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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 trade-weighted 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 the model fits the data 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. The trade-weighted Grubel-Lloyd (TWGL) index of intra-industry trade is derived as a function of the model's parameters. We show that the model yields determinants of the TWGL index which are new to the literature. These are the number of industries exported and imported by a country; the former is positively related to the TWGL index, while the latter is negatively related to it. The model's predictions find supportive empirical evidence from a sample of 118 countries in 2010, using data from the UN Comtrade database.

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 2 sets out the model, while Section 3 discusses the no-trade equilibrium, and Section 4 discusses the open economy equilibrium. We derive two main theoretical results. First, we show in Section 4 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 5, 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 trade-weighted Grubel-Lloyd (TWGL) index of intra-industry trade. In particular, own country size and the number of exported sectors are positively related to the TWGL index, while average partner country size, the number of imported sectors and transport costs are negatively related to the TWGL index.

Section 6 documents the data used in the empirical analysis. In Section 7 we show that the empirical evidence is mostly consistent with what the theoretical model predicts about the determinants of the TWGL index. The TWGL 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 TWGL index. The variables based on the model explain a larger fraction of the variation in the TWGL index for OECD countries than for non-OECD countries. Section 8 provides some brief conclusions.

2 The model

There are T countries, $i = 1, \ldots, T$ and S sectors, $s = 1, \ldots, S$. Labour is the only factor of production, and is perfectly mobile across sectors but perfectly immobile across countries.

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

Each country has L_i units of labour. Define $L_W = \sum_i L_i$ 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. 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. 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 i in producing a good g in sector s is given by:

$$l_{gs} = \gamma\left(a + bq_{gs}\right) \qquad \text{for} \qquad s \in S_1 \tag{3}$$

$$l_{gs} = a + bq_{gs} \qquad \text{for} \qquad s \in S_2 \tag{4}$$

where q_{gs} is the output of good g in sector s, and $\gamma < 1$ reflects the comparative advantage of country i 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. Let the number of comparative advantage sectors be proportional to the labour force in each country: $S_{1i} = \lambda L_i$, where λ is constant across countries.[3] Each sector has the same number 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, the number of sectors which countries have a comparative advantage in, exceeds the total number of sectors. This ensures that there is at least one country which has a comparative advantage in each sector.

The assumption on the number of comparative advantage sectors plays a key role in simplifying the analysis below. By fixing the number of comparative advantage sectors, it prevents agglomeration forces (see Krugman (1980), Fujita et al (1999)), so that, whilst

[3] For simplicity we ignore the integer constraints on the number of sectors a country has a comparative advantage in, and on the number of countries with a comparative advantage in each sector.

because of iceberg trade costs prices and hence real wages do differ across countries, they do not lead to concentration of labour beyond that predicted by comparative advantage. This therefore has implications for the welfare analysis and for obtaining a relatively simple expression for the TWGL index later on.

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 following the same steps as in Krugman (1980), the solution to the model gives:

$$p_1 = \frac{\gamma wb}{\rho} \qquad q_{g1} = \left(\frac{a}{b}\right)\left(\frac{\rho}{1-\rho}\right) \qquad n_1 = \frac{(1-\rho)L_s}{\gamma a} \qquad \text{for} \qquad s \in S_1 \qquad (5)$$

$$p_2 = \frac{wb}{\rho} \qquad q_{g2} = \left(\frac{a}{b}\right)\left(\frac{\rho}{1-\rho}\right) \qquad n_2 = \frac{(1-\rho)L_s}{a} \qquad \text{for} \qquad s \in S_2 \qquad (6)$$

Where w is the wage rate, p_1 is the price of each good g in each sector in S_1, and n_1 is the endogenously-determined number of goods in each sector in S_1. 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), although output of each good is the same across sectors.

3 Autarkic equilibrium

In autarky, each country must produce all sectors, and given the Cobb-Douglas utility and free movement of labour across sectors, will devote $L_s = L_i/S$ labour to each sector[4]. Then:

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

Total consumption equals output and is identical across goods so individual consumption is $c_{gs}^A = q_{gs}/L_i$. Because all goods in each sector are symmetric, we have:

$$C_s^A = \sum_{g=1}^{G}\left(c_{gs}^A\right)^\rho = n_s\left(c_{gs}^A\right)^\rho$$

$$= n_1\left(c_{gs}^A\right)^\rho = \frac{(1-\rho)L_i}{S\gamma a}\left(\frac{a}{b}\frac{\rho}{1-\rho}\frac{1}{L_i}\right)^\rho \qquad \text{for} \qquad s \in S_1 \qquad (8a)$$

$$= n_2\left(c_{gs}^A\right)^\rho = \frac{(1-\rho)L_i}{Sa}\left(\frac{a}{b}\frac{\rho}{1-\rho}\frac{1}{L_i}\right)^\rho \qquad \text{for} \qquad s \in S_2 \qquad (8b)$$

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[4] 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.

Hence, utility under autarky is:

$$U_i^A = \left[n_1\left(c_{gs}^A\right)^\rho\right]^{\frac{\lambda L_i}{S}}\left[n_2\left(c_{gs}^A\right)^\rho\right]^{\frac{S-\lambda L_i}{S}} = \left[\frac{(1-\rho)L_i}{Sa}\left(\frac{a}{b}\frac{\rho}{1-\rho}\frac{1}{L_i}\right)^\rho\right]\left[\frac{1}{\gamma}\right]^{\frac{\lambda L_i}{S}} \quad (9)$$

Equation (9) shows that utility under autarky is increasing in the size of the country L_i, the number of comparative advantage sectors λ, and the degree of comparative advantage in the S_1 sectors (the smaller is γ). On the other hand utility is decreasing in the cost parameters a and b, and in the number of sectors S. Finally, utility under autarky has a U-shaped relationship with the elasticity of substitution ρ. Note also that if $\gamma = 1$ (no comparative advantage differences across sectors) and $S = 1$ (only one sector), equation (9) reduces to utility under autarky in the Krugman (1980) model.

4 Open economy equilibrium

When international trade is allowed, each country will specialise in and export the $S_1 = \lambda L_i$ sectors in which it has a comparative advantage, and will import the other $S_2 = S - \lambda L_i$ sectors from the other countries[5]. 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 $\lambda L_W/S > 1$ 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 $S_1 = \lambda L_i$ 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. That is, $L_s = L_i/\lambda L_i = 1/\lambda$. 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

[5] 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.

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[6] 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 and sectors. Assume that the trade cost is always small enough so that all countries always find it beneficial to engage in international trade. That is, every country will export its comparative advantage goods to every other country in the world. 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):

$$p_g = \frac{\gamma w b}{\rho} \qquad c_{gs}^{FT} = \frac{a}{b}\frac{\rho}{1-\rho}\frac{1}{L_W} \tag{10}$$

$$p_g^* = \frac{p_g}{\tau} = \frac{\gamma w b}{\tau \rho} \qquad \left(c_{gs}^{FT}\right)^* = c_{gs}^{FT}\tau^{\frac{1}{1-\rho}} = \frac{a}{b}\frac{\rho}{1-\rho}\frac{1}{L_W}\tau^{\frac{1}{1-\rho}} \tag{11}$$

$$n_s^{FT} = \frac{1-\rho}{\lambda\gamma a} \qquad n_{sW}^{FT} = n_s^{FT}\left(\frac{\lambda L_W}{S}\right) = \frac{(1-\rho)L_W}{\gamma a S} \tag{12}$$

Where n_{sW}^{FT} is the number of goods produced in the world in that sector. Note that, comparing equations (10) and (11), consumers consume a larger quantity of domestically-produced goods than foreign-produced goods. Hence there is a home bias in consumption, driven by the trade cost.

For sectors S_2 where a country does *not* have a comparative advantage in, all goods are imported so total consumption is:

$$C_{s\in S_2} = n_{sW}^{FT}\left[\left(c_{gs}^{FT}\right)^*\right]^\rho = n_{sW}^{FT}\left(c_{gs}^{FT}\right)^\rho \tau^{\frac{\rho}{1-\rho}} \tag{13}$$

For sectors S_1 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:

$$C_{s\in S_1} = n_s^{FT}\left(c_{gs}^{FT}\right)^\rho + (n_{sW}^{FT} - n_s^{FT})\left(c_{gs}^{FT}\right)^\rho \tau^{\frac{\rho}{1-\rho}} \tag{14a}$$

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

Hence utility when international trade is allowed is:

[6] 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.

$$U_i^{FT} = \left(c_{gs}^{FT}\right)^{\rho}\left[n_s^{FT} + (n_{sW}^{FT} - n_s^{FT})\tau^{\frac{\rho}{1-\rho}}\right]^{\frac{\lambda L_i}{S}}\left[n_{sW}^{FT}\tau^{\frac{\rho}{1-\rho}}\right]^{\frac{S-\lambda L_i}{S}} \tag{15}$$

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

$$\text{Gain}_\text{i} = \frac{U_i^{FT}}{U_i^A} = \left(\frac{L_i}{L_W}\right)^{\rho-1}\left(\frac{\tau^{\frac{\rho}{1-\rho}}}{\gamma}\right)^{\frac{S-\lambda L_i}{S}}\left[\tau^{\frac{\rho}{1-\rho}} + \left(1-\tau^{\frac{\rho}{1-\rho}}\right)\frac{S}{\lambda L_W}\right]^{\frac{\lambda L_i}{S}} \tag{16}$$

Gains from trade arise if $U_i^{FT}/U_i^A > 1$. 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:

$$\frac{d\text{Gain}_\text{i}}{d(L_i/L_W)} < 0, \qquad \frac{d\text{Gain}_\text{i}}{dS} > 0, \qquad \frac{d\text{Gain}_\text{i}}{d\lambda} < 0, \tag{17a}$$

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

That is, the gains from trade increase as the relative size of the country L_i/L_W decreases, the number of sectors S increases, the number of sectors each country has a comparative advantage in λ decreases, γ 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 λ or γ), the greater the gain (see Ethier (2009)).

5 Trade patterns

With international trade, each country is specialised in the $S_1 = \lambda L_i$ sectors in which it has a technological advantage. Assume that trade is balanced, and that a country devotes $1/\lambda$ labour to each of its comparative advantage sectors. Trade costs influence the value of trade in three related ways. First, it raises the price of imports relative to domestically-produced goods. This is the approach used in the data, where exports are measured net of freight and insurance (free on board, f.o.b.), while imports are measured including freight and insurance (cost, insurance and freight, c.i.f.). Second, because traded goods are more expensive than domestically produced goods, the quantity of goods traded is reduced. These two effects can be seen in equations (10) and (11) above.

The third way in which trade costs influence the value of trade is that trade costs use real resources – the quantity of a good available for consumption is reduced by the trade cost. The real resource used in consuming one unit of a foreign-produced good domestically is $1/\tau > 1$ units of the good. Therefore, the total domestic demand for foreign-produced goods relative to domestically-produced goods is:

$$\frac{\left(c_{gs}^{FT}\right)^*}{c_{gs}^{FT}}\frac{1}{\tau} = \tau^{\frac{\rho}{1-\rho}} \qquad (18)$$

This is also the demand in any one country for goods produced in every other country relative to goods produced in that country.

Recall from equations (10) to (12) 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 times the demand from the rest of the world for the country's output, divided by total world demand for the country's output:

$$(\text{Exports})_{s\in S_1} = \left(\frac{w}{\lambda}\right)\left[\frac{(L_W - L_i)\tau^{\frac{\rho}{1-\rho}}}{L_i + (L_W - L_i)\tau^{\frac{\rho}{1-\rho}}}\right] \qquad (19)$$

Exports depend on the size of the country relative to the rest of the world, and on the trade cost τ.

Because $\lambda L_W/S > 1$ countries are assumed to have a comparative advantage in any one sector, these countries will export different goods 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 times the country's demand for each country's output in that sector times the number of countries exporting that sector to the country in question, divided by total world demand for each country's output in that sector:

$$(\text{Imports})_{s\in S_1} = \left(\frac{w}{\lambda}\right)\left[\frac{L_i\tau^{\frac{\rho}{1-\rho}}\left(\frac{\lambda L_W}{S}-1\right)}{L_i^{*}+(L_W-L_i^{*})\tau^{\frac{\rho}{1-\rho}}}\right] \quad (20)$$

Where L_i^* is the average labour force in the other countries that specialise in these sectors, and $(\lambda L_W/S)-1$ is the number of other countries which produce each sector in S_1. Define the Grubel-Lloyd (GL) index for country i in a sector s as:

$$\text{GL}_{\text{is}} = \left(1-\frac{|\text{Exports}_{\text{is}}-\text{Imports}_{\text{is}}|}{\text{Exports}_{\text{is}}+\text{Imports}_{\text{is}}}\right) \quad (21a)$$

$$= \left\{1-\frac{\left|\frac{(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}{L_i+(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}-\frac{L_i\tau^{\frac{\rho}{1-\rho}}\left(\frac{\lambda L_W}{S}-1\right)}{L_i^{*}+(L_W-L_i^{*})\tau^{\frac{\rho}{1-\rho}}}\right|}{\frac{(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}{L_i+(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}+\frac{L_i\tau^{\frac{\rho}{1-\rho}}\left(\frac{\lambda L_W}{S}-1\right)}{L_i^{*}+(L_W-L_i^{*})\tau^{\frac{\rho}{1-\rho}}}}\right\} \quad \text{for} \quad s\in S_1 \quad (21b)$$

$$= 0 \quad \text{for} \quad s\in S_2 \quad (21c)$$

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

$$\text{TWGL}_{\text{i}} = \sum_{s=1}^{S}\left[GL_{is} * \left(\frac{\text{Exports}_{\text{is}}+\text{Imports}_{\text{is}}}{\text{Exports}_{\text{i}}+\text{Imports}_{\text{i}}}\right)\right] \quad (22a)$$

$$= \left\{1-\frac{\left|\frac{(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}{L_i+(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}-\frac{L_i\tau^{\frac{\rho}{1-\rho}}\left(\frac{\lambda L_W}{S}-1\right)}{L_i^{*}+(L_W-L_i^{*})\tau^{\frac{\rho}{1-\rho}}}\right|}{\frac{(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}{L_i+(L_W-L_i)\tau^{\frac{\rho}{1-\rho}}}+\frac{L_i\tau^{\frac{\rho}{1-\rho}}\left(\frac{\lambda L_W}{S}-1\right)}{L_i^{*}+(L_W-L_i^{*})\tau^{\frac{\rho}{1-\rho}}}}\right\}\left(\frac{\lambda L_i}{S}\right) \quad (22b)$$

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. In the empirical analysis we will work 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.

It can be shown that:

$$\frac{dTWGL_i}{dL_i} > 0, \qquad \frac{dTWGL_i}{dL_i^*} < 0, \qquad \frac{dTWGL_i}{dL_W} > 0, \quad (23a)$$

$$\frac{dTWGL_i}{d\lambda} > 0, \qquad \frac{dTWGL_i}{dS} < 0, \quad (23b)$$

$$\frac{dTWGL_i}{d\tau} < 0, \qquad \frac{dTWGL_i}{d\rho} > 0 \qquad \text{if} \qquad L_i > L_i^* \quad (23c)$$

$$\frac{dTWGL_i}{d\tau} > 0, \qquad \frac{dTWGL_i}{d\rho} < 0 \qquad \text{if} \qquad L_i < L_i^* \tag{23d}$$

The TWGL 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 (which is equal to the number of sectors imported).

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 TWGL 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 $L_i > L_i^*$: 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 TWGL 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. The following Propositions summarise the main theoretical results of the paper:

Proposition 1: The Trade-Weighted Grubel-Lloyd Index of intra-industry trade for a country is positively related to the size of the economy, the size of the world economy, and the number of comparative advantage sectors in the economy, and is negatively related to the average size of its trading partners and the total number of sectors (also the number of sectors imported).

Proposition 2: If the country is larger than the average of its trading partners, the Trade-Weighted Grubel-Lloyd Index is positively related to the trade cost, while if the country is smaller than the average of its trading partners, the Trade-Weighted Grubel-Lloyd Index is negatively related to the trade cost.

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 as summarised in Proposition 1 is that our model predicts a relationship between the number of sectors exported and imported and the TWGL index. In the empirical sections we will investigate whether this is an important determinant of the TWGL index.

6 Data and methods

We use 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, the Euro debt crisis of 2011-12, or the Fukushima nuclear disaster in March 2011 which disrupted global supply chains. 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.

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 4, 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 2,652 sectors) exported and imported by all the countries in the database, where each data point 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. This is also true of the average number of sectors exported and imported, which are 1,417 and 2,083 sectors respectively. 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 data shows that the average TWGL index increases the more aggregated is the data. The average TWGL 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 1 shows the countries with the largest and smallest values of the TWGL index at the 5-digit level. 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.

The key empirical prediction of the model as summarised in Propositions 1 and 2 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 and the average size of its trading partners. In addition, trade costs are negatively related to the TWGL 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 for country i we estimate the following equation:

$$TWGL_i = \beta_0 + \beta_1 N_{Export} + \beta_2 N_{Import} + \beta_3 \ln GDP_i + \beta_4 \ln \overline{GDP_{j \neq i}} + \beta_5 TC + \beta_6 D + \beta_7 TC \times D + \epsilon_i \quad (24)$$

We measure country size and average trading partner size[7] by 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

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

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 TWGL index depending on relative country sizes. Note also that we do not include a measure of World GDP in equation (24) since we only use data from one time period.

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 instances where the empirical bilateral GL index is equal to zero, we document no cases of the aggregate TWGL index being equal to zero in our sample. Nevertheless, we report the results using a Tobit estimator in addition to standard OLS estimates. We also report the results of a weighted regression, weighting observations by the natural log of each country’s total trade, to take into account the fact that countries are not equally important in world trade.

7 Empirical results

The results of estimating equation (24) excluding the interaction terms are reported in Table 2. All regression results are reported with heteroskedastic-robust standard errors. Columns (1) to (3) report OLS estimates, columns (4) to (6) report Tobit estimates, and column (7) reports Tobit results with the observations weighted by the natural log of each country’s total trade. 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 TWGL index, while the number of imported sectors is negatively related to the TWGL index. The coefficients are highly statistically significant, and hold across the different specifications in the rest of Table 2. Reporter country GDP is positively related to the TWGL index while average trading partner GDP is negatively related to the TWGL 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 TWGL 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 2 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 2 perform the same regressions as columns (1) to (3), using a Tobit estimator. We obtain exactly the same coefficient estimates as in columns (1) to (3). The standard errors are slightly different, but the statistical significance of the results is not affected. This is perhaps unsurprising; as noted in Section 6, there are no censored observations in our dataset, hence the Tobit estimator yields the same coefficient estimates as OLS. As a result, the regression results reported in the rest of the paper make use of OLS estimates. Finally, column (7) performs the same regression as in column (6), but weighting each observation by the natural log of each country's total trade. The results are very similar to the unweighted results.

Overall the results of Table 2 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.

Table 3 reports the results of the interaction between the trade cost measures with a dummy for whether the country is larger than its trading partners on average, as suggested by

Proposition 2. As noted in Section 5, only four countries have $D = 1$: the US, China, Japan and Germany. In column (1), the dummy variable has a positive and significant coefficient, indicating that the four countries that are larger than their trading partners on average have a higher TWGL index, while the interaction with average distance is negative but not significant. Similar results are obtained in column (2) when distance is replaced by average partner tariffs. However, when both measures of trade cost are included in column (3), 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 TWGL 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 for the relationship between the TWGL index and trade barriers. 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[8].

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 TWGL index for OECD countries is 0.46, while it is 0.17 for non-OECD countries.

Table 4 reports the results of estimating equation (24) for OECD and non-OECD countries separately. We focus on the analogues to columns (1) to (3) in Table 2, excluding the interaction terms. 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

[8] We have also estimated Table 2 excluding the four countries for which $D = 1$; the results are very similar to those reported.

significantly related to the TWGL index, while the number of imported sectors is negatively and significantly related to the TWGL 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. Trade costs have no significant impact on the TWGL 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 TWGL index when these measures are included separately in the regression. When both measures of trade costs are included together, only distance from trading partners has a negative and significant effect on the TWGL index.

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

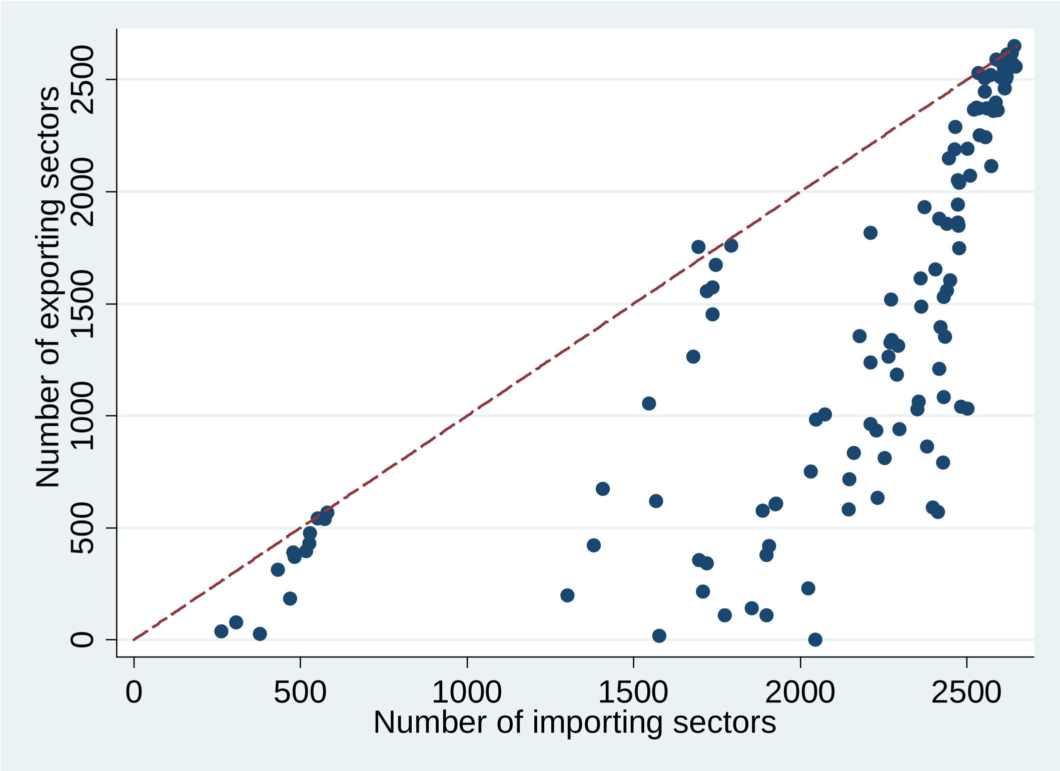

Table 1: Countries with the largest and smallest values for the trade-weighted Grubel-Lloyd (TWGL) index (5-digit SITC).

Largest TWGL Index		**Smallest TWGL Index**	
Country	**TWGL Index**	**Country**	**TWGL Index**
Belgium	0.736	Samoa	0.0142
Singapore	0.727	Tonga	0.0120
Netherlands	0.721	Cape Verde	0.0104
Panama	0.687	Belize	0.0099
France	0.665	Maldives	0.0055

Table 2: The determinants of the trade-weighted Grubel-Lloyd index.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimation method	OLS	OLS	OLS	Tobit	Tobit	Tobit	Weighted Tobit
Exported sectors	0.021***	0.022***	0.021***	0.021***	0.022***	0.021***	0.022***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Imported sectors	-0.010***	-0.011***	-0.011***	-0.010***	-0.011***	-0.011***	-0.011***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
Reporter GDP	1.299*	0.983	1.292*	1.299*	0.983	1.292*	1.321*
	(0.756)	(0.734)	(0.746)	(0.740)	(0.718)	(0.727)	(0.750)
Average partner GDP	-0.828	-3.012	-0.800	-0.828	-3.012*	-0.800	-0.641
	(1.602)	(1.822)	(1.627)	(1.568)	(1.783)	(1.585)	(1.656)
Average distance	-2.182***		-2.557***	-2.182***		-2.557***	-2.635***
from trading partners	(0.601)		(0.644)	(0.588)		(0.627)	(0.631)
Average partner tariff		-1.173	1.252		-1.173	1.252	1.273
		(1.061)	(1.138)		(1.038)	(1.109)	(1.141)
Constant	19.989	83.245*	16.686	19.989	83.245*	16.686	11.981
	(41.422)	(47.473)	(41.454)	(40.522)	(46.447)	(40.376)	(41.658)
R^2	0.67	0.62	0.68				
N	118	118	118	118	118	118	118

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), Tobit in columns (4) to (6), and Tobit weighted by log trade flows in column (7). Figures in parentheses are heteroskedastic-robust standard errors.

Table 3: Results of the interaction terms in equation (24).

	(1)	(2)	(3)
Exported sectors	0.021***	0.022***	0.021***
	(0.003)	(0.003)	(0.003)
Imported sectors	-0.011***	-0.011***	-0.011***
	(0.003)	(0.003)	(0.003)
Reporter GDP	1.194	0.914	1.244
	(0.830)	(0.850)	(0.831)
Average partner GDP	-0.774	-2.971	-0.604
	(1.616)	(1.867)	(1.647)
Average distance from trading partners	-2.144***		-2.504***
	(0.604)		(0.648)
Reporter GDP > Average partner GDP (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)
Average partner tariff		-1.152	1.116
		(1.079)	(1.152)
D * Average partner tariff		-0.025	0.269***
		(0.091)	(0.062)
Constant	20.736	83.516*	13.614
	(41.799)	(47.989)	(41.823)
R^2	0.67	0.62	0.68
N	118	118	118

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. Figures in parentheses are heteroskedastic-robust standard errors. D is a dummy equal to 1 if Reporter GDP > Average Partner GDP.

Table 4: Dividing the sample into OECD and non-OECD countries.

Sample	OECD	OECD	OECD	Non-OECD	Non-OECD	Non-OECD
	(1)	(2)	(3)	(4)	(5)	(6)
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)
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)
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	-3.120***		-2.970***	-0.984		-1.369
from 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: 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. Figures in parentheses are heteroskedastic-robust standard errors.