

Empirical intra-industry trade: what we know and what we need to know*

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September 2003

Abstract

Empirical intra-industry trade has a history that began in the mid-1960s. As with most empirical exercises, it has been wrought with criticism and defenses that have molded the work that is done on intra-industry trade today. This paper brings together the various measures and econometric studies on intra-industry trade. A complete review of the literature is beyond the scope of this paper, but it highlights the general trends and common features in measurement and econometric studies, as well as the advancements that have taken place over the development of this literature.

JEL codes: F12; F14

Keywords: Empirical intra-industry trade

*I would like to thank Brian Copeland for his support during the writing of this paper.

Contents

1	Introduction	1
2	Measuring Intra-Industry Trade	2
2.1	The Balassa and Grubel-Lloyd Indices	3
2.2	Measuring Marginal Intra-Industry Trade	6
2.3	Disentangling Horizontal and Vertical Intra-Industry Trade . .	12
3	The Determinants of Intra-Industry Trade	17
3.1	Country-Specific Determinants	18
3.2	Industry-Specific Determinants	21
3.3	Estimation	24
4	Empirical Studies on the Determinants of Intra-Industry Trade	25
4.1	Country Studies	26
4.2	Industry Studies	31
4.3	Country-Industry Studies	36
4.4	Disentangling the Determinants of Intra-Industry Trade	43
5	Directions for Future Research	49
6	Conclusion	52
7	References	53

List of Tables

1	<i>Simple aggregation bias in the GL Index</i>	4
2	<i>Trade imbalance bias in the GL Index</i>	5
3	<i>The dynamics of the GL Index</i>	7
4	<i>Differences in product quality measures</i>	15
5	<i>Country studies</i>	29
6	<i>Industry studies</i>	33
7	<i>Country-industry studies</i>	39
8	<i>Disentangling the determinants of intra-industry trade</i>	46

1. Introduction

Empirical work on the measurement of intra-industry trade began in the mid-1960s with Balassa (1966) and the most well known work on intra-industry trade by Grubel and Lloyd (1975). These works were then followed by, what we know as today as, the theory of intra-industry trade. These models of intra-industry trade developed on the heels of the work on monopolistic competition and product differentiation by Dixit and Stiglitz (1977). They began with the work of Krugman (1979, 1980, 1981), Lancaster (1980), and Helpman (1981) who developed models of horizontally differentiated intra-industry trade with monopolistic competition—these models, and their derivatives, are summarized in Helpman and Krugman (1985). Models of horizontally differentiated intra-industry trade under oligopolistic competition, of the form of Eaton and Kierzkowski (1984), followed shortly after. Vertically differentiated intra-industry trade with perfect competition has been modelled by Caves (1981) using a version of the classical Heckscher-Ohlin international trade model as well as oligopolistic models of vertically differentiated intra-industry trade, such as Shaked and Sutton (1984).

Empirical investigations of these models are omnipresent. They cover issues dealing with the measurement of intra-industry trade and the estimation of its determinants based on the models named above. Generally focussing on determinants most of the models have in common, these studies investigate intra-industry trade between and within both developed and developing countries. This paper brings together the various measures and econometric studies on intra-industry trade into one place. A complete review of the literature is well beyond the scope of this paper, but it highlights the general trends and common features in measurement and econometric studies, as well as the

advancements that have taken place over the development of this literature.

The remainder of the paper is structured as follows: section 2 discusses the various measures of intra-industry trade that have been used; section 3 discusses the determinants of intra-industry trade; section 4 reviews the econometric literature on intra-industry trade; section 5 discusses directions for future research; section 6 concludes.

2. Measuring Intra-Industry Trade

The purpose of this section is to discuss the methodological aspects of the measurement of intra-industry trade, rather than a documentary study of intra-industry trade applied to a country, or group of countries. Most of the references in this section, as well as the section below on the determinants of intra-industry trade, contain documentation of intra-industry trade levels for the countries under study that are too numerous to mention here in this review.

Usually, intra-industry trade is defined as the simultaneous export and import of goods in the same industry. But before we can discuss any measurement of intra-industry trade, we must decide what we are to measure. This is not a philosophical question, but a practical one as the history of empirical intra-industry trade has been mired by allegations of being a “statistical phenomenon” (Lipsey, 1976). The charge of being a statistical phenomenon is not an idle one. At the 3-digit SITC level of aggregation, canoes and 200,000 tonne tankers are in the same “ships and boats” industry; at the same level of aggregation, table model radios and airport flight control equipment are in the “telecommunications apparatus” industry (Lipsey, 1976). Also, Finger (1975) notes that trade overlap is not inconsistent with classical trade theory if empirical product groups do not correspond with the appropriate factor

proportions groupings.

Industry/product categories have become sufficiently disaggregated to disregard these early claims of intra-industry trade being a statistical phenomenon. The Harmonized Tariff Schedule (HTS) has a 10-digit classification system with over 20 000 entries that not only separate canoes from 200 000 tonne tankers, but also from any other boat not designed to be used with motors or sails—a classification that is even distinct from a rowboat. However, aggregation should not be forgotten since it may still be an issue for other reasons. Nevertheless, we will now move on to the various measures.

2.1. *The Balassa and Grubel-Lloyd Indices*

Balassa (1966) proposed the first index of intra-industry trade that measured the degree of trade overlap—simultaneous import and export—of goods within an industry:

$$B_j = \frac{|X_i - M_i|}{(X_i + M_i)}. \quad (1)$$

where $i \equiv$ commodity within industry j . This index, the ratio of net trade to gross trade, ranging from 0 to 1, with 0 representing “perfect” trade overlap, and therefore pure intra-industry trade, while 1 represents pure inter-industry trade. In order to calculate the degree of intra-industry trade for all industries (country level), Balassa took an unweighted average for each B_j :

$$B = \frac{1}{n} \sum B_j \quad (2)$$

where $n \equiv$ number of industries. This can be generalized to be a weighted index:

$$B = \sum_j w_j B_j \quad (3)$$

where $w_j \equiv$ industry j 's share of total trade.

Though the essence of this index has remained intact to this day, an index that measured intra-industry trade that gave pure intra-industry trade a value of zero was not intuitively appealing. Grubel and Lloyd (1975) proposed an alternative index:

$$GL = \frac{(X_i + M_i) - |X_i - M_i|}{(X_i + M_i)} = 1 - \frac{|X_i - M_i|}{(X_i + M_i)} = 1 - B_j \quad (4)$$

where $i \equiv$ commodity within industry j , that assigned pure intra-industry trade a value of 1 and pure inter-industry trade a value of 0. As with the Balassa Index, the Grubel-Lloyd Index has been calculated as an (un)weighted average to measure the degree of intra-industry trade at the country level.

This class of index has been criticized for suffering from categorical/sub-group aggregation issues. These issues have two basic forms that bias the index towards 1: the grouping of two products in the same industry that should not be classified together, the canoe and tanker example above; and trade imbalance. The grouping of two, or more, categories together that should not be in the same industry is best explained using the following table:

Table 1: *Simple aggregation bias in the GL Index*

Category	X_i	M_i	$ X_i - M_i $	$(X_i + M_i)$	GL Index
3-Digit	150	160	10	310	0.968
Sub-Group 5-Digit	0	160	160	160	0.00
Sub-Group 5-Digit	150	0	150	150	0.00

Suppose we have one 3-digit “industry” that contains 2 sub-groups and each sub-group is independently engaged in (pure) inter-industry trade. We can see that the Grubel-Lloyd Index is zero for each of these sub-groups, so if we took an average, weighted or unweighted, of the two, the Grubel-Lloyd Index would still be zero. If, however, the import and export values are summed to form the 3-digit category, it appears that we have almost pure intra-industry trade

with a Grubel-Lloyd Index of 0.968. Though this is an extreme example, it should be clear that aggregating across improper categories can lead to a misrepresentation of the degree of intra-industry trade.

The simple aggregation bias example above is a particular case of trade imbalance bias—trade imbalance, however, can occur when sub-groups are appropriately aggregated. This problem arises when the net trade-gross trade ratio is characterized by opposite trade imbalances for the sub-groups (Greenaway and Milner, 1983). Suppose there are two commodities/sub-groups within an industry:

$$\frac{|X_i - M_i|}{(X_i + M_i)} = \frac{|(X_{1i} - M_{1i}) + (X_{2i} - M_{2i})|}{(X_{1i} + X_{2i} + M_{1i} + M_{2i})} \quad (5)$$

If the country in question is a net exporter (importer) in both sub-groups the weighting effect of the ratio is maintained, but if the country is a net exporter of one good and a net importer of the other good, the weighting effect is lost and the Grubel-Lloyd Index will take on a different value (Greenaway and Milner, 1983). This can be seen in the following table:

Table 2: *Trade imbalance bias in the GL Index*

Category	X_i	M_i	$ X_i - M_i $	$(X_i + M_i)$	GL Index
3-Digit	180	310	130	490	0.735
Sub-Group 5-Digit	80	160	80	240	0.667
Sub-Group 5-Digit	100	150	50	250	0.800
3-Digit	230	260	30	490	0.939
Sub-Group 5-Digit	80	160	80	240	0.667
Sub-Group 5-Digit	150	100	50	250	0.800

In the first category the country is a net importer in both sub-groups, but in the second category the country is a net importer in one good and a net exporter in the other. Since the Grubel-Lloyd Index does not recognize the direction of trade, the sub-group Grubel-Lloyd Indices are the same in both

cases, but when the sub-groups are aggregated the Grubel-Lloyd Index for the second category is biased upward.

The index can be corrected by replacing the original net trade-gross trade ratio with the following net trade-gross trade ratio:

$$\frac{\sum_{i=1}^n |X_{ij} - M_{ij}|}{(X_j + M_j)} \quad (6)$$

where $i \equiv$ sub-group i within industry j . This adjustment removes the trade imbalance bias that results from countries being a net exporter in one sub-group of an industry and a net importer in another sub-group as well as the simple aggregation bias. We are left with the following index of intra-industry trade:

$$GL'_j = 1 - \frac{\sum_{i=1}^n |X_{ij} - M_{ij}|}{(X_j + M_j)}. \quad (7)$$

Generally speaking, if a country is a net exporter/importer in both goods, $GL = GL'$, but if a country is a net exporter in one good and a net importer in another, $GL > GL'$: $0 \leq GL' \leq GL \leq 1$ (Greenaway and Milner, 1983). There was another adjustment suggested to the Grubel-Lloyd Index by Aquino (1978) in response to an imbalance in *overall* trade. Greenaway and Milner (1981) subsequently showed that the suggested adjustment is more likely to induce, rather than remove, distortions in the Grubel-Lloyd Index. Not surprisingly, this Aquino adjustment has fallen out of favour.

2.2. *Measuring Marginal Intra-Industry Trade*

Despite the ability to calculate the Grubel-Lloyd Index over time, it does not have desirable dynamic properties. An increase or decrease in the Grubel-Lloyd Index is not necessarily associated with corresponding increases or decreases in intra-industry trade. Caves (1981) and Hamilton and Kniest (1991) have noted that an equal/proportional increase in the exports and imports

within an industry from trade liberalization would raise the quantity of intra-industry trade, but its proportion measured by the Grubel-Lloyd Index would remain the same. Suppose that trade liberalization doubled both imports and exports within a particular industry.

Table 3: *The dynamics of the GL Index*

Category	X_i	M_i	$ X_i - M_i $	$(X_i + M_i)$	GL Index
Pre-Liberalization	200	100	100	300	0.667
Pre-Trade Barrier	200	100	100	300	0.667
Post-Liberalization	400	200	200	600	0.667
Post-Trade Barrier	100	100	0	200	1.00

We can see from Table 3 that the net trade-gross trade ratio is multiplied and divided by the same scalar, two in this case, the value of the net trade-gross trade ratio, and hence the Grubel-Lloyd Index, remains the same:

$$\frac{|2X_i - 2M_i|}{(2X_i + 2M_i)} = \frac{2|X_i - M_i|}{2(X_i + M_i)} = \frac{|X_i - M_i|}{(X_i + M_i)}. \quad (8)$$

Also in Table 3, we see the possible effect of some trade barrier imposed. The exports of one country are decreased, and thus the quantity of intra-industry trade has fallen, yet this decrease in exports has put the two countries in perfect trade balance in this industry. The Grubel-Lloyd Index has actually risen from 0.667 to 1.00 even though intra-industry trade has decreased. This does not mean the Grubel-Lloyd Index is of no use when comparing trade over time, we must simply be cautious when interpreting change in the index.

Changes in intra-industry trade over time have significant effects on adjustment costs resulting from that change in trade—adjustment costs that have no doubt been taking place in recent years from the implementation of the FTA, NAFTA, and EU. In the first work on empirical intra-industry trade, Balassa (1966) noted that due to the presence of intra-industry trade, difficulties

of adjustment have been overstated. Of particular importance to Canadian trade, if the FTA and/or the NAFTA brought about adjustment within the motor vehicle industry—manufacturing a different type of motor vehicle or switching to parts manufacturing—these adjustment costs would be much less than adjustment from the motor vehicle industry to another industry, such as textiles. Manufacturing a different type of motor vehicle, whether it be different on the quality or variety spectrum, would most likely entail similar production methods and employment practices such that any adjustment process would not be difficult. In fact, this is an adjustment that occurs quite regularly with the introduction of new automobile models. Even a switch from automotive manufacturing to automotive parts manufacturing would benefit from previous industry knowledge; automobile and automotive parts manufacturers would necessarily have knowledge of each others' markets since one supplies the other with an intermediate good(s). Production methods, as well as employment practices, would undergo much more change than the previous example, but not as much as a switch to the textile industry.

Due to the concern of measuring adjustment costs due to trade liberalization and because of the dynamic problem of the Grubel-Lloyd Index, a variant of the Grubel-Lloyd Index, called the Marginal Intra-Industry Trade Index, was developed by Hamilton and Kniest (1991):

$$MIIT = \begin{cases} \frac{X_t - X_{t-n}}{M_t - M_{t-n}} & \text{for } M_t - M_{t-n} > X_t - X_{t-n} > 0 \\ \frac{M_t - M_{t-n}}{X_t - X_{t-n}} & \text{for } X_t - X_{t-n} > M_t - M_{t-n} > 0 \\ \text{undefined} & \text{for } X_t < X_{t-n} \text{ or } M_t < M_{t-n} \end{cases} \quad (9)$$

where n is the number of years between the two years of measurement. This index of marginal intra-industry trade captures the proportion of the increase in exports (imports) within an industry with a corresponding increase in imports

(exports) within that same industry. Since this index will only measure new trade flows, by definition, it captures the relative importance of intra-industry trade generated by trade liberalization. As with the Grubel-Lloyd Index, the Marginal Intra-Industry Trade Index takes on values between 0 and 1, with 1 representing new trade that is pure intra-industry trade (Hamilton and Kniest, 1991).

We now have a representation of the dynamic nature of inter- and intra-industry trade for the purpose of evaluating adjustment costs over some time period. However, as with most first attempts, this index has complications. Greenaway, Hine, Milner and Elliott (1994) state that this index of marginal intra-industry trade that is undefined whenever ΔX or ΔM is negative ignores precisely what it is trying to measure. Using United Kingdom trade data, they find that no less than 32 percent of all 5-digit SITC categories are undefined by this index. Also, this measure indicates the importance of new intra-industry trade without any reference to the amount of new trade—a high index value may not be meaningful. There is also a problem of inflation causing an upward bias in this measure if the same quantity of exports (imports) now commands an inflated price. This will give the appearance of increased intra-industry trade that was really a nominal phenomenon; using real-valued trade data easily corrects for this bias (Greenaway et al., 1994).

Greenaway et al. (1994) propose the following index, which differs from the Hamilton and Kniest (1991) index by representing intra-industry trade in values, rather than as a ratio:

$$MIIT' = [(X + M) - |X - M|]_t - [(X + M) - |X - M|]_{t-n} \quad (10)$$

$$= \Delta[(X + M) - |X - M|]. \quad (11)$$

As a consequence, this ratio is always defined and can easily be related to levels

of new trade in order to assess the significance of this new trade. However, this measure suffers from the same trade imbalance bias discussed with the Grubel-Lloyd Index above, which was precisely the criticism held by Hamilton and Kniest (1991).

Brühlhart (1994) suggests an index of marginal intra-industry trade that is always defined and does not suffer from the trade imbalance bias of previous indices:

$$MIIT'' = 1 - \frac{|(X_t - X_{t-n}) - (M_t - M_{t-n})|}{|X_t - X_{t-n}| + |M_t - M_{t-n}|} = 1 - \frac{|\Delta X - \Delta M|}{|\Delta X| + |\Delta M|}. \quad (12)$$

As with previous indices, this index takes on values between 0 and 1, with 1 representing pure marginal intra-industry trade. Like the Hamilton and Kniest Index, this index of marginal intra-industry trade captures the nature of the change in export and import flows, which is the desired property of such an index. In order to ensure this index is of economic significance, one only needs to take reference to the absolute (real) value of new trade.

Brühlhart (1994) has also suggested an index of marginal intra-industry trade to capture industry performance; this index will allow for an investigation into the distribution of trade-induced gains (losses) between countries:

$$MIIT''' = \frac{\Delta X - \Delta M}{|\Delta X| + |\Delta M|}. \quad (13)$$

Unlike previous Grubel-Lloyd type indices, this index of marginal intra-industry trade ranges between -1 and 1. The closer $MIIT'''$ is to zero, the higher is marginal intra-industry trade, whereas values close to -1 and 1 represent higher marginal *inter*-industry trade: if $\Delta X > \Delta M$, $MIIT''' > 0$, and if $\Delta X < \Delta M$, $MIIT''' < 0$. So, values of $MIIT''' > 0$ indicate that exports are expanding at the expense of imports (strong domestic industry performance), conversely for $MIIT''' < 0$ (weak domestic industry performance). Unlike

previous Grubel-Lloyd type indices, this index cannot have a (un)weighted average taken to assess marginal intra-industry trade at the country level; an average of -1 and 1 is zero, which grossly misrepresents the type of trade.

One final issue with the measurement of marginal intra-industry trade comes from Thom and McDowell (1999). They claim that the Brühlhart Index cannot distinguish between inter-industry trade and vertical intra-industry trade, and therefore, overestimates the costs of adjustment due to changes in trade composition—though the costs of adjustment for vertical intra-industry trade (quality differentiated goods) may be higher than horizontal intra-industry trade (variety differentiated goods), both will have lower adjustment costs than inter-industry trade. As we shall see in the next section, this is not entirely true. The Brühlhart Index captures all intra-industry trade for which there is a simultaneous export and import of the same commodity classification; this includes horizontal intra-industry trade and vertical intra-industry trade that is defined by quality differentiation, but does not include vertical intra-industry trade along the lines of vertical integration within an industry—two, or more, distinct commodities traded between two countries, which are usually deemed as being within the same industry. The latter of the definitions of vertical intra-industry trade is usually not considered in empirical studies, and for good reason; grouping distinct commodity classifications together, although intuitively appealing at times since different sizes of automobiles have distinct commodity classifications, returns us to the difficulties of categorical aggregation discussed above. Commodity categories have become sufficiently disaggregated to avoid categorical aggregation issues and meaningfully disentangle vertical and horizontal product differentiation, but we must be careful not to take two steps backward from this one step forward.

2.3. *Disentangling Horizontal and Vertical Intra-Industry Trade*

Although the measurement of intra-industry trade as a whole has come a long way since Balassa (1966) first proposed a measure, we have seen above, for reasons of measuring adjustment costs, that there are reasons to disentangle horizontal and vertical intra-industry trade from each other. Also, as we will see below, vertical and horizontal intra-industry trade have different expectations with respect to parameter values of the determinants of intra-industry trade. We will now discuss how these two trade types have been disentangled in the literature.

Unfortunately, the Grubel-Lloyd Index, and its variants, gives us no explicit way to differentiate between one-way and two-way trade; the index tells us the degree of trade overlap, but doesn't tell us when we are dealing with two-way trade. If we are to take the definition of two-way trade literally, the simultaneous import and export of the same commodity classification, any commodity that has a Grubel-Lloyd Index greater than zero will be deemed two-way trade. More generally, we can consider trade within a commodity classification two-way trade when the value of the minority value flow of trade represented at least γ percent of the majority value flow of trade, which is the following condition:

$$\text{Two-way trade if: } \frac{\text{Min}(X_{p,t}, M_{p,t})}{\text{Max}(X_{p,t}, M_{p,t})} > \gamma\% \quad (14)$$

where $p \equiv$ product and $t \equiv$ year. Below this level, the minority value flow would not be considered significant since it does not represent a structural feature of trade. This criterion can then be used to calculate an index of two-way trade:

$$\text{Share of Two-Way Trade} = \frac{\sum_i (X_i + M_i)}{\sum_j (X_j + M_j)} \quad (15)$$

where $i \equiv$ two-way traded goods and $j \equiv$ all traded goods.

Abd-el-Rahman (1991) pioneered this method in disentangling intra-industry trade. The index of two-way trade, however, had been proposed by Fontagné, and Freudenberg (1997). Although the Grubel-Lloyd Index and the Two-Way Trade Index measure two different phenomenon—the Grubel-Lloyd Index measures the degree of trade overlap, while the two-way trade index considers all trade over the γ percent threshold to be two-way trade—when they are compared, they are quite similar. Fontagné, and Freudenberg (1997), using regression analysis and a quadratic specification, found the fit between the two indices to be impressive: $R^2 = 0.97$. Given the longevity of the Grubel-Lloyd Index, this goodness of fit has provided some comfort to researchers.

Thus far, we have only differentiated between one- and two-way trade. We now must move to disentangle horizontal and vertical intra-industry trade. Within a given commodity classification that experiences two-way trade, products may or may not differ in their quality. In models of intra-industry trade, horizontal product differentiation is characterized by products with similar quality levels, with different attributes, while vertical differentiation is characterized by products with significantly different quality levels. Following Stiglitz (1987), empirical work that has disentangled intra-industry trade has assumed that prices represent quality, even under imperfect information. From this assumption, differences in the unit values (UV) or prices of these commodities can be assumed to represent these quality differences. Unit values have been defined for each commodity classification as the value of trade divided by the quantity traded, giving an average price of the goods traded in this category. Clearly, the more disaggregated the classification system, the better

this method will be in capturing the price of the commodities. A classification system such as the 10-digit Harmonized Tariff Schedule with 20 000 commodity classifications will capture this well. The categories are so specific that different commodities will have different quantity measures: liters, kilograms, number, etc. while the SITC classification system is more general and uses tonnes as its quantity variable for all commodity categories.

Regardless of the level of disaggregation, horizontal product differentiation is defined as having the ratio of the export unit value to the import unit value falling within a range:

$$1 - \alpha \leq \frac{UV^X}{UV^M} \leq 1 + \alpha \quad (16)$$

where α is the threshold for the range. Vertical product differentiation is then defined as:

$$\frac{UV^X}{UV^M} > 1 + \alpha \quad \text{or} \quad \frac{UV^X}{UV^M} < 1 - \alpha. \quad (17)$$

Fontagné, and Freudenberg (1997) have suggested a modified criteria that preserves the relative nature of the threshold:

$$\frac{1}{1 + \alpha} \leq \frac{UV^X}{UV^M} \leq 1 + \alpha \quad (18)$$

for horizontal product differentiation, and:

$$\frac{UV^X}{UV^M} > 1 + \alpha \quad \text{or} \quad \frac{UV^X}{UV^M} < \frac{1}{1 + \alpha} \quad (19)$$

for vertical product differentiation. For small values of α there is little difference between the two methods, but as α gets large the relative “distance” from the lower bound to unity becomes increasingly larger than the distance from unity to the upper bound.

We can see from Table 4 that as α increases the unit value ratio range becomes increasingly skewed to the lower bound in accounting for horizontal

Table 4: *Differences in product quality measures*

α	Relative Distance	Relative Distance
	to Unity from Lower Bound $1 - \alpha$	to Unity from Lower Bound $1/(1 + \alpha)$
5 %	5 %	5 %
10 %	11 %	10 %
15 %	18 %	15 %
20 %	25 %	20 %
25 %	33 %	25 %

product differentiation. The modification suggested, and used, by Fontagné, and Freudenberg (1997) corrects for this difficulty.

The two thresholds used for the distinction between vertical and horizontal product differentiation in the literature are 15 and 25 percent. The 15 percent threshold is generally used, and considered appropriate, when price differences reflect only differences in quality—the assumption of perfect information, such that a consumer will not purchase a similar, or lower, quality good at a higher price. However, in case of imperfect information the 15 percent threshold may be too narrow and the 25 percent threshold may be more appropriate. Alternatively, both thresholds could be used in order to evaluate the robustness of results (Greenaway, Hine, and Milner, 1995). Thus far, results of work on intra-industry trade have not been sensitive to the choice of the threshold.

The preceding criteria for trade overlap and product similarity lead to three different categories of trade:

1. two-way trade in similar, horizontally differentiated products (significant overlap and low unit value differences)
2. two-way trade in vertically differentiated products (significant overlap and high unit value differences)

3. one-way trade (no significant overlap).

With quality ranges of goods defined as up-market, middle-market, and down-market goods:

- up-market: unit value ratio $> 1 + \alpha$
- middle-market: $1/(1 + \alpha) \leq$ unit value ratio $\leq 1 + \alpha$
- down-market: unit value $< 1/(1 + \alpha)$,

one can investigate which price/quality segments of the market countries or industries lie, or move towards over time.

The share of two-way trade in horizontally differentiated products in industry j , the ratio of the value of two-way trade for which UV^X/UV^M falls within the horizontally differentiated products range, $1/(1 + \alpha) \leq \frac{UV^X}{UV^M} \leq 1 + \alpha$, to the total value of trade in that industry is calculated:

$$TWHD_j = \frac{\sum_{p_i \in j} \sum_{HD} (X_{p,t} + M_{p,t})}{\sum_{p_i \in j} \sum_Z (X_{p,t} + M_{p,t})} \quad (20)$$

where $TWHD_j \equiv$ two-way horizontally differentiated trade share, $HD \equiv$ horizontally differentiated trade, $Z \equiv$ all trade types, $p_i \in j \equiv$ product i in industry j , and $t \equiv$ year. A similar formula is used in the calculation of the share of two-way trade in vertically differentiated products in industry j ; that is, when $\frac{UV^X}{UV^M} < 1/(1 + \alpha)$ or $\frac{UV^X}{UV^M} > 1 + \alpha$:

$$TWVD_j = \frac{\sum_{p_i \in j} \sum_{VD} (X_{p,t} + M_{p,t})}{\sum_{p_i \in j} \sum_Z (X_{p,t} + M_{p,t})} \quad (21)$$

where $TWVD_j \equiv$ two-way horizontally differentiated trade share, $VD \equiv$ horizontally differentiated trade, $Z \equiv$ all trade types, $p_i \in j \equiv$ product i in industry j , and $t \equiv$ year. And of course, the share of one-way trade in industry j would be calculated as follows:

$$OWT_j = 1 - TWHD_j - TWVD_j \quad (22)$$

where $OWT_j \equiv$ one-way trade share.

Subsequent empirical work on the determinants of intra-industry trade by Greenaway, Hine, and Milner (1994, 1995) and Greenaway, Milner, and Elliott (1999) have used the initial threshold measure of product quality initiated by Abd-el-Rahman (1991) and a trade overlap value of $\gamma = 0$ percent, while Fontagné, Freudenberg, and Péridy (1997) have used the alternative threshold measure of product quality provided by Fontagné, and Freudenberg (1997) and a trade overlap value of $\gamma = 10$ percent.

3. The Determinants of Intra-Industry Trade

In the previous section we discussed a number of ways that intra-industry trade has been measured. Though there may be some difficulties and issues with the measurement of intra-industry trade there has been a general consensus in the literature of what to measure. The same cannot be said for the determinants of intra-industry trade.

Since the first models of intra-industry trade, a great diversity of models in both horizontal and vertical intra-industry trade as well as alternative market structures such as monopolistic competition and oligopoly have come to pass. Some of these models have differing determinants/predictions while others have determinants that would prove difficult to discriminate between. Despite these difficulties, a multitude of empirical studies have sought to identify characteristics that are common to all, or most, of these models. These characteristics, of course, are subject to measurement error and are in large part proxy variables, which makes some of the measurement issues above seem insignificant. These characteristics have been broadly classified as country-specific and industry specific determinants (Greenaway and Milner, 1989).

3.1. Country-Specific Determinants

The country-specific determinants, which include determinants relating to trade policy, fall into five broad categories: economic development, market size, geographic proximity, economic integration, and barriers to trade.

Economic development is deemed a determinant of intra-industry trade between two countries in two ways: 1) the level of economic development; and 2) the difference in economic development. High levels of economic development are seen as conducive to intra-industry trade since highly developed economies have the capacity to develop and produce differentiated products, and corresponding to this capacity to produce differentiated products is a highly differentiated demand. The most common variable used to capture this determinant is gross domestic (national) product per capita, GDP/capita. The capital-labour endowment has also been used since highly developed economies are assumed to have greater stocks of capital, per capita.

At the extreme, the intensity of intra-industry trade will be highest when the two trading countries are identical—both for economic development and market size. Therefore, these measures of economic development can be used capture the level of economic development for each individual country, or an average can be taken to represent the average level of economic development of the two countries. If this measure is averaged, as is commonly done, it is necessary to include a variable that captures the difference between the two countries. A high average level of economic development may arise from two highly developed economies or from one very highly developed economy and a lower developed economy. In the former, we would expect a high degree of intra-industry trade for reasons outlines above, but we would not have the same expectation in the latter situation. Therefore, we generally expect a

negative relationship between intra-industry trade and the inequality of the two levels of economic development.

The most common measure of this inequality is the absolute value difference between the GDP/capita of the two countries under study. As with the level of economic development, the capital-labour ratio, as well as the land-labour ratio, absolute value difference is also used to measure inequality. There has, however, been an alternative offered by Balassa (1986b). Balassa (1986b) formulated an index of relative inequality since a large absolute difference in economic development between two highly developed economies is of less importance to the structure of trade than that same absolute value difference between lesser developed economies:

$$\text{INEQ} = 1 + \frac{[w \ln w + (1 - w) \ln(1 - w)]}{\ln 2}, \quad (23)$$

where $w = GDP_i^{PC} / (GDP_i^{PC} + GDP_j^{PC})$, i, j are the respective countries, and PC stands for per capita. This index takes on values between 0 and 1, with relative inequality increasing as the index increases.

Market size is held to be positively related to the intensity of intra-industry trade. Whether the model of intra-industry trade follows the love of variety approach (Krugman, 1979) or the love of a particular variety approach (Lancaster, 1980), larger markets have the potential for greater differentiation in products that is conducive to both models. Larger markets also have greater potential for the exploitation of economies of scale. As with economic development, there are a variety of measures used for this determinant. All studies use GDP, but some separate the GDPs of the two trading countries while others sum the GDPs or average them and use one of the inequality measures mentioned above. The Balassa (1986b) inequality index is easily modified to capture a relative market size differential rather than an economic development

differential by using $w = GDP_i / (GDP_i + GDP_j)$.

Geographic proximity considers three determinants of intra-industry trade. The first is transport costs: two geographically close countries will have lower transport costs, and therefore, have a greater trade intensity, *ceteris paribus*; second, two geographically close countries are more likely to be similar in culture and tastes, which increases the potential for intra-industry trade; and third, geographically close countries are more likely to have a similar resource base, and therefore, participate in the same industries. Geographic proximity is captured by a dummy variable taking a value of one if the two countries share a border and/or by a measure of the distance between the two countries. Some studies, in order to give weight to small distances, use the inverse of the distance between the two countries. Both a shorter distance and a common border are expected to increase the intensity of intra-industry trade.

Economic integration is usually represented by a dummy variable taking on the value of one if two countries have entered into a customs or monetary union. Such countries have taken measures to lower, or eliminate, barriers to trade and the transactions costs of that trade. Also, economic integration usually, but not exclusively, can be used as a proxy for culturally similar countries, which as noted above, increases the potential for intra-industry trade.

Barriers to trade such as the average tariff level, the inequality of tariffs all hinder international trade, in general, and intra-industry trade, in particular. In order to capture non-tariff barriers to trade, Balassa (1986a, 1986b) calculates a trade orientation variable that measures deviations from a hypothetical level of per capita exports. Countries that have higher than the hypothetical value have low non-tariff barriers to trade, while countries with lower than hypothetical values have high non-tariff barriers to trade.

3.2. *Industry-Specific Determinants*

Though the country-specific determinants had some variation in the types of variables used for the determinants of intra-industry trade, that variation is dwarfed by the variation of variables used for industry-specific determinants. These determinants cover the categories of product differentiation, economies of scale, market structure, product life cycle, and the role of multinational corporations.

As mentioned above under the country-specific determinants, increased opportunities for product differentiation increases the intensity of intra-industry trade. The most common measure of the degree of product differentiation within an industry is the number of product categories within that industry—this is the variable labelled product differentiation in the following section. If an industry is defined at the 3-digit SITC level of aggregation, then the number of 4- or 5-digit commodity classifications within the 3-digit industry can be considered a measure of how much product differentiation is present—similarly for the Harmonized Tariff Schedule. Though this counting of sub-categories may represent the degree of product differentiation within an industry, it may also represent the whimsy of a bureaucrat making classifications who may or may not have knowledge of the industry in question. Indices of product differentiation have arisen to address this issue.

The first, and most commonly used, index was developed by Hufbauer (1970):

$$H = \frac{\sigma_{ij}}{M_{ij}} \quad (24)$$

where σ_{ij} represents the standard deviation of export unit values for shipments of good i to country j , and M_{ij} is the unweighted mean of those unit values. This variable is interpreted as product differentiation increasing as the variance

of the export unit values increases.

Another index used by Fontagné, Freudenberg, and Péridy (1997), who differentiate between horizontal and vertical product differentiation, is an industry trade-weighted average of unit value ratios:

$$\text{Differentiation} = \sum_{i=1}^n \left[\frac{\text{Value}_{ij}}{\text{Value}_j} \left(\frac{\text{MAX}(UV_{ij})}{\text{MIN}(UV_{ij})} \right) \right], \quad (25)$$

where $\text{Value}_{ij} \equiv$ value of trade for good i in industry j , $\text{Value}_j \equiv$ value of trade in industry j , $\text{MAX}(UV_{ij}) \equiv$ the higher unit value (export or import) of good i in industry j , $\text{MIN}(UV_{ij}) \equiv$ the lower unit value (export or import) of good i in industry j and ranges from $1 \rightarrow \infty$ —measuring the dispersion of unit value ratios for an industry. The expected sign for horizontal product differentiation is negative, since a greater dispersion in unit value ratios within an industry should be associated with a greater potential for vertical product differentiation, and therefore, a positive relation is expected with vertical differentiation.

Product differentiation is also associated with intensity in research and development and sales techniques. New varieties must be developed (R&D) and these varieties must be marketed so consumers are aware of new varieties. To capture this intensity, ratios of R&D, purchased advertising, marketing other than purchased advertising, and sales costs relative to total sales have been used. These variables are all assumed to vary positively with intra-industry trade. Related to this measure is the proportion of non-manufacturing, professional, or technical staff in total employment. Low degrees of manufacturing employment relative to total employment is associated with increased product differentiation since these staff are deemed necessary to differentiate their products from the products of other firms.

Economies of scale, central to most theories of intra-industry trade, basi-

cally measures the degree of decreasing costs in an industry/firm—the larger the firm, the greater the economies of scale, the greater the intra-industry trade. The minimum efficient scale of production, usually measured by the average firm size or value added in the industry is a common measure of economies of scale. Others have used the degree of capital in production, the share of employment in firms with greater than 500 employees, and the relative productivity of large firms. Combinations of these measures have also been used.

Generally speaking, intra-industry trade will tend to be greater when the market structure tends toward monopolistic competition. As mentioned in the introduction, there are also models of oligopolistic competition in the intra-industry trade literature, but most empirical studies focus on, or assume, a monopolistically competitive market structure—this variable can be used to differentiate between these two classes of models. The number of firms in an industry or the concentration ratio, the market share of the i top firms in the industry, can be used to measure the market structure.

The longer a product has been manufactured, the greater is the potential for differentiation in that product, and correspondingly, the greater the potential for intra-industry trade. This differentiation can take three forms. The first is just the time needed to develop varieties of a product before differentiated trade can take place. The second is the potential for import and export for various vintages of the same product. And the third, related to the first two, is trade in vertically differentiated products—as a product passes through its life cycle, different levels of the quality of that product are manufactured and traded. The product life cycle has been measured as the age of product multiplied by the number of patents in its industry.

The role of multinational corporations in international trade is usually positively associated with intra-industry trade. Intra-firm transfers and joint-firm production are likely to be within the same industry, as is off-shore assembly. The percentage of sales accounted for by multinational corporations or foreign direct investment at the industry level can measure the intensity of multinational corporations' activity in international trade. Some studies, however, associate foreign direct investment as a substitute for intra-industry trade since firms may serve foreign markets directly rather than through trade, which then would be negatively associated with intra-industry trade.

3.3. Estimation

Most econometric studies of the determinants of intra-industry trade employ ordinary least squares (OLS) for their estimation, usually after some degree of diagnostics. There are, however, a number of studies that are concerned with this specification in light of the dependent variable. The Grubel-Lloyd Index varies between zero and one, and OLS may provide forecasts outside of the 0-1 interval. To correct for this, the logistic transformation:

$$\ln \left(\frac{IIT}{1 - IIT} \right) \quad (26)$$

has been used. This complication is also relevant for studies that disentangle intra-industry trade into horizontal and vertical product differentiation and use the share that these classifications occupy in international trade.

Balassa (1986a, 1986b) as well as Balassa and Bauwens (1987, 1988) have noted that the logistic transformation is problematic when there is a zero value for intra-industry trade, not uncommon at the industry level, since the natural logarithm of zero is undefined. In order to incorporate these values into estimation, these studies used non-linear least squares with the following

equation being estimated:

$$IIT = \frac{1}{1 + \exp(-\beta'x)} \quad (27)$$

where x is a matrix of explanatory variables. This estimation procedure is based on the logistic functional form and preserves the valuable information provided by these zero observations and is easily performed in most econometrics software programs.

4. Empirical Studies on the Determinants of Intra-Industry Trade

This section does not endeavour to provide a comprehensive set of all the empirical studies of the determinants of intra-industry trade—that is far beyond the scope of this modest review. The purpose is to provide those studies which have: been deemed seminal, by the literature on empirical intra-industry trade itself; shown to be representative of many studies, and therefore, commonly cited by the empirical intra-industry trade literature; and finally, shown the multiple ways of testing similar hypotheses.

Many of the studies below estimate both their entire sample of countries as well as sub-sets of their countries, usually to test for differences between developed country trade and developing country trade. The tables in the following sections represent the general outcomes of the variables under study, with the specifics discussed in the text. Also, since different studies use different variables and estimation techniques for similar hypotheses, only the sign of the variable and whether or not it is significant at the 10 percent level is reported.

Although there is some overlap of determinants in the following studies, they have been divided into those which dominantly consider country or industry characteristics, simultaneously consider country and industry characteris-

tics, and the studies that disentangle horizontal and vertical intra-industry trade.

4.1. Country Studies

Balassa (1986a) tests the country-specific hypotheses of intra-industry trade on a set of 38 countries that are major exporters of manufactured goods—trade data was for the year 1971. Major exporters were defined as those countries that had manufactured exports exceeding \$300 million in 1979 and these exports accounted for at least 18% of their total exports. Estimates are obtained for all countries together, as well as separating the 18 developed and 20 developing countries. Countries are deemed to be developed if their 1973 gross domestic product per capita is greater than or equal to \$2250 U.S.. The dependent variable is an adjusted Grubel-Lloyd Index and estimation is undertaken using ordinary and non-linear least squares.

As can be seen from Table 5, positive and significant parameter values were the general outcome. All signs were expected to be positive except for distance, which was positive and significant for all three regressions. When developed and developing countries were separated, all parameters remained positive, however, some became insignificant. The border dummy, GNP, and trade orientation became insignificant for the developed countries most probably due to multicollinearity issues, while GNP per capita became insignificant for the developing countries for the same reason. Overall, the results of the paper support the theoretical literature.

Balassa (1986b) is quite similar to the previous study: 38 countries that are major exporters of manufactured goods, by the same criteria as above; and the separation of developed and developing countries using the same GNP year and measure. The differences between this study and the previous one

are the inclusion of new variables, bilateral trade only between developed and developing countries is also examined, and only non-linear least squares is used in the estimation. The new variables included are the inequality indices for both economic development and market size, outlined in the section defining the determinants of intra-industry trade as well as variables for economic integration.

Though the results in the previous study generally supported the theoretical literature on intra-industry trade, this study fares even better. All the variables used except the inequality variables and distance are expected to have positive parameter values. Table 5 shows that the variables all have the expected signs and are significant when all countries are estimated together. The results for only developed countries and only developing countries are the same as the entire sample with the inequality of economic development becoming significant, most probably due to lack of variation. And intra-industry trade between developed and developing countries give the same results as the entire sample.

The results of Helpman (1987) are not as promising as those of Balassa (1986a, 1986b). Intra-industry trade, measured by the Grubel-Lloyd Index, is regressed against a set of explanatory variables for fourteen industrial countries. Twelve years of data (1970 - 1981) are used, but each year is considered in a separate regression. Two models are estimated for each year: one with the absolute value difference of GDP per capita and the separate GDP values of each country and the second model with the absolute value difference of GDP per capita, the sum of the GDP values of the countries, and a relative country size variable. Estimation is undertaken using ordinary least squares.

For both models, the absolute value difference of GDP per capita has its

expected negative parameter value. Significance of that parameter, however, varied by year. From 1970 to 1976 and 1979 the parameter is significant, but insignificant for other years. The parameter for the smaller of the two GDP values is always positive and significant in the first model, indicating that, *ceteris paribus*, increases in the market size of the smaller country increases intra-industry trade, as expected since this would decrease the size differential between the two countries. The parameter on the larger of the two GDP values is negative, as expected for the same reason, but is insignificant for all years. In the second model, the parameter for the sum of GDP values is always positive, but only significant for the first four years estimated. And the parameter for the relative market size differential is positive, as expected, and significant for all but two years. One interesting result of this study is that the effect of the economic development differential seems to be weakening over time. Since all the countries under study are industrialized, and therefore developed, this may just be a result of economic differentials decreasing over time and causing the loss of variation in this variable. This result is similar to Balassa's (1986b) result for the inequality of economic development variable in the regression of only developed countries.

Bergstrand (1990) uses the Grubel-Lloyd Index for fourteen industrialized countries and 1976 international trade data. This study differentiates itself from the previous literature by incorporating capital-labour endowment ratios, and their corresponding inequalities, into the analysis. Two regression models are estimated, one with the capital-labour endowment ratio variables, and other without. The regressions are estimated using ordinary least squares. In the first regression, without the capital-labour endowment ratio variables, all variables have the expected sign on their parameters, with significance, except

Table 5: *Country studies*

Variable	Hummels				
	Balassa (1986a)	Balassa (1986b)	Helpman (1987)	Bergstrand (1990)	Levinsohn (1995)
Country GDPs			(+/-)*		+/-
Average GDP	+	+		+	
Sum of GDPs			+		
GDP Difference				-	
Average GDP/Capita	+	+		+/-	
GDP/Capita Difference			-	-	-
Relative Country Size (Helpman)			+		
Inequality Index (Balassa)		-			
Inequality/Capita Index (Balassa)		-			
Average Capital-Labour Endowment				-	
Capital-Labour Endowment Inequality				-	-
Land-Labour Endowment Inequality					-
Distance	+	-			-
Border Dummy	+	+		+	
Integration Dummy		+			
Trade Orientation	+	+			
Average Tariff Level				-	
Inequality of Tariffs				-	
R^2 Range	0.81 - 0.99	0.67 - 0.95	0.03 - 0.27	0.41 - 0.44	0.003 - 0.97

* indicates significance at the 10% level.

average GDP per capita, which is negative and significant. In the second regression, all of the variables in the first regression have the expected sign, with significance. The change in sign for the average GDP per capita is attributed, by Bergstrand (1990), to the inclusion of the capital-labour endowment ratio variables. The parameter for the inequality variable has its expected negative sign, with significance. The average capital-labour endowment ratio also has a significant and negative sign, but Bergstrand (1990) has no prior expectation for the sign of this variable.

Building on Bergstrand's (1990) use of endowment variables as a determinant of intra-industry trade, Hummels and Levinsohn (1995) incorporate not only variables pertaining to the capital-labour endowment ratio, but also the

land-labour endowment ratio. The sample used is OECD countries for international trade between 1962 and 1983. Three regressions are estimated in this study; the first two follow the methodology of Helpman (1987) by treating each year as a separate regression; the third regression pools all years into a panel data set and tests for fixed and random effects.

The specification of the first regression is almost identical to the first estimation performed by Helpman (1987): absolute value difference of GDP per capita and the GDP values separately—the difference is that Hummels and Levinsohn (1995) use the labour force instead of population for their per capita calculations. The results are also quite similar to Helpman (1987): absolute value difference of GDP per capita is always negative and initially significant, with that significance falling over time; the parameter on the smaller GDP value is always positive with initial significance that falls over time; and the larger GDP value is always insignificant, with positive and negative parameter values.

The second regression replaces the absolute value difference of GDP per capita with the absolute value difference of both the capital-labour and land-labour endowment ratio. The results for the smaller and larger GDP parameters are the same as before, except the large GDP value parameter is always negative. The absolute value difference of the land-labour endowment ratio parameter is always negative and significant, while the parameter for the absolute value difference of the capital-labour endowment ratio follows a similar pattern to the parameter of the absolute value difference of the GDP per capita parameter in the first regression.

The panel regression reports the smaller and larger GDP values, and the absolute value difference of GDP per capita or the capital-labour endowment

ratio. The panel data is estimated using no fixed effects, fixed effects, and random effects each using the absolute value difference of GDP per capita or the capital-labour endowment ratio. The parameter for the smaller GDP value is always positive and significant, while the parameter for the larger GDP value is positive or negative, significant or insignificant depending on the specification. Both of the absolute value difference variables are positive and significant under the fixed and random effects specifications, but negative under the no fixed effects specification—GDP per capita is significant, but the capital-labour endowment ratio is not. Lastly, country-pair dummy variables are included in the fixed effects specification, which account for a substantial portion of the variation.

Table 5 shows that overall the country-specific determinants for intra-industry trade, when considered independently from industry-specific determinants, are fairly consistent across studies, and in some cases, have significant explanatory power supporting the theoretical models. We now move on to studies that consider only industry-specific determinants of intra-industry trade.

4.2. Industry Studies

Caves (1981) studies 13 industrialized countries and 94 industries, defined by the Standard International Trade Classification (SITC) system at the 3-digit level of aggregation. International trade data for 1970 was utilized for the calculation of the dependent variable, the Grubel-Lloyd Index. One regression model is estimated using both ordinary least squares and the logistic transformation.

Product differentiation has its expected positive parameter value, which was significant in both estimation procedures. The remaining variables to

proxy for product differentiation have mixed results, none of which are significant. The parameter for the standard deviation of profit rates, used to capture market structure, is positive and insignificant in both cases. Economies of scale, however, is always negative with significance only in the logistic estimation. Distance and tariff rate parameters do not have the expected signs but are insignificantly different from zero. Foreign affiliate activity always has a positive parameter, but is only significant for the ordinary least squares estimation and foreign direct investment has a negative and significant parameter suggesting that FDI can be a substitute for intra-industry trade. One striking feature of this study compared with the country-specific studies is the sensitivity of results depending on the estimation procedure.

Toh (1982) investigates industry-specific determinants of intra-industry trade for the United States' manufacturing industries for both 1970 and 1971, in separate regressions. Only those industries for which industry-specific variables were available were used: 112 industries at the 4-digit level of aggregation. The parameters for product differentiation, using the Hufbauer (1970) Index, trade with high income countries, the concentration ratio, and product cycle variables all have their expected signs with significance in all regressions estimated—all positive except for the concentration ratio. The U.S. export share, used to capture international oligopolistic market structure, always has a negative parameter value, complementing the concentration ratio, but is only significant in the 1970 regressions. The parameters for average distance shipped, negative in the 1970 regressions and positive in the 1971 regressions is always insignificant. The parameters for tariff and non-tariff barriers are positive and negative, respectively, but rarely significant. The overall effect of the parameter(s) for economies of scale is always positive and significant. The

three models estimated use an overall calculation for economies of scale, and the components of that variable separately, with the combined effect being the same.

Table 6: *Industry studies*

Variable	Greenaway			
	Caves (1981)	Toh (1982)	Milner (1984)	Hughes (1993)
Product Differentiation	+		+	+
Hufbauer Index	+	+		
Advertising-Sales Ratio	-		+	
R&D Expenditures	+		+/-	+
Share of Professional and Technical Employment				(+/-)*
Share of Operations Employment				+/-
Standard Deviation of Profit Rates	+			
Concentration Ratio		-*	-*	+/-
High Income Trade Intensity		+		
U.S. Market Share		-		
Economies of Scale	-	+	-*	-
Product Life Cycle		+		
Average Distance of Shipments	+	+/-		
Foreign Direct Investment	-*			
Foreign Affiliate Trade	+		+/-	
Average Tariff Rate	+	+		
Tariff Rate Dispersion	-			
R^2 Range	0.27 - 0.29	0.26 - 0.33	0.20 - 0.75	0.04 - 0.94

* indicates significance at the 10% level.

Greenaway and Milner (1984) estimate the industry-specific determinants for intra-industry trade in the United Kingdom during the year 1977. As with all of the studies thus far, the Grubel-Lloyd is the dependent variable. Both the GL and GL' , in their calculated form and natural logarithms, are estimated: the full sample of 68 industries and a sub-sample of 37 industries that includes the advertising-sales ratio. Estimation is undertaken using ordinary least squares and the logistic transformation, but only the ordinary least squares results are reported.

In the first model, the parameter for product differentiation is positive and significant in all cases. The parameter for research and development, specified quadratically, has the expected initial positive effect that becomes negative with the quadratic term—only GL' has significant parameter values. Foreign affiliate trade is always positive, but insignificant; scale economies is always negative and significant; and the concentration ratio is always negative, with significance for the non-logarithmic models. In the second model, the addition of the advertising–sales ratio changes little for the other parameters—parameter signs are the same, but significance is lost on a few variables. The advertising–sales ratio is positive in all cases, with significance in 3 of the 4 regressions.

Hughes (1993) tests industry-specific determinants for the major OECD countries from 1980 - 1987 as a panel data set for 68 industries—major countries are France, Germany, Italy, Japan, United Kingdom, and the United States. The Grubel-Lloyd Index is used in both its calculated and natural logarithm form. The panel initially pooled industries, countries, and time, but specification tests rejected the pooling of countries so their results are reported individually—only general trends will be reported here. Estimation is undertaken using ordinary least squares with and without fixed effects.

The parameters for product differentiation and research and development have their expected positive signs, with significance; the other two variables included to capture product differentiation—the share of professional/technical staff and operations staff, respectively—vary in sign and significance depending on the country and specification of the dependent variable. The parameters for economies of scale and concentration ratios are all negative and mostly significant, with the variation being across countries. The magnitudes of the

parameter values also varies significantly across countries and specification. In the fixed effect estimation, dummy variables for all years and industries are included. Parameter values for all variables except research and development—that remains positive and significant—vary between positive and negative parameter values, as well as significance and insignificance. Hughes (1993) suggests that the sensitivity of these results and the substantially increased explanatory power with the inclusion of the industry specific dummy variables implies the need to incorporate both country- and industry-specific determinants in studies of intra-industry trade.

The consistent aspect of the industry-specific studies is the lack of consistency in the results, unlike the general tendency of consistency for the country-specific studies. One of the possible reasons for this inconsistency is data availability; most studies that investigate industry-specific determinants must use the industry characteristics of only one country to proxy for all countries due to the lack of data availability. These shortcomings clearly apply no fault to the authors of these studies, and can only be resolved with better data availability.

Torstensson (1996) investigates the robustness of econometric estimates of these industry-specific variables using Swedish international trade data for 1983 and 1989. Using a technique called extreme bounds analysis, Torstensson (1996) finds that none of the commonly used industry-specific determinants of intra-industry trade are robust. Extreme bounds analysis calculates the minimum and maximum parameter values, using maximum likelihood estimation, on a variety of model specifications. These specifications involve including and excluding the variables under study—multiple variables are used for each of the industry-specific determinants. If these upper and lower parameter

bounds includes zero, the coefficient variable is deemed fragile and if zero is not included the variables is considered robust.

Although instructive on the sensitivity of the variables used to test the industry-specific determinants of intra-industry trade, both extreme bounds analysis and the application of this technique by Torstensson (1996) is suspect. The process of randomly including and excluding variables to calculate parameter values will necessarily lead to the imposition of bias in estimates. Though the inclusion of an irrelevant variable should have no effect on the remaining parameter values, exclusion of a relevant variable, if correlated at all with the remaining variables, inevitably leads to biased estimates. Also, as noted above, the expected parameter values of the industry-specific determinants are particularly sensitive to whether the intra-industry trade is of horizontal or vertical intra-industry trade—Torstensson (1996) is aware of this differentiation since studies that disentangle intra-industry trade are cited. By using the Grubel-Lloyd Index as a measure of intra-industry trade, error is induced from the beginning of the sensitivity analysis, but the use of this variable may be due to data availability. Nevertheless, studies that only consider industry-specific determinants have proven to be problematic, which leads us to the next set of studies.

4.3. Country-Industry Studies

Loertscher and Wolter (1980) use international trade data for OECD countries at the 3-digit SITC level of aggregation. An average of 1971 and 1972 trade data is used to diminish the effect of random trade. The same model is estimated using two different dependent variables; a Grubel-Lloyd Index and

another calculated variable:

$$IIT_{ijk} = - \left| \ln \left(\frac{X_{ijk}}{M_{ijk}} \right) \right| \quad (28)$$

were used, where i, j , and k represent the commodity, country, and the country's trading partner, respectively. Estimation for the Grubel-Lloyd Index used the logistic transformation, while estimation of the above variable utilized ordinary least squares.

The country-specific determinants, with the exception of average GDP per capita, have their expected sign with significance for both regressions/dependent variables. For the variable IIT_{ijk} , the parameter for average GDP per capita has its expected positive sign with significance, but is negative though insignificant for the Grubel-Lloyd Index. For the industry-specific determinants, all the parameters basically have the same qualitative dimension in both regression results. The parameter for product differentiation is insignificant, though positive for IIT_{ijk} and negative for Grubel-Lloyd. The insignificance of this parameter is probably due to the inclusion of another very similar variable: this variable measures the number of tariff classifications within each 3-digit industry, while the other variable measures the number of 4-digit categories in each 3-digit industry; the latter variable has an expected positive and significant parameter in both regressions. Economies of scale has an unexpected significant and negative parameter, while average distance shipped and product cycle goods have their expected and significant parameters that are negative and positive, respectively.

Tharakan (1984) focusses on international trade between the industrialized world—the United States, Germany, Japan, the United Kingdom, and Italy—and the developing world, as deemed by the OECD. The Grubel-Lloyd Index calculated at the 3-digit level is estimated for 1972, 1973, and 1974,

all separately. Four models are estimated, all using the logistic transformation. Industries are separated into low and high economies of scale, and the advertising–sales ratio and the Hufbauer (1970) Index are used each in the separate regressions. Tharakan (1984) chose not to include a variable for economies of scale and separated industries instead, based on the claim by Bergstrand (1983) that the degree of increasing returns is a positive function of the degree of product differentiation so any proper econometric specification can only include one of the variables. No effort was made to test this claim.

Only two country-specific determinants of intra-industry trade are tested in this study: the absolute value difference of GDP per capita and distance; both parameters are negative and significant in all four models, as expected. The industry-specific determinants did not fare so well. Product differentiation and the advertising–sales ratio are both positive and negative, always insignificant. The Hufbauer (1970) Index is unexpectedly negative and significant for those industries deemed with low economies of scale, but positive and negative with insignificance with the high economies of scale industries.

Culem and Lundberg (1986) study international trade of manufactured products for 11 industrialized countries for the years 1970 and 1980 using 4-digit SITC data. Country-specific determinants are measured using country-specific data, however, the industry-specific determinants are proxied for all countries using Swedish industrial data for 1977/1978 assuming the data are representative for the other 11 countries. The Grubel-Lloyd Index, its natural logarithm, and the logistic transformation are used as the dependent variables with ordinary least squares estimation. The estimated parameters for the country-specific determinants are only reported for the entire sample, but the industry-specific determinants are separated for trade developed and

Table 7: *Country-industry studies*

	Loertscher Wolter (1980)	Tharakan (1984)	Culem Lundberg (1986)	Balassa Bauwens (1987)	Balassa Bauwens (1988)
Country Specific Variables					
Average GDP	+			+	+
GDP Difference	-		-		
Average GDP/Capita	+			+	+
GDP/Capita Difference	-	-			
Inequality Index (Balassa)				-	-
Inequality/Capita Index (Balassa)				-	-
Distance	-	-	-	-	-
Trade Balance			-		
Trade Orientation				+	+
Border Dummy				+	+
Integration Dummy	+			+	+
Industry Specific Variables					
Product Differentiation	+	+/-			
Hufbauer Index		+/-	+	+	+
Advertising-Sales Ratio		+/-		+	+
Standard Deviation of Profit Rates				+	
Economies of Scale	-			-	-
Concentration Ratio				-	-
Employment Share in Large Firms			(+/-)*		
Product Cycle Good	+				
Unit Value of Exports			(+/-)*		
Tariff Rate Dispersion				-	
Average Distance of Shipments	-				
Offshore Assembly				+	+
Foreign Direct Investment				-	
Foreign Affiliate Trade				-	
R^2 Range	0.07 - 0.07	0.45 - 0.60	0.18 - 0.21	0.22 - 0.57	0.58 - 0.74

* indicates significance at the 10% level.

underdeveloped countries.

The country-specific determinants, as before, have their expected results. The parameters for geographic distance are negative and significant for all

three estimation procedures. The parameter for the absolute value difference of GDP is negative in all estimations and significant for all but the logistic transformation. Trade balance's, $\max(X, M)/\min(X, M)$, parameter, which measures the degree of trade overlap at the fully aggregated level, is negative and significant for all three estimations, as expected. The Hufbauer (1970) Index parameter is generally positive and significant, as expected. The employment share in large firms, used to capture economies of scale and monopolistic competition is positive and significant for intra-industry trade with developed countries, but negative and significant for developing countries, which may represent different market structures for intra-industry trade between the developed and developing world. And the unit value of exports, thought to capture the presence of low transport costs and trade resistance follows the same pattern as the employment share in large firms: always significant, but positive for developed countries and negative for developing countries.

The study performed by Balassa and Bauwens (1987) covers 38 countries that are considered major exporters of manufactured goods at the 4-digit SITC level of aggregation, which represents 152 industries—major exporters are defined as those countries that had manufactured exports exceeding \$300 million in 1979 and these exports accounted for at least 18 percent of their total exports, similar to Balassa (1986a, 1986b) above. Countries are also divided into developed, 18, and developing, 20, countries, where a country is deemed to be developed if their 1973 gross domestic product per capita is greater than or equal to \$2250 U.S.. The Grubel-Lloyd Index is used as the dependent variable and non-linear estimation is used. Four estimations are done: the entire sample, trade among developed countries, trade among developing countries, and trade between developed and developing countries.

The parameter values for all country-specific determinants in the entire sample are significant, positive and negative, as expected. The results for the country-specific determinants are the same for intra-industry trade between developed and developing countries. Trade among the developed countries also has the same results except the inequality index for GDP per capita becomes insignificant, most probably due to lack of variation. The parameters for intra-industry trade among developing countries do not correspond to expectations as well as the other estimations, differing from Table 7 in the following way. The parameter for average GDP is negative and significant and the parameter for the inequality of GDP is positive and significant, opposite of what was expected. The authors attribute this to low levels of intra-industry trade for these countries and the possibility of poor data.

The industry-specific determinants fare quite well in this study, compared to previous results. Product differentiation is captured by three variables: the Hufbauer (1970) Index, the advertising–sales ratio, and the standard deviation of profit rates. The parameter for the Hufbauer (1970) Index is positive in all cases, and significant for all cases except trade between the developed and developing world; the advertising–sales ratio parameter is positive and significant in all cases; and the parameter for the standard deviation of profit rates is always positive, but only significant for the entire sample and trade between the developed and developing world. All variables have their expected signs and the insignificance of some of the results is most probably due to multicollinearity between variables that capture the same determinant. In fact, it is surprising the results are so strong given they are all included.

Market structure is captured by two variables, the concentration ratio and a variable calculated by Caves (1981) to capture the degree of economies of

scale. Balassa and Bauwens (1987) note that the signs of these determinants is dependent on the models assumed for intra-industry trade: both are negative and significant in all cases. Foreign direct investment, foreign affiliate trade, and offshore assembly are only reported for the three cases that include developed country intra-industry trade. The parameters for foreign direct investment and foreign affiliate trade are negative and significant, as expected, for the entire sample and trade between developed and developing countries, and insignificant for trade between developed countries. The parameter for offshore assembly, expected to be positive and representing vertical intra-industry trade, is positive and significant in the cases reported. The country- and industry-specific determinants are also estimated separately with similar results. This study, and the one that follows, have clearly had the best success with industry-specific determinants.

Balassa and Bauwens (1988) follows the same methodology as the previous study, except only intra-European trade is considered so there is only one sample used. The following variables are also excluded: standard deviation of profit rates, tariff rate dispersion, foreign direct investment, and foreign affiliate trade. Of those determinants that remained, the results are the same as the previous study; stocks and flows of human and physical capital were also included, but did not alter any of the results.

Though the studies presented above have included both country- and industry-specific determinants of intra-industry trade, little has changed with the results. Country-specific determinants are generally robust across studies, as with the studies that only looked at these determinants; industry-specific determinants are not robust across studies, just with the studies that only considered those determinants. It was hoped that the poor results of the

industry-specific determinants was a result of bias imposed by the exclusion of the country-specific determinants. Clearly, this has not been the case.

4.4. Disentangling the Determinants of Intra-Industry Trade

One possible reason for the poor performance of industry-specific determinants in the studies shown above is that different models of intra-industry trade have different expectations for the parameter values of the same determinants. These models differ for the type of market structure assumed, monopolistic or oligopolistic competition, and whether intra-industry trade is of horizontal or vertical. This is the great advantage of the following studies: they disentangle horizontal and vertical intra-industry trade, which allows for clearer expectations on parameter values.

The country-specific determinants such as the average level of economic development, average market size, geographic distance, economic integration, and barriers to trade all have the same expectation for parameter signs in both horizontal and vertical product differentiated intra-industry trade. The absolute value differences, or inequalities, of economic development and market size do not, however. Similarities in economic development and market size are expected to increase the intensity of intra-industry trade. Since economic development is highly correlated with capital abundance within a country and capital intensity—whether human or physical—in production tends to represent quality in production, we would expect to see capital abundant countries to be producing higher quality goods than capital scarce countries. This is precisely vertical product differentiation. So, differences in economic development, which are assumed to represent differences in capital abundance, will have a positive effect on the intensity of intra-industry trade in vertically differentiated products. Similarly for differences in market size.

Of the five industry-specific determinants name above, only product life cycle and the prevalence of multinational corporations maintain their positive parameter expectations in both horizontal and vertical product differentiation; product differentiation, economies of scale, and market structure all have ambiguous signs. When horizontal and vertical intra-industry trade are disentangled, all of the ambiguity can be removed from the expected parameter signs for horizontal intra-industry trade and one of the parameter signs for vertical intra-industry trade.

With regard to horizontal intra-industry trade, both the love of variety and the love of a particular variety approaches give the prior expectation of a positive relationship between horizontal intra-industry trade and product differentiation—as was shown in the industry-specific determinants section above, horizontal intra-industry trade can have a negative relationship with product differentiation depending on how the variable is defined, but we stick here to the definition of product differentiation as the number of product categories within an industry. Models of horizontally differentiated intra-industry trade also assume monopolistic competition, which comprises of many small firms competing on the basis of their variety. This gives the expectation of low market concentration (many firms) and increasing returns to scale to come into effect quickly (low minimum efficient scale). Vertical intra-industry trade is predicated on the trade of the *same* product but with different qualities, the degree of product differentiation is expected to be negatively related to the intensity of vertical intra-industry trade. Market structure and scale economies depend on the use of a small or large number of firms model is employed, as discussed in the introduction.

Greenaway, Hine, and Milner (1994) is the first econometric study that

disentangles horizontal and vertical intra-industry trade using the technique first hypothesized by Abd-el-Rahman (1991) using OECD international trade data for 1988 at the 5-digit level of aggregation between the United Kingdom and 62 of its trading partners. Intra-industry trade is assumed to have occurred with a trade overlap greater than zero, $\gamma = 0$, and the thresholds used for product quality are 15 and 25 percent, $\alpha = 15$ and 25 percent.

The parameter results for horizontal intra-industry trade are all as expected and significant. Average GDP and an economic integration dummy are positive and the absolute value difference of both GDP and GDP per capita are negative. These results are not sensitive to the choice of α . Vertical intra-industry trade has its expected positive parameter values, with significance, for average GDP and economic integration, but the absolute value difference of GDP per capita is negative and significant. Vertical intra-industry trade was further separated into low- and high-quality trade, with similar results. None of these results were sensitive to the choice of α .

Greenaway, Hine, and Milner (1995) analyze international trade between the United Kingdom and its trading partners for 77 industries defined at the 3-digit level of aggregation using OECD trade data for 1988. As with Greenaway, Hine, and Milner (1994), $\gamma = 0$ and $\alpha = 15$ and 25 percent. Estimation is undertaken using ordinary least squares and Tobit.

Vertical intra-industry trade had the most promising results. Both parameters for the product differentiation variables have their expected sign with significance. Market structure, with no prior expectation, has positive and significant parameters supporting the large number of firms theoretical models. The parameters for economies of scale and minimum efficient scale are negative for $\alpha = 15$ percent and positive for $\alpha = 25$ percent, but always in-

Table 8: *Disentangling the determinants of intra-industry trade*

	Greenaway Hine (1994)		Greenaway Hine (1995)		Fontagné Freudenberg Péridy (1997)		Greenaway Milner Elliott (1999)	
	HIIT	VIIT	HIIT	VIIT	HIIT	VIIT	HIIT	VIIT
Country Specific Variables								
Average GDP	+	*	+	*	+	*	+	*
GDP Difference	-	*			-	*	+	*
Average GDP/Capita					+	*		
GDP/Capita Difference	-	*	-	*			-	*
Inequality Index (Balassa)					-	*	-	*
Distance					-	*	-	*
Integration Dummy	+	*	+	*	+	*		
Industry Specific Variables								
Product Differentiation			+/	-			-	*
Vertical Product Differentiation				+			-	*
CEPII Differentiation Variable					-	*	+/	-
Relative Productivity					+	*	+	*
Average Firm Size			-	*	+/	-	+	*
Number of Firms in Industry			-	*	+	*	+	*
Share of Sales by Foreign Firms			+	*	+/	-	+	*
R^2 Range	0.65	-	0.06	-	0.46	-	0.08	-
	0.76		0.39		0.93		0.29	

* indicates significance at the 10% level.

HIIT \equiv Horizontally Differentiated Intra-Industry Trade

VIIT \equiv Vertically Differentiated Intra-Industry Trade

significant. The parameters for multinational corporations are insignificant for $\alpha = 15$ percent and negative and significant for $\alpha = 25$ percent, not as expected.

The parameters for product differentiation in horizontal intra-industry trade is positive for $\alpha = 15$ percent and negative for $\alpha = 25$ percent, but always insignificant. The economies of scale parameter is always negative and significant as expected, but the parameter for market structure is always negative and significant. When significant, $\alpha = 25$ percent, multinational cor-

porations has its expected positive parameter sign, but is insignificant, though still positive, for $\alpha = 15$ percent.

Fontagné, Freudenberg and Périidy (1997) investigate international trade between the member countries of the European Union for the period of 1980 - 1994, using the European equivalent to the Harmonized Tariff Schedule. Both country- and industry-specific determinants are used, and rather than assume that any trade overlap greater than zero constitutes intra-industry trade, Fontagné, Freudenberg and Périidy (1997) use $\gamma = 10$ and only set $\alpha = 15$ percent. Ordinary least squares was used on both the value and share of each type of intra-industry trade.

Whether the dependent variable is value or share of intra-industry trade, the parameter values and significance are the same for horizontal intra-industry trade. The parameters for average GDP and average GDP per capita are both positive and significant, as expected. The parameters for relative inequality of GDP and the absolute value distance of GDP per capita are both negative and significant, as was geographic distance. Parameters for economic integrations are positive and significant, as expected. The parameters for the product differentiation variable, defined above, is negative and significant. Economies of scale, defined as the relative productivity of large firms, is positive and significant, but there is no prior expectation due to the ambiguity that arises from not knowing if the small or large number of firms model applies.

The parameters for vertical intra-industry trade are somewhat sensitive to the choice of value or share of trade. Average GDP, average GDP per capita, and economic integration are positive and significant, as expected. The parameters for the absolute value difference of GDP per capita and geographic distance have their expected negative and significant signs. But the relative

inequality of GDP is unexpectedly negative for value and insignificant for share—the authors do not report the sign of the estimated parameter if it is insignificant. The economies of scale parameter is positive and significant. And the product differentiation variable has the expected positive and significant sign for the share, but is insignificant for value.

The final study to look at in this review is Greenaway, Milner, and Elliott (1999). It focusses on international trade between the United Kingdom and its European Union neighbours using both country- and industry-specific determinants with OECD international trade data for 1988—11 countries and 75 industries. Using $\gamma = 0$, and $\alpha = 15$ percent, intra-industry trade is divided into horizontal and vertical at the 5-digit SITC level of aggregation. Both horizontal and vertical intra-industry trade are estimated using the entire sample of European Union countries and separately for the European Union North and South. All estimation is undertaken using non-linear least squares.

The results for the horizontal intra-industry trade parameters are generally in line with expectations. The absolute value difference in GDP per capita and average GDP parameters are negative and positive, respectfully, and significant as expected. The absolute value difference of GDP is unexpectedly positive and significant. The parameter for horizontal product differentiation is negative, but insignificant; however, the parameter for vertical product differentiation is negative and significant, as expected. Both of the parameters for market structure and multinational corporation activity are positive and significant, as expected, but economies of scale has an unexpected positive and significant parameter value.

The results for the vertically differentiated parameters are similar to those above. The absolute value difference of GDP per capita is negative and signif-

icant, but the opposite result was expected. The average GDP parameter is positive and significant, as above. The parameter for vertical product differentiation is positive and significant as expected; when the horizontal product differentiation variable is used in its place it also has its expected negative and significant parameter value. The multinational corporation activity parameter is negative and insignificant when using the vertical product differentiation variable, but positive and significant, as expected, when using the horizontal product differentiation variable. The market structure and economies of scale parameters are positive and negative, respectively, with significance showing support for a model for many small firms. When the countries are separated into the European North and South, the results are essentially the same for intra-industry trade between the United Kingdom and its Northern European neighbours, but these results are not robust when only looking at the European South countries.

Though the preceding studies have made progress through the disentangling of horizontal and vertical intra-industry trade, both with more precise expectations for parameter values and the results of estimation, there are still shortcomings. Industry-specific determinants remain a difficulty in estimation for consistency of results, the wide variation of proxy variables used, and the use of one country's industrial characteristics to proxy for all others. These are clearly areas for future research on empirical intra-industry trade.

5. Directions for Future Research

The previous sections have outlined what we know about empirical intra-industry trade. Here, the paper will discuss those aspects of empirical intra-industry trade that we need to know.

For measurement, the high degree of disaggregation has undoubtedly dis-

missed the old concerns about categorical aggregation by lumping canoes and oil tankers together, as well as grouping size categories together (15*ml* with 15*l*) that has implications for measuring the quality of a product. However, categorical aggregation, in terms of vertically differentiated intra-industry trade is still an issue. Currently, vertically differentiated intra-industry trade is only defined as the simultaneous import and export of a quality differentiated good. But this is a very narrow definition of vertically differentiated intra-industry trade with such disaggregated commodity classifications today. Are not automotive parts and automobile manufacturing in the same “Motor Vehicle” industry? Is their not knowledge commonly situated within these classifications? Each would need to have some knowledge regarding each others’ markets in order to be able to supply/order from one another efficiently. This may be a case of vertically integrated firms, potentially operating within the same industry. There are literally hundreds of classifications for automotive parts and automobiles in the Harmonized Tariff Schedule, some of which undoubtedly can be grouped together.

This is not merely an academic curiosity, however, but has serious implications to adjustment costs in any transition of trade composition that may arise from trade liberalization, as mentioned in the section discussing marginal intra-industry trade. As it stands, the measure for intra-industry trade is understated, and therefore, costs of adjustment are overstated. Nevertheless, we do need to be careful about subjectively grouping product categories together to avoid the original categorical aggregation issue—similarity in manufacturing techniques may be too narrow, while products within the 2-digit Harmonized Tariff Schedule may be too broad to define an industry.

For both the measurement and the determinants of intra-industry trade,

the disentangling of vertical and horizontal intra-industry trade has undoubtedly been a great step forward. But this movement forward did not come without its costs. In order to disentangle these two types of intra-industry trade, the potential for two sources of measurement error have been induced—trade overlap and product quality ranges. In the industry studies that have disentangled vertical and horizontal intra-industry trade, the results have not been sensitive to whether a 15 or 25 percent quality range was specified. Also, this issue is for which *type* of intra-industry trade a product classification will be. Though adjustment costs may differ depending on the type of intra-industry trade, both types of intra-industry trade will have significantly less costs of adjustment than inter-industry trade. So, this potential area of measurement error may not be of much significance if its impact on adjustment costs is low and is not sensitive in econometric studies. We cannot say the same for trade overlap. Trade overlap, as it has been used, designates whether a product is inter- or intra-industry trade. This has a direct impact on the measurement of adjustment costs since trade may be incorrectly classified, but it also has a direct impact on econometric studies. Some researchers have used any trade overlap greater than zero to define intra-industry trade, while others have used a trade overlap of 10 percent. But at what point of trade overlap will trade begin to express the qualitative features of intra-industry trade models? This may well be why some studies have had less than favourable results when intra-industry trade had been disentangled. Products that surpass the threshold of intra-industry trade actually portrayed characteristics of inter-industry trade causing parameter values to be insignificant and/or have the incorrect sign.

This leads us to another measurement error problem: proxy variables used in industry studies. Most countries that have been represented in industry

studies on intra-industry trade have had their own industry characteristics, such as market structure, proxied by that of another country—this is particularly true of developing countries that have been proxied by the industry characteristics of developed countries. Since we expect, theoretically, the trade composition of developed—developed trade to be different from developed—developing trade, it is important to have industry characteristics that vary accordingly. Though this data acquisition may be difficult or suspicious it would be a step in the right direction.

6. Conclusion

We have seen that the history of empirical intra-industry trade has made great strides forward from the initial measurement of its phenomenon in the mid-1960s and its theoretical development approximately 15 years later. Yet, we have also seen that this history has not been one of linear progress, but one of improvements in one area at the sacrifice of another, or introducing new difficulties altogether.

Empirical intra-industry trade is at no loss of attempts to improve both its measurement and the econometric investigation of its determinants. New methods of measurement and estimation are promising, but at the same time are constrained by data quality and its availability. Therefore, future research in this area will have its greatest gains through higher quality data and its availability for that research.

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