the model. This is especially true for the two variables which are new to the literature: the number of sectors imported and exported.

< Table 5 here >

As shown in Table 3, the number of sectors exported and imported and reporter GDP are highly correlated with each other. This may have affected the results of Table 4 through multicollinearity. Therefore, in Table 5 we report the results of dropping one of the three variables from the model, using OLS/FE in columns (1) to (3), and two-stage GMM in columns (4) to (6). In columns (1) and (4), we drop the number of imported sectors, and find that the number of exported sectors is still positively and significantly related to the TWGL index. On the other hand, when we drop the number of exported sectors in columns (2) and (5), the number of imported sectors is no longer significantly related to the TWGL index. When we drop reporter GDP in columns (3) and (6), the number of exported and imported sectors remain significantly related to the TWGL index, with the same signs as in Table 4. Taken together, the results in Table 5 suggest that our main results in Table 4 do not suffer from multicollinearity, and that the inclusion of both the number of exported and imported sectors is needed to obtain the positive coefficient on the former, and the negative coefficient on the latter.

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 138 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 TWGL index for OECD countries is 0.44, while it is 0.15 for non-OECD countries.

< Table 6 here >

Table 6 reports the results of estimating equation (17) for OECD and non-OECD countries separately. We focus on the analogues to columns (1) and (4) of Table 4. The table does indeed suggest that the model explains more of the variation in the TWGL index for OECD countries better than non-OECD countries; the R-squared of the regressions are much higher for OECD countries: around 0.5 compared to 0.3 for non-OECD countries. However, for OECD countries, the coefficients of interest are only marginally significant at best (for the number of imported sectors), and the signs of the coefficients often do not agree with the predictions of the model. On the other hand, for non-OECD countries, although the overall explanatory power of the regression is lower than for OECD countries, the coefficients on the two main variables of interest, the number of sectors exported and imported, are both statistically significant and of the "correct" signs as predicted by the model. As with previous results, reporter and partner GDP are not significantly related to the TWGL index, for either set of countries. We therefore conclude that the predictions of our model are a better fit to non-OECD countries than to OECD countries. This conclusion, which differs from that of Hummels and Levinsohn (1995), may indicate that trade patterns have changed in the intervening years. Alternatively, it may also suggest that our model, by focussing on technological rather than endowment differences across countries, is a better match to the trading patterns of non-OECD countries than the one used by Hummels and Levinsohn.

VI. 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 a continuum of sectors and countries which combines Ricardian comparative advantage and monopolistic competition. The main theoretical result obtained is that the share of intra-industry trade as measured by the trade-weighted-Grubel-Lloyd index is positively related to the number of sectors exported, the size of the country and the size of its trading partners, and is negatively related to the number of sectors imported. The predictions regarding the number of sectors exported and imported are new to the literature, and find supportive evidence from a large panel of countries from 1988 to 2013. In addition, we find that non-OECD countries fit the predictions of the model better than OECD countries. This suggests that the pattern of trade has changed compared to the time of Hummels and Levinsohn (1995), despite the fact that OECD countries still engage in much more intra-industry trade than non-OECD countries. 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 extension is left to future work.

ACKNOWLEDGEMENTS

Thanks to Holger Breinlich, Dimitra Petropoulou, Daniel Trefler, seminar participants at Lancaster University and two anonymous referees for useful suggestions. The author is responsible for any errors and omissions.

NOTES

[1] Bernard et al (2007) incorporate firm heterogeneity into a Helpman and Krugman (1985) model of monopolistic competition and factor endowments. They find that, relative to the homogeneous firms case, introducing heterogeneous firms increases the average productivity in comparative advantage sectors by more than in comparative disadvantage sectors, and this has the effect of increasing the comparative advantage differences across countries. This results in a smaller share of intra-industry trade relative to the homogeneous firms case. However, the effect is a quantitative rather than a qualitative one. Here, we focus on the homogeneous firm case, for two reasons: (1) Our theoretical predictions are qualitative rather than quantitative in nature; and (2) Our data, which is at the country-sector level, does not enable us to identify the effects of firm heterogeneity on intra-industry trade.

[2] From equations (5) and (6), output of each good in each sector is the same, but labour used in each good in each comparative advantage sector is $\gamma < 1$ times the labour used in each non-comparative advantage sector. However, each comparative advantage sector has $1/\gamma$ times the number of goods as in each non-comparative advantage sector, so the total labour used in each sector is the same.

[3] An earlier version of this paper included iceberg trade costs. This has been dropped as empirically it turns out to have only a small and insignificant effect on the TWGL index.

[4] Unlike Helpman and Krugman (1985) or Romalis (2004), where countries continue to produce their comparative disadvantage sectors in free trade, this does not occur in our model, because in those models, comparative advantage is based on relative factor abundance and intensity, with identical technologies across countries. In our model, comparative advantage is based on technological differences across countries, so that, similarly to Davis (1995), only the countries with a technological advantage continue to produce the good in the free trade equilibrium.

[5] To be precise, the indeterminacy arises because, with identical technologies in the comparative advantage sectors, agents in a country are indifferent between the comparative advantage sectors. There then exists a large number of possible production structures for each economy. The assumption made in the text eliminates these alternative production structures.

[6] It is possible to test the model's prediction of constant GL indices across industries. This can be done using the standard F-test for whether the variance of the GL index across sectors for a country in a particular year is equal to zero. This test is rejected for all countries in all years. It is also possible to test whether or not the variance of the GL index is constant over time. The null hypothesis of common variance over time is almost always not rejected; results are available from the author upon request. Taken together, these results suggest that, although the GL index is not the same across industries, the distribution of the GL index does not change very much over time. In addition, although the model's prediction on the distribution of the GL index does not hold, the prediction on the TWGL index at the aggregate level is less restrictive and fits the data better.

[7] Using total importing partner size or total exporting partner size yields almost identical results to those reported in the results below.

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Appendix A: Derivation of equations (16a) and (16b).

First, rewrite the TWGL index (15b) as follows:

$$TWGL_z = \left(\frac{\lambda L_z}{S}\right) \left[\frac{S(L_W - L_z) - L_Z(\lambda L_W - S)}{S(L_W - L_z) + L_Z(\lambda L_W - S)}\right] \tag{A1}$$

Define $[A] = \left[\frac{S(L_W - L_z) - L_Z(\lambda L_W - S)}{S(L_W - L_z) + L_Z(\lambda L_W - S)}\right] > 0$, $W = S(L_W - L_z) - L_Z(\lambda L_W - S)$ and $V = S(L_W - L_z) + L_Z(\lambda L_W - S)$. Then, differentiating (A1) with respect to L_z gives:

$$\frac{dTWGL_z}{dL_z} = [A]\left(\frac{\lambda}{S}\right) + \left(\frac{\lambda L_z}{S}\right)\left\{-\frac{V(-S - \lambda L_W + S) - W(-S + \lambda L_W - S)}{V^2}\right\}$$

$$= [A]\left(\frac{\lambda}{S}\right) + \left(\frac{\lambda L_z}{S}\right)\left\{\frac{2S\{S(L_W - L_z) + (\lambda L_W - S)L_z\}}{V^2}\right\} > 0 \tag{A2}$$

Since $L_W > L_z$ and $\lambda L_W > S$.

Differentiating (A1) with respect to L_W gives:

$$\frac{dTWGL_z}{dL_W} = \left(\frac{\lambda L_z}{S}\right)\left\{-\frac{V(S - \lambda L_z) - W(S + \lambda L_z)}{V^2}\right\}$$

$$= \left(\frac{\lambda L_z}{S}\right)\left\{\frac{2SL_z(S - \lambda L_z)}{V^2}\right\} > 0 \tag{A3}$$

Since $\lambda L_z < S$.

Differentiating (A1) with respect to λ gives:

$$\frac{dTWGL_z}{d\lambda} = [A]\left(\frac{L_z}{S}\right) + \left(\frac{\lambda L_z}{S}\right)\left\{-\frac{V(-L_W L_z) - W(L_W L_z)}{V^2}\right\}$$

$$= [A]\left(\frac{L_z}{S}\right) + \left(\frac{\lambda L_z}{S}\right)\left\{\frac{2SL_W L_z(L_W - L_z)}{V^2}\right\} > 0 \tag{A4}$$

Since $L_W > L_z$.

Differentiating (A1) with respect to S gives:

$$\frac{dTWGL_z}{d\lambda} = [A]\left(-\frac{\lambda L_z}{S^2}\right) + \left(\frac{\lambda L_z}{S}\right)\left\{-\frac{V(L_W - L_z + L_z) - W(L_W - L_z - L_z)}{V^2}\right\}$$

$$= [A]\left(-\frac{\lambda L_z}{S^2}\right) + \left(\frac{\lambda L_z}{S}\right)\left\{-\frac{2(L_W - L_z)L_z\lambda L_W}{V^2}\right\} < 0 \quad \text{(A5)}$$

Since $L_W > L_z$.

Figure 1: The number of exporting and importing sectors: UN Comtrade data, 5-digit SITC, 1988-2013.

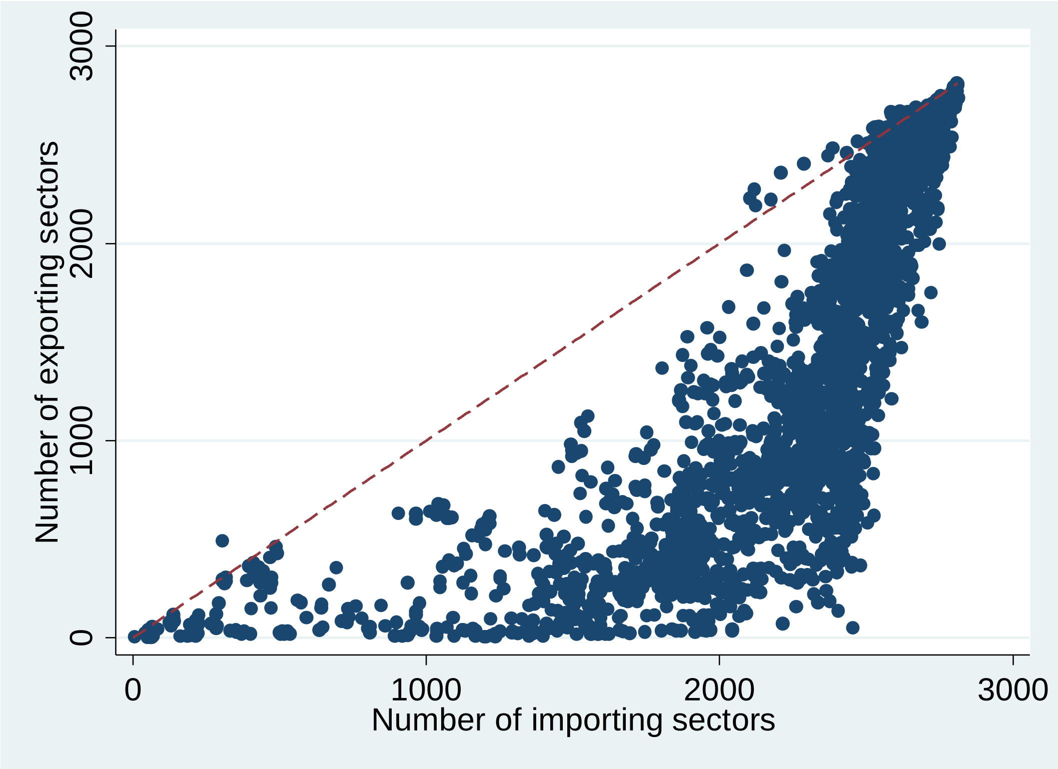

Table 1: Descriptive Statistics of the variables used in the analysis

Variable	Mean	Standard Deviation
Trade-Weighted GL index	22.966	19.658
Number of exporting sectors	1484.4	891.57
Number of importing sectors	2255.1	534.73
Real GDP, constant US$ (millions)	332,448	1,191,344
Total partner real GDP, constant US$ (billions)	42,008.9	8,004.3

Notes: N = 3,044, comprising an unbalanced panel of 172 countries from 1988 to 2013.

Table 2: Countries with the largest and smallest values for the trade-weighted Grubel-Lloyd (TWGL) index (5-digit SITC) in 2010.

Largest TWGL Index		**Smallest TWGL Index**	
Country	**TWGL Index**	**Country**	**TWGL Index**
Hong Kong	0.8364	Mauritania	0.00126
Belgium	0.7390	Myanmar	0.00326
United Arab Emirates	0.7047	Cape Verde	0.00419
Singapore	0.7009	Kiribati	0.00510
Netherlands	0.6975	Maldives	0.00567

Table 3: Correlation between the variables used in the analysis.

	TWGL index	Exporting sectors	Importing sectors	Reporter GDP	Total partner GDP
TWGL index	1.0000				
Exporting sectors	0.7813	1.0000			
Importing sectors	0.5076	0.7710	1.0000		
Reporter GDP	0.6725	0.8347	0.6462	1.0000	
Total partner GDP	0.0499	0.0310	0.0861	0.0214	1.0000

Notes: N = 3,044, comprising an unbalanced panel of 172 countries from 1988 to 2013.

Table 4: The determinants of the trade-weighted Grubel-Lloyd index.

	(1)	(2)	(3)	(4)
Estimation Method	FE	Tobit	2S-GMM	2S-GMM
Exported sectors	0.012***	0.012***	0.011***	0.011***
	(0.003)	(0.003)	(0.002)	(0.002)
Imported sectors	-0.006***	-0.006***	-0.005***	-0.005***
	(0.002)	(0.002)	(0.001)	(0.001)
Reporter GDP	0.309	0.279	-1.038	-1.127
	(1.731)	(1.721)	(1.858)	(1.855)
Total partner GDP	-1.328	0.266	-1.687	-14.495
	(3.763)	(4.942)	(3.907)	(20.648)
R^2	0.33		0.30	0.30
$N \times T$	3,044	3,044	2,632	2,632
N	172	172	161	161
T	26	26	24	24
Country and year fixed effects	Yes	Yes	Yes	Yes
Hansen J test			2.09	2.57
Hansen J test p-value			0.35	0.46
UnderID test			18.83	12.78
UnderID test p-value			0.00	0.01
WeakID test			196.33	18.11
First stage F-test of excluded instruments, Exported sectors			52.93	36.42
First stage F-test of excluded instruments, Imported sectors			12.81	8.84
First stage F-test of excluded instruments, Total partner GDP				10.45

Notes: The dependent variable is the trade-weighted Grubel-Lloyd index of intra-industry trade. *** significant at 1%; ** significant at 5%; * significant at 10%. Estimation method is OLS in column (1), Tobit in column (2), and two-stage GMM in columns (3) and (4), in which the number of exported and imported sectors (column (3)) and the number of exported and imported sectors and the total trading partner GDP (column (4)) are assumed to be endogenous and are instrumented using the first two lags of the endogenous variables. All regressions include a full set of country and year fixed effects. Figures in parentheses are standard errors clustered by country.

Table 5: Sensitivity of results to omitting the number of exported and imported sectors, and reporter GDP.

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation Method	FE	FE	FE	2S-GMM	2S-GMM	2S-GMM
Exported sectors	0.008***		0.012***	0.011***		0.011***
	(0.002)		(0.003)	(0.003)		(0.002)
Imported sectors		0.000	-0.006***		0.001	-0.005***
		(0.001)	(0.002)		(0.001)	(0.001)
Reporter GDP	-0.131	2.582		-1.642	1.533	
	(1.744)	(2.074)		(1.790)	(2.235)	
Total partner GDP	-6.232	-2.514	-1.302	-41.121*	-22.775	-15.684
	(4.839)	(3.920)	(3.745)	(23.648)	(23.555)	(20.584)
R^2	0.29	0.20	0.33	0.23	0.14	0.30
$N\times T$	3,044	3,044		2,632	2,632	2,632
N	172	172		161	161	161
T	26	26		24	24	24
Country and year fixed effects	Yes	Yes		Yes	Yes	Yes
Hansen J test				0.41	0.41	2.53
Hansen J test p-value				0.82	0.81	0.47
UnderID test				13.07	11.02	12.83
UnderID test p-value				0.00	0.01	0.01
WeakID test				28.12	27.17	18.04
First stage F-test, Exported sectors				51.66		42.59
First stage F-test, Imported sectors					10.52	8.98
First stage F-test, Total partner GDP				15.17	13.84	10.82

Notes: The dependent variable is the trade-weighted Grubel-Lloyd index of intra-industry trade. *** significant at 1%; ** significant at 5%; * significant at 10%. Estimation method is OLS in columns (1) to (3), and two-stage GMM in columns (4) to (6), in which the number of exported and imported sectors and the total trading partner GDP are assumed to be endogenous and are instrumented using the first two lags of the endogenous variables. All regressions include a full set of country and year fixed effects. Figures in parentheses are standard errors clustered by country.

Table 6: Dividing the sample into OECD and non-OECD countries.

Estimation Method	FE	2S-GMM	FE	2S-GMM
Sample	OECD	OECD	Non-OECD	Non-OECD
	(1)	(2)	(3)	(4)
Exported sectors	0.006	0.003	0.013***	0.011***
	(0.005)	(0.007)	(0.003)	(0.003)
Imported sectors	0.020*	0.026	-0.006***	-0.005***
	(0.012)	(0.016)	(0.002)	(0.001)
Reporter GDP	-2.926	-7.005	0.887	-0.643
	(6.340)	(5.754)	(2.058)	(2.296)
Total partner GDP	-37.098	-38.844	-0.529	-6.567
	(53.408)	(35.204)	(3.322)	(21.279)
R^2	0.55	0.49	0.30	0.27
$N \times T$	815	750	2,229	1,882
N	34	34	138	127
T	26	24	26	24
Country and year fixed effects	Yes	Yes	Yes	Yes
Hansen J test		5.38		2.21
Hansen J test p-value		0.15		0.53
UnderID test		8.85		8.96
UnderID test p-value		0.07		0.06
WeakID test		4.78		8.44
First stage F-test, Exported sectors		7.44		37.09
First stage F-test, Imported sectors		2.66		8.01
First stage F-test, Total partner GDP		1636.57		7.48

Notes: The dependent variable is the trade-weighted Grubel-Lloyd index of intra-industry trade. *** significant at 1%; ** significant at 5%; * significant at 10%. Estimation method is OLS in columns (1) and (3), and two-stage GMM in columns (2) and (4), in which the number of exported and imported sectors and the total trading partner GDP are assumed to be endogenous and are instrumented using the first two lags of the endogenous variables. All regressions include a full set of country and year fixed effects.. Figures in parentheses are standard errors clustered by country.