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THE HECKSCHER–OHLIN–SAMUELSON MODEL, THE LINDER HYPOTHESIS AND THE DETERMINANTS OF BILATERAL INTRA-INDUSTRY TRADE*

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In the past ten years, several econometric studies of intra-industry trade have examined the determinants of the degree of this trade between pairs of countries for a particular industry, cf., Balassa and Bauwens (1987). These cross-country studies have found systematic empirical relationships between the share of intra-industry trade between two countries and the average levels of and inequalities between their gross domestic products (GDPs), per capita GDPs, and tariffs.

Although these relationships are robust across econometric studies, a unified theoretical framework for including each one of these particular variables has not yet been established. This paper extends the theoretical work of Dixit and Norman (1980), Helpman (1981, 1987), Krugman (1979, 1980, 1981), Helpman and Krugman (1985), and Markusen (1986) by analysing how each of the six determinants noted above, as well as the average level of and inequality between their capital-labour endowment ratios, specifically influences their share of intra-industry trade in a given commodity group. Empirical results are provided to evaluate the theoretical propositions.

Section I provides a motivation. Section II summarises the theoretical model developed in Bergstrand (1989) and extended here to address these particular issues. Section III describes the determinants of the volume and pattern of bilateral trade. Section IV presents the empirical results. Section V summarises the paper's results and qualifies them.

I. MOTIVATION

Theoretical rationales for the robust empirical relationships between the share of intra-industry trade between two countries and the average levels of and inequalities between their GDPs, per capita GDPs, and tariffs have either varied or not been demonstrated formally. In the case of inequality between per capita incomes, rationales have varied. Pagoulatos and Sorensen (1975), Loertscher and Wolter (1980), Toh (1982), Lundberg (1982) and Havrylyshyn and Civan (1983) interpret the inequality between two countries' per capita incomes as taste differences, as suggested by Linder (1961); the share of

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bilateral intra-industry trade is lower the greater the difference in their per capita incomes. Yet formal theoretical models of intra-industry trade, such as Helpman (1981), Krugman (1981) and Helpman and Krugman (1985), explain this negative correlation by interpreting per capita income differences as capital-labour endowment ratio differences. Helpman (1981) notes this has the 'flavor of the Linder hypothesis', but adds that his framework reflects supply considerations whereas Linder's hypothesis is 'based on the assumption that relative demands change with per capita income' (p. 337).

Similarly, most econometric studies have explained the positive relationship between the share of intra-industry trade and average level of per capita income using Linder (1961). Higher average per capita income represents a higher 'level of economic development', raising the extent of demand for differentiated products, increasing the share of intra-industry trade, cf., Loertscher and Wolter (1980), Havrylyshyn and Civan (1983), Balassa (1986*a*, *b*), and Balassa and Bauwens (1987). Yet theoretical models, such as Helpman and Krugman (1985), suggest that higher average per capita income represents a higher average capital-labour endowment ratio. On the assumption that industries that are capital intensive tend to have 'relatively more production of differentiated products', countries with higher average capital-labour ratios will experience a greater share of intra-industry specialisation. Along similar lines, Markusen (1986) argues that if capital intensity in production is positively correlated with a high income elasticity of demand in consumption, relatively capital-rich countries will have a higher share of intra-industry trade, although he notes that this 'empirical connection between factor intensities and income elasticities has not yet been established' (p. 1011).

On the other hand, some of the empirical correlations have no formal theoretical rationale. Some econometric studies have found a negative (positive) correlation between countries' average tariff and/or nontariff barrier levels (custom union dummies) and the share of intra-industry trade, cf., Pagoulatos and Sorensen (1975), Loertscher and Wolter (1980), Caves (1981), Toh (1982), Bergstrand (1983), Havrylyshyn and Civan (1983), Balassa (1986*a*, *b*) and Balassa and Bauwens (1987). Although Falvey (1981) showed theoretically that the volume of intra industry trade should vary inversely with the average level of trade restrictions, Balassa (1986*b*) notes 'the question is if tariffs will affect intra-industry trade more than inter-industry trade' (p. 29). Similarly, a formal justification for the inequality between countries' tariff levels is lacking.

This literature is extended in three directions. First, the analytical framework uses familiar utility and production assumptions, except that the high income-elasticity good need not be capital intensive in production. Second, the gravity equation plays a prominent role; other studies have typically ignored this device.[1] Greenaway and Milner (1986) suggest that gravity equations provide

[1] Dixit and Norman (1980) and Markusen (1986) do not discuss gravity models; Helpman and Krugman (1985) derive one where bilateral trade flows are a multiplicative function of exporter and importer GDPs only. Helpman and Krugman (1985) note that 'gravity equations tend to fit the trade pattern better, the more important are increasing returns' (p. 167).

all relevant empirical phenomena 'even if they are not able to tell us precisely how they are relevant' (p. 109). Extending Bergstrand (1989), the gravity equation is shown to be a tractable pedagogical tool for explaining simultaneously the impacts of larger and widening national incomes, per capita incomes, capital-labour ratios, and tariffs on the degree of intra-industry trade between pairs of countries. Third, empirical work confirms several formally-presented theoretical propositions.

II. THEORETICAL ISSUES

This section summarises the behaviour of the representative consumer and firm. Since the theoretical foundation follows Bergstrand (1989) fairly closely, only essential differences vis-à-vis that study will be highlighted.

The representative consumer-worker maximises a 'nested' Cobb-Douglas-CES-Stone-Geary utility function subject to an income constraint. The consumer-worker has Cobb-Douglas preferences between two tradeable goods (X, Z). Industry X produces differentiated manufactured commodities which are symmetric, but imperfect, substitutes in demand; products are differentiated by country of origin ($i = 1, \ldots, N$) and by firm within each country ($h = 1, \ldots, H_{Xi}$). The sub-utility function for good X has a constant elasticity of substitution (CES). Industry Z produces a homogeneous non-manufactured commodity for which the representative consumer-worker has a minimum consumption requirement, common to the Stone-Geary utility function which is used as the sub-utility function for Z.

The constrained utility maximisation yields bilateral import demand function:

$$X_{hij} = \delta Y_j(1 - y_j^{-1}) \, (P_{hij} D_{ij} \, T_{ij}/E_{ij})^{-\sigma} (\bar{P}_j)^{-1} \tag{1}$$

where X_{hij} is aggregate demand in country j for output of country i's firm h, Y_j is j's national income, y_j is j's per capita income (where 'capita' is expressed in terms of the value of the minimum consumption requirement of Z), P_{hij} is the f.o.b. i-currency price of firm h's output of X sold in j, D_{ij} is the exogenous transport-cost (c.i.f.-f.o.b.) factor to ship X from i to j, T_{ij} is one plus the exogenous tariff rate on exports of X from i to j, E_{ij} is the exogenous exchange rate defined as i's currency per unit of j's currency, $\bar{P}_j$ is an index of the c.i.f. prices of good X supplied by all firms in all countries to j, and σ is the elasticity of substitution in consumption ($\sigma > 1$). Equation (1) differs from the typical Armington (1969) bilateral import demand function only by the addition of y_j; this term implies an income elasticity of demand for X (Z) greater (less) than one. Hence, X (Z) is the luxury (necessity) by assumption.

The representative firm in industry X in country i maximises profits subject to technology constraints in a market characterised by Chamberlinian monopolistic competition using two factors of production, labour and capital, which are in fixed supply. The firm faces (internal) increasing returns to scale because of fixed setup costs and constant marginal costs; this is captured by the standard linear cost function, as used by Helpman, Krugman, and Markusen.

Different from their models, output of each firm is considered a 'composite commodity' here.

Recent empirical evidence on the price responsiveness of firms substituting output between domestic and foreign markets is inconsistent with the notion that such substitution is costless. As in Geraci and Prewo (1982), Bergstrand (1985, 1989), Deardorff and Stern (1986) and de Melo and Robinson (1985, 1989), shipments by the firm to domestic and foreign markets are considered imperfect substitutes, represented here by a constant-elasticity-of-transformation (CET) function.

Two conditions characterise Chamberlinian monopolistic competition, profit maximisation by firms and zero economic profits in equilibrium. Profit maximisation by the firm given demand function (1) yields mark-up pricing function:

$$P_{hij} = [(1-\sigma^{-1})^{-1}(X_{hij}/X_{hi})^{1/\gamma}](W_i\beta_{LX}+R_i\beta_{KX}) \tag{2}$$

where W_i (R_i) is the wage (rental) rate for labour (capital) in country i, determined in competitive factor markets and taken as given by the firm, β_{LX} (β_{KX}) is the constant marginal input requirement of labour (capital) to produce a unit of X, X_{hij} is the output of firm h in country i exported to country j, X_{hi} is the (composite) output of firm h, and γ is the elasticity of transformation of output among all domestic and foreign markets, i.e.,

$$X_{hi} = [\Sigma_{j=1}^{N} X_{hij}^{(\gamma+1)/\gamma}]^{\gamma/(\gamma+1)}, \quad \gamma > 0.$$

Price is a markup over marginal cost $(W_i\beta_{LX}+R_i\beta_{KX})$. While the markup is characteristically a negative function of the elasticity of substitution in consumption, it is uncharacteristically a positive function of the share of the firm's output exported to market j. If output was costlessly substitutable among markets ($\gamma = \infty$), $(X_{hij}/X_{hi})^{1/\gamma}$ would be unity, leaving the standard markup.

Second, setting profits equal to zero allows solving for the equilibrium (composite) output of the firm:

$$X_{hi} = (\sigma-1)[(W_i\alpha_{LX}+R_i\alpha_{KX})/(W_i\beta_{LX}+R_i\beta_{KX})] \tag{3}$$

where $(W_i\alpha_{LX}+R_i\alpha_{KX})$ is the fixed cost of the firm and recall $\sigma > 1$. That the firm's output is a positive (negative) function of fixed (marginal) costs is common, cf., Krugman (1981) and Markusen (1986).

The value of the bilateral trade flow exported by firm h in country i to country j is determined by substituting output function (3) and demand function (1) into markup pricing function (2), then solving for equilibrium price and quantity. To find the value of the aggregate trade flow from i to j in X, the number of producers (and products) in industry X in i needs to be determined. Assuming labour ($\bar{L}_i$) and capital ($\bar{K}_i$) in each country i are in fixed supply and fully employed:

$$\bar{L}_i = (\alpha_{LX}H_{Xi}+\beta_{LX}H_{Xi}X_{hi})+\beta_{LZ}H_{Zi}Z_{hi} \tag{4a}$$

$$\bar{K}_i = (\alpha_{LX}H_{Xi}+\beta_{KX}H_{Xi}X_{hi})+\beta_{KZ}H_{Zi}Z_{hi} \tag{4b}$$

where the first (second) RHS term in each equation represents the amount of the respective factor used up by industry X (Z). Homogeneous non-manufactured good Z is produced under constant returns to scale; its setup costs are zero. With X_{hi} determined by equation (3), equations (4*a*) and (4*b*) can be solved for the number of firms in X in country i (H_{Xi}) and the output of Z in country i ($H_{Zi} Z_{hi}$).

The equilibrium number of firms producing X in country i is:

$$H_{Xi} = \{[(\beta_{KX}\beta_{LZ} - \beta_{KZ}\beta_{LX})(\sigma - 1)(W_i\alpha_{LX} + R_i\alpha_{KX})/(W_i\beta_{LX} + R_i\beta_{KX})] + (\alpha_{KX}\beta_{LZ} - \beta_{KZ}\alpha_{LX})\}^{-1}(\beta_{LZ}\bar{K}_i - \beta_{KZ}\bar{L}_i). \quad (5)$$

At given factor prices, changes in factor endowments alter the number of goods produced in industry X, not the level of output of the representative firm, as common to these models. The effect of augmenting a factor's endowment on the equilibrium number of firms depends on relative factor intensities in production, a 'Rybczynski-like' result. Equation (5) readily illustrates that if X(Z) is relatively capital (labour) intensive in production and $\sigma > 1$, a higher capital (labour) stock in country i would increase (decrease) the number of firms producing X in i.[2] In the context of a monopolistically competitive market for X, these results are analogous to the Rybczynski effect in a perfectly competitive market. In perfectly competitive industry Z, conventional Rybczynski results hold.

III. DETERMINANTS OF THE VOLUME AND PATTERN OF BILATERAL TRADE

The value of the bilateral trade flow from i to j in X (PX_{ij}) is determined by multiplying the value of the flow of firm h by the number of firms, equation (5). This yields 'gravity equation' (6) which is similar, but not identical, to that in Bergstrand (1989) because here the number of firms is endogenous:

$$\begin{aligned} PX_{ij} = {} & \sigma^{-\gamma(\sigma-1)/(\gamma+\sigma)}(\sigma - 1)^{(\gamma+1)(\sigma-1)/(\gamma+\sigma)}\,\delta^{(\gamma+1)/(\gamma+\sigma)}\bar{K}_i \\ & \times \{[(\beta_{KX}\beta_{LZ} - \beta_{KZ}\beta_{LX})(\sigma - 1)(W_i\alpha_{LX} + R_i\alpha_{KX})/(W_i\beta_{LX} + R_i\beta_{KX}) \\ & + (\alpha_{KX}\beta_{LZ} - \beta_{KZ}\alpha_{LX})]^{-1}[\beta_{LZ} - \beta_{KZ}(\bar{K}_i/\bar{L}_i)^{-1}]\}\,Y_j^{(\gamma+1)/(\gamma+\sigma)} \\ & \times (1 - y_j^{-1})^{(\gamma+1)/(\gamma+\sigma)}\,D_{ij}^{-\sigma(1+\gamma)/(\gamma+\sigma)}\,T_{ij}^{-\sigma(\gamma+1)/(\gamma+\sigma)}\,E_{ij}^{\sigma(\gamma+1)/(\gamma+\sigma)} \\ & \times [(W_i\beta_{LX} + R_i\beta_{KX})^{-(\gamma+1)}(W_i\alpha_{LX} + R_i\alpha_{KX})]^{(\sigma-1)/(\gamma+\sigma)}(\bar{P}_j)^{-(\gamma+1)/(\gamma+\sigma)}. \quad (6) \end{aligned}$$

The share of intra-industry trade between i and j in industry X is usually measured using a bilateral version of the Grubel-Lloyd index:

$$GL_{Xij} = 1 - [|PX_{ij} - PX_{ji}|/(PX_{ij} + PX_{ji})], \quad 0 \leqslant GL_{Xij} \leqslant 1. \quad (7)$$

Substitution of (6) for PX_{ij} and its analogue for PX_{ji} in (7) yields a complex function (not shown here, but available from the author on request) illustrating

[2] X is considered capital (labour) intensive in production when $\beta_{KX}\beta_{LZ} - \beta_{KZ}\beta_{LX} > 0$ (< 0) and $\alpha_{KX}\beta_{LZ} - \beta_{KZ}\alpha_{LX} > 0$ (< 0). The equilibrium number of firms producing X in i, H_{Xi} will be assumed to be positive; this implies that, if X is relatively capital (labour) intensive in production, then $\beta_{LZ}\bar{K}_i - \beta_{KZ}\bar{L}_i$ ($-\beta_{LZ}\bar{K}_i + \beta_{KZ}\bar{L}_i$) is positive. Unlike Helpman and Krugman (1985) and Markusen (1986), differentiated manufactures industry X is neither assumed to be capital nor labour intensive.

explicitly how average levels of and inequalities between two countries' GDPs, per capita GDPs, capital-labour ratios, and tariffs influence their degree of intra-industry trade. For brevity, only relevant comparative statics are presented. Since these are complex, assume initially an equilibrium where countries i and j are identical in all respects, i.e., identical capital stocks, labour, incomes, factor prices, etc., as in Helpman (1981). In this initial equilibrium, $GL_{Xij} = 1$; all trade is intra-industry in nature. Though some propositions are not new, they have not yet been derived together from a common formal theoretical model.

PROPOSITION 1. *The share of intra-industry trade between countries i and j* (GL_{Xij}) *will be lower the greater the inequality between their relative capital-labour endowment ratios.*

A marginal reallocation of the (initially equal) capital stocks from j to i and of the labour stocks from i to j that alters their relative factor endowments, but not their incomes, commodity prices, factor prices, or per capita incomes (the last restriction to be relaxed shortly) yields:

$$GL_{Xij} = 1 - \left|\frac{\beta_{LZ}\bar{K}_i - \beta_{KZ}\bar{L}_i}{\beta_{LZ}\bar{K}_j - \beta_{KZ}\bar{L}_j} - 1\right| \bigg/ \left(\frac{\beta_{LZ}\bar{K}_i - \beta_{KZ}\bar{L}_i}{\beta_{LZ}\bar{K}_j - \beta_{KZ}\bar{L}_j} + 1\right) < 1. \tag{8}$$

The new inequality between relative factor endowments has created Heckscher-Ohlin-Samuelson trade. This accords with a proposition in Helpman (1981), in a similar model, 'if we reallocate the world's labour and capital stock in a way which [widens the two countries' capital-labour ratios] without disturbing commodity prices and factor rewards, then the share of intra-industry trade...will decline' (p. 325).

PROPOSITION 2. *The share of intra-industry trade will be lower the greater the inequality between per capita incomes because of a greater divergence in tastes.*

In this model, per capita income seems to influence the volume and pattern of trade via two channels, one supply and one demand. On the supply side, national income is attributable ultimately to capital or labour; a larger capital-labour endowment ratio must be associated with higher per capita income, as cross-country empirical comparisons reveal. Greater inequality between two countries' per capita incomes reflects greater inequality between their capital-labour ratios, and the smaller should be their intra-industry trade, as shown above. However, in Helpman (1981), tastes were homothetic. In this model, tastes are nonhomothetic, as in Markusen (1986). Consequently, wider per capita income differences can reduce the share of intra-industry trade here by widening taste differences, even after removing the effect of greater inequality in their capital-labour ratios. Consider the initial equilibrium. A marginal adjustment creating an inequality between per capita incomes of i and j, without altering relative capital-labour ratios or other variables (including average per capita income) yields:

$$GL_{Xij} = 1 - \frac{|(1-y_j^{-1})^{(\gamma+1)/(\gamma+\sigma)} - (1-y_i^{-1})^{(\gamma+1)/(\gamma+\sigma)}|}{[(1-y_j^{-1})^{(\gamma+1)/(\gamma+\sigma)} + (1-y_i^{-1})^{(\gamma+1)/(\gamma+\sigma)}]} < 1. \quad (9)$$

The observed negative empirical correlation between greater inequality between two countries' per capita GDPs and the share of intra-industry trade potentially has both supply and demand explanations. Since econometric studies have not explicitly included capital-labour ratio differences as an independent variable along with per capita income differences, these two channels have not been able to be distinguished empirically. The empirical results in the next section will show that both channels have influence on the degree of intra-industry trade.

PROPOSITION 3. *The share of intra-industry trade will be higher or lower the greater the average capital-labour endowment ratio of the two countries, depending upon relative factor intensities in production.*

If X is capital intensive in production, equation (8) can be more usefully rewritten as:

$$GL_{Xij} = 1 - |\beta_{LZ}(\bar{K}_i - \bar{K}_j) - \beta_{KZ}(\bar{L}_i - \bar{L}_j)| / [\beta_{LZ}(\bar{K}_i + \bar{K}_j) - \beta_{KZ}(\bar{L}_i + \bar{L}_j)].$$

Consider an epsilon (ϵ) increase in both countries' capital stocks that does not alter the difference between their capital stocks (nor consequently between their capital-labour ratios), i.e., $(K_i + \epsilon) - (K_j + \epsilon) = K_i - K_j$. Since X is capital intensive, the capital stocks' augmentation will enlarge the number of differentiated products in each country's industry X, raising the denominator of the second RHS term, and increasing the share of intra-industry trade.

But if X is labour intensive, equation (8) can be more usefully rewritten as:

$$GL_{Xij} = 1 - |-\beta_{LZ}(\bar{K}_i - \bar{K}_j) + \beta_{KZ}(\bar{L}_i - \bar{L}_j)| / [-\beta_{LZ}(\bar{K}_i + \bar{K}_j) + \beta_{KZ}(\bar{L}_i + \bar{L}_j)].$$

The epsilon increase in both capital stocks, without altering the difference between their capital stocks, reduces the number of differentiated products in each country's industry X, decreasing the share of intra-industry trade.

The effect of a higher average capital-labour ratio on GL_{Xij} depends on relative factor intensities. In this regard, this model departs from Helpman and Krugman (1985) and Markusen (1986) which assumed the differentiated manufactured goods industry was capital intensive. In Markusen (1986), the higher the average capital-labour endowment ratio of two countries, the higher would be their share of intra-industry trade because capital-intensive manufactured goods were assumed to have income elasticities greater than one. In this model, the effects of higher average capital-labour endowment ratio and higher average per capita income of two countries on the share of intra-industry trade are 'uncoupled'. As will be empirically shown, for some manufacturing industries a higher average capital-labour endowment ratio for two countries can lower the share of intra-industry trade, even though a higher average per capita income can raise it.

Proposition 4. *The share of intra-industry in the luxury (necessity) good will be higher (lower) the higher the average level of economic development.*

Although I do not assume that the differentiated (homogeneous) good is capital (labour) intensive in production, I do assume that the differentiated good (homogeneous commodity) is the luxury (necessity) in consumption. Hence, the share of intra-industry trade between two countries should rise unambiguously the larger is their average per capita income because, as equation (6) suggests, the volume of bilateral trade will be augmented in industry X, assuming no change in the difference between their per capita incomes. To illustrate, consider an epsilon increase in both countries' per capita incomes that does not alter the difference between their per capita incomes. Only the denominator of the second RHS term in equation (9) changes; the increase in the denominator raises GL_{Xij}.

Proposition 5. *The share of intra-industry trade will be lower the greater the inequality between their economic sizes.*

From the initial equilibrium, a marginal reallocation of the two countries' capital and labour stocks (say, from j to i) that does not alter the countries' combined capital and labour stocks, combined incomes, relative factor endowments, per capita incomes, etc., yields:

$$GL_{Xij} = 1 - |\bar{K}_i Y_j^{(\gamma+1)/(\gamma+\sigma)} - \bar{K}_j Y_i^{(\gamma+1)/(\gamma+\sigma)}| / [\bar{K}_i Y_j^{(\gamma+1)/(\gamma+\sigma)} + \bar{K}_j Y_i^{(\gamma+1)/(\gamma+\sigma)}] < 1. \tag{10}$$

The new inequality of economic sizes lowers the share of intra-industry trade below unity. The reallocation of capital and labour from j to i has expanded the number of firms producing and varieties produced of X in one country and reduced them in the other country; which country's industry X expands and which contracts is indeterminate *a priori* without knowing relative factor intensities in production at prevailing wage-rental ratios. The rise in $\bar{K}_i$ relative to $\bar{K}_j$ is dampened by the fall in Y_j relative to Y_i; however, since $\sigma > 1$, the fall (rise) in $Y_j^{(\gamma+1)/(\gamma+\sigma)}$ ($Y_i^{(\gamma+1)/(\gamma+\sigma)}$) is less than proportionate to the rise (fall) in $\bar{K}_i$ ($\bar{K}_j$). This proposition illustrates formally the notion that the scope for exchange of product diversity is narrowed the greater the inequality between two countries' economic sizes, and corroborates a proposition in Helpman (1987), in a similar context, 'the more similar countries are in size the larger the share of intra-industry trade.'

Proposition 6. *The share of intra-industry trade will be higher the greater their average economic size.*

For convenience, equation (10) can be rewritten as:

$$GL_{Xij} = 1 - |kY_j^{(\gamma+1)/(\gamma+\sigma)} - Y_i^{(\gamma+1)/(\gamma+\sigma)}| / [kY_j^{(\gamma+1)/(\gamma+\sigma)} + Y_i^{(\gamma+1)/(\gamma+\sigma)}]$$

where $k = \bar{K}_i/\bar{K}_j$. Consider an epsilon increase in both countries' capital and labour stocks that leaves unchanged their capital-labour ratios, per capita incomes, relative capital stocks (k), and absolute difference between their incomes (specifically, the numerator of the second RHS term). In this case, only the denominator of the second RHS term rises with both countries' incomes, causing the share of intra-industry trade to rise.

PROPOSITION 7. *The share of intra-industry trade will be lower the greater the inequality between their tariff levels.*

From the initial equilibrium, suppose T_{ij} (T_{ji}) is raised (lowered) slightly without altering their average tariff rate. The share of intra-industry trade falls below unity:

$$GL_{Xij} = 1 - \frac{|T_{ij}^{-\sigma(\gamma+1)/(\gamma+\sigma)} - T_{ji}^{-\sigma(\gamma+1)/(\gamma+\sigma)}|}{[T_{ij}^{-\sigma(\gamma+1)/(\gamma+\sigma)} + T_{ji}^{-\sigma(\gamma+1)/(\gamma+\sigma)}]} < 1. \quad (11)$$

PROPOSITION 8. *The share of intra-industry trade between two countries will be lower the greater their average tariff level, i.e., artificial barriers to trade.*

Consider an epsilon increase in tariff levels in both countries that lowers the denominator of equation (11), without altering the absolute difference between their tariffs (specifically, the numerator of the second RHS term in (11)). The lower denominator will decrease the share of intra-industry trade.

IV. EMPIRICAL EVIDENCE

Although inequalities between and average levels of national incomes, per capita incomes, and tariffs have been included in previous cross-country econometric analyses, inequalities between and average levels of capital-labour endowment ratios have not. Only two regressions will be estimated: one including all eight variables mentioned above (along with three dummies) and one excluding the two capital-labour ratio variables.

The dependent variable in both regressions is the logit of an average of three-digit SITC bilateral Grubel-Lloyd intra-industry trade indexes calculated for each two-digit SITC industry grouping in SITC 7. Formally:

$$GL_{Xij} = 1 - \frac{1}{M}\sum_{m=1}^{M} [|PX_{ijm} - PX_{jim}|/(PX_{ijm} + PX_{jim})] \quad (12)$$

where M is the number of three-digit SITC industries in two-digit SITC industry group X and PX_{ijm} is the U.S. dollar value of the bilateral trade flow from country i to country j in three-digit SITC industry m. The three-digit SITC classification is typically considered an 'industry' for econometric purposes. This particular unweighted average of three-digit SITC intra-industry trade indexes to generate an 'average' two-digit SITC index for cross-country econometric analysis is also found in this literature, cf., Greenaway and Milner (1986, pp. 62–5).

Calculating bilateral intra-industry trade indexes for all three-digit SITC industries is far beyond the scope of this paper. However, the industry groups comprising SITC 7 – nonelectrical machinery (71), electrical machinery (72), and transportation equipment (73) – possess several characteristics summarised in Bergstrand (1983, p. 210) that make them suitably representative of most manufacturing industries.

Using equation (12), the dependent variable was calculated for each two-digit industry group in SITC 7 for each possible pairing of fourteen major industrialised countries using 1976 data; this yielded 91 indexes for each industry group, or 273 when pooled. Before calculating these indexes, each three-digit SITC bilateral trade flow was 'adjusted' to reflect multilateral aggregate trade balance. The methodology and rationale for this adjustment is discussed in Bergstrand (1983, pp. 206–9); see Greenaway and Milner (1986, pp. 70–1) and Kol (1989) for support.

A unique aspect of this empirical study is the inclusion of capital-labour endowment ratios to help distinguish between the supply and demand influences of per capita incomes. Leamer (1984, Appendix B) provides measures of capital stocks, labour stocks, and GNP for each of the fourteen countries for 1975. Population data for each country for 1975 were collected from the World Bank's *World Tables* (1983). Average tariff levels for the countries were collected from the GATT's *Basic Documentation for Tariff Study* (1970). That study provides post-Kennedy Round nominal tariff data for fourteen major industrialised countries (the constraint behind the countries chosen for this empirical work), disaggregated by industry categories (for SITC 7, such categories correspond to 71, 72 and 73).[3]

Three dummy variables were appended. A dummy variable captured 'border trade,' assuming a value of one if two countries shared a common land border and zero otherwise. Two dummy variables accounted for differences across industry groups in their average levels of intra-industry trade owing to innate differences in industry characteristics. The regressions are estimated using weighted least squares. Although the logit of an intra-industry trade index, GL_{Xij}, yields unbiased estimates, the variance of the error terms associated with OLS estimation would be $[GL_{Xij}(1-GL_{Xij})]^{-1}$. To avoid heteroskedasticity, all variables are weighted first by $[GL_{Xij}(1-GL_{Xij})]^{\frac{1}{2}}$, cf., Bergstrand (1983) or Balassa (1986*a*).

Regression 1 is distinguished from regression 2 by the former omitting the average of and inequality between each pair of countries' capital-labour endowment ratios. Propositions 2, 5, and 7 suggest unambiguously that the share of intra-industry trade will be *lower* the greater the inequality between two countries' per capita GDPs, national incomes, and tariffs, respectively. Empirical results for regression 1 in table 1 confirm this; using one-tailed *t*-tests, all three coefficient estimates are statistically significant at the 10% level at least. Proposition 6 (8) suggests unambiguously that the share of intra-industry trade will be higher (lower) the higher the average level of the countries' GDPs

[3] The inequality between two countries' GDPs, etc., was calculated using the 'inequality' measure used in Balassa (1986*a*) and Balassa and Bauwens (1987). This measure, *INEQY*, shown below for the inequality between GDPs in *i* and *j*, Y_i and Y_j, has values between 0 and 1:

$$INEQY_{ij} = 1+\{[Y_i/(Y_i+Y_j)]\ln[Y_i/(Y_i+Y_j)]+[Y_j/(Y_i+Y_j)]\ln[Y_j/(Y_i+Y_j)]\}/\ln 2$$

Table 1

Coefficient Estimates of Determinants of Cross-Country Bilateral Intra-Industry Trade Indexes (t-statistics in parentheses)

Independent variable	Regression 1	Regression 2	Expected coefficient sign for Regression 2
Inequality of capital-labour endowment ratio		−0·86 (−0·64)	−
Inequality of per capita GDPs	−1·42* (−1·30)	−1·21 (−0·82)	−
Inequality of GDPs	−0·69*** (−3·60)	−0·50*** (−2·58)	−
Inequality of tariff levels	−0·91* (−1·30)	−0·90* (−1·31)	−
Average capital-labour endowment ratio		−1·19*** (−3·14)	?
Average per capita GDP	−0·46** (−1·95)	0·46 (1·18)	+
Average GDP	0·37*** (6·10)	0·27*** (4·00)	+
Average tariff level	−0·34*** (−6·57)	−0·34*** (−6·53)	−
Adjacency dummy	0·30*** (3·00)	0·31*** (3·16)	+
Dummy for SITC 71	−0·08 (−0·96)	−0·08 (−0·95)	?
Dummy for SITC 73	−0·76*** (−8·05)	−0·77*** (−8·30)	?
WLS Intercept	1·31 (0·14)	5·38** (2·01)	?
R^2	0·41	0·44	
Adjusted R^2	0·39	0·42	
S.E.E.	0·28	0·27	
Number of observations	273	273	
Degrees of freedom	263	261	

Note: *, **, *** denote statistical significance in one-tail t-tests at the 10%, 5%, and 1% levels, respectively.

(tariffs). The results for regression 1 confirm this; these results are statistically significant at the 1% level.

However, the expected coefficient sign in regression 1 for the average level of the countries' per capita GDPs is ambiguous. Proposition 4 suggests that the share of intra-industry trade will be higher (lower) among two countries the higher their average per capita GDP if the good is the luxury (necessity). But Proposition 3 claims that the share of intra-industry trade will be higher (lower) among two countries the higher their average capital-labour ratio if the good is capital (labour) intensive in production. Since capital-labour ratios and per capita incomes across countries are highly correlated, the exclusion of average capital-labour ratios in regression 1 may cause per capita income variation across countries to reflect both demand and supply channels of influence. Even if goods in SITC 7 were luxuries, the coefficient estimate for average per capita GDPs may be negative if SITC 7 industries are labour intensive in production, i.e., an omitted variables bias may be present. Indeed, in regression 1, average per capita GDP has a statistically significant negative coefficient estimate; in the model's context, this is consistent with SITC 7 goods being necessities in consumption or labour intensive in production or both.

The addition of the average of and inequality between capital-labour ratios in regression 2 is intended to distinguish empirically between the demand and supply influences of per capita income. Coefficient estimates for the average of and inequality between GDPs and tariffs need no discussion as these estimates are not significantly different between regressions 1 and 2. Instead, note that the addition of the average of and inequality between capital-labour ratios has significantly altered the coefficient estimates of the average of and inequality between per capita incomes in a consistent and economically meaningful way.

First, Proposition 1 suggests that the share of intra-industry trade between two countries should be unambiguously lower the greater the inequality of their capital-labour endowment ratios. The coefficient estimate for this variable in regression 2 is negative, although statistically insignificant at conventional levels. Note the coefficient estimate for the inequality in per capita incomes, while still negative, is smaller in regression 2 than in regression 1. This reduction is consistent with the model's hypothesis that wider per capita income differences tend to reduce the share of intra-industry trade as a proxy both for wider taste differences (demand) and wider relative factor endowments (supply); the coefficient estimate for per capita income inequality falls because some of that variable's explanatory power has shifted to the capital-labour ratio inequality variable. The coefficient estimates, however, are not statistically significant.

Second, the addition of the average capital-labour endowment ratio in regression 2 has reversed the coefficient estimate sign for average per capita GDP. The average per capita income coefficient estimate changes from a statistically significant negative value to a positive value, the latter having statistical significance only at a 15% level in a one-tailed test. But the average capital-labour ratio coefficient estimate is negative and statistically significant at the 1% level, suggesting that machinery and transport equipment is relatively labour intensive in production. Thus, the explicit inclusion of average capital-labour ratios has 'released' the variation of average per capita incomes across countries from reflecting both demand and supply influences. In the context of the theoretical model, average per capita income variation now influences only demand and its (statistically insignificant) positive coefficient estimate in regression 2 modestly suggests that differentiated manufactured machinery and transport equipment products are luxuries in consumption.

The coefficient estimate for land adjacency is positive and statistically significant; this is consistent with other empirical evidence that the share of intra-industry trade between two countries is influenced by 'cross-border' trade. The industry dummies' coefficient estimates suggest that the average degree of intra-industry trade in electrical machinery (SITC 72) is not significantly different from that in nonelectrical machinery (SITC 71), but is significantly greater than that in transport equipment (SITC 73).

Summarising, the regression results generally support the propositions addressed in section III. The data suggest that the share in intra-industry trade between two countries in SITC 7 tends to be significantly lower the greater their average capital-labour ratio (Proposition 3), implying – in the context of the theoretical model – that these manufactured products are labour intensive in production. The data modestly suggest that the share of intra-industry trade between two countries in SITC 7 tends to be higher the greater their average per capita income (Proposition 4), consistent in the model's context with these products being luxuries in consumption. These results are economically plausible. Moreover, the analysis here suggests that the assumption in Helpman and Krugman (1985) and Markusen (1986) that the differentiated manufactures industry is capital intensive in production may not be necessary to demonstrate a relationship between per capita income and the share of intra-industry trade. Finally, the explanatory power here ($R^2 = 0{\cdot}44$ in regression 2) using only 273 observations is equal to that in other studies using 62,000 observations, cf. Balassa and Bauwens (1987).

V. CONCLUSIONS

Prominent systematic empirical relationships between the share of intra-industry trade between pairs of countries and the average levels of and inequalities between their national incomes, per capita incomes, capital-labour endowment ratios, and tariffs were rationalized theoretically using a synthesised framework. The model revealed that a greater similarity of two countries' per capita incomes would be associated with more intra-industry trade both for supply (Heckscher-Ohlin-Samuelson) and demand (Chamberlin-Linder) reasons simultaneously. Several other testable propositions evolved from the model, which used a gravity-like equation as a pedagogical device.

It should be emphasised, however, that these propositions evolve from a restricted set of assumptions. Intra-industry trade in this model evolves only among horizontally differentiated products; other models have shown such trade among homogenous goods under different market structures. Heckscher-Ohlin-Samuelson models have predicted two-way trade in vertically differentiated goods.

In structuring the empirical model, emphasis was given to selecting an SITC industry grouping that was representative of the bulk of OECD trade. Our empirical results generally confirm the theoretical propositions. However, the lack of statistical significance in all of the suggested relationships suggests a path for future research in this area.

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