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The Role of Inter- and Intraindustry Trade in Technology Diffusion

Prepared by Dalia Hakura and Florence Jaumotte[1]

Authorized for distribution by Saleh Nsouli

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Abstract

Research shows that international trade is an important channel for the transfer of technology. Building on this evidence, this paper examines the effects of inter- and intraindustry trade on technology transfer. The paper develops and tests the hypothesis that intraindustry trade stimulates more technology transfer than interindustry trade because countries are likely to absorb foreign technologies more easily when their imports are from the same sectors as their production and export sectors. The results of empirical tests for 87 countries during 1970–93 support this hypothesis.

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Author's E-Mail Address: dhakura@imf.org

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[1]Dalia Hakura is an economist in the IMF Institute. Florence Jaumotte is a graduate student at Harvard University and a research fellow of the Belgian National Fund for Scientific Research (F.N.R.S.). This paper was written while Ms. Jaumotte was a summer intern at the IMF Institute. An earlier version of this paper was presented at the Conference on Policies for Competitiveness in Manufacturing in Sub-Saharan Africa held in Johannesburg, South Africa, November 6–7, 1998. The authors wish to thank Geert Almekinders, Robert Barro, Ehsan Choudhri, David Coe, Roland Daumont, Samir El-Khouri, Dominique Gross, Elhanan Helpman, Suheil Kawar, Mohsin Khan, Saleh Nsouli, Jean-Francois Ruhashyankiko, and Abdelhak Senhadji for helpful comments. The authors are grateful also to Barry Bosworth for providing the data on output, physical capital, labor, and education.

Contents

I. INTRODUCTION

This paper investigates the role of trade in transferring technology from industrial countries to developing countries. Trade is considered a major channel of technology transfer among countries. Defined broadly, technology covers production methods, product design, and organizational methods. According to Grossman and Helpman (1991) trade can foster technology transfers through two main avenues: production and information. Through trade with technological leaders developing countries can gain access to intermediate products and capital equipment of higher quality (vertical differentiation) and broader variety (horizontal differentiation). They can also gain access to more open channels of communication about production methods, product design, organizational methods and market conditions. Finally, they can adapt to their use the foreign technologies used in their imported products, often at less cost than innovation would require.

Recent research has empirically tested the role of trade in cross-country technology transfer. Coe, Helpman, and Hoffmaister (1997) and Jaumotte (1998), for example, show that trade plays a significant role in the transfer of technology across countries. Building on this evidence, this paper investigates which type of trade—intra- or interindustry—is more effective in transfer of technology among countries.

Intraindustry trade refers to two-way trade in a given sector, while interindustry trade refers to one-way trade in a sector. The paper tests the hypothesis that intraindustry trade is more effective for technology transfer because countries are more likely to absorb foreign technologies when their imports are from the same sectors as the products they produce and export. Indeed, the possibility of using foreign technology in domestic production is likely to be greater when the country is already a large producer of the same type of goods as it imports, particularly if it is to maintain its competitiveness on international markets.

The paper extends the theoretical framework used in Jaumotte (1998) where growth of total factor productivity (TFP),[2] as a proxy for absorption of technology, is specified as a function of the technological gap of the country weighted by the country's degree of exposure to foreign technologies. The degree of exposure to foreign technologies is captured by the ratio of imports to GDP. The Grubel-Lloyd intraindustry trade index (IIT) is calculated to determine each sector's involvement in intraindustry trade.

The paper estimates both linear and nonlinear regression specifications. In the linear regression, the ratios of imports to GDP are split into intra- and interindustry components on the basis of a specific cut-off for IIT. The import shares are then aggregated separately for the two components in order to estimate separately the effect of each sector's openness on growth of TFP. The robustness of the results is tested by excluding from interindustry trade sectors those that are net exporters. Indeed, net exporters could bias the results to show that

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[2] TFP is defined as the log of output minus the weighted logs of factor inputs, where the weights equal factor shares.

interindustry trade is less efficient in transferring technologies because net exporters are presumably technologically advanced and thus less likely to learn from the technologies inherent in their imports. Finally, a nonlinear specification is also estimated where each sector's imports are weighted by some function of the sector's IIT index.

The sample used in this paper covers intra- and interindustry trade in 87 countries over the period 1970–93. The tests yield three findings. First, they confirm that developing country trade with industrial countries enhances the technological development of developing countries. Second, in both the linear and nonlinear regression specifications, evidence showed that intraindustry trade had a stronger effect on TFP growth than did interindustry trade. Finally, evidence showed that certain country-specific factors could, if unchanged, keep developing countries from reaching the steady-state level of technology that OECD countries have reached. Evidence for Sub-Saharan Africa confirms this conclusion.

In the rest of the paper, Section II describes the methodology. Section III briefly describes the construction of the variables and of the broad trends in the data. Section IV reports and comments on the results of the estimations. The final section summarizes the findings and discusses some policy implications.

II. METHODOLOGY

This section presents the framework of analysis and then outlines the linear and nonlinear approaches to evaluating the respective roles of intra- and interindustry trade. Finally, it discusses the extension of the framework to several technological leaders.

2.1. Framework of analysis

Technology is measured by total factor productivity (TFP), defined as the residual part of output once the contributions of factor inputs have been accounted for. The relationship between the TFP growth of a country and its degree of openness to the technological leader is modeled as follows:

$$g_i = g_l + \mu * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i \qquad \textbf{(1)}$$

where

$$\mu = f(\frac{m_{il}}{y_i})$$

and where l denotes the technological leader, i the importing country, g the growth rate of TFP, m imports, and y output. The first part of the model, derived from Barro and Sala-i-Martin (1995), relates the deviation of the importing country's TFP growth from that of the leader, to the technological gap between the two countries. The specification embodies two important assumptions. First, it assumes that, all else being equal, the technologically backward countries tend to have a faster TFP growth than the leader. Indeed, $g_i > g_l$ if and only if $TFP_i < TFP_l$. This is because the cost of imitation is less than the cost of innovation. Second, the specification assumes that the discrepancy between the TFP growth of the backward country and that of the leader is increasing in the technological gap. This would be the case if, for example, the cost of imitation was decreasing in the gap. Intuitively, it makes sense that as the technological gap expands and the pool of innovations from which to imitate increases, the cost of imitation becomes smaller. Finally, the parameter μ denotes the speed of convergence of country i toward the leader.

In accordance with the theoretical literature that emphasizes trade as a major channel of technology transfer across countries, Jaumotte (1998) specifies the speed of convergence of a country, μ, as a function of the degree of its openness to trading with the leader. She finds empirical evidence that trade plays a significant role in the technological catch up of follower countries. This paper builds on this approach to investigate the relative importance of intra- and interindustry trade in technology transfers.

2.2. Linear regression specification

The distinction between intra- and interindustry trade is based on the Grubel-Lloyd intraindustry trade index defined as

$$IIT_s = \frac{(X_s+M_s) - |X_s-M_s|}{(X_s+M_s)}$$

where s denotes sector s, X denotes exports, and M denotes imports. The index measures the share of intraindustry trade in sector s. If there is no intraindustry trade in sector s — that is, if the country is exclusively importing or exclusively exporting — the IIT index is zero. Conversely, if all trade is intraindustry trade — that is if $X_s = M_s$ — the IIT index takes the value 1.

In the linear approach, the sectors of each country are classified as intra- or interindustry trade sectors depending on the value of their IIT index. Let b denote a cut-off, IR the set of interindustry trade sectors, and IA the set of intraindustry trade sectors.

$$s \in IR \text{ if } IIT_s \leq b$$

$$s \in IA \ if \ IIT_s > b$$

The import shares are then aggregated separately for each type of sectors and a different coefficient is estimated for each aggregate. Thus, the following specification is estimated:

$$g_i = c + \alpha * g_l + [\beta * \Sigma_{s \in IR} \frac{m_{ils}}{y_i} + \gamma * \Sigma_{s \in IA} \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i \qquad (2)$$

The paper explores IIT cut-offs ranging from 0.1 to 0.9, by increments of 0.1. If intra- and interindustry trade has the same effect on technology transfers, their coefficients should not be significantly different, irrespective of the cut-off. If instead, intraindustry trade has a significantly larger impact than interindustry trade, two results can be expected. First, the coefficient on intraindustry trade should be larger than the coefficient on interindustry trade, irrespective of the cut-off. Moreover, the difference between the two should become more significant as the chosen cut-off nears the "true" cut-off. Second, as the cut-off is raised, both the coefficients on intra- and interindustry trade should increase. The latter assertion can be seen in the following way. Figures 1–4 illustrate four different ways in which the technological benefits from importing in a given sector can relate to the degree of intraindustry trade of the sector. In accordance with our hypothesis, all four schemes show that the benefits from trade are increasing, though not necessarily strictly so, in the degree of intraindustry trade of the sector. It can easily be seen that in all schemes, the coefficients on inter- and intraindustry trade are increasing, at least over a range, in the cut-off for the IIT index.

Figure 1 shows that the benefits from intraindustry trade are continuously increasing. In this first scheme, both coefficients increase continuously as the cut-off is raised. In the second scheme (Figure 2), the benefits can only take two values, a constant low value for sectors with low degrees of intraindustry trade and a constant high value for sectors with high degrees of intraindustry trade. As the cut-off is raised, this scheme is characterized by two phases: one in which the coefficient on interindustry trade is constant, while the one on intraindustry trade increases, followed by a phase in which the coefficient on interindustry trade is increasing while the one on intraindustry trade is constant. The "true" cut-off C_m is at

Figure 1: Scheme 1

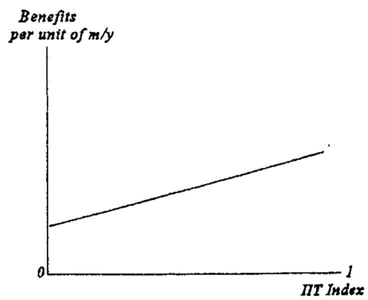


Figure 2: Scheme 2

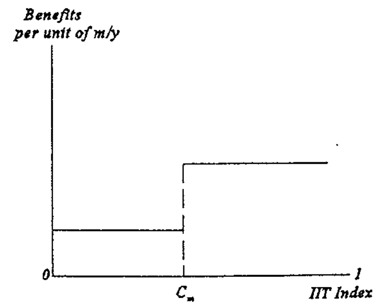


Figure 3: Scheme 3

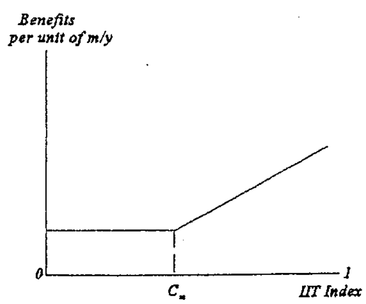
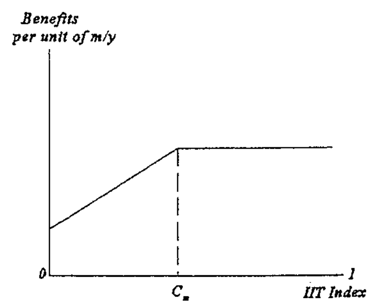


Figure 4: Scheme 4



the point where the coefficient on interindustry trade stops being constant and the on intraindustry trade starts being constant. In the third scheme (Figure 3), the coefficient on intraindustry trade increases continuously while the one on interindustry trade is at first constant and then increases. The point at which the coefficient on interindustry trade starts increasing identifies the true cut-off C_m. Finally, in the fourth scheme, the coefficient on interindustry trade increases continuously while the one on intraindustry trade at first increases and then is constant. In this case, the true cut-off is at the point where intraindustry trade starts being constant.

2.3. Testing for Robustness: excluding net exporters from the interindustry trade category

Interindustry trade includes two types of sectors: those that are net importers and those that are net exporters. Net exporters are presumably technologically advanced and thus less likely to adopt the technologies used in their imports. Including them with net importers would bias the results to show that interindustry trade is less efficient in transfer of technology. To test the robustness of the results, the sectors are classified into three groups, based on the value of their export to import ratio: no base sector (*NB*), base sector (*B*), and good sector (*G*). Let b_1 and b_2 denote two cut-offs.

$$s \in NB \ \text{if} \ \frac{X_s}{M_s} \leq b_1$$

$$s \in B \ \text{if} \ b_1 < \frac{X_s}{M_s} \leq b_2$$

$$s \in G \ \text{if} \ \frac{X_s}{M_s} > b_2$$

Note that there is a direct correspondence between the cut-off for the IIT index, *b*, and the two cut-offs for the ratio of exports to imports, b_1 and b_2, which can be expressed as:

$$b_1 = \frac{b}{2-b} = \frac{1}{b_2}$$

With the corresponding cut-offs for the export to import ratio, the robustness of the results obtained based on the distinction between inter- and intraindustry trade can be verified using the following specification:

$$g_i = c + \alpha * g_l + [\beta * \Sigma_{s \in NB} \frac{m_{ils}}{y_i} + \gamma * \Sigma_{s \in B} \frac{m_{ils}}{y_i} + \delta * \Sigma_{s \in G} \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i \quad (3)$$

2.4. Nonlinear regression specification

This is the continuous version of the cut-off based approach. Instead of splitting the sectors into two groups based on the value of their IIT index, the imports of each sector are weighted by a function of their IIT index.

$$g_i = c + \alpha * g_l + [\Sigma_s h(IIT_s) * \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i \tag{4}$$

The IIT index is entered in a flexible form, namely a quadratic, that will allow explicit testing of the role of the IIT index.

$$h(IIT_s) = \beta + \gamma * IIT_s + \delta * IIT_s^2$$

2.5. Extending the framework to several technological leaders

The model is specified with a unique technological leader. In practice, however, the technological leader is the group of OECD countries and the TFP growth of the importing country is assumed to depend on the sum of the technology transfers from each technological leader. Thus, for example, equation 1 becomes

$$g_i = \alpha * \Sigma_{j \in OECD}\, g_j + \beta * \Sigma_{j \in OECD} (\frac{m_{i,j}}{y_i} * \ln \frac{TFP_j}{TFP_i}) + \varepsilon_i$$

This aggregation procedure excludes the possibility of duplication or synergy amongst the technological transfers from different leaders. This is the assumption usually made in the literature. It was tested in Jaumotte (1998) and could not be rejected.

III. DATA

The sample contains 87 countries, of which 63 are developing countries and 24 are OECD countries. The developing countries are grouped into five regions: East Asia (8 countries), Latin America (22 countries), Middle East and North Africa (8 countries), South Asia (5 countries), and Sub-Saharan Africa (20 countries). See the appendix for a complete list of countries. The data cover the period 1970–93.

To measure TFP the paper uses the growth accounting approach, which imposes conventional values for factor shares. It then uses three alternative measures of TFP to test the robustness of the results to a particular specification of the aggregate production function. These are given by

$$TFP_1 = \frac{Y}{K^{\alpha} \, . \, L^{1-\alpha}}, \qquad \alpha = 0.4$$

$$TFP_2 = \frac{Y}{K^{\alpha} \, . \, H^{\beta} \, . \, L^{1-\alpha-\beta}}, \qquad \alpha = \beta = 1/3$$

$$TFP_3 = \frac{Y}{K^{\alpha} \, . \, (H \, . \, L)^{1-\alpha}}, \qquad \alpha = 0.4$$

where Y denotes GDP, K denotes the total stock of physical capital, L denotes the labor force, and H denotes the stock of human capital. Note that the last specification exhibits increasing returns to scale, while the other two specifications feature constant returns to scale. The data needed to measure TFP are from a revised version of the data set compiled by Bosworth, Collins, and Chen (1995). The definition and the original source of the data for each variable is given in the appendix. To make the TFP levels comparable across countries, the data on output and physical capital were converted into 1987 international prices, using the purchasing power parities for 1987, respectively for GDP and investment.[3]

The trade data for measuring the import to GDP ratios, IIT indexes, and export to import ratios are from Feenstra, Lipsey, and Bowen (1997). Feenstra and others (1997) report manufacturing trade flows disaggregated by trade partners and sectors in 34 industries classified according to the Bureau of Economic Analysis Manufacturing Industry Classification. The trade data are aggregated into 10 sectoral categories matching the International Standard of Industrial Classification system. The data for nominal GDP are from the World Economic Outlook. The import to GDP ratios are calculated using imports from OECD countries only, whereas the IIT indexes and export to import ratios are based on trade flows with the world.

Tables 1 and 2 summarize the TFP data for the sample of countries examined in the paper. Table 1 reports the average annual growth rate of TFP over the period 1970–93 by region. Table 2 reports the average TFP gap of each region with respect to OECD countries in 1970 and 1993 and the TFP growth rate during 1970–93. An increase in the gap indicates that the region has been diverging from the OECD countries, while a decrease reflects catch-up.

Table 1 shows that the TFP growth rates of OECD countries have been significantly positive over the entire period, though not surprisingly, the growth rate was larger in East Asia. TFP growth was also positive for the MENA and South Asia regions but less significantly so. Strikingly, Sub-Saharan Africa and Latin America have had significantly negative TFP growth rates over the same period. In accordance with Table 1, Table 2 shows

[3]These data are provided in the Penn World Tables compiled by Summers and Heston (1991).

that East Asia has been catching up with OECD, while Sub-Saharan Africa and Latin America have significantly diverged from OECD.

Tables 3–5 summarize the trade data for the sample. Table 3 reports the share of imports from OECD in GDP, averaged over the period 1970–90 by region. Apart from South Asia, the data are similar across regions, ranging from 14 percent to 21 percent. Tables 4 and 5 report the percentage of countries that have an intraindustry trade index greater than 0.7, by region and sector, respectively in 1970 and 1990. Two main facts emerge from these tables. First, as the sector totals indicate, no sector is interindustry or intraindustry by nature. The proportion of countries in which a given sector is considered to be an intraindustry trade sector is similar across all sectors. Second, the regional totals show great variation across regions. South Asia and Latin America started in 1970 with more intraindustry trade sectors than MENA, East Asia, and Sub-Saharan Africa. However, by 1990, East Asia had more intraindustry trade sectors than MENA, South Asia, and Sub-Saharan Africa had.

IV. RESULTS

The structure of the data is as follows. The data for the 1970–93 period was split into 5 sub-periods: 1970–74, 1975–79, 1980–84, 1985–89, 1990–93. The use of five-year intervals helps smooth business cycle effects and isolate longer run evolutions. The dependent variable in the regressions is measured as the average annual TFP growth over each subperiod. However, the explanatory variables — the technological gap and the ratio of imports to GDP — are measured as the beginning of period values instead of the five-year averages of the variables. This timing of the explanatory variables helps minimize the risk of endogeneity. The time dimension of the panel is relatively small compared with the number of countries. This allows us to ignore time-series issues, for which the techniques have not yet been fully developed in the context of panel data.

To test the robustness of the results across regions each equation was estimated first for the total sample and then by regions. The two main regions considered were the OECD and developing countries. The developing countries were further disaggregated into East Asia, Latin America, MENA, South Asia, and Sub-Saharan Africa. The estimates for the total sample are reported both with and without country-specific fixed effects. For the regional estimates, fixed effects are included only when an F test indicated they were necessary. The F-test statistics are also reported in the tables. All estimates have heteroskedastic-consistent standard errors.

The equations were estimated for each of the three TFP measures in the data section. Only the results for TFP_1 are reported, however, because the results for the alternative measures of TFP were similar. Table 6 reports the estimation results of equation 1. The TFP gap, weighted by the share of imports from OECD in GDP, enters significantly in most regressions, confirming the finding by previous studies that trade with OECD plays an important role in the transfer of technologies. The model holds not only for the total sample but also for most of the regions.[4] The results suggest it is important to control for initial conditions that might affect the TFP growth potential of countries. Indeed, the results are stronger when country-specific fixed effects are introduced or when the regressions are estimated by region. For instance, in the regression for the total sample, the adjusted R^2 increases from 0.6 without fixed effects to 18 when fixed effects are included. The size of the coefficient on the import-weighted gap also increases considerably, from 0.01 to 0.10. Similarly, the adjusted R^2 and the size of the coefficient on the import-weighted gap are much larger for the regional regressions than for the total sample regression without fixed effects.

The difference between the two sets of results can be interpreted in terms of unconditional versus conditional convergence. The regression in the total sample without fixed effects assumes that all countries are converging toward a same steady-state level of technological development and measures the speed of convergence toward this unconditional steady-state. But when controlling for fixed effects or estimating the regression by region, countries are allowed to have different steady-states and the regression measures the speed of convergence of countries toward their own steady-state — hence the term conditional convergence. As the results show, conditional convergence is much faster than unconditional convergence.

In the case of Sub-Saharan Africa, the fixed effects are negative suggesting that Sub-Saharan Africa is characterized by conditions, which if unchanged, will prevent it in the long run from attaining the same level of technological development as the OECD countries have achieved. Its steady-state technology, conditional on these factors, is lower.

Next, the ratio of imports from OECD to GDP is divided into two sub-aggregates: one grouping imports in sectors classified as intraindustry trade and the other grouping imports in sectors classified as interindustry trade. Table 7 reports the estimation results of equation 2 for a range of cut-offs for the IIT index. First, the coefficient on IA (the term that interacts the import shares of intraindustry sectors to TFP gaps) is consistently larger than the coefficient on IR (the term that interacts the import shares of interindustry sectors to TFP gaps). The difference between the two coefficients becomes more significant as the cut-off for the IIT index is raised. Table 7 also shows the F tests of the null hypothesis that the coefficients are not significantly different.

Second, as the cut-off is raised, both coefficients on IA and IR increase. The coefficient on IR is first stable at the level 0.077, until the cut-off for the IIT index is raised above 0.7, at which point the coefficient starts increasing. The magnitude of the coefficient on IA, however, increases continuously. This pattern corresponds to the one described in Figure 3. Both results indicate that intraindustry trade is a more efficient channel of technology transfer than interindustry trade. In particular, that the technology transfers through trade start increasing dramatically when the degree of intraindustry trade of the sector rises above 0.7.

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[4] The absence of significant results for East Asia and South Asia might be due to the small sample size for these regions.

Hence, the appropriate cut-off separating intra- and interindustry trade sectors appears to be 0.7.

Table 8 reports the entire estimation results of equation 2 for a cut-off of 0.7 for the IIT index. Note that the coefficient on the TFP growth in OECD countries has a point estimate close to one, as the theoretical model predicts. The null hypothesis that the coefficient is one cannot be rejected and is generally significantly different from zero. Regarding the respective roles of intra- and interindustry trade, the coefficient on intraindustry trade is three to four times larger than the coefficient on interindustry trade, and significantly so. The results for the total sample are confirmed both for developing countries and OECD countries but more strongly for developing countries. Among the latter, the results are particularly strong for Sub-Saharan Africa. The difference between intra- and interindustry trade takes a different form in East Asia, with a nonsignificant effect of IA but a significantly negative effect of IR. Thus, the null hypothesis that the two coefficients are the same can also be rejected with confidence.

Table 9 tests the robustness of these results by excluding net exporters from the interindustry trade category. The classification into net importer or net exporter sectors is based on the export to import ratio of the sector, with cut-offs of 0.5 and 1.9 corresponding to the cut-off of 0.7 for the IIT index. Thus, a sector is classified as a net importer if its ratio of exports to imports is below 0.5, indicating that the sector has no production base (NB); as a sector with intraindustry trade if its ratio falls between 0.5 and 1.9, indicating the existence of a production base (B); and as a net exporter if its ratio is greater than 1.9, indicating a strong production base (G). In accordance with a priori expectations, the coefficient on G is negative or nonsignificant. The results for NB and B are similar to those obtained previously for inter- and intraindustry trade, confirming the greater importance of intraindustry trade.

Table 10 reports the estimation results of the nonlinear specification. This is the continuous equivalent of the cut-off-based approach. Instead of dividing the sectors into two subgroups based on the value of their IIT index, the imports of each sector are weighted by some — possibly nonlinear — function of the sectors' IIT index. The IIT index is entered in the form of a second-order polynomial, whose coefficients are estimated freely. The regression for the total sample when fixed effects are included clearly indicates a positive and increasing influence of the IIT index on TFP growth. The coefficient on the linear term γ is negative but nonsignificant while the coefficient on the squared IIT index δ is positive and strongly significant. Restricting the sample to developing countries or to OECD countries yields the same pattern of results, though less strongly for the OECD countries.

V. CONCLUSIONS AND POLICY IMPLICATIONS

This paper investigated the role of international trade in transferring technology from more developed to less developed countries. In particular, it tested the hypothesis that intraindustry trade is more effective in transferring technology than is interindustry trade. The rationale for this hypothesis is that a country is more likely to absorb the innovations embodied in foreign technology when it is already engaged in producing and exporting goods from the same product category as those it is importing.

The paper takes a general framework already developed by researchers and modifies it to test for the effects of interindustry trade versus those of intraindustry trade. The tests were conducted using data for the absorption of technology (measured by growth of TFP) and trade of 87 countries during 1970–93. Of the countries in the sample, 20 were Sub-Saharan African countries. The findings are summarized as follows:

First, tests confirmed the results of earlier research, which showed that developing countries acquired technology by trading with developed countries. Results were confirmed for both the full sample and the subgroup of 20 African countries. The findings indicate that, other factors being constant, developing countries that imported more from OECD countries (as measured by their import to GDP ratio) experienced faster TFP growth. Furthermore, the wider the initial technology gap the larger the gain. Thus, countries that were technologically farther behind in 1970 gained more from trade with OECD countries than did countries that were technologically more advanced.

Second, intraindustry trade played a larger and more significant role in transferring technology than did interindustry trade. The TFP growth was much more pronounced when the IIT index of a sector exceeded 0.7. This finding was even more strongly evident in the subgroup of 20 African countries. The 0.7 cut-off for the IIT index was used to differentiate sectors according to their export/import intensity (X/M). Both the import-intensive sectors (with $X/M < 0.5$) and the export-intensive sectors (with $X/M > 1.9$) had an IIT below 0.7, while sectors with more significant two-way trade ($0.5 < X/M < 1.9$) had an IIT above 0.7. The findings were reconfirmed when the tests were repeated without data from export-intensive sectors. The exclusion of the data was justified because export-oriented industries are presumed to be more advanced technologically and thus have less need to adopt the technologies of their import sectors.

Third, test results showed the existence of country-specific factors that could prevent Sub-Saharan Africa from attaining the same steady-state level of technological development as OECD countries have attained but the coefficients calculated from the tests could not identify the precise factors. Nonetheless, the general economic literature suggests several factors that might affect the long-run equilibrium level of technology of a country. These factors may be grouped under "general productivity parameters"; they include political stability, institutional environment, and human capital.

Several important policy implications may be drawn from these results, including confirmation of the case for accelerating trade liberalization to encourage technology transfers. Based on these results, the following recommendations could be made:

- Developing countries, in the course of negotiating trade agreements with more developed countries, should seek a reduction of trade barriers in sectors with high IIT at the outset of the liberalization. This is contrary to current developing country practices, which usually seek to retain trade protection for products they produce. This paper's findings suggest, however, that rapid liberalization of such sectors offers greater benefit to the developing country.

- Developing countries should adopt domestic policies that actively promote intraindustry trade. This may include policies to provide key infrastructure or vocational training to enhance production and exports in new sectors and to adopt measures to encourage foreign direct investment (FDI). As other researchers have argued, FDI may lower the cost of adopting and producing new technologies since foreign agents are likely to be already familiar with them. Thus, FDI may lower the cost of producing and exporting new goods.

- Finally, developing countries should focus on identifying the specific factors that can prevent them from reaching their technological potential and adopting needed remedial actions. It should be emphasized, however, that policy reform would need to take a coordinated approach to address the entire mix of policies rather than focus on a sequential change.

Table 1. Average TFP Growth

	1970–1990		
Regions	TFP1	TFP2	TFP3
East Asia	0.02	0.03	0.01
	(0.004)	(0.004)	(0.004)
Middle East and North Africa	0.01	0.01	0.001
	(0.004)	(0.004)	(0.004)
OECD	0.01	0.01	0.004
	(0.002)	(0.002)	(0.002)
South Asia	0.01	0.02	0.01
	(0.01)	(0.005)	(0.01)
Sub-Saharan Africa	-0.01	0.002	-0.01
	(0.003)	(0.003)	(0.003)
Western Hemisphere	-0.005	0.11	-0.01
	(0.002)	(0.002)	(0.002)

Note: Standard errors in parentheses.

Table 2. Descriptive Statistics on TFP Gaps

Regional Averages	Gap 1 1970	Gap 1 1993	Gap 1 Growth 70–93	Gap 2 1970	Gap 2 1993	Gap 2 Growth 70–93	Gap 3 1970	Gap 3 1993	Gap 3 Growth 70–93
East Asia	2.17	1.77	-0.15	1.85	1.32	-0.29	1.89	1.61	-0.11
	(0.26)	(0.32)	(0.12)	(0.54)	(0.68)	(0.11)	(0.21)	(0.26)	(0.13)
Middle East and North Africa	1.41	1.45	0.14	3.23	2.42	-0.03	1.19	1.23	0.19
	(0.26)	(0.32)	(0.12)	(0.54)	(0.68)	(0.11)	(0.21)	(0.26)	(0.13)
OECD	1.03	1.02	0.00	1.38	1.32	-0.01	1.02	1.01	0.00
	(0.15)	(0.18)	(0.07)	(0.31)	(0.39)	(0.06)	(0.12)	(0.15)	(0.07)
South Asia	2.43	2.40	-0.02	2.06	1.87	-0.12	2.01	1.99	-0.03
	(0.33)	(0.40)	(0.16)	(0.68)	(0.86)	(0.14)	(0.26)	(0.33)	(0.16)
Sub-Saharan Africa	2.24	3.02	0.42	3.39	3.92	0.25	1.78	2.36	0.39
	(0.16)	(0.20)	(0.08)	(0.34)	(0.43)	(0.07)	(0.13)	(0.16)	(0.08)
Western Hemisphere	1.45	2.06	0.40	2.78	3.68	0.24	1.27	1.82	0.43
	(0.16)	(0.19)	(0.08)	(0.32)	(0.41)	(0.07)	(0.12)	(0.16)	(0.08)

Note: Standard errors in parentheses.

Table 3. Share of Imports from OECD

	1970–90		1970		1990	
Regional Averages	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
East Asia	0.16	0.08	0.14	0.07	0.19	0.10
Middle East and North Africa	0.21	0.09	0.14	0.04	0.24	0.11
OECD	0.21	0.12	0.18	0.10	0.21	0.12
South Asia	0.08	0.05	0.05	0.02	0.06	0.05
Sub-Saharan Africa	0.14	0.06	0.15	0.06	0.14	0.08
Western Hemisphere	0.21	0.09	0.14	0.08	0.18	0.11

Note: East Asia excludes Singapore.
MENA excludes Malta and Cyprus.
Western Hemisphere excludes Panama.

Table 4. Percent of Countries with an Intraindustry Trade Index Greater Than 0.7 in 1970, by Region

Sectors	Regions: East Asia	South Asia	Sub-Saharan Africa	MENA	Latin America	Industrial	All Regions
Nonmanufacturing	12.5	60.0	9.5	25.0	36.4	37.5	28.4
Manufacturing							
Food, beverages & tobacco	37.5	40.0	42.9	37.5	36.4	37.5	38.6
Textile, wearing apparel & leat	0.0	0.0	9.5	37.5	18.2	54.2	25.0
Wood & wood products	25.0	20.0	9.5	0.0	18.2	25.0	17.1
Paper, printing & publishing	25.0	0.0	0.0	0.0	4.6	37.5	13.6
Chemicals	0.0	0.0	9.5	25.0	13.6	50.0	21.6
Non-metallic mineral products, except fuel	0.0	20.0	14.3	0.0	18.2	29.2	17.1
Basic Metal Industries	0.0	20.0	14.3	12.5	13.6	37.5	19.3
Fabricated Metal Products	12.5	0.0	4.8	0.0	4.6	41.7	14.8
Other Manufacturing	12.5	40.0	14.3	0.0	22.7	37.5	22.7
All sectors	12.5	15.6	13.2	12.5	16.7	38.9	

Table 5. Percent of Countries with an Intraindustry Trade Index Greater Than 0.7 in 1990, by Region

Sectors	Regions						All Regions
	East Asia	South Asia	Sub-Saharan Africa	MENA	Latin America	Industrial	
Nonmanufacturing	50.0	60.0	19.1	37.5	31.8	45.8	36.4
Manufacturing							
Food, beverages & tobacco	50.0	60.0	38.1	25.0	45.5	54.2	45.5
Textile, wearing apparel & leat	37.5	20.0	33.3	62.5	27.3	50.0	38.6
Wood & wood products	25.0	0.0	14.3	0.0	22.7	37.5	21.6
Paper, printing & publishing	25.0	0.0	9.5	12.5	9.1	54.2	22.7
Chemicals	50.0	20.0	4.8	37.5	13.6	75.0	34.1
Non-metallic mineral products, except fuel	62.5	20.0	9.5	25.0	22.7	58.3	33.0
Basic Metal Industries	37.5	0.0	4.8	0.0	18.2	62.5	26.1
Fabricated Metal Products	62.5	0.0	0.0	12.5	4.6	66.7	26.1
Other Manufacturing	12.5	40.0	19.1	25.0	13.6	58.3	29.6
All sectors	40.3	17.8	14.8	22.2	19.7	57.4	

Table 6. Estimation Results of Equation 1 for TFP1

Coefficient	C	α	β	Fixed Effects	R^2	R^2 Adjusted	F Test No Fixed Effects
Total (432 obs.)	-0.005 (0.004)	0.793 (0.469)	0.013 (0.014)	No	0.011	0.006	2.0626**
		0.908 (0.415)	0.098 (0.024)	Yes	0.348	0.180	
OECD (120 obs.)	-0.002 (0.003)	0.965 (0.320)	0.129 (0.030)	No	0.202	0.189	1.054
LDCs (312 obs.)		0.882 (0.565)	0.098 (0.024)	Yes	0.336	0.164	1.911**
East Asia (40 obs.)	0.020 (0.014)	0.146 (1.344)	-0.041 (0.054)	No	0.008	-0.045	1.445
Latin America (110 obs.)		1.166 (1.053)	0.157 (0.049)	Yes	0.302	0.115	1.750**
MENA (40 obs.)	-0.021 (0.013)	0.751 (1.595)	0.180 (0.047)	No	0.355	0.320	0.398
South Asia (24 obs.)	0.018 (0.008)	-1.004 (1.038)	-0.004 (0.055)	No	0.036	-0.056	0.256
Sub-Saharan Africa (98 obs.)	-0.028 (0.010)	2.249 (1.177)	0.035 (0.013)	No	0.082	0.063	1.236

Note: Equation 1: $g_i = c + \alpha * g_l + \beta * \frac{m_{il}}{y_i} * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i$

Heteroskedasticity consistent standard errors in parentheses.

For the F tests only, a * indicates a 10% significance level and a ** indicates a 5% significance level.

Table 7. Estimation Results of Equation 2: Sensitivity to the Cut-off for the IIT Index for Total Sample

Cut-off	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
β	0.086 (0.022)	0.085 (0.022)	0.077 (0.023)	0.077 (0.023)	0.087 (0.025)	0.076 (0.028)	0.076 (0.029)	0.080 (0.042)	0.077 (0.042)
γ	0.447 (0.107)	0.287 (0.091)	0.261 (0.070)	0.211 (0.075)	0.152 (0.078)	0.152 (0.062)	0.147 (0.051)	0.119 (0.044)	0.114 (0.034)
R^2	0.368	0.360	0.362	0.357	0.350	0.351	0.352	0.349	0.349
R^2 adjusted	0.204	0.193	0.196	0.189	0.181	0.182	0.183	0.180	0.180
F test β=γ	11.123	6.368	7.417	4.790	1.045	1.709	2.139	0.602	0.787

Note: Equation 2: $g_i = c + \alpha * g_l + [\beta * \Sigma_{s \in IR} \frac{m_{ils}}{y_i} + \gamma * \Sigma_{s \in IA} \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i$

Table 8. Estimation Results of Equation 2 for TFP1

Coefficient	C	α	β	γ	Fixed Effects	R^2	R^2 Adjusted	F Test No Fixed	F Test β=γ
Total	-0.006	0.929	-0.007	0.157	No	0.035	0.029	2.033**	10.984**
(432 obs.)	(0.004)	(0.463)	(0.014)	(0.052)					
		1.066	0.077	0.261	Yes	0.362	0.196		7.417**
		(0.416)	(0.023)	(0.070)					
LDCs		1.113	0.077	0.266	Yes	0.350	0.179	1.881**	5.420**
(312 obs.)		(0.574)	(0.024)	(0.075)					
OECD	-0.002	0.964	0.086	0.205	No	0.213	0.193	1.046	1.632
(120 obs.)	(0.003)	(0.321)	(0.052)	(0.063)					
East Asia	0.021	0.995	-0.175	0.028	No	0.136	0.064	1.342	5.302**
(40 obs.)	(0.013)	(1.316)	(0.067)	(0.068)					
Latin America		1.163	0.159	0.150	Yes	0.302	0.105	1.676**	0.003
(110 obs.)		(1.059)	(0.059)	(0.141)					
MENA	-0.021	0.753	0.180	0.181	No	0.355	0.301	0.386	0.000
(40 obs.)	(0.013)	(1.691)	(0.077)	(0.147)					
South Asia	0.019	-1.076	0.004	-0.122	No	0.040	-0.104	0.272	0.088
(24 obs.)	(0.007)	(0.951)	(0.072)	(0.349)					
Sub-Saharan Africa	-0.029	2.257	0.021	0.284	No	0.109	0.081	1.461	2.843*
(98 obs.)	(0.010)	(1.165)	(0.012)	(0.110)					
		2.129	0.018	0.554	Yes	0.350	0.159	1.461	5.876**
		(1.051)	(0.027)	(0.205)					

Note: Equation 2: $$g_i = c + \alpha * g_l + [\beta * \Sigma_{s \in IR} \frac{m_{ils}}{y_i} + \gamma * \Sigma_{s \in IA} \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i$$

IA and IR categories are calculated based on a benchmark of 0.7 for the IIT index.
Heteroskedasticity consistent standard errors in parentheses.
For the F tests only, a * indicates a 10% significance level and a ** indicates a 5% significance level.

Table 9. Estimation Results of Equation 4 for TFP1

Coefficient	C	α	β	γ	δ	Fixed Effects	R^2	R^2 Adjusted	F Test No Fixed Effect	F Test $\beta=\gamma$
Total (432 obs.)	-0.006 (0.004)	0.914 (0.462)	0.015 (0.016)	0.147 (0.055)	-0.267 (0.132)	No	0.051	0.042	1.933 **	6.649 **
		1.057 (0.419)	0.082 (0.028)	0.254 (0.069)	0.017 (0.160)	Yes	0.362	0.194		5.398 **

Note: Equation 4:

$$g_i = c + \alpha * g_l + [\beta * \Sigma_{s \in NB} \frac{m_{ils}}{y_i} + \gamma * \Sigma_{s \in B} \frac{m_{ils}}{y_i} + \delta * \Sigma_{s \in G} \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i$$

Heteroskedasticity consistent standard errors in parentheses.
For the F tests only, a * indicates a 10% significance level and a ** indicates a 5% significance level.
Base, No Base, and Good Categories are calculated based on benchmarks of 7/13 and 13/7 for the export-import ratio corresponding to a cut-off of 0.7 for the IIT index.

Table 10. Nonlinear Estimation Results for TFP1

Coefficient	c	α	β	γ	δ	Fixed Effects	R^2	R^2 Adjusted	F test No fixed Effects
Total	-0.006	0.892	-0.021	0.059	0.124	No	0.035	0.026	2.051**
(432 obs.)	(0.004)	(0.458)	(0.029)	(0.245)	(0.270)				
		1.099	0.091	-0.302	0.618	Yes	0.364	0.196	
		(0.369)	(0.043)	(0.279)	(0.280)				
OECD	-0.002	0.962	0.179	-0.547	0.662	No	0.217	0.190	1.089
(120 obs.)	(0.003)	(0.308)	(0.267)	(0.988)	(0.836)				
Developing Countries		1.158	0.089	-0.296	0.623	Yes	0.353	0.179	1.906**
(312 obs.)		(0.507)	(0.044)	(0.284)	(0.289)				
East Asia	0.023	1.032	-0.287	0.202	0.144	No	0.153	0.056	1.410
(40 obs.)	(0.012)	(1.240)	(0.134)	(0.467)	(0.436)				
Latin America		1.207	0.301	-0.682	0.458	Yes	0.335	0.137	1.704**
(110 obs.)		(0.947)	(0.062)	(0.513)	(0.676)				
MENA	-0.028	1.118	0.278	-0.979	1.253	No	0.372	0.300	0.900
(40 obs.)	(0.014)	(1.505)	(0.207)	(1.155)	(1.281)				
South Asia	0.017	-1.020	-0.108	1.745	-2.291	No	0.084	-0.109	0.262
(24 obs.)	(0.007)	(0.887)	(0.095)	(0.891)	(1.328)				
Sub-Saharan Africa		2.012	-0.113	0.646	0.431	Yes	0.400	0.213	1.698**
(98 obs.)		(0.855)	(0.067)	(0.518)	(0.575)				

Note: Nonlinear Estimation Results: $g_i = c_i + \alpha * g_l + [\sum_s h(IIT_{is}) * \frac{m_{ils}}{y_i}] * \ln \frac{TFP_l}{TFP_i} + \varepsilon_i$

$$h(IIT_{is}) = \beta + \gamma * IIT_{is} + \delta * IIT_{is}^2$$

Heteroskedasticity consistent standard errors in parentheses.
For the F tests only, a * indicates a 10% significance level and a ** indicates a 5% significance level.

Data Sources and Construction

The definition and the original source of the data for each variable needed to measure Total Factor Productivity (TFP) as described in the paper by Bosworth, Collins, and Chen (1995) is listed below.

GDP:

Definition: local currency, 1987 constant prices

Primary source: OECD for the industrial countries, World Bank and IMF for the developing countries

Stock of physical capital:

Definition: local currency, 1987 constant prices. The measure of the capital stock is based on a perpetual inventory estimation with a common fixed annual geometric depreciation rate of 0.04.

Primary source: Nehru and Dhareshwar (1993)

Labor force:

Definition and source: actual employment for the industrial countries and estimates from the International Labor Organization of the economically-active population for developing countries

Education:

Definition:

$$H = \sum_j w_j \,.\, P_j$$

where H denotes the stock of human capital, w_j denotes the wage weight of people at the jth education level and P_j denotes the fraction of the population in the jth education level. The wage weights are standardized at 1.0 for those who have completed the primary level of education. The relevant wage weights are 0.7 for no schooling, 1.4 for completion of the secondary level, and 2.0 for completion of the third level. Note that the few studies that have examined the structure of relative wage rates by education find surprisingly little variation across countries.

Source: Barro-Lee (1994) for the fractions of the population at the different education levels.

Appendix Table 1. Sample Countries, by Region

East Asia
China
Indonesia
Malaysia
South Korea
Singapore
Taiwan
Philippines
Thailand

South Asia
Bangladesh
India
Myanmar
Pakistan
Sri Lanka

Industrial Countries
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Iceland
Ireland
Israel
Italy
Japan
Netherlands
Norway
New Zealand
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
USA

Middle East and North Africa
Algeria
Cyprus
Egypt
Iran
Jordan
Malta
Morocco
Tunisia

Latin America
Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Guatemala
Guyana
Haiti
Honduras
Jamaica
Mexico
Nicaragua
Panama
Paraguay
Peru
Trinidad & Tobago
Uruguay
Venezuela

Sub-Saharan Africa
Cameroon
Cote d'Ivoire
Ghana
Kenya
Madagascar
Malawi
Mali
Mauritius
Mozambique
Nigeria
Rwanda
South Africa
Senegal
Sierra Leone
Sudan
Tanzania
Uganda
Zaire
Zambia
Zimbabwe

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