Market Structure, International Trade and Technological Diffusion: A Theoretical Analysis

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MARKET STRUCTURE, INTERNATIONAL TRADE AND TECHNOLOGICAL DIFFUSION: A Theoretical Analysis*

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I. Introduction

It has been argued that openness of and industry to international trade promotes technical efficiency. This hypothesis has been proposed and tested by both industrial organization[1] and development[2] scholars.

The purpose of this paper is to explore the dynamic nature of international technological diffusion (ITD) and its implications for industrial structure -- average plant size, international concentration and technical efficiency -- in a general equilibrium framework. While earlier literature has examined ITD in the context of incentives to perform R&D,[3] we argue that there are two fundamental types of ITD, each with profoundly different implications for the impact of international trade on industrial structure. We define ITD as a process through which countries learn about the production technologies of each other and this learning reduces costs. The first type of costs are those associated with introduction and imitation costs -- the fixed or setup costs for opening up a new plant or developing a new product. The second type of costs are the variable production costs associated with the expansion of plant output. We argue that the relative impact of ITD on variable relative to fixed costs plays a significant role in industrial factor reallocation. We examine how each type of ITD affects industrial structure in a two country, two factor, two sector model where one sector is a product differentiated monopolistically competitive sector and the second is a fully competitive one.[4]

Empirical work on the diffusion of innovations have found that the probability of a firm incorporating a new technology depends positively on the number of firms that have already introduced it. As firms introduce new products problems associated with both the technology and the identification of demand characteristics are solved, hence reducing introduction costs. Moreover, as more products have been developed and introduced in an industry, the costs of developing a new version are smaller since imitation and reverse engineering costs are reduced.[5] New firms also learn from existing firms on the production technology for expanding output volume. On both theoretical and empirical grounds, it seems plausible that the parameters underlying the production function of a new firm depend upon the number of existing firms.

We define autarchic equilibrium as one where there is neither trade with other countries nor ITD so that the diffusion of technology depends only on the number of country specific plants. The movement from autarchy to free international trade not only involves the introduction of free trade in products, but extends the diffusion process to the international environment.[6] Under free trade, we postulate that both variable and fixed costs will depend upon the number of products produced worldwide. It might be argued that ease of imitation may depend on being close to the source of the original product. However, the existence of multinational companies may reduce the divergence in learning from foreign vis-à-vis domestic sources.[7] A closed economy (that is, one with large tariff barriers) may not be able to benefit from international diffusion, or at least not as much as a more open one.

In Chamberlin-Hecksher-Ohlin models the opening to trade leads the relatively capital abundant countries to transfer resources out of the labor intensive competitive industry (such as agriculture) into the product variety sector (such as high technology electronics) expanding not only the number of products but also the size of each plant. Thus comparative advantage helps capital rich countries exploit their economies of scale. This theoretical proposition is consistent with the empirical findings of Caves, et al. (1980) who find higher technical efficiency for firms engaged in the intraindustry sector of developed nations, positively related to the industries' export exposure and negatively to tariff protection. But, theoretically, relative labor rich countries (LDC's or NIC's) would have to contract both the number and size of operating firms and transfer resources to the labor intensive competitive sector so as to exploit their comparative advantage. Thus international trade would impede technical efficiency as well as boost domestic concentration in these labor abundant countries. This effect would be stronger, the greater the difference in capital-labor ratios between countries. Such a proposition would seem inconsistent with empirical evidence for NIC's. In this paper we show that the above theoretical finding can be reconciled with the empirical evidence by considering the role of ITD. If the ITD is primarily associated with reducing variable costs rather than fixed costs, it is quite possible for labor abundant countries also to witness expansion in plant size.

ITD induces competition for resources within the intraindustry sector either to expand plant size or towards the creation of new products. This trade off between plant size and product diversity will depend critically on the structure of ITD in addition to the usual comparative advantage created by factor endowment differentials. If ITD reduces variable costs relative to fixed costs, resources will be allocated to the expansion of plant size and hence enhance technical efficiency. However if reductions in fixed costs (usually R&D costs) are the crucial dimension of the ITD process, incentives to create new products would result in relatively smaller plant size.

The structure of the paper is as follows: in section II, we describe the structure of the world economy describing the technology, preferences and the ITD process. In section III we analyze the impact of the opening of trade on the industrial strucutre. This includes an explanation of how ITD and Hecksher-Ohlin comparative advantage affect the average plant size and the degree of both domestic and international concentration. Also analyzed are the effect of ITD on the volume of international trade undertaken by each individual firm, the degree of intraindustry trade as well as ITD and the gains from trade. In section IV we present our conclusions and comments for further research.

II. The Structure of the World Economy

The world is composed of 2 economies indexed by j = 1, 2. The representative utility function in each country is described as[1]

$$U_j = \tilde{y}_j^{1-s} \left| \sum_{k=1}^{n_1} \tilde{x}_{kj} + \sum_{\ell=1}^{n_2} \tilde{x}_{\ell j} \right|^{s/\theta} \qquad \text{for } j = 1, 2. \tag{2.1}$$

where ~ refers to consumption (as opposed to production). y is a homogeneous product produced in perfectly competitive markets. The x's are of a heterogeneous quality where the elasticity of substitution between any x and y is identically θ for both countries. The home country (j = 1) produces n_1 different qualities indexed by k = 1, n, and the foreign country (j = 2) produces n_2 different qualities indexed by $\ell = 1, n_2$.

Technology and International Technological Diffusion (ITD)

The production of any x involves both fixed costs -- introduction and imitation costs -- and variable costs. The cost function for any x_{ij}

is described as,

2.2 $$TC_i^j = \gamma^j r^j + w^j \beta^j x_i^j \quad \text{for } j = 1, 2. \quad i = 1, 2, \ldots, n_j.$$

where γ is the required fixed capital cost, r is the rental price of capital, w the wage rate and β^{-1} the marginal product of capital. Thus fixed costs involve only capital and variable costs only labor.[2]

The process of technological diffusion is defined at both national and international levels. The variables γ and β depend inversely on the number of plants existing in the industry.[3] At a national level (i.e., autarchy implies both barriers to trade and to the international dissemination of information), γ and β are respectively,

2.3 $$\gamma^j = \gamma(n_j) \qquad \partial\gamma/\partial n_j < 0,$$

$$\beta^j = \beta(n_j) \qquad \partial\beta/\partial n_j < 0.$$

In autarchic equilibrium only additional plants at a domestic (foreign) level will enhance technical efficiency at home (abroad). At an international level, γ and β both depend inversely on domestic as well as foreign plants,

2.4 $$\gamma^j = \gamma^j(n_1,n_2) \qquad \partial\gamma/\partial n_1 < 0,\ \partial\gamma/\partial n_2 < 0$$

$$\beta^j = \beta^j(n_1,n_2) \qquad \partial\beta/\partial n_1 < 0,\ \partial\beta/\partial n_2 < 0.$$

Thus the movement from autarchy to free trade has implications for the transmission of external economies. We make two further assumptions. First, international technological diffusion (ITD) is symmetrical under free trade so that after the commencement of free trade $\gamma^j = \gamma$ and $\beta^j = \beta$ and second, learning is independent of the location -- either on domestic or foreign soil.[4] The restrictions imply that 2.4 can be simplified to, 2.5 $$\gamma = \gamma(m), \qquad \partial\gamma/\partial m < 0$$

$$\beta = \beta(m), \qquad \partial\beta/\partial m < 0$$

$$m = n_1 + n_2.$$

where m is the number of products produced worldwide. Under free trade according to 2.5, both countries will have identical technologies.[5] We furthermore assume that a steady state solution exists such that the marginal firm introducing a new product will have a technology $\gamma(m)$ and $\beta(m)$ where m is the steady state number of products introduced worldwide.[6] We are thus abstracting from sequential solutions on the path to the steady state.

Competitive Sector

The second sector is a competitive sector (called "agriculture") whose technology is constant returns to scale,

2.6 $$y^j = L_y^j f(k_y^j) \qquad f' > 0 \qquad f'' < 0 \qquad j = 1, 2$$

where L_y^j is the amount of labor used in y and k_y^j is the capital-labor ratio in the y sector. The usual regularity restrictions are assumed to hold.

Balance of Trade and Factor Endowments

Since preferences are identical across countries and production is assumed to be symmetrical across qualities, the balance of payments constraint in each country is given by,

2.7 $$p_1\tilde{x}_1^j n_1 + p_2\tilde{x}_2^j n_2 + \tilde{y}_j = p_1 x^j n_j + y_j \qquad j = 1, 2$$

where $\tilde{x}_i^j$ is a consumption of output produced in country i by consumers in country j at price p_i.

The stocks of labor and capital are assumed constant in each country and the factor endowment constraints in each country are,

2.8 $$L^j = L_y^j + n_j L^j; \quad K^j = K_y^j + \gamma n_j \qquad j = 1, 2$$

Autarchic Equilibrium[7]

Under the assumption of free entry into both industries, firms will continue entering the product diverse sector until abnormal profits are driven to zero. Due to the economies of scale, no two firms will produce the same x product. The zero profit condition implies that average costs will equal average revenue. This can be written as,

2.9 $$x^j = \frac{\theta}{1 - \theta}\left(\frac{r}{w}\right)^j \frac{\bar{\gamma}^j}{\bar{\beta}^j} \qquad \text{for } j = 1, 2.$$

Clearly then as economies open to trade the size of each plant will be sensitive to the rental:wage ratio as well as to external economies emanating from ITD. The rental-wage ratio will depend inversely on the country's capital-labor endowment,[8]

2.10 $$\left(\frac{r}{w}\right)^j = \phi(k^j) \quad \frac{\partial \phi}{\partial k^j} < 0 \qquad \text{for } j = 1, 2.$$

Thus the relationship between the rental-wage rate and capital-labor endowment in the Chamberlin-Hecksher-Ohlin model is in the spirit of the traditional Hecksher-Ohlin, given our assumption of preferences and technology. Utilizing the first order conditions of profit maximization and the factor constraints (1.8), in the appendix (section 1) we show that the number of products produced in autarchy is,

2.11 $$n_j = \frac{K^j s(1 - \theta)}{\bar{\gamma}^j z} \qquad \text{for } j = 1, 2.$$

where $z = s(1 - \theta) + \varepsilon(1 - s)$ with ε defined as the share of capital costs in the production of agricultural products.[9] Note that (2.11) is not a closed form solution -- the latter can be derived by combining the diffusion process (2.3) with (2.11). While the equilibrium size of plants in (2.9) is shown to depend on $(\bar{\gamma}/\bar{\beta})^j$, the number of firms n_j depends only on $\bar{\gamma}^j$, due to the assumption that fixed costs involve only capital inputs.

III. Industrial Structure in the World Economy

ITD and Plant Size

By manipulation of the optimization conditions posed bv the structural model presented in section II, the size of industrial plants under free trade is found to be,[1]

$$x = x^j(\gamma/\beta)(\bar{\beta}/\bar{\gamma})^j\delta_j \qquad (3.1)$$

where x^j is the size of production under autarchy, $(\bar{\beta}/\bar{\gamma})^j$ is the ratio of variable to fixed costs under autarchy in country j and δ_j is the ratio of country j's capital-labor ratio relative to the world capital-labor ratio. γ and β are the post trade values and depend upon the number of plants, m, produced worldwide according to equation 2.5.

According to (3.1) the impact of international trade on world plant size depends upon two fundamental factors: (a) the differential effect of technological diffusion on fixed relative to variable costs and (b) the relative degree of capital abundance in each country.

In the absence of ITD, and assuming each country had identical technologies under autarchy, trade would increase (decrease) plant size of the relative capital (labor) abundant country (i.e., in 3.1 $\gamma = \bar{\gamma}$ and $\beta = \bar{\beta}$). This is the standard Chamberlin-Hecksher-Ohlin result.[2]

International technological diffusion may however alter this result. There are three distinct possibilities.

Case I: $\gamma/\bar{\gamma}^j = \beta/\bar{\beta}^j$ if ITD affects fixed and variable costs equiproportionately in each country, the previous result will continue to hold.

Case II: $\beta/\bar{\beta}^j > \gamma/\bar{\gamma}^j$ if ITD reduces fixed costs relative to variable costs, the contraction in plant size in the labor abundant country is reinforced. In such a case not only does traditional comparative advantage attract resources out of capital intensive plants in the labor abundant country, but the relative profitability of establishing new (but smaller) plants also encourages resources out of existing plants. Unambiguously then international trade will reduce the average size of plants in labor abundant countries in the presence of ITD. In the capital abundant country, ITD could reverse the expansion of plant size despite a comparative advantage in this capital intensive industry. The comparative advantage effect will dominate the ITD effect -- and hence plant size will expand in the capital abundant country -- if $(\gamma/\beta)(\bar{\beta}/\bar{\gamma})^j < \delta^j$.

Case III: $(\beta/\bar{\beta}^j) < (\gamma/\bar{\gamma}^j)$. In this case variable costs fall by more than fixed costs, so that international technological diffusion stimulates plant size expansion in all countries. In the capital abundant country, size will unambiguously increase since not only will more variable inputs be employed in each plant, but each input's marginal productivity has increased. In the labor abundant country, the ITD effect will mitigate the comparative advantage contraction of plant size. If $(\beta/\bar{\beta}^j)(\bar{\gamma}^j/\gamma)\delta^j > 1$, plant size will expand. Thus although comparative advantage attracts variable inputs out of the capital intensive industry, variable inputs have become so productive that plant size expands.

It might also be stated that if countries had identical capital labor ratios ($\delta = 1$), the impact of trade on plant size will depend exclusively on ITD. If ITD reduces variable costs by more than fixed costs, plant size will expand in that particular country. When $\delta = 1$ only intraindustry trade will take place but again the rationale for resource competition created by ITD is the same as that explained in the previous paragraph: ITD creates competition for resources between product diversity and plant size. To summarize, in the presence of ITD and Chamberlin-Hecksher-Ohlin trade:

Proposition 1: If international technological diffusion reduces imitation and introduction costs relative to variable costs, labor abundant countries will witness declines in average plant size, while capital abundant countries could experience either a contraction or expansion, as countries move from autarchy to free trade. On the other hand, if ITD reduces variable relative to fixed costs, the capital abundant country will witness an expansion in average plant size, with an ambiguous effect in the labor abundant country.[3]

ITD and the Number of Industrial Firms

To analyze the effect of international trade on the degree of domestic concentration, we introduce the following notation: $K^2 = a\lambda\bar{K}$

and $L^2 = (2 - a)\lambda\bar{K}$, where the "2" refers to the foreign country, $\bar{K} = \sum_{j=1}^{2} K^j$, "a" is a measure of the capital labor endowment differential and λ is a measure of country size. If $a > 1$, the home country ($j = 1$) is labor abundant and if $\lambda < 1$ the home country is larger.[4]

The number of products in each country is found to be[5]

$$n_j = n_j^A(\bar{\gamma}^j/\gamma)Q^j \qquad \text{for } j = 1, 2. \tag{3.2}$$

where $$Q^1 = \frac{1 - \psi\delta^{-1}}{1 - \psi}, \quad Q^2 = \frac{1 - \psi a^{-1}(2 - a)\delta^{-1}}{1 - \psi},$$

and $$\psi = [\varepsilon(1 - z)]/[z(1 - \varepsilon)]. \qquad 0 \leqq \psi \leqq 1.$$

As shown in the appendix, ψ is equal to the ratio of capital per worker in the agricultural sector relative to capital per worker in the world.[6] If the home country ($j = 1$) is labor abundant $Q^1 < 1$ and $Q^2 > 1$. By inspection of (3.2) in the absence of diffusion, the labor abundant country would become more concentrated while the opposite is true for the capital abundant country. However, if both countries had the same capital abundance, international trade would not change the number of products produced in each country. International technological diffusion changes these results. Opening to trade in the presence of ITD in fixed costs reduces the initial investment required to introduce a product. This would stimulate the introduction of new products. If countries differ in their capital abundance, technological diffusion reinforces the comparative advantage of the capital abundant country in capital intensive products and hence leads to an expansion of its number of firms. If the extent of technological diffusion is sufficiently strong (or if the labor abundant country is not too different in its endowments relative to the capital abundant country), despite the comparative advantage of the labor abundant country in labor intensive products, the reduction in fixed costs could also imply an increase in its number of industrial plants. Hence,

Proposition 2: The capital abundant country will witness an expansion in its number of firms, while it is ambiguous whether or not the number of firms will increase in the labor abundant country, as the world moves from autarchy to free trade in the presence of ITD.

While the effect of international trade on domestic concentration (i.e. on the number of domestic producers) depends upon the relative capital abundance of the country -- (i.e. as a sufficient but not necessary condition), the effect of ITD on world concentration (i.e. the number of international firms)--is straightforward. The world number of firms, m, can be derived using (3.2),

3.3 $$m = \Sigma n_j = \frac{s(1 - \theta)}{Z} \frac{\bar{K}}{\gamma}$$

where $\bar{K}$ is world capital stock. By inspection of (3.3) we obtain:

Proposition 3: Whatever the nature of ITD, as long as fixed costs are reduced, the worldwide number of products m will increase as countries open to trade. The expansion in the world number of products is exclusively due to ITD in fixed costs.[7]

If countries had the same capital requirements in autarchy (i.e. $\bar{\gamma} = \bar{\gamma}^j$, j = 1, 2), then in the absence of ITD, m would remain constant as countries entered trade. The effect of ITD is then to reduce effective world concentration and hence to increase the degree of worldwide competition. The rationale is clear, opening to trade reduces worldwide fixed costs of introducing new products. In the cases where the labor abundant country experiences a reduction in its number of products, the expansion in the capital abundant country would more than compensate the reduction in the labor abundant country, implying an overall increase in product variety.

ITD and Patterns of Exports and Imports

The trade surplus for any firm in the x industry is given by

3.4 $$T = x - \tilde{x}^{j} - x^{j}(\bar{\beta}^{j}/\beta)(\gamma/\bar{\gamma}^{j})S \qquad j = 1, 2;\ S > 0$$

where x^j is the volume of x produced under autarchy. S is a parameter depending on δ, a, λ and z and in the special case, where countries are identical, S will equal unity and only intraindustry trade will take place.[8] In general, however, the volume traded by each plant depends crucially on the type of ITD -- setup versus variable costs.

Proposition 4: If fixed and variable costs were reduced equiproportionately, as a result of ITD ($\bar{\beta}^j/\beta = \bar{\gamma}^j/\gamma$), the volume of products exported by each firm engaged in intraindustry trade would be unaffected by the technological diffusion. If ITD involved relatively greater reductions in variable (fixed) relative to fixed (variable) costs, the volume of products per plant entering international trade would increase (decline).

Because technological diffusion does not occur (by assumption) in the y sector, it manifests itself in the reallocation of factors between expanding plant sizes and introducing new products. If fixed costs were reduced without significant changes on variable costs (i.e. $\gamma/\bar{\gamma}^j < \beta/\bar{\beta}^j$) technological diffusion would lead to the introduction of more products while to achieve this result, resources would be attracted out of existing plants. Under such circumstances, countries would create more products selling relatively fewer of each kind in the international market. On the other hand, if variable costs were significantly reduced ($\beta/\bar{\beta}^j < \gamma/\bar{\gamma}^j$), firms would expand the size of plants, and trade in each product would be greater.

Empirical analyses of the conventional Chamberlin-Hecksher-Ohlin model have focused their tests on analyzing the effect of factor endowments on the degree of intraindustry trade.[9] Hence, it is important to see whether ITD affects the degree of intraindustry trade in the economy. Jones (1981) uses the relative measure of within industry trade for industry i,

$$I_i = \frac{|x_i - m_i|}{x_i + m_i}$$

where x_i (m_i) is the export (import) of industry i.

In our context a similar measure would be,

$$3.4 \qquad I_i = \frac{x - \tilde{x}}{x - \tilde{x}} = \frac{1 + a\lambda}{\delta^{-1} + z(1 - \delta^{-1})} - 1.$$

I_i is unity when $\rho = a = \lambda = \delta = 1$, that is, when the countries are identical. I depends upon parameters affecting factor endowment differentials (a), relative country size (λ), the utility function parameters (θ and s) and the production function of y (z). However, we find that I is independent of the extent of international technological diffusion, hence, Proposition 5: The degree of intraindustry trade depends on the degree of product differentiation, θ, but is independent of international diffusion in reducing fixed and variable costs.[11]

ITD and the Gains from Trade

In the conventional Chamberlin-Hecksher-Ohlin framework, there are two main sources of gains from trade: (1) consumers obtain greater product variety (intraindustry trade), and (2) countries exploit their comparative advantage (interindustry trade). It has been shown that the gains from trade would be larger the more capital abundant and larger the partner country.[12] In our framework, ITD will also promote gains due to greater technical efficiency from the sharing of technological knowledge. To see this, we compute the ratio of utility after and before trade for the fully symmetric case (i.e., identical countries). Then from (2.1) and symmetry we obtain

$$\frac{u^T}{u^A} = 2^{\frac{s}{\theta}(1-\theta)} (\bar{\gamma}^j/\gamma)^{\frac{s}{\theta}(1-\theta)} (\bar{\beta}^j/\beta)^s$$

where u^T (u^A) is the utility level under free trade (in autarchy).[13] The effect of ITD on the gains from trade depends on its type. If ITD only reduces variable costs (i.e. only β falls) the gains from trade would be obtained purely from a production efficiency source. However, if fixed costs are reduced, diffusion plays a dual role as can be seen by the fact that the power of $\gamma/\bar{\gamma}^j$ depends on s and θ in (3.5). On the one hand, lower fixed costs imply a gain in efficiency. On the other hand, the number of products is being increased internationally (Proposition 3) providing a further consumption gain. This latter gain will be larger the smaller is θ or intuitively, the greater consumers value diversity. To summarize we state our final welfare proposition:

Proposition 6: ITD stimulates world welfare by enhancing the marginal productivity of fixed and variable inputs and hence the technical efficiency of production. Furthermore, ITD, in the form of reducing introduction and imitation costs boosts welfare by stimulating the diversity of products produced worldwide.

IV. Conclusions

We have investigated the role of symmetrical technological diffusion in a two country two factor multiproduct world. We have distinguished between two types of international diffusion: the first is the actual reduction in fixed (e.g. R&D) costs needed to introduce a new product while the second is the reduction in variable costs of production. This distinction has been shown to have important effects on industrial structure and patterns of international trade. As long as fixed R&D costs are reduced due to the dissemination of information, the world number of products produced will increase so that fixed cost savings will reduce international industrial concentration. Domestic concentration in the capital abundant country will fall due to an increase in the number of plants, while the labor abundant country will increase its number of plants if the fixed cost reduction offsets the comparative advantage outflow of capital from the industrial sector.

International technological diffusion, instead of reallocating resources between the agricultural and industrial sector, induces competition for resources within the latter sector, either to create new plants or to expand the size of existing ones. To predict the outcome of this trade-off one must specify both the capital-labor endowment ratio relative to the world ratio and the structure of ITD. If variable costs fall relative to fixed costs, capital abundant countries will unambiguously expand plant size and hence technical efficiency. However, the result is ambiguous in the labor abundant country as comparative advantage reallocation competes with the diffusion process. ITD induces gains from trade by enhancing the productivity of factors in both fixed and variable inputs as well as by stimulating the degree of product diversity.

There are several ways of extending our model. It would be of interest to explore how asymmetrical diffusion affects the patterns of trade. Such a model would lead to a breakdown in Hecksher-Ohlin factor price equalization and would be tantamount to studying a Ricardian model of trade. A further modification would be to investigate the type of policies that would be designed to protect countries' trade secrets. Finally, we have analyzed a dynamic model with comparative statics. It would be of interest to analyze how sequential learning would affect industrial structure and the pattern of international trade in a sequential comparative dynamic framework.

Footnotes

Section I

[1]For example, Caves et al. (1980), Auquier and Caves (1978), Balassa (1966) and Bloch (1976). For a survey of the impact of trade on industrial structure, see Caves (1983).

[2]For the NBER studies of foreign trade regions and economic development, see Bhagwati (1978) and Krueger (1978). Also see Behrman (1976) and Diaz Alejandro (1976) for two studies on the Latin American experience. For a survey of the above studies and further references see Behrman (1982).

[3]This line of research can be traced back to Vernon's (1966) product cycle approach. More recent contributors include Rodriguez (1975), Teubal (1975), Findlay (1975), Krugman (1979) and Feenstra and Judd (1982).

[4]For previous models dealing with increasing returns and product differentiation in the context of international trade see Krugman (1979), Ethier (1979), Dixit and Norman (1980), Lancaster (1980), Helpman (1981) and Lawrence and Spiller (1983).

[5]This diffusion process is closely associated with learning curve. See Porter (1980) for a recent discussion and references therein.

[6]Ethier (1979, 1982) has investigated how national versus international diffusion affects the patterns of international trade. He argues that international diffusion depends on total world output.

[7]See Caves et al. (1980) for a discussion of the role of multinationals in transferring technologies. Also see Helpman (1983) for a model of the multinational firm.

Section II

[1]This specification of the utility function is that proposed by Dixit and Stiglitz (1977) and used in the framework of international trade with differentiated products by, among others, Krugman (1980), Ethier (1982) and Lawrence and Spiller (1983). For an alternative specification of the utility function see Lancaster (1980) and Helpman (1982). Since the results seem to be insensitive to the specification chosen (see Caves (1983)) we choose the above specification for its convenience. Without any conceptual difficulty, the paper can also be interpreted in the Ethier (1982) spirit. The product diverse sector produces intermediate inputs, so that output of homogenous good X is produced with an array of product diverse inputs together with labor and capital. The reader is free to interpret our results in accord wtih this framework. The algebraic manipulations would be identical.

[2]For simplicity of exposition we have assumed that the fixed costs involve only capital and the variable costs only labor. More general nonhomothetic technologies would not add much more insight into the analysis. In fact as long as variable costs are relatively more labor intensive than fixed costs, we conjecture that all our results would continue to hold.

[3]This assumption assumes away the problem of entry barriers. For example, as more firms enter the amount of advertising required may in fact increase. For a discussion and some insights into this issue see Commanor and Wilson (1974).

[4]Some countries might have tighter security on information dissemination (trade secrets) relative to others and trading with these countries might lead to differential benefits due to the asymmetrical flow of information. This could also justify the presence of tariff or plant licensing intervention.

[5]This is in the spirit of the Hecksher-Ohlin model. Asymmetrical technological diffusion would imply "Ricardian" type motives for the basis of trade patterns. Also note that although the economies are Ricardian in autarchy, ITD creates a unified international technology.

[6]Sequential R&D investment has been recently analyzed by Reinganum (1982). This approach utilizes game theoretical strategic behavior, which is not the focus of this paper.

[7]See appendix section I for an explicit derivation of 2.10 and 2.11.

[8]See for example Helpman (1981) and Lawrence-Spiller (1983) for a derivation of this result in the synthesized Chamberlin-Hecksher-Ohlin model.

[9]In the class of CES production functions ε will depend on the wage:rental ratio. For simplicity z is assumed constant and this can be justified if the elasticity of substitution between labor and capital in the agricultural sector is unity (i.e. Cobb-Douglas).

<u>Section III</u>

[1]See appendix, section II for a derivation of this result.

[2]See for example Lawrence-Spiller (1983).

[3]Studies of developed countries have found that export and import exposure reduces the extent of domestic concentration (e.g. Caves et al. (1980) and Jacquemin et al. (1979)). Moreover, there is some evidence that NIC experienced an expansion in their average size of industrial plants as they became more exposed to international trade. Both the above facts may imply that the prevalent type of ITD is one that tends to reduce variable costs by more than fixed costs.

[4]Note that by using the definitions of K^2 and L^2, "δ" used earlier in the text can be written as $\delta^{-1} = \frac{1 + a\lambda}{1 + (2 - a)\lambda}$.

[5]For a proof of this see appendix section III.

[6]If the elasticity of substitution is unity in the agricultural sector then ψ will be a constant.

[7]In the absence of ITD, by inspection of (3.3) it is clear that the worldwide number of products will not change so that for each new plant opened up in the capital abundant country, one will be shut down in the labor abundant country. Since $\partial\gamma/\partial m < 0$, γ must be larger under autarchy.

[8]See appendix section IV for a derivation of (3.4). S is defined as, $S = \delta[1 + a\lambda - (1 - z)\delta^{-1} - z][1 + a\lambda]^{-1}$.

[9]See, for example, Pagoulatos and Sorensen (1976), Tharakian, Soete and Busschaer (1978) and Caves (1981).

[10]See Ethier (1982) for a different result.

[11]Proposition 5 depends upon three critical assumptions: (a) there is no technological diffusion in the competitive sector, (b) there are no variable capital inputs in the production of industrial goods and (c) θ, the degree of monopoly power is constant. A relaxation of any of these three would allow external economies generated by ITD to have an impact on the degree of intraindustry trade.

[12]See Helpman (1982).

[13]This is the case where only intraindustry trade takes place but is fully applicable to the general case. By inspection of (3.5) it is obvious that $U^T < U^A$ since $\gamma < \overline{\gamma}$ and $\beta < \overline{\beta}$.

Appendix

Section I

Maximize 2.1 subject to 2.7 for the autarchic cases where $x_j = \tilde{x}_j$ and $y_j = \tilde{y}_j$. Under the assumption of symmetry in production the first order condition is

$$p^j = \frac{s}{1 - s} \frac{y_j}{n_j x_j} \qquad \text{for } j = 1, 2. \tag{A1}$$

The first order profit maximization condition for the product diverse sector is found by setting MR equal to MC. Using A1, 2.2 and 2.7 this condition is

$$p^j = \bar{\beta}^j w^j \theta^{-1} \tag{A2}$$

The profit maximizing conditions for competitive firms are found by setting price of inputs equals the value of marginal product. Under CRS these conditions are,

$$w^j L^j_y = (1 - \varepsilon)y^j; \; r^j K^j_y = \varepsilon y^j \qquad j = 1, 2. \tag{A3}$$

where ε is the share of capital out of total costs. For simplicity assume an elasticity of substitution of unity so that ε is constant and equal across countries. By substitution of A1, A2, A3 into 2.8 one can specify n_j as equation 2.1. The reader should note that since variable costs in the x sector involve only labor inputs, the w/r ratio is independent of the production technology in the product diverse sector. By dividing A3 and A4 the w/r is found to be an increasing function of k^j_y. The latter can be written as a function of the economy-wide capital-labor ratio k by using 2.8, 2.11 and A3. The w/r ratio can then be written as

$$w^j/r^j = \frac{1 - z}{z} k^j \qquad \text{where } z = s(1 - \theta) + \varepsilon(1 - s). \tag{A4}$$

Substitute the f.o.c. A1 into A2, and utilizing the plant size equation (2.9) and factor constants (2.8), one can derive (2.11) in the text.

Section II

Factor price equalization has been proved by Lawrence-Spiller (1983) in the absence of ITD. The first order condition of the consumer can be found by maximizing 2.1 subject to the balance of payment restriction (2.7). Given factor price equalization and symmetry in production, this condition is

A5 $$p = \frac{s}{1 - s}\frac{\tilde{y}^j}{m\tilde{x}^j} \qquad j = 1, 2$$

The zero profit Chamberlin equilibrium together with ITD 2.5 [$\gamma(m) = \gamma^j$, $j = 1, 2$] and factor price equalization imply that the (average) worldwide size of plant is,

A6 $$x = (\frac{r}{w})\frac{\gamma(m)}{\beta(m)}\frac{\theta}{1 - \theta}$$

Much like the closed economy case, utilizing A3 and invoking factor price equalization the world w/r is

A7 $$w/r = \frac{1 - z}{z} k \quad \text{where k is the world capital labor ratio.}$$

Substitute A7 into A6 and obtain

A8 $$x = \frac{z\theta}{(1 - z)(1 - \theta)}\frac{\gamma(m)}{\beta(m)}$$

Recalling $\delta = k^j/k$, by substituting 2.9 into A8 and using the definition of z, the term (3.1) in the text is readily derived.

Section III

Under factor price equalization the CRS equilibrium condition A3 can be rewritten as

A9 $$r = f'(k_y);\; w = f(k_y) - k_y f'(k_y)$$

where k_y is the world capital-labor ratio in the y sector. To find the relationship between k_y and k substitute A7 into the ratio of r/w derived from A9. One obtains

A10 $$k_y = \phi k,$$

where ϕ is defined in the text. Using 2.8, A9 and A10 the production function 2.6 can be rewritten as

A12 $$y_j = f(k)\psi^{\varepsilon}[(1 - \varepsilon)(1 - \theta) - \theta\varepsilon/\psi s][1 - \theta - \varepsilon]^{-1}L^j$$

where L^j is the labor stock in country j. To derive n_j substitute A12 and A9 into 2.8 and obtain

A13 $$n_1 = \frac{s(1 - \theta)}{z} \frac{k}{\gamma(m)} Q$$

Compare A13 to 2.11 in the text and derive the specification 3.2. A similar exercise can be carreid out to obtain n_2.

Section IV

Using the first order optimization condition of consumers A5 together with the budget constraint (2.7) one can derive demand functions for $\tilde{y}$ and $\tilde{x}$. By substitution of the f.o.c. A9 and A2 into A5 and utilizing (3.3) in the text one can derive $\tilde{x}^j$ as,

A14 $$\tilde{x}^j = \frac{\gamma 2\theta}{\beta(1 - \varepsilon)(1 - \theta)(1 + a\lambda)}[1 - \varepsilon + \varepsilon(\psi s)^{-1}] \cdot \frac{1}{k}$$

Subtract A14 from 3.1 in the text and after rearrangement obtain,

A15 $$T = xS$$

where S is defined in footnote 8. Substitute (3.1) into A15 and obtain (3.4).

References

Auquier, A. A., and R. E. Caves. "Monopolistic Export Industries, Trade Taxes and Optimal Competition Policy." Economic Journal, 89 (September 1978), pp. 559-581.

Balassa, B. "Tariff Reduction and Trade in Manufacturers among the Industrial Countries." American Economic Review, 56 (June 1966), pp. 466-473.

Behrman, J. R. Foreign Trade Regimes and Economic Development: Chile. New York: Columbia University Press for NBER (Special Conference Series on Foreign Trade Regimes and Economic Development, Vol. 8) (1976).

____________. "The Developing Country Experience with Industry Policies." F. G. Adams and L. R. Klein, eds., Economic Evaluation of Industrial Policies for Growth and Competitiveness. Lexington, Mass.: Lexington-Helath (1982).

Bhagwati, J. Foreign Trade Regimes and Economic Development: Anatomy and Consequences of Exchange Control Regimes. Cambridge, Mass.: Ballinger Publishing Co. (1978).

Bloch, H. "Prices, Costs and Profits in Canadian Manufacturing: The Influence of Tariffs and Concentration." Canadian Journal of Economics, 7 (November 1974), pp. 594-610.

Caves, R. E. "Intraindustry Trade and Market Structure in the Industrial Countries." Oxford Economics Papers, 33 (July 1981), pp. 208-233.

____________. "International Trade and Industrial Organization: Problems, Solved and Unsolved." Special lecture presented at the Xth EARIE Conference, Bergen (1983).

Caves, R. E., M. E. Porter, A. M. Spence, with J. T. Scott. Competition in the Open Economy. Cambridge, Mass.: Harvard University Press (1980).

Diaz-Alejandro, C. Foreign Trade Regimes and Economic Development: Colombia. New York: Columbia University Press for NBER (1976).

Dixit, A. and V. Norman. Theory of International Trade. Cambridge, Mass.: Cambridge University Press (1980).

Ethier, W. J. "International Decreasing Costs and World Trade." Journal of International Economies, IX (1979), pp. 1-24.

____________. "National and International Returns to Scale in the Modern Theory of Trade." American Economic Review, Vol. 90, No. 6 (December 1982), pp. 1142-1165.

Findlay, R. "Relative Backwardness, Direct Foreign Investment and the Transfer of Technology: A Simple Dynamic Model." Quarterly Journal of Economics, Vol. 92 (February 197_), pp. 1-16.

Helpman, E. "International Trade in the Presence of Product Differentiation Economics of Scale and Monopolistic Competition: A Chamberlin-Hecksher-Ohlin Approach." Journal of International Economics, Vol. 11 (1981), pp. 305-340.

____________. "Increasing Returns, Imperfect Markets and Trade Theory." Chapter 7 in the forthcoming Jones, R. W. and P. B. Kenen, eds., Handbook of International Economics (June 1983).

____________. "A Theory of Multinational Corporations and the Structure of Foreign Trade." Harvard University Discussion Paper #961 (January 1983).

Jacquemin, A. E. de Ghellinck, and C. Huveneers. "Concentration and Profitability in a Small Open Economy." Journal of Industrial Economics,

Krueger, A. O. "The Political Economy of the Rent-Seeking Society." American Economic Review, 64, No. 3 (June 1974), pp. 291-303.

____________. Foreign Trade Regimes and Economic Development: Liberalization Attempts and Consequences. Cambridge, Mass.: Ballinger Publishing Co. (1978).

Krugman, P. "Increasing Returns, Monopolistic Competition and International Trade." Journal of International Economics, 9 (1979), pp. 496-579.

Lancaster, K. "Intraindustry Trade Under Perfect Monopolistic Competition and International Trade." Journal of International Economics, X (May 1980), pp. 151-235.

Lawrence, C. and P. T. Spiller. "Product Diversity, Economies of Scale and International Trade." Quarterly Journal of Economics (February 1983).

Leibeinstein, H. General X-Efficiency Theory and Economic Development. New York: Oxford University Press (1978).

Pagoulatos, E. and R. Sorensen. "Foreign Trade, Concentration and Profitability in Open Economics." European Economic Review (1976), pp. 255-267.

Reingaum, J. F. "A Dynamic Game of R&D: Patent Protection and Competi-tive Behavior." Econometrica, Vol. 50, No. 3 (May 1982), pp. 671-688.

Rodriguez, C. A. "Trade in Technical Knowledge and the National Advantage." Journal of Political Economy, Vol. 83, No. 1 (February 1975), pp. 121-135.

Scherer, F. M. Industrial Market Structure and Economic Performance. Chicago: Rand McNally (1980).

Teubal, M. "Toward a Neotechnology Theory of Comparative Costs." Quarterly Journal of Economics, Vol. 89 (August 1975), pp. 414-437.

Tharakian, P. K. M., L. G. Soete, and J. A. Busschaer. "Hecksher-Ohlin and Chamberlin Determinants of Comparative Advantage." European Economic Review, 11 (1978), pp. 221-239.

Vernon, R. "International Investment and International Trade in the Product Cycle." Quarterly Journal of Economics, Vol. 80 (May 1966), pp. 190-207.