Intra-industry Trade and Industry Distribution of Productivity: A Cournot–Ricardo Approach

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1. INTRODUCTION

The monopolistic competition model of trade, founded by Krugman (1979), Lancaster (1979) and Dixit and Norman (1980), dominates economists’ way of thinking on intra-industry trade (IIT). The influence of the model is equally strong in empirical research. Helpman (1981) and Helpman and Krugman (1985) derived a testable implication from the monopolistic competition model that the extent of IIT in bilateral trade should be inversely related to the difference in relative factor endowments between trading partners. Helpman (1987) put this implication to test and opened the stage for theory-based empirical research on IIT. Subsequent research, such as Hummels and Levinsohn (1995) and Cieslik (2005), found mixed results, but this line of research firmly placed the Chamberlinian perspective in the empirics of IIT.

This study attempts to introduce a Cournot–Ricardian perspective in our understanding of IIT. In a partial equilibrium framework, we have a well-developed body of research taking the Cournotian approach. Brander (1981) and Brander and Krugman (1983) showed that international Cournot competition in segmented markets generates IIT. Bernhofen (1998) found a good fit between the Cournotian model and the pattern of IIT observed in petrochemical industries. This study extends this approach to a general equilibrium framework. We merge Brander (1981) with the Ricardian model of Dornbusch et al. (1977). From this Cournot–Ricardo model, we derive a testable implication that the share of IIT in bilateral trade should be inversely related to the difference in

This study is an extension of our earlier work, Song and Sohn (2003). Authors would like to thank two anonymous referees for their invaluable comments.
the industry distribution of labour productivity. We test this hypothesis and find
good empirical support.

This study interprets this result from a larger theoretical framework. Song
(2011) derived a general relationship that the share of IIT is decreasing in a
specialisation index and is increasing in bilateral trade volume relative to the
product of partner incomes. We show that this specialisation index turns out to
be equal to the difference between trading partners in the industry distribution
of labour productivity in our Cournot–Ricardo model, while it is given by the
difference in capital-labour ratio in the well-known monopolistic competition
model.

We let the two determinants of specialisation compete in explaining bilateral
IIT. Using production and trade data compiled by Nicita and Olarreaga (2006),
we construct panel data on bilateral IIT and the specialisation measures. In
pooled ordinary least squares (OLS) estimations, we find that both determinants
of specialisation have strong negative effects on IIT. In fixed-effects models,
the difference in the industry distribution of labour productivity remains signifi-
cant, but the difference in capital-labour ratio loses significance. Subdividing
the sample, we find that the difference in the industry distribution of productiv-
ity is significant in explaining North–North trade, while the difference in factor
endowments is significant in explaining North–South trade.

This study is organised as follows: Section 2 constructs the Cournot–Ricardo
model. Section 3 makes some theoretical observations on the relationship
between IIT and specialisation. Section 4 conducts empirical investigations.
Section 5 concludes the paper.

2. A COURNOT–RICARDO MODEL

The specifications for technologies and preferences are the same as in the
Ricardian model of trade with a continuum of goods by Dornbusch et al.
(1977: henceforth, the DFS model). Two countries, Home and Foreign, produce
a continuum of goods on the interval $[0, 1]$ using labour. Unit labour require-
ments for good $z$ in Home and Foreign are given by $a(z)$ and $a^*(z)$. We index
goods such that Home’s comparative advantage diminishes as $z$ increases.
Defining relative unit labour requirements as

$$A(z) \equiv \frac{a^*(z)}{a(z)},$$

$A(z)$ is decreasing in $z$. Labour is perfectly mobile between industries. We
use $w$ and $w^*$ to denote the competitive wages in Home and Foreign. We use
$\omega$ to denote Home’s relative wage, $w/w^*$. 

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The two countries are populated by consumers with identical Cobb–Douglas tastes. Denoting the expenditure share of good \( z \) by \( b(z) \), the demand for good \( z \) in each country is determined by the following equations.

\[
q(z) = \frac{b(z)Y}{p(z)},
\]

\[
q^*(z) = \frac{b(z)Y^*}{p^*(z)},
\]

with \( \int_0^1 b(z)dz = 1 \). \( p(z) \) and \( p^*(z) \) are the prices of good \( z \) in Home and Foreign. \( Y \) and \( Y^* \) are the income levels of two countries.

The DFS model assumes that each industry is perfectly competitive. Each good is supplied solely by the country with a lower unit cost and thus no IIT occurs. We introduce a twist by assuming that each industry is governed by a Cournot duopoly composed of one Home firm and one Foreign firm. As in Brander (1981), we assume that Home and Foreign markets are segmented, and each firm makes distinct quantity decisions for each market. Given the unit-elastic demand curves in (2) and (3), it is easy to show that the following conditions hold in equilibrium.

\[
p(z) = p^*(z) = w a(z) + w^* a^*(z),
\]

\[
s(z) = \frac{A(z)}{A(z) + \omega}.
\]

The price of good \( z \) is identical in two countries and is determined by the sum of the duopolists’ unit costs. The Home market share is given by \( s(z) \), which is increasing in Home’s comparative advantage \( A(z) \) and is decreasing in its relative wage \( \omega \). By (2) and (3), the world supply of good \( z \) by Home is given by

\[
s(z)(q(z) + q^*(z)) = s(z) \frac{b(z)(Y + Y^*)}{p(z)}.
\]

Likewise, the world supply of good \( z \) by Foreign is given by

\[
(1 - s(z))(q(z) + q^*(z)) = (1 - s(z)) \frac{b(z)(Y + Y^*)}{p(z)}.
\]
Let us define $E[s]$ as the mean of $s(z)$ over goods, where the density is given by the expenditure share of a good, $b(z)$.

$$E(s) \equiv \int_0^1 s(z)b(z)dz. \quad (8)$$

In equilibrium, $L$ must be equal to the sum of Home firms’ labour demand across industries.

$$L = \int_0^1 a(z)s(z)(q(z) + q^*(z))dz$$

$$= \int_0^1 s(z)(1 - s(z))b(z)dz \frac{Y + Y^*}{w}. \quad (9)$$

Similarly, the Foreign labour market clears when

$$L^* = \int_0^1 a^*(z)(1 - s(z))(q(z) + q^*(z))dz$$

$$= \int_0^1 s(z)(1 - s(z))b(z)dz \frac{Y + Y^*}{w^*}. \quad (10)$$

Dividing (10) by (9),

$$\omega = \frac{L^*}{L}. \quad (11)$$

The relative wage is determined by the ratio of labour endowments. Then using (5), we can express Home’s market share in each industry as a function of two parameters: comparative advantage and relative labour endowment.

$$s(z) = \frac{A(z)}{A(z) + L^*/L} = \frac{L/a(z)}{L/a(z) + L^*/a^*(z)}. \quad (12)$$

Home’s income is given by

$$Y = \int_0^1 s(z)b(z)(Y + Y^*)dz = E[s](Y + Y^*). \quad (13)$$
Thus, the mean market share $E[s]$ also determines Home’s share in world GDP.

By construction, we have IIT in every industry. Each country supplies a fraction of each other’s market and cross-hauling occurs in every industry. Because the size of the Foreign market is equal to $b(z)Y^*$ and the Home firm supplies a fraction $s(z)$, Home’s exports of good $z$ are given by

$$x(z) = s(z)b(z)Y^* = s(z)b(z)(1 - E[s])(Y + Y^*). \tag{14}$$

Home’s imports of good $z$ are given by

$$m(z) = (1 - s(z))b(z)Y = (1 - s(z))b(z)E[s](Y + Y^*). \tag{15}$$

Then, Home’s net exports of good $z$ are equal to

$$x(z) - m(z) = (s(z) - E[s])b(z)(Y + Y^*). \tag{16}$$

Thus in an industry where Home is more competitive than in the average market, it becomes a net exporter. Recall that $s(z)$ is increasing in $A(z)$. Thus, the ratio of net exports to the market size increases as Home’s comparative advantage increases. Net exports are determined by the Ricardian force.

Using (14), (15) and (16), we can calculate the Grubel–Lloyd index of IIT as

$$GL = 1 - \frac{\int_0^1 |x(z) - m(z)|dz}{\int_0^1 (x(z) + m(z))dz} = 1 - \frac{E||s(z) - E(s)||}{2E[s](1 - E[s])}. \tag{17}$$

Note that $E|s(z) - E[s]|$ is the mean absolute deviation of market shares from the national mean. The intensity of IIT between two countries decreases as the dispersion of market shares across industries increases. To link the dispersion index to the parameters of the model, let us denote Home’s labour productivity in industry $z$ by $\alpha(z)$ ($=1/a(z)$) and Foreign’s by $\alpha^*(z)$ ($=1/a^*(z)$). We first linearise $s(z)$ in equation (12) in terms of $\alpha(z)$ and $\alpha^*(z)$ around their respective means $E[\alpha]$ and $E[\alpha^*]$. Then, we substitute the linearised function $s(z)$ into equation (17) and obtain the following equation.

$$GL \approx 1 - \frac{1}{2} E\left[ \frac{\alpha(z)}{E[\alpha]} - \frac{\alpha^*(z)}{E[\alpha^*]} \right]. \tag{18}$$

The proof is in the Appendix A. Equation (18) is the key result of this study. The intensity of IIT increases as the distribution of $\alpha(z)/E[\alpha]$ across industries matches more closely with that of $\alpha^*(z)/E[\alpha^*]$. In other words, IIT will be intense between countries with similar industry distributions of labour productivity (relative to the national mean).
It is of no doubt that the simplicity of the formula hinges on the assumption that each industry is governed by Cournot duopoly. However, we believe that its basic message is robust. Note that the overall trade is assumed to be balanced and inter-industry trade is generated by sectoral trade imbalances. Then, something similar to equation (18) would emerge in a model that satisfies two properties: trade imbalance in each sector increases as the relative competitiveness of a country in that sector deviates more from the economy-wide average; and the relative competitiveness is systematically linked to the relative labour productivity. These two properties might be met in a Heckscher–Ohlin model. In this model, IIT can occur when sector classification is not fine enough such that each sector contains both capital-intensive and labour-intensive products. In this situation, we can expect that the trade surplus of a capital-abundant country will be higher in a sector that contains a larger percentage of capital-intensive products. The properties might also be met in a monopolistic competition model where heterogeneity among firms determines the direction of trade and a sector in trade surplus is the one that contains a large number of domestic firms with superior productivity.

3. SOME GENERAL OBSERVATIONS

The main purpose of this study is to test equation (18). Before we do that, we make some general observations to understand our result from a larger perspective.

Let us use the following notations. $X_{ij}^k$ is the value of good $k$ shipped from country $i$ to country $j$. $X_{ij}$ is the value of all goods shipped from country $i$ to country $j$. $Y_i^k$ is the value of good $k$ produced in country $i$, and $Y_i$ is the value of all goods produced in country $i$. We use $Y_W$ to denote the world production, $\sum_i Y_i$. Using these notations, we present the following propositions. Song (2011) has shown that the following relationship holds.

**Proposition 1:** The world is composed of two countries $i$ and $j$. They trade with each other with zero costs and trade is balanced. Consumers have identical homothetic preferences.

Then

$$IIT = \frac{GRAV}{SPEC},$$

where

$$IIT = \frac{1}{1 - GL} \quad \text{and} \quad GL = 1 - \frac{\sum_k |X_{ij}^k - X_{ji}^k|}{X_{ij} + X_{ji}},$$

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\[ GRAV = \frac{X_{ij}}{Y_i Y_j Y_w}, \]

\[ SPEC = \frac{1}{2} \sum_k \left| \beta^k_i - \beta^k_j \right| \quad \text{with} \quad \beta^k_i = \frac{Y^k_i}{Y_i}. \]

The proof can be found in the Appendix A. \( GL \) is the Grubel–Lloyd index of IIT. \( IIT \) stands for intra-industry trade. It increases from 1 to infinity as \( GL \) goes from 0 to 1. \( GRAV \), which stands for gravity, is the ratio of bilateral trade to the product of partner incomes (scaled by world income). Let us call this ratio the gravity coefficient. It is well known that the gravity coefficient is equal to unity in a world where the simple or ‘frictionless’ gravity equation holds. With trade frictions, the coefficient can fall below one. \( SPEC \) is an index of specialisation between trading partners. This index takes the minimum value of zero when two countries have an identical industry structure, and the maximum value of one when there is complete specialisation. It is increasingly used as an index of specialisation between two regions (Krugman, 1991; Clark and van Wincoop, 2001; Imbs, 2004).

Proposition 1 states that given the volume of trade (relative to the product of partner incomes), the share of IIT in bilateral trade is decreasing in the degree of specialisation between trading partners. It is important to understand that this relationship holds as an accounting identity under the hypothesis of Proposition 1. No economic theory has been used to derive the equation. However, specific theories impose restrictions on these variables. For example, the following proposition can be derived from the Heckscher–Ohlin model.

**Proposition 2:** The world is composed of two countries \( i \) and \( j \) that produce two goods using capital \( K \) and labour \( L \). Two countries have identical technologies and trade is costless. Under free trade with factor price equalisation,

\[ SPEC = c \frac{k_i - k_j}{y_i y_j}, \quad (20) \]

where \( k_i = K_i/L_i \), \( y_i = Y_i/L_i \) and \( c \) is a constant that depends on the prices of two goods. \( K_i \) and \( L_i \) are capital and labour endowments of country \( i \). The proof is in the Appendix A. Proposition 2 is interesting as it reveals the influential theory of IIT by Helpman and Krugman (1985) and Helpman (1987) as a special case of Proposition 1. From the monopolistic competition model, they derive the prediction that the share of IIT in bilateral trade volume increases as countries get more similar in their capital-labour ratios. To see the link with
Proposition 1, suppose that two goods produced in Proposition 2 are product differentiated and subject to economies of scale as in the monopolistic competition model. Then, we can easily show that the simple gravity condition holds and $GRAV$ is equal to one. By Proposition 1,

$$IIT = \frac{1}{c} \frac{y_i y_j}{k_i - k_j}.$$  (21)

As trading partners become more similar in capital-labour ratio, $IIT$ increases. Thus, the inverse relationship between IIT and the difference in capital-labour ratio under monopolistic competition is a special case of Proposition 1. Here, we go a little further than the previous studies. We provide the exact functional form for the inverse relationship as expressed in equation (21). Furthermore, Proposition 2 suggests an important control variable for this relationship: the product of per capita incomes. Researchers on IIT repeatedly observed that the average development level of trading partners positively influences IIT. The product of per capita incomes can be thought as a variable representing the level of development.

Now we reinterpret our result in section II as a special case of Proposition 1.

**Proposition 3:** In the Cournot–Ricardo model of Section 2,

$$SPEC \approx \frac{1}{2} E \left[ \frac{\alpha(z)}{E(z)} - \frac{\alpha^*(z)}{E(z^*)} \right],$$  (22)

$$GRAV = 1.$$  (23)

The proof is simple. The value of good $z$ produced in Home is equal to $p(z)s(z)(q(z) + q^*(z)) = s(z)b(z)(Y + Y^*)$. Home’s GDP is equal to $E(s) (Y + Y^*)$. Thus the share of good $z$ in Home GDP is given by $s(z)b(z)/E(z)$. Similarly, the share of good $z$ in Foreign GDP is equal by $(1-s(z))b(z)/(1-E(z))$. The absolute value of the difference integrated over all goods and divided by 2 results to our specialisation index $SPEC$. It is easy to show that this is equal to $E[s(z) - E(s)]/2E[s(1 - E[s])].$ Using the linear approximation that we used to derive equation (18), equation (22) immediately follows. To obtain Home’s total exports, we integrate $x(z)$ in equation (14) over $z$:

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1 Proposition 2 holds in a standard Heckscher–Ohlin model as well as in a monopolistic competition model where two monopolistically competitive industries differ in their factor intensity, and all firms in each industry are identical and make zero profit.

2 See for example Greenaway and Milner (1986).
\[ X = \int_{0}^{1} s(z)b(z)Y^* dz = E(s)Y^* = \frac{YY^*}{Y + Y^*}. \] (24)

Thus \( GRAV \) is equal to 1.\(^3\)

With Proposition 3, we can see that equation (18) is a special case of proposition 1. With the gravity coefficient equal to one, the Grubel–Lloyd index must be equal to one minus the specialisation index, which in the Cournot–Ricardo model is determined by the difference in the industry distribution of labour productivity.

4. EMPIRICAL RESULTS

In this section, we put our propositions to a test. We construct two regression equations. The first one is based on Proposition 1. Taking the natural logarithm of equation (19) and adding country and time subscripts and an error term, we obtain the following regression equation.

\[ \ln IIT_{ijt} = \beta_0 + \beta_1 \ln SPEC_{ijt} + \beta_2 \ln GRAV_{ijt} + \varepsilon_{ijt}. \] (25)

If all the conditions of Proposition 1 are satisfied, equation (25) with \( \beta_1 = -1 \) and \( \beta_2 = 1 \) will have a perfect fit. The error term arises because these conditions are violated in actual data. The most important violation is that we are living in a multi-country world and trade barriers exist among these countries. Further, preferences are neither identical nor homothetic, and there are heavy measurement errors in all these variables. What we would like to check is if Proposition 1 still explains a significant part of the world despite all these violations.

Our second regression equation comes from Propositions 2 and 3. In the Cournot–Ricardo model, the degree of specialisation is given by the difference in the industry distribution of labour productivity. To match with data, we use the following discrete version of the index.

\[ PRODIF \equiv \frac{1}{2} E \left[ \frac{\alpha_k}{E(\alpha)} - \frac{\alpha_k^*}{E(\alpha^*)} \right], \] (26)

where \( \alpha_k \) denotes labour productivity in industry \( k \). In the monopolistic competition model, the degree of specialisation is determined by the difference in capital-labour ratio scaled by the product of \textit{per capita} incomes.

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\(^3\) This demonstrates that, contrary to the popular belief, specialisation is not necessary for the gravity equation to hold. Song (2011) extends this observation and derives the general condition for the gravity equation.
We do not view the two theories as mutually exclusive. Both the industry distribution of technology and relative factor endowments would influence the formation of specialisation among countries. So we let them compete in the following regression equation.

$$\ln \text{IIT}_{ijt} = \beta_0 + \beta_1 \ln \text{PRODIF}_{ijt} + \beta_2 \ln \text{KDIF}_{ijt} + \beta_3 \ln \text{GRAV}_{ijt} + \epsilon_{ijt}. \tag{28}$$

We do not force GRAV to take the value of unity as dictated by the theory, because in the real world, trade barriers would be sure to reduce gravity.

We have to address several econometric issues. One is endogeneity bias. All variables in regression equations are endogenous in a strict sense, but variables like SPEC, PRODIF and KDIF might be thought as more of exogenous character. Particularly worrying is the presence of GRAV on the right-hand side of equations. Trade volume appears both in the denominator of IIT and the numerator of GRAV. Fluctuations of trade volume, for example, caused by exchange rate variations, would introduce spurious negative correlation between the two variables. Thus, whenever applicable, we prefer to use instrument variables for GRAV, such as distance between trading partners or an FTA dummy. Another issue is omitted variable bias. To address this bias, we consider the following error structure in our regressions.

$$\epsilon_{ijt} = \mu_t + u_{ij} + v_{it} + v_{jt} + \eta_{ijt}. \tag{29}$$

$\mu_t$ is a year effect that is common to all country pairs. We will use year dummies in all of our regressions, including pooled OLS estimations. In fixed-effects panel estimations, we include $u_{ij}$ to capture a time-invariant fixed effect for country pair $i$ and $j$. In some fixed-effects regressions, we also include $v_{it}$ and $v_{jt}$, which are a fixed effect for country $i$ and for country $j$, respectively. The country fixed effects are increasingly included in gravity equations after Anderson and Van Wincoop (2003) who argued that ‘multilateral resistance’ variables should be included in gravity equations to have unbiased estimates. The multilateral resistance can vary over time as trade costs do. Thus, we allow country effects to vary over years. $\eta_{ijt}$ is a white noise.

The data that we use come from Nicita and Olarreaga (2006). They provide data on outputs and the number of employees in 28 manufacturing industries (ISIC 3 digit level) for 100 countries. From the data, we can calculate output share and labour productivity by industry for each country, and hence SPEC and PRODIF for each country pair. They also report bilateral trade flows at ISIC 3 digit level. The data well suit our purpose as they follow the same
industry classification as productivity data. From these, we calculate the gravity and Grubel–Lloyd index for each country pair. Data on capital stock and GDP per worker are obtained from the Penn World Table version 6.2 by Heston et al. (2006). We use the perpetual inventory method to create data on capital stock from investment flows. From this data set, we construct KΔf for each country pair. We also use variables that are frequently used in the estimation of gravity equations: distance and dummies for common language, common border, island, landlockedness, colony and regional trade agreement. These variables come from Rose (2004).

To construct SPEC and PRODIF, we should observe output shares and labour productivities in all industries of trading partners. A large number of missing values in output data severely restrict the size of our panel. To lessen this restriction, we drop four industries that seem to generate too many missing values. The availability of data on capital stock puts a further restriction on the size of the panel. Because of these problems, almost all low-income countries drop out of the sample. We use annual data. The data span 26 years from 1976 through 2001, though observations are very thin at the front and rear end. The panel is unbalanced. The total number of observations is 7,109. The number of country pairs included in the data set is 697, and the average number of observations per country pair is 10.2.

Table 1 reports summary statistics for major variables. The table also divides observations into three income groups. Using the World Bank’s classification, we define a high or upper middle income country as a North country and a lower middle and low-income country as a South country. 4,425 observations (62 per cent) are from North–North trade, and 2,514 (36 per cent) from North–South trade. For the reasons mentioned above, South–South trade is very weakly represented.

The means of major variables are reported in Table 1. As expected, the Grubel–Lloyd index is higher in North–North trade than in North–South trade. The measures of specialisation, SPEC, PRODIF and KΔf, are higher in North–South trade than in North–North trade. The gravity coefficient is higher in North–South trade than in North–North trade. The numbers in the parentheses report standard deviations. We see a significant amount of variations in variables. However, most of them come from variations between trading partners and time-series variations within trading partners are very limited. Using separate regressions (not reported), we can check that more than 80 per cent of total variations come from variations between trading partners for every variable in the table. This feature of data makes fixed-effects estimation challenging.

4 These industries are tobacco (314), other petro and coal products (354), petro refineries (353), pottery and chinaware (361).
Table 2 reports correlations among major variables. All variables now are in natural logarithm. In the first column, we can see that the correlation between IIT and SPEC is negative, and that between IIT and GRAV is positive, supporting proposition 1. In the second column, we observe that SPEC is positively correlated both with PRODIF and with KDIF, as implied by Propositions 2 and 3. In the third and fourth column, we see that GRAV is not strongly correlated with PRODIF or KDIF, but PRODIF and KDIF are positively correlated with each other.

Table 3 reports the results of estimating equation (25). We include year dummies in all regressions. In regression (1), we use OLS estimation. The estimated coefficient on SPEC is $-0.4$, which is greater than the theoretical value of $-1$, but is significant at 1 per cent. The coefficient on GRAV is positive, but far smaller than unity implied by Proposition 1. However, it still is significant at 1 per cent. In regression (2), we replace GRAV with variables frequently used in estimating gravity equations to address endogeneity bias. It is well
known that these gravity variables are highly significant in explaining variations of $GRAV$ across trading partners. For example, in a typical analysis, $GRAV$ decreases as distance between trading partners increases, and increases when trading partners share a common language or a common border. It has also been noted by many researchers that one of these variables, distance between trading partners, has a significant negative effect on $IIT$. This observation is particularly important to us because the negative correlation between $IIT$ and $SPEC$ might have been driven by the common factor of distance, or some other variables. A shorter distance between trading partners may increase $IIT$

\[ \begin{array}{|c|c|c|c|c|} \hline \text{ln IIT} & \text{(1) OLS} & \text{(2) OLS} & \text{(3) Fixed Effects} & \text{(4) Fixed Effects} \\ \hline \text{ln SPEC} & -0.41^{**} & -0.30^{**} & -0.13^{**} & -0.10^{**} \\ & (-50.24) & (-37.65) & (-8.53) & (-4.81) \\ \text{ln GRAV} & 0.07^{**} & -0.01^{*} & (28.23) & (-2.40) \\ & & & & \\ \text{ln Distance} & -0.10^{**} & (-23.28) \\ & & & & \\ \text{Language} & 0.06^{**} & (7.92) \\ & & & & \\ \text{Border} & 0.10^{**} & (6.82) \\ & & & & \\ \text{Island} & 1 & -0.20^{**} & (-2.70) \\ & & & & \\ & 2 & -0.05^{*} & (-2.32) \\ & & & & \\ \text{Landlock} & -0.00 & (-0.29) \\ & & & & \\ \text{Colony} & -0.03^{*} & (-2.15) \\ & & & & \\ \text{FTA} & 0.18^{**} & 0.18^{**} & 0.01 \\ & (15.56) & (15.56) & (0.96) \\ \hline \end{array} \]

Notes:
(i) $\text{Language (0, 1), Border (0, 1), Island (0, 1, 2), Landlock (0, 1, 2), Colony (0, 1) and FTA (0, 1)}$ are dummy variables.
(ii) The numbers in the parentheses are $t$-ratios.
(iii) The $R^2$ of fixed-effects regressions are from within regressions.
(iv) $T$ denotes the average number of observations per country pair.
(v) **Significant at 1 per cent; *significant at 5 per cent.

\[ \begin{array}{|c|c|c|c|} \hline \text{Fixed Effects} & \text{Year} & \text{Year Country Pair} & \text{Year Country Pair} \\ \hline \text{Country year} & \text{Country year} \\ \hline \text{$R^2$} & 0.30 & 0.41 & 0.21 & 0.45 \\ \text{Obs.} & 7,109 & 7,109 & 7,109 & 7,109 \\ & \text{T = 10.2} & \text{T = 10.2} \\ \hline \end{array} \]
and decrease specialisation at the same time, because of more similar climate conditions or consumer tastes. So we control for these effects by adding gravity variables in the regression equation. Regression (2) reports the results. *Language* and *Border* are dummy variables that take the value of 1 when trading partners share a language or a border. *Island* takes the value of 0, 1 and 2, depending on the number of island countries in a country pair. *Landlock* counts the number of landlocked countries in a country pair, but no country pair takes the value of 2 in our sample. *Colony* takes the value of 1 when one country was the colony of the other. *FTA* is a dummy that takes the value of 1 when trading partners are in a preferential trade agreement. As expected, IIT decreases with distance and increases with a common language and a common border. We also find that *FTA* is highly significant in explaining IIT. After controlling for all these gravity variables, we still find that *SPEC* is significantly negative, though its influence has been reduced a little.

There may be omitted variables other than the gravity variables. To eliminate their influence and extract a time-series relationship between IIT and SPEC, we estimate a fixed-effects model in regression (3). Regression (3) controls for unobservable time-invariant country-pair effects. As we can see, *SPEC* still has a significant negative effect on IIT. However, the coefficient on *GRAV* has a wrong sign and is significant at 5 per cent. A potential problem in using *GRAV* as an explanatory variable has been mentioned above. In regression (4), we drop this variable and include country-year fixed effects and a FTA dummy. We still find that *SPEC* has a significant negative effect on IIT.

Having confirmed the predictions of Proposition 1, especially the negative correlation between IIT and specialisation, we now turn to our main interests: Propositions 2 and 3. In Table 4, we put *PRODIF* and *KDIF* instead of *SPEC* and let them compete. Regression (5) reports pooled OLS estimation results. The estimation confirms both Propositions 2 and 3. The estimation coefficient on *PRODIF* is negative and significant at 1 per cent, as that on *KDIF* is. In regression (6), as in regression (2), we replace *GRAV* with gravity variables. The coefficients on *PRODIF* and *KDIF* still are negative and significant at 1 per cent. In regression (7), we estimate a model controlling for country-pair fixed effects. *GRAV* has been dropped for the reason mentioned above, but its inclusion does not affect our results. We still find that the coefficient on *PRODIF* is significant at 1 per cent. However, the coefficient on *KDIF* becomes zero and loses significance. Measurement errors in calculating productivity and capital per worker might be a source of weak correlations. The lack of within variations combined with a small number of observations might be another. However, a more significant reason might be that variable *KDIF* has been derived from a two sector framework, and it is simply too crude to explain time-series variations of 24 sector economies. Finally, regression (8) reports results with both country-pair fixed effects and country-year fixed...
effects. This is a very stringent test. What is left in data are time-varying coun-
try-pair effects that are not explained by country-year effects and FTA. We are
testing whether PRODIF and KDIF have any explanatory power over these
residuals. We find that PRODIF still is significant at 1 per cent. KDIF is signif-
icant at 1 per cent, but has a wrong sign. We find it puzzling, but it has shown
up in other studies, too.

To probe the matter further, in Table 5, we run fixed-effects regressions in
two subsamples: North–North trade and North–South trade. In regression (9),

<table>
<thead>
<tr>
<th>TABLE 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determinants of Intra-industry Trade: Productivity vs. Factor Proportion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ln IIT</th>
<th>(5) OLS</th>
<th>(6) OLS</th>
<th>(7) Fixed Effects</th>
<th>(8) Fixed Effects</th>
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<tr>
<td>ln PRODIF</td>
<td>−0.23**</td>
<td>−0.16**</td>
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<td>−0.04**</td>
</tr>
<tr>
<td>(−25.89)</td>
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<td>(−2.98)</td>
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<tr>
<td>ln KDIF</td>
<td>−0.06**</td>
<td>−0.05**</td>
<td>−0.00</td>
<td>0.01**</td>
</tr>
<tr>
<td>(−30.17)</td>
<td>(−27.29)</td>
<td>(−1.06)</td>
<td>(3.02)</td>
<td></td>
</tr>
<tr>
<td>ln GRAV</td>
<td>0.06**</td>
<td>0.06**</td>
<td>0.00</td>
<td>0.01**</td>
</tr>
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<td>(24.48)</td>
<td>(24.48)</td>
<td>(3.02)</td>
<td>(1.12)</td>
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<tr>
<td>ln Distance</td>
<td>−0.10**</td>
<td>−0.04*</td>
<td>0.01</td>
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<td>(−23.70)</td>
<td>(−2.01)</td>
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<td>0.07**</td>
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<td>(9.96)</td>
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<td>0.15**</td>
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<tr>
<td>(9.96)</td>
<td>(9.96)</td>
<td>(1.47)</td>
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</tr>
<tr>
<td>Island</td>
<td>1</td>
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<td>0.00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>−0.04*</td>
<td>−0.04*</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Landlock</td>
<td>−0.01</td>
<td>−0.01</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Colony</td>
<td>−0.00</td>
<td>−0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>FTA</td>
<td>0.15**</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>(13.01)</td>
<td>(1.56)</td>
<td>(1.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Effects</td>
<td>Year</td>
<td>Year</td>
<td>Year Country Pair</td>
<td>Year Country Pair</td>
</tr>
<tr>
<td>R²</td>
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<td>0.43</td>
<td>0.20</td>
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<td>7,109</td>
<td>7,109</td>
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</tr>
<tr>
<td>T = 10.2</td>
<td>T = 10.2</td>
<td>T = 10.2</td>
<td>T = 10.2</td>
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</tr>
</tbody>
</table>

Notes:
(i) Language (0, 1), Border (0, 1), Island (0, 1, 2), Landlock (0, 1, 2), Colony (0, 1) and FTA (0, 1) are
dummy variables.
(ii) The numbers in the parentheses are t-ratios.
(iii) The R² of fixed-effects regressions are from within regressions.
(iv) T denotes the average number of observations per country pair.
(v) **Significant at 1 per cent; *significant at 5 per cent.
we report estimation results for North–North trade. We turn to North–South trade in regression (10).

It is interesting to find that PRODIF is highly significant in North–North trade, but it becomes insignificant in North–South trade. Thus, the good performance of PRODIF in the entire sample stems from its ability to explain North–North IIT. In contrast, KDIF has no explanatory power over North–North IIT, while it has a significant negative effect on North–South IIT. Because of the smaller sample size, its significance in the North–South subsample does not show up in the entire sample. In regressions (11) and (12), we add country-year fixed effects. The estimation results for North–North trade are similar to those for the entire sample: PRODIF is highly significant, but KDIF is significant with a wrong sign. In North–South trade, both measures of specialisation lose significance.

Finally, we discuss some aspects of East Asian integration to which our analysis might add some insights. Two major tools for economic integration are regional trade agreement and currency union. A lingering question is whether East Asia is an ideal area for regional trade agreement or currency union. While there is no consensus on how to answer this question, a popular approach is to investigate whether there is intra-regional bias in trade among member countries. The idea behind this criterion, which has been popularised by Frankel (1997), is that if member countries tend to trade more with each other than with non-members, regional trade agreement or currency union will create trade with less risk of trade diversion.
We run regression (13) to find out where there is intra-regional bias in trade among East Asian countries. East Asian countries are not well represented in our sample, and only nine economies are included because of the data problem: Korea, Japan, Hong Kong, Indonesia, Malaysia, Thailand, the Philippines, Australia and New Zealand. East Asia is a dummy variable that takes the value of 1 when trade occurs between these East Asian countries. We control for the effects of existing regional trade agreements by adding a FTA dummy. We find in Table 6 that the East Asian effect is highly significant and positive. This result is in line with other studies such as Lee and Park (2005). A difference from them is that we control for new variables that can systematically affect trade volume: PRODIF and KDIF. We saw in the previous section that PRODIF and KDIF exercise positive influence on trade volume through their effect on specialisation, but they have negative influence on trade volume as they reduce IIT. Regression (13) shows that in the case of PRODIF, the former effect dominates the latter: PRODIF is significantly positive. However, KDIF is insignificant, suggesting that two effects cancel each other out.

A few studies find that increased trade does not necessarily lead to a higher degree of business cycle synchronisation among member countries. They find that IIT is the main channel through which the outputs of trading partners are synchronised (Fidrmuc, 2001; Shin and Wang, 2004; 2005). Because the cost of currency union decreases with synchronised output movements of member countries, these studies suggest that we should look for intense IIT rather than large trade volume in search for an optimal currency area. Thus in regression (14), we check whether IIT is more intense among East Asian countries than among other traders. We find that the East Asian dummy has a significant positive effect on IIT, suggesting that East Asia may be a good candidate for a currency union.

5. CONCLUSION

This study finds a new variable that affects IIT: the difference in the industry distribution of productivity. IIT is inversely related to the degree of specialisation among trade partners. In many plausible models, both the difference in the industry distribution of productivity and the difference in capital-labour ratio would determine the degree of specialisation, and thus, both variables would negatively influence IIT.

5 Australia and New Zealand are included in our analysis of East Asia to incorporate current discussion of ‘ASEAN plus Six’ for an East Asian free trade agreement.
We largely confirm this conjecture in production and trade data. However, our new variable, the difference in the industry distribution of productivity, seems to perform better than the difference in factor endowments in explaining IIT. While the former is significant in both pooled OLS and fixed-effect estimation, the latter is significant only in pooled OLS estimation. In particular, the former seems better in explaining North–North IIT, but the latter seems superior in explaining North–South IIT.

We also apply our new finding to the question whether East Asia is an ideal region for free trade zone or currency union. We extend the previous results by incorporating our new variables and find that there is intra-regional bias both in overall trade and IIT among East Asian countries.

### TABLE 6
East Asian Dummy

<table>
<thead>
<tr>
<th></th>
<th>(13) $\ln GRAV$</th>
<th>(14) $\ln IIT$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln PRODIF$</td>
<td>0.72**</td>
<td>−0.17**</td>
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<tr>
<td></td>
<td>(24.94)</td>
<td>(−19.93)</td>
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<tr>
<td>$\ln KDIF$</td>
<td>−0.00</td>
<td>−0.05**</td>
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<tr>
<td></td>
<td>(−0.02)</td>
<td>(−27.80)</td>
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<td>East Asia</td>
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<td></td>
<td>(19.98)</td>
<td>(7.22)</td>
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<td>$\ln Distance$</td>
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<td>−0.09**</td>
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<td></td>
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<td>0.16**</td>
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<td></td>
<td>(12.87)</td>
<td>(10.86)</td>
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<td>Island 1</td>
<td>0.06*</td>
<td>−0.03**</td>
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<tr>
<td></td>
<td>(2.06)</td>
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<tr>
<td>Island 2</td>
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<td>−0.11**</td>
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<tr>
<td></td>
<td>(5.94)</td>
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<td>Landlock</td>
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<tr>
<td></td>
<td>(−0.56)</td>
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<td>0.41**</td>
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<td>(0.03)</td>
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<td>Colony 2</td>
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<td>0.16**</td>
</tr>
<tr>
<td></td>
<td>(1.69)</td>
<td>(13.93)</td>
</tr>
<tr>
<td>FTA</td>
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</tr>
<tr>
<td></td>
<td>(0.56)</td>
<td>(0.43)</td>
</tr>
<tr>
<td>Fixed Effects</td>
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<tr>
<td>Year</td>
<td>0.56</td>
<td>0.43</td>
</tr>
<tr>
<td>Obs.</td>
<td>7,109</td>
<td>7,109</td>
</tr>
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</table>

Notes:
(i) East Asia (0, 1), Language (0, 1), Border (0, 1), Island (0, 1, 2), Landlock (0, 1, 2), Colony (0, 1) and FTA (0, 1) are dummy variables.
(ii) The numbers in the parentheses are t-ratios.
(iii) IIT, intra-industry trade.
(iv) **Significant at 1 per cent; *significant at 5 per cent.
Proof for Equation (18)

A first-order Taylor approximation of \( s(z) \) around \( E[x] \) and \( E[x^*] \) yields

\[
s[z] \approx \frac{E[x]L}{E[x]L + E[x^*]L^*} + \frac{E[x^*]LL^*}{(E[x]L + E[x^*]L^*)^2} (x - E[x]) - \frac{E[x]LL^*}{(E[x]L + E[x^*]L^*)^2} (x^* - E[x^*]) \quad (A1)
\]

Using (A1),

\[
E[s] \approx \frac{E[x]L}{E[x]L + E[x^*]L^*}. \quad (A2)
\]

Substituting (A1) and (A2) into (17), we obtain (18).

Proof for Proposition 1

By the definition of \( \beta_i^k \), the following equation holds.

\[
X_{ii}^k + X_{ij}^k = \beta_i^k Y_i. \quad (A3)
\]

Under the assumptions made, the price of each good is identical in two countries, and the expenditure share of good \( k \) is equal to \( x^k \) in both countries. Thus

\[
X_{ii}^k + X_{ji}^k = x^k Y_i. \quad (A4)
\]

From these two equations,

\[
X_{ij}^k - X_{ji}^k = (\beta_i^k - x^k) Y_i, \quad (A5)
\]

\[
\beta_i^k Y_i + \beta_j^k Y_j = x^k Y_W. \quad (A6)
\]

(A6) implies that

\[
\beta_i^k - x^k = (\beta_i^k - \beta_j^k) \frac{Y_j}{Y_W}. \quad (A7)
\]

Plugging (A7) into equation (A5),
\[ X_{ij}^k - X_{ji}^k = (\beta_i^k - \beta_j^k) \frac{Y_i Y_j}{Y_w}. \] (A8)

Thus

\[ \sum_k \left| X_{ij}^k - X_{ji}^k \right| = \sum_k \left| \beta_i^k - \beta_j^k \right| \frac{Y_i Y_j}{Y_w}, \]

or

\[ \frac{\sum_k \left| X_{ij}^k - X_{ji}^k \right|}{2X_{ij}} = \frac{1}{2} \sum_k \left| \beta_i^k - \beta_j^k \right| \frac{Y_i Y_j}{Y_w}. \]

The left-hand side of the equation is the share of inter-industry trade in total trade, \(1 - GL\). The right-hand side is equal to the ratio, \(SPEC/GRAV\). Thus

\[ \frac{1}{1 - GL} = \frac{GRAV}{SPEC}. \]

**Proof for Proposition 2**

Let \(P_X\) and \(P_Z\) be the prices of two goods \(X\) and \(Z\) in a trade equilibrium. Let \(W\) and \(R\) denote the wage and the rental rate of capital. Using \(X_i\) and \(Z_i\) to denote the production of \(X\) and \(Y\) in country \(i\), we can express the full employment condition as

\[ \begin{bmatrix} a_{XX} & a_{ZK} \\ a_{XL} & a_{ZL} \end{bmatrix} \begin{bmatrix} X_i \\ Z_i \end{bmatrix} = \begin{bmatrix} K_i \\ L_i \end{bmatrix}. \] (A9)

\(a_{kv}\) denotes the input of factor \(v\) used to produce one unit of good \(k\). With factor price equalisation, two countries have identical \(a_k\). Solving for the outputs of two good,

\[ X_i = \frac{1}{\Delta} (a_{ZL} K_i - a_{ZK} L_i), \] (A10)

where \(\Delta = a_{ZK} a_{ZL} - a_{XL} a_{ZK}\).

Using this equation,

\[ \beta_i^X = \frac{P_X X_i}{R K_i + W L_i} = \frac{P_X a_{ZL} k_i - a_{ZK}}{\Delta \cdot R k_i + W}. \] (A11)

In a similar way, we can calculate \(\beta_j^X\) and derive the following equation.
\[ \beta_i^X - \beta_j^X = \frac{P_X}{\Delta} \left( \frac{a_{ZL}k_i - a_{ZK}}{Rk_i + W} - \frac{a_{ZL}k_j - a_{ZK}}{Rk_j + W} \right). \]

\[ = \frac{P_X}{\Delta y_i y_j} \left[ (a_{ZL}k_i)(Rk_j + W) - (a_{ZL}k_j)(Rk_i + W) \right] \]

\[ = \frac{P_X}{\Delta y_i y_j} (k_i - k_j)(a_{ZK}R + a_{ZL}W) \]

\[ = \frac{P_XP_Z}{\Delta} \frac{k_i - k_j}{y_i y_j}. \]

The last equality used the zero profit condition that \( P_Z = a_{ZK}R + a_{ZL}W. \)

Finally, since \( \beta_i^Z = 1 - \beta_i^X, \)

\[ SPEC = \frac{1}{2} \sum_{k=X,Z} \left| \beta_i^k - \beta_j^k \right| = \left| \beta_i^X - \beta_j^X \right| = \frac{P_XP_Z}{\Delta} \frac{k_i - k_j}{y_i y_j} \] (A13)

REFERENCES


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