

Differentiated Products, International Trade and Simple General Equilibrium Effects*

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Abstract

Using a simple general equilibrium model with two countries and two sectors including one manufacturing sector producing (vertically) differentiated products, we first show that an international barrier to trade in the manufacturing sector creates *inter-industry* trade, whereas an international barrier to trade in the other sector generates *intra-industry* trade among vertically differentiated products. We generalize the model to arbitrary (but feasible) symmetric levels of barriers to trade in both sectors and investigate its implications for trade liberalization. In particular, the empirically observed increase in intra-industry trade in vertically differentiated products is shown to be consistent with general equilibrium effects associated with deeper trade liberalization in the manufacturing sector than in the non-manufacturing sector.

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1. Introduction

Several papers (see for instance Abd-el-Rahman, 1991; Aturupane et al. 1999; Greenaway, Hine and Milner, 1995; Fontagné, Freudenberg and Gaulier, 2006; Greenaway, Milner and Elliott, 1999; Blanes and Martin, 2000; Gullstrand, 2002) have shown that the share of intra-industry trade in vertically differentiated products is very high (40% in the EU) and that this share has increased significantly at the expense of both one-way trade and intra-industry trade in horizontally differentiated products. This phenomenon has first been described for trade among EU members but has also been found for pairs of countries outside the EU. Although the methodology used to separate trade in vertically and horizontally differentiated products is ad hoc, this is still a surprising result as most models would predict that, when similar countries liberalize their trade, prices converge and the share of intra-industry trade increases at the expense of one-way trade. This paper proposes a model with a straightforward explanation for these empirical observations: they are due to general equilibrium effects associated with deeper trade liberalization in the differentiated product sector than in the homogeneous product sector.

The literature on intra-industry trade has focused most of its attention on imperfect competition whether with monopolistic competition or oligopoly. In the case of vertically differentiated products, most papers are cast in an oligopolistic environment (see for instance Gabszewicz and Thisse, 1980; Shaked and Sutton, 1983). This literature is useful insofar as strategic considerations among firms are believed to play an important role including for the determination of product characteristics. If this literature suggests that trade liberalization tends to increase the extent of differentiation among products (Schmitt, 1995; Boccard and Wauthy, 2006), prices generally still converge with lower barriers to trade. More importantly, these models are ill equipped to address the broad shifts uncovered by these empirical studies as they seem to hold for a wide range of sectors.

An alternative approach is the one proposed by Falvey and Kierzkowski (1987) and Flam and Helpman (1987). They set their analysis in a general equilibrium model with two perfectly competitive sectors, one producing a homogeneous product and the other one producing a continuum of quality products. Cast in a two-country environment, Flam and Helpman (1987) look at North-South trade in the presence of technical progress or population growth, whereas Falvey and Kierzkowski (1987) show that imperfect competition

and economies of scale are not needed to generate intra-industry trade. They show that conventional forces such as differences in technology and in factor endowments between two countries are consistent with intra-industry trade provided this trade is in vertically differentiated products.

In this paper, we adopt a formulation similar to Falvey and Kierzkowski (1987). However, whereas they look at the pattern of trade in a world without barriers to trade, we investigate how transport costs and trade policies determine not only the pattern of trade but also the composition of trade between two countries.¹ In particular, we build a simple general equilibrium model in which the *intra*-industry trade pattern in quality products is indeterminate in the absence of any friction between the two countries (there is no difference in technology between the two countries) even though the *inter*-industry trade pattern is well defined (there is a difference in factor endowment and/or country size). We then introduce international barrier to trade in each sector to show that well-defined patterns of trade in quality good emerge. In particular, we show that, depending on the importance of the sector-specific transport cost, one can generate inter-industry trade only (there is no intra-industry trade in quality goods), generate intra-industry trade only (there is no trade in the homogeneous product), or a mixture of both types of trade. This allows us to look at the effect of trade liberalization on the composition and on the pattern of trade. We find that, when the homogeneous product sector receives some protection, trade liberalization in the vertically differentiated products increases intra-industry trade at the expense of inter-industry trade. We further show that such trade liberalization is consistent with diverging average prices of exports and imports, at least if the trading countries are not too similar. Essentially, a barrier to trade in non-manufacturing not only decreases trade between the two countries but also increases the price of the factor used in both sectors (labor) in the capital-abundant country. This generates intra-industry trade in vertically differentiated products as the capital-abundant country still exports quality products but prefers importing quality products using relatively more labor. Hence, the recent observed increase in intra-industry trade of vertically differentiated products may be attributed to the general equilibrium implications of asymmetric trade liberalization between the two sectors.²

¹ Falvey (1981) looks at the effect of commercial policies in a similar model. Intra-industry trade however is imposed at the outset through international differences in labor productivity.

² Hence, the pattern and the composition of trade rely exclusively on traditional forces (endowments, country size, barriers to trade), not on imperfect competition and economies of scale. Some restricts intra-industry trade to international exchange of similar products using the same mix of factors of production (Brander, 1987; Davis, 1995). The recent literature has become considerably more agnostic about this issue.

The paper is organized as follows. In the next section, the model is proposed and the free-trade equilibrium is derived. In Section 3, we consider separately the effects of an international barrier to trade in the manufacturing sector and in the agricultural sector. In Section 4, we characterize the pattern and the composition of trade for arbitrary (but feasible) levels of barriers to trade. This allows to trace in Section 5 the effects of trade liberalization on the pattern and the composition of trade. Section 6 concludes.

2. Model

In this Section, we develop the basic model, based on Mussa and Rosen (1978), and provide an intuitive explanation of the main forces at work.

Consider two countries, Country H and Country F where each of them has two sectors of production, Manufacturing (M) and Non-manufacturing (N).³ Both sectors are perfectly competitive. Production in N uses labor only according to

$$N_i = \frac{L_i^N}{a_i}, \quad i = H, F, \quad (1)$$

where L_i^N is the total number of units of labor used in N, and a_i is the number of units of labor required to produce one unit of N in Country i .

Production of the manufacturing good requires both labor and capital. The cost of producing one unit of the quality good is

$$c_i(q) = w_i + r_i m_i(q). \quad (2)$$

where $m_i(q)$ is the number of units of capital necessary to produce one unit of the good with quality q . Thus, one unit of the good with quality q necessitates one unit of labor and $m_i(q)$ units of capital. We assume that $m_i(q)$ is a continuous and strictly convex function of q ($m_i' > 0$, $m_i'' > 0$). Also, $m_i(0) > 0$ so that some units of capital are also needed at the 'zero' quality level. Since the technology to produce a quality good exhibits perfect

³ Sector N could be agriculture, service or even basic manufacturing. We think of M as being high manufacturing where quality matters most.

complementarity between capital and labor, the production function in Country i for a good with quality q is

$$Q_i(q) = \text{Min}\left[l_i^Q, \frac{k_i^Q}{m_i(q)}\right], \quad (3)$$

where $l_i^Q(k_i^Q)$ is the minimum number of units of labor (capital) necessary to produce Q_i units of the product i having quality q .

On the demand side, we assume that consumers value differently their marginal utility of quality. A consumer's (indirect) utility is given by

$$\begin{aligned} U &= v(q) + y \\ &= \theta q - p(q) + y, \end{aligned} \quad (4)$$

where θ is the marginal utility of quality assumed to be uniformly distributed over $[0, \bar{\theta}]$ with D_i ($i = H, F$) consumers at every point, $p(q)$ is the price of the quality good bought by the consumer, and y represents total spending on good N. It is apparent from (4) that each consumer is assumed to buy a single unit of the quality product.

For the time being, simply assume that $\frac{K_H}{D_H} \leq \frac{K_F}{D_F}$; that is, Country F is a relatively capital abundant country, not with respect to labor, but with respect to the *potential* number of consumers of quality products. We adopt this formulation because labor has no influence on the pattern of trade in this model. Whoever is not employed in the manufacturing sector is employed in the non-manufacturing sector at a constant marginal productivity and non-manufacturing does not use any capital. Non-manufacturing acts then simply as a residual sector.

The model has two types of gains from trade. The first one is the standard gain from comparative advantage between the two countries. The second one is a gain in product diversity. Since tastes differ, consumers are on average better off when they can consume a wider range of qualities and when, given θ , they can consume products with a higher quality. We now consider the free-trade equilibrium when there is no other difference between the two countries other than the difference in K_i and D_i .

2.1. Free-Trade with Identical Technologies

Suppose that labor productivity and the technology to produce quality goods are the same in both countries. Hence, $m_H(q) = m_F(q)$ and, without loss of generality, assume that $a_H = a_F = 1$. We also treat N as the numéraire product so that $p_N = 1$. The model is now a Heckscher-Ohlin trade model.

With perfect competition in the production of the quality goods, $p(q) = c(q)$, so that the indirect utility function (4) can be rewritten as

$$U = \theta q - w - rm(q) + y. \quad (5)$$

A consumer with marginal utility of quality θ selects the differentiated product satisfying

$$\begin{aligned} \theta &= c'(q) \\ &= rm'(q), \end{aligned} \quad (6)$$

or,

$$q = \gamma\left(\frac{\theta}{r}\right), \quad (7)$$

where the function γ corresponds to $(m')^{-1}$. Assuming that buying a quality product brings non-negative utility, we require

$$v(q) = \theta q - w - rm(q) \geq 0. \quad (8)$$

The consumer buying the lowest product quality \hat{q} has also the lowest marginal utility for quality ($\hat{\theta}$). For $\hat{\theta} > 0$, this lowest quality is determined by $v(\hat{q}) = rm'(\hat{q})\hat{q} - w - rm(\hat{q}) = 0$ where $\hat{q} = \gamma(\frac{\hat{\theta}}{r})$. The highest product quality offered is such that $\bar{q} = \gamma(\frac{\bar{\theta}}{r})$. Hence, we can define the set of equilibrium product qualities as $\Omega \in [\hat{q}, \bar{q}]$.

Figure 1 illustrates the range of qualities supplied by each country in free trade. The marginal cost curve, $c(q)$, is drawn for given w and r and it is the same for both countries. The consumer who is indifferent between buying and not buying a quality product is found at the tangency between the (linear) indifference curve $v(\hat{q}) = 0$ and $c(q)$ while the consumer buying the highest product quality is found at the tangency between the indifference curve (with slope $\bar{\theta}$) and $c(q)$. Any product quality between these two limits is consumed in both

countries. Note that $v(q)$ can be read along the vertical axis since, for $q = 0$, (8) can be written as $p = -v(q)$.

[Insert Figure 1 about here]

To characterize the free-trade equilibrium, two additional elements are needed: the factor prices and the balance of trade condition. When both countries are incompletely specialized, free trade equalizes factor prices across countries. Denoting by w and r the free-trade price of labor and capital, respectively, w is necessarily equal to one since $a_H = a_F = 1$ and $p_N = 1$. The international price of capital is such that demand is equal to the supply of capital when evaluated at the same price r :

$$K_H + K_F = \int_{\hat{\theta}_H}^{\bar{\theta}} D_H m[\gamma(\frac{\theta}{r})] d\theta + \int_{\hat{\theta}_F}^{\bar{\theta}} D_F m[\gamma(\frac{\theta}{r})] d\theta, \quad (9)$$

where D_i is the density of consumers in Country i ($i = H, F$), $\hat{\theta}_i$ satisfies $\hat{\theta}_i \gamma(\hat{\theta}_i/r) - w - r m[\gamma(\hat{\theta}_i/r)] = 0$ and $\bar{\theta}$ is the upper bound of θ . Note that, given our assumptions, $\hat{\theta}_H = \hat{\theta}_F = \hat{\theta}$. The demand for capital is downward sloping since, given θ_i , an increase in r decreases product quality (i.e., $\partial q/\partial r < 0$ in (7)) and thus the demand for capital necessary to produce one unit of the quality good.

What about the balance of trade? If $D_H = D_F$, the total number of consumers is exactly the same in both countries so that the capital content of total consumption is also the same in both countries. Since Country F has relatively more units of capital, trade can be balanced only if, through trade in goods, Country F is a net exporter of capital and Country H is a net exporter of labor. This implies that Country F must be a net exporter of quality products and Country H be an exporter of product N. If intra-industry trade in quality products is possible, the free-trade pattern of intra-industry trade is indeterminate.⁴

If Country H has more consumers than Country F ($D_H > D_F$), the overall pattern of trade is the same as when $D_H = D_F$ since, *a fortiori*, Country F must export quality goods to satisfy the demand in H. It is only when $D_H < D_F$ that trade may be eliminated or that the overall pattern of trade may be reversed since Country H could become a capital abundant country relative to the number of consumers of quality goods. In other words, in

⁴ This is why (9) is expressed as the equality between the international demand and supply of capital, and not as the equality between the national supply and demand of capital.

the absence of barriers to trade, the pattern of inter-industry trade is such that Country F is a net exporter of quality products whenever

$$\frac{K_F}{D_F[\bar{\theta} - \hat{\theta}_F]} > \frac{K_H}{D_H[\bar{\theta} - \hat{\theta}_H]}, \quad (10)$$

where $D_i(\bar{\theta} - \hat{\theta}_i)$ represents the *effective* number of consumers of quality products in Country i . Since each consumer buys only one unit of the quality product, only their number matters. And since labor plays no role, the only determinant of the inter-industry pattern of trade is the relative comparison of the size of the supply of capital with respect to the size of the demand for quality products.

3. Barriers to Trade in One Sector

We now show that trade frictions not only determine the pattern and the composition of trade between the two countries but, more importantly, that they have quite different effects depending on whether the barrier to trade affects the non-manufacturing or the manufacturing sector only. To show this, we introduce a specific trade friction t_N or t_M affecting trade in the non-manufacturing or the manufacturing sector. We assume this barrier to trade is an international transport cost but we could easily adapt the model so as to be a specific tariff. We also assume that, in a given sector, the barrier to trade is the same in both directions.⁵

3.1. Barrier to Trade in Manufacturing

The impact effect of introducing a barrier to trade in the manufacturing sector of both countries is to increase the price of imported quality goods by t_M in both countries. In terms of Figure 1, this implies there are now two relevant curves for each country, vertically separated by t_M : one capturing quality goods produced and consumed domestically and the other capturing quality goods as faced by foreign consumers. Clearly, since imported products are, on impact, more expensive than domestic variants, consumers in both countries buy domestic variants only. Recall from the free-trade equilibrium that Country H is a

⁵ We could also interpret t_M as the implicit protection associated with different national standards and lower t_M with trade liberalization induced by mutual recognition of standards such as in the EU.

net importer of quality products. Since capital is fully employed in both countries, the complete substitution to domestic quality products implies that the price of capital must increase in Country H (on impact, there is an excess demand for capital in this country) and falls in Country F (there is an excess supply of capital in this country). This has one key consequence: in the trade equilibrium with positive t_M , Country F does not buy any quality good from Country H. In effect, the combination of a positive t_M and a higher price of capital relative to Country F's make Country H's entire range of quality goods more expensive than any domestic quality product in Country F.⁶ Hence, if there is an international trade equilibrium in the presence of positive t_M , it cannot exhibit intra-industry trade.

It is now easy to determine the pattern of trade. Recall that t_M increases $c(q)$ equally irrespective of q ($c(q)$ shifts vertically by t_M) whereas an increase in the price of capital increases relatively more the high- than the low-quality products as the former goods require more units of capital. Since only Country H's consumers can possibly buy Country F's products, we need to compare $c_F(q) + t_M$ and $c_H(q)$. Three possibilities exist: $c_F(q) + t_M < c_H(q)$ for all q , $c_F(q) + t_M > c_H(q)$ for all q , or $c_F(q) + t_M < c_H(q)$ for high q only. The first inequality is inconsistent with an equilibrium as K_H would be completely unemployed. The second inequality is also inconsistent with a trade equilibrium since it implies that Country H does not import any product from Country F violating its balance of trade. Only the third possibility is consistent with an international equilibrium. It is illustrated in Figure 2. Consumers in Country F buy only domestic quality products since its price of capital is necessarily lower than in Country H. Consumers in Country H, however, buy low quality products from domestic producers and import high quality products from Country F in exchange for product N. They prefer high quality products from Country F because the lower price of capital there makes them cheaper than in Country H.

[Insert Figure 2 about here]

Result 1 then follows:

Result 1: *If a specific barrier to trade distorts trade in quality products, inter-industry trade is the only pattern of trade. Moreover, the relatively capital-abundant country (F) exports high-quality products to the relatively consumer-abundant country (H) in exchange for the homogeneous product.*

⁶ Note that the price of labor remains equal to one in both countries.

In Figure 2, the range of domestic qualities consumed in Country F is given by $[\hat{q}_F, \bar{q}]$. Country H's consumers buy domestic quality products over the range $[\hat{q}_H, \tilde{q}_H]$ and they buy foreign quality products over the range $[\tilde{q}'_H, \bar{q}]$. Since, for Country H, the net value of these imports is equal to the area below c_F over the range $[\tilde{q}'_H, \bar{q}]$, it must also correspond to the value of exports of non-manufacturing products.

Result 1 is different from Falvey (1981) who considers the effect of protection in the quality product sector *given* the existence of intra-industry trade in this sector. This is achieved by assuming different technologies to produce the quality goods in the two countries. In the present model, technologies are identical between the two countries and Result 1 shows that trade frictions in the quality sector cannot, by itself, generate intra-industry trade.

3.2. Barrier to Trade in Non-Manufacturing

Consider now the effect of a barrier to trade t_N in the non-manufacturing sector of both countries. Since, in free trade, Country F imports N, t_N increases the price of imports of agricultural products in this country to $1 + t_N$. Since N requires labor only, the domestic price of N in F is equal to w_F so that there is no import of this product in F if $w_F < 1 + t_N$. Suppose it is the case (i.e., t_N is high enough). Clearly, a trade equilibrium, if it exists, must exhibit intra-industry trade in vertically differentiated products.

What is then the pattern of trade? Like in the previous case, there are three candidates: $c_H(q) < c_F(q)$ for all q , $c_H(q) > c_F(q)$ for all q , or $c_H(q) < c_F(q)$ for some range of quality. The two first cases are inconsistent with an intra-industry trade equilibrium (Country H, respectively Country F, would not buy foreign variants). Not surprisingly, intra-industry trade is possible only when $c_H(q) < c_F(q)$ for part of the quality range. While the price of labor has no reason to change in Country H (it is equal to the price of the numéraire), w_F increases in Country F as there is no longer any import of non-manufacturing products in this country. This increases the cost of production and the price of quality products in Country F inducing consumers in both countries to substitute away from quality goods produced in Country F into quality goods produced in Country H. Since there is a direct link between the change in the demands for products and for capital, these changes must be accompanied by an increase in r_H and a fall in r_F . These changes in factor prices occur so as to satisfy both the balance of trade condition and the equality between the demand and

supply of capital in both countries. Since the changes in r affects more the high than the low quality products, $c_H(q) < c_F(q)$ for low product qualities while the converse holds for high product qualities. Result 2 summarizes the discussion:

Result 2: *When t_N is high enough, the only international trade equilibrium exhibits intra-industry trade. Since $\frac{K_F}{D_F[\bar{\theta}-\hat{\theta}_F]} > \frac{K_H}{D_H[\bar{\theta}-\hat{\theta}_H]}$, Country F specializes in high quality products and Country H specializes in low quality products.*

Figure 3 illustrates this case. Consumers in both countries consume the same range of qualities ($[\hat{q}_i, \tilde{q}_i]$ and $[\tilde{q}'_i, \bar{q}_i]$) since there is no barrier to trade in the manufacturing sector, but Country F produces and exports the upper range of product qualities, while Country H produces and exports the lower range. When the number of potential consumers is the same in both countries, the value of trade is proportional to the area below each curve so that, for trade to be balanced, the range of quality produced in F must be smaller than in H.

[Insert Figure 3 about here]

The model has simple and clear-cut predictions about the composition of trade since a positive barrier to trade in the manufacturing sector generates inter-industry trade only, while a high enough barrier to trade in non-manufacturing generates intra-industry trade only. One can already anticipate an important result of this paper. If trade liberalization occurs in the manufacturing but not in non-manufacturing, intra-industry trade in vertically differentiated products is being created. We now characterize all the trade equilibria for arbitrary but feasible values of t_M and t_N so as to be better able to trace the effects of trade liberalization on the composition and the pattern of trade.

4. Characterization of the Trade Equilibria

For the remainder of the paper, we assume that

$$m(q) = e^{\alpha q}, \tag{11}$$

where $\alpha > 0$ is a parameter determining the slope of the function. With such a function, identical for both countries, utility maximization requires (see (7))

$$\theta = r_i \alpha e^{\alpha q}, \tag{12}$$

where we now allow r to be different between countries. Hence,

$$q = \ln \left(\frac{\theta}{\alpha r_i} \right)^{\frac{1}{\alpha}}, \quad i = H, F. \quad (13)$$

Assuming that $t_N \geq 0$ and $t_M \geq 0$, we now characterize all the possible trade equilibria between the two countries. We have already described two of them: one exhibiting inter-industry trade only and the other having intra-industry trade only. The third (and general) case has both types of trade. We consider separately each of them.

4.1. Inter-Industry Trade Equilibrium

The trade equilibrium with inter-industry trade is characterized by Country F exporting quality products and importing the homogeneous products from Country H. For this to occur, $w_H = 1$ and $w_F = 1 + t_N$. Country H's consumers who are indifferent between imported product quality \tilde{q}'_H and domestic product quality \tilde{q}_H has a willingness to pay for quality $\tilde{\theta}_H$ (see Figure 2). It is determined by $v(\tilde{q}_H) = v(\tilde{q}'_H)$ and thus by

$$\tilde{\theta}_H \tilde{q}_H - (1 + r_H e^{\alpha \tilde{q}_H}) = \tilde{\theta}_H \tilde{q}'_H - (1 + t_N + t_M + r_F e^{\alpha \tilde{q}'_H}). \quad (14)$$

Since utility maximization implies $\tilde{q}_H = \ln \left(\frac{\tilde{\theta}_H}{\alpha r_H} \right)^{\frac{1}{\alpha}}$ and $\tilde{q}'_H = \ln \left(\frac{\tilde{\theta}_H}{\alpha r_F} \right)^{\frac{1}{\alpha}}$, then (14) becomes

$$\tilde{\theta}_H = \frac{\alpha(t_N + t_M)}{\ln r}, \quad (15)$$

where $r = \frac{r_H}{r_F}$. The minimum quality consumed in Country i , \hat{q}_i , corresponds to $v(\hat{q}_i) = 0$ and so to $\hat{\theta}_i \hat{q}_i - (w_i + r_i e^{\alpha \hat{q}_i}) = 0$. Since $\hat{q}_i = \ln \left(\frac{\hat{\theta}_i}{\alpha r_i} \right)^{\frac{1}{\alpha}}$ then $\hat{\theta}_i$ satisfies

$$\hat{\theta}_i \ln \left(\frac{\hat{\theta}_i}{\alpha r_i} \right)^{\frac{1}{\alpha}} - w_i - \frac{\hat{\theta}_i}{\alpha} = 0, \quad i = H, F. \quad (16)$$

The maximum quality consumed is the same for consumers of both countries; it is given by $\bar{q} = \ln \left(\frac{\bar{\theta}}{\alpha r_F} \right)^{\frac{1}{\alpha}}$.

With inter-industry trade, it is easy to find the equilibrium price of capital in each country. Since capital in Country H is entirely used in products consumed domestically, r_H is determined by

$$K_H = \int_{\hat{\theta}_H}^{\tilde{\theta}_H} D_H e^{\alpha q(\theta)} d\theta = \int_{\hat{\theta}_H}^{\tilde{\theta}_H} D_H \frac{\theta}{r_H} d\theta = \frac{D_H}{2\alpha r_H} (\tilde{\theta}_H^2 - \hat{\theta}_H^2), \quad (17)$$

where $\tilde{\theta}_H$ is given by (15) and $\hat{\theta}_H$ by (16). In Country F, capital is used in products consumed domestically and exported so that r_F is determined by

$$K_F = \int_{\hat{\theta}_H}^{\bar{\theta}} D_H e^{\alpha q(\theta)} d\theta + \int_{\hat{\theta}_F}^{\bar{\theta}} D_F e^{\alpha q(\theta)} d\theta = \frac{1}{2\alpha r_F} [D_H(\bar{\theta}^2 - \tilde{\theta}_H^2) + D_F(\bar{\theta}^2 - \hat{\theta}_F^2)], \quad (18)$$

where $\tilde{\theta}_H$ is given by (15) and $\hat{\theta}_F$ is given by (16).

The balance of trade requires that the value of trade be equalized. Since t_N and t_M represent international transport costs, we assume that one country, Country H, transports the products between the two countries. This implies that for Country H the balance of trade condition is

$$\int_{\tilde{\theta}_H}^{\bar{\theta}} D_H (w_F + r_F e^{\alpha q(\theta)}) d\theta - N_t (1 + t_N) = 0. \quad (19)$$

The first term represents the value of the quality products imported by Country H and the second term represents the value of the non-manufacturing products exported by Country H, including the transport cost paid by Country F. Since $w_F = 1 + t_N$, then, after integration,

$$N_t = D_H (\bar{\theta} - \tilde{\theta}_H) \left[1 + \frac{\bar{\theta} + \tilde{\theta}_H}{2\alpha(1 + t_N)} \right]. \quad (20)$$

The equilibrium with inter-industry trade only is fully determined by equations (15), (16) for $i = H, F$, (17), (18) and (20). These six equations solve for $\tilde{\theta}_H$, $\hat{\theta}_H$, $\hat{\theta}_F$, r_H , r_F and N_t given t_N , t_M , $w_H = 1$, K_H , K_F , D_H , D_F and α .

4.2. Intra-Industry Trade Equilibrium

Consider now the equilibrium with intra-industry trade only. Figure 4 illustrates a more general case than Figure 3 since t_N and t_M are both positive. For this equilibrium to hold, $w_F < 1 + t_N$ since Country F's production of non-manufacturing goods should be cheaper than imports.

[Insert Figure 4 about here]

Like for the previous equilibrium, we determine first the willingness to pay of the consumers who are indifferent between domestic and foreign products. In Country H, they have a willingness to pay $\tilde{\theta}_H$ determined by $v(\tilde{q}_H) = v(\tilde{q}'_H)$ and thus by $\tilde{\theta}_H \tilde{q}_H - (1 + r_H e^{\alpha q(\tilde{\theta}_H)}) = \tilde{\theta}_H \tilde{q}'_H - (w_F + t_M + r_F e^{\alpha q(\tilde{\theta}_H)})$. Solving for $\tilde{\theta}_H$,

$$\tilde{\theta}_H = \frac{\alpha(w_F + t_M - 1)}{\ln r}. \quad (21)$$

Similarly, Country F's indifferent consumer satisfies $v(\tilde{q}_F) = v(\tilde{q}'_F)$ and thus $\tilde{\theta}_F \tilde{q}_F - (1 + t_M + r_H e^{\alpha q(\tilde{\theta}_F)}) = \tilde{\theta}_F \tilde{q}'_F - (w_F + r_F e^{\alpha q(\tilde{\theta}_F)})$. Solving for $\tilde{\theta}_F$,

$$\tilde{\theta}_F = \frac{\alpha(w_F - t_M - 1)}{\ln r}. \quad (22)$$

The consumer in Country i indifferent between buying and not buying a quality product satisfies $v(q(\hat{\theta}_i)) = 0$. Since the lowest quality corresponds to a domestic (respectively, a foreign) product for Country H's (respectively, Country F's) consumer, $\hat{\theta}_i$ ($i = H, F$) satisfies respectively,

$$\hat{\theta}_H \ln \left(\frac{\hat{\theta}_H}{\alpha r_H} \right)^{\frac{1}{\alpha}} - 1 - \frac{\hat{\theta}_H}{\alpha} = 0, \quad (23)$$

and

$$\hat{\theta}_F \ln \left(\frac{\hat{\theta}_F}{\alpha r_H} \right)^{\frac{1}{\alpha}} - 1 - t_M - \frac{\hat{\theta}_F}{\alpha} = 0. \quad (24)$$

With intra-industry trade, the stock of capital in each country is used for domestic consumption and exports of quality products. The rental price of capital r_H , respectively r_F , is determined by

$$\begin{aligned} K_H &= \int_{\hat{\theta}_H}^{\tilde{\theta}_H} D_H e^{\alpha q(\theta)} d\theta + \int_{\hat{\theta}_F}^{\tilde{\theta}_F} D_F e^{\alpha q(\theta)} d\theta = \frac{1}{2\alpha r_H} [D_H(\tilde{\theta}_H^2 - \hat{\theta}_H^2) + D_F(\tilde{\theta}_F^2 - \hat{\theta}_F^2)]; \\ K_F &= \int_{\tilde{\theta}_H}^{\bar{\theta}} D_H e^{\alpha q(\theta)} d\theta + \int_{\tilde{\theta}_F}^{\bar{\theta}} D_F e^{\alpha q(\theta)} d\theta = \frac{1}{2\alpha r_F} [D_H(\bar{\theta}^2 - \tilde{\theta}_H^2) + D_F(\bar{\theta}^2 - \tilde{\theta}_F^2)]. \end{aligned} \quad (25)$$

For trade to be balanced with intra-industry trade, the value of exports in quality products must be equal to the value of imports in quality products. Thus, from Country H's point of view,

$$\int_{\tilde{\theta}_H}^{\bar{\theta}} D_H (w_F + r_F e^{\alpha q(\theta)}) d\theta - \int_{\hat{\theta}_F}^{\tilde{\theta}_F} D_F (1 + t_M + r_H e^{\alpha q(\theta)}) d\theta = 0. \quad (26)$$

The above condition can be interpreted as determining w_F (recall $w_H = 1$) given the values of the other variables since w_F must be high enough to make sure that the foreign demand for Country F's high-quality products is low enough for its value to be equal to that of the trade in low quality products. Rearranging (26),

$$w_F = \frac{D_F}{D_H(\bar{\theta} - \tilde{\theta}_H)} \left[(1 + t_M)(\tilde{\theta}_F - \hat{\theta}_F) + \frac{1}{2\alpha}(\tilde{\theta}_F^2 - \hat{\theta}_F^2) \right] - \frac{1}{2\alpha}(\bar{\theta} + \tilde{\theta}_H) \quad (27)$$

Equations (21), (22), (23), (24), (25) and (27) determine the equilibrium with intra-industry trade only since they determine $\tilde{\theta}_H$, $\tilde{\theta}_F$, $\hat{\theta}_H$, $\hat{\theta}_F$, r_H , r_F and w_F for given values of t_N , t_M , $w_H = 1$, K_H , K_F , D_H , D_F and α .

4.3. Trade Equilibrium with Both Regimes

The last possible equilibrium has both inter- and intra-industry trade and is thus a combination of the two previous equilibria. Since there is trade in non-manufacturing products, necessarily, $w_H = 1 + t_N$. It is then easy to derive the willingness to pay for consumers indifferent between buying domestic and foreign products. Indeed, in (21) and (22), just substitute w_F by $1 + t_N$. Hence,

$$\tilde{\theta}_H = \frac{\alpha(t_N + t_M)}{\ln r} \quad \text{and} \quad \tilde{\theta}_F = \frac{\alpha(t_N - t_M)}{\ln r}. \quad (28)$$

The consumers buying the lowest product qualities are still captured by (23) and (24) since, in equilibrium, consumers from both countries buy these products from Country H.

Interest rates in each country can then be determined by equating supply and demand of capital in each country. Since capital is used to produce quality goods only, (25) still determines r_H and r_F . The balance of trade, however, is different than in the two previous cases since, with both inter- and intra-industry trade, it is

$$\int_{\tilde{\theta}_H}^{\bar{\theta}} D_H(w_F + r_F e^{\alpha q(\theta)}) d\theta - \int_{\hat{\theta}_F}^{\tilde{\theta}_F} D_F(w_H + t_M + r_H e^{\alpha q(\theta)}) d\theta - N_t(1 + t_N) = 0. \quad (29)$$

The first term represents the value of Country F's exports while the two last terms represent the value of Country F's imports of quality products, non-manufacturing products and transportation. Since $w_F = 1 + t_N$ and $w_H = 1$, then after integration,

$$N_t = \frac{1}{1 + t_N} \left\{ D_H[(1 + t_N)(\bar{\theta} - \tilde{\theta}_H) + \frac{1}{2\alpha}(\bar{\theta}^2 - \tilde{\theta}_H^2)] - D_F[(1 + t_M)(\tilde{\theta}_F - \hat{\theta}_F) + \frac{1}{2\alpha}(\tilde{\theta}_F^2 - \hat{\theta}_F^2)] \right\}. \quad (30)$$

The equilibrium is determined by (23), (24), (25), (28) and (30). That is, the endogenous variables are $\hat{\theta}_H$, $\hat{\theta}_F$, $\tilde{\theta}_H$, $\tilde{\theta}_F$, r_H , r_F and N_t .

The three equilibria can be illustrated in (t_M, t_N) space.

[Insert Figure 5 about here]

The space is divided in four regions:⁷ there is no trade when both t_N and t_M are sufficiently high (region IV). When t_N and t_M are both low enough for trade to exist, there is inter-industry only (region I). This is the Heckscher-Ohlin region where the trade barriers, particularly t_N is not high enough to distort each country's comparative advantage. In region II, intra-industry trade emerges alongside inter-industry trade: t_N is now high enough to make wages in Country F, and thus the price of quality products in this country, high enough for consumers to import some quality products from Country H. Since $r_H > r_F$, they do so only for low quality products. In region III, t_N is too high to sustain trade in non-manufacturing products so that a trade equilibrium is consistent only with intra-industry trade. Two additional points are worth noting. First, t_N^p and t_M^p are the lowest prohibitive barriers to trade in each sector. Second, consistent with our analysis of Section 2, complete free trade exhibits only inter-industry trade.

⁷ See Appendix 1 for a precise characterization of the frontiers between each region.

5. Trade Liberalization

There are obviously many possible paths for trade liberalization. But if t_M decreases more than t_N , it is likely that, along such a path, intra-industry trade will emerge if it does not already exist, and increase in importance if it already exists. In order to capture the importance of intra-industry trade, the Grubel-Lloyd index is an obvious measure. Since there is only one sector with differentiated products, the index is simply

$$IIT \equiv 1 - \frac{|X_q - M_q|}{X_q + M_q}, \quad (31)$$

where X_q , respectively M_q , is the value of exports, respectively imports, in quality products for one of the two countries. In general, $0 \leq IIT \leq 1$ with $IIT = 0$ corresponding to inter-industry trade only and $IIT = 1$ to intra-industry only. Thus, in Figure 5, IIT is equal to zero in Region I, between zero and one in Region II and equal to one in Region III. Since the only ambiguity is the value of IIT in Region II, X_q and M_q for Country H in Region II are:

$$\begin{aligned} X_q &= \int_{\hat{\theta}_F}^{\tilde{\theta}_F} D_F(w_H + t_M + r_H e^{\alpha q(\theta)}) d\theta = D_F[(1 + t_M)(\tilde{\theta}_F - \hat{\theta}_F) + \frac{1}{2\alpha}(\tilde{\theta}_F^2 - \hat{\theta}_F^2)]; \\ M_q &= \int_{\tilde{\theta}_H}^{\bar{\theta}} D_H(w_F + r_F e^{\alpha q(\theta)}) d\theta = D_H[w_F(\bar{\theta} - \tilde{\theta}_H) + \frac{1}{2\alpha}(\bar{\theta}^2 - \tilde{\theta}_H^2)]. \end{aligned} \quad (32)$$

We are also interested in the terms of trade in the quality products in order to evaluate whether intra-industry trade becomes more similar or more dissimilar when its volume increase. The terms of trade is found by computing the ratio of the average prices of export and import in quality products for one of the two countries. For Country H, the country transporting the products,

$$P \equiv \frac{\bar{p}_x}{\bar{p}_m} = \frac{\frac{\int_{\hat{\theta}_F}^{\tilde{\theta}_F} D_F(1+t_M+r_H e^{\alpha q(\theta)}) d\theta}{D_F(\tilde{\theta}_F - \hat{\theta}_F)}}{\frac{\int_{\tilde{\theta}_H}^{\bar{\theta}} D_H(w_F+r_F e^{\alpha q(\theta)}) d\theta}{D_H(\bar{\theta} - \tilde{\theta}_H)}} = \frac{2\alpha(1 + t_M) + \tilde{\theta}_F + \hat{\theta}_F}{2\alpha w_F + \bar{\theta} + \tilde{\theta}_H}. \quad (33)$$

P exists only when there is intra-industry trade ($IIT > 0$) and thus in Regions II and III of Figure 5. It should be clear that, for H, $P < 1$ as Country H exports low quality products and imports high quality products (indeed, $\tilde{\theta}_F < \tilde{\theta}_H$ (see Figure 4) and $\hat{\theta}_F < \bar{\theta}$). A decrease

in t_M has a direct effect which decreases P further below one but has a number of indirect effects through the changes in w_F , $\tilde{\theta}_H$, $\tilde{\theta}_F$ and $\hat{\theta}_F$.

The model of Section 4 contains non-linearities making the comparative static exercises difficult without simulations. Accordingly, Tables 1 to 4 give the Grubel-Lloyd Index (IIT) and $P = \frac{\bar{p}_x}{\bar{p}_m}$ in Regions II and III for a variety of parameters.

We concentrate our attention on one issue: how are P and IIT changing with lower t_m ? Changes in P are associated with the changes in average quality in the trade of differentiated products, and IIT tells us the relative importance of intra-industry trade with respect to total trade. We want to know what it takes in terms of parameter values for IIT to increase and P (given by (33) and thus concerning Country H, the exporter of low quality products) to either decrease (reflecting more international vertical differentiation) or to increase (reflecting less international vertical differentiation).

Table 1 shows that, given t_N , lower t_M generally increases IIT and P . This means that, as the share of intra-industry trade increases at the expense of one-way trade, international vertical differentiation is decreasing with lower t_M and thus that the average quality of the goods traded by each country is becoming more similar. Making Country F more capital abundant with respect to Country H (Table 2) or increasing the consumer population of Country H (Table 3) makes P decrease with trade liberalization in the quality sector. Whether IIT increases or decreases depends on the level of protection in non-manufacturing. If t_N is relatively low, IIT does increase showing an unambiguous increase in international vertical differentiation.

In all these cases, trade liberalization in non-manufacturing alone (lower t_N) increases P and lowers IIT . The latter result is expected since lower t_N should increase trade in non-manufacturing products and thus one-way trade (lower IIT). The former result comes from the fact that trade liberalization in non-manufacturing generates smaller differences in wage between the two countries resulting in more similar average quality produced and traded by each country (P closer to one). Hence, international vertical differentiation generally decreases with trade liberalization in non-manufacturing.

Not surprisingly, it is easy to generate increases in IIT with trade liberalization in the quality sector. A simultaneous increase in IIT and a decrease in P are not very difficult to obtain either. The above results suggest that, from an empirical point of view, the change in

the share of trade in vertically differentiated product may be poorly correlated with changes in P . Our results show that changes in P away from one are can be consistent with trade liberalization provided the non-manufacturing sector has a high enough level of distortion t_N and countries are not identical in terms of their endowment and/or the number of consumers.

6. Conclusion

We have shown that the increase in the share of intra-industry trade in vertically differentiated products at the expense of one-way trade that is often empirically observed is consistent with a simple general equilibrium model where trade liberalization is more extensive in the manufacturing sector producing differentiated products than in the non-manufacturing sector.

Is there an alternative explanation to the observed increase in the share of trade in vertically differentiated products? It is often observed that the bulk of international trade is in intermediate products. Recent evidence suggest that the share trade due to vertical specialization in production is as high as 50% for small countries (Hummels, Rapoport and Yi, 1998; Yi, 2003). Could the fragmentation of production process explains the shift in the nature of intra-industry trade? More and more firms now rely on parts and services produced by geographically distinct units giving rise to trade in intermediate and final products that would not exist without vertical international specialization in production. The literature casts doubts that vertical fragmentation of production is the main cause behind the observed shift in intra-industry trade. First, one would expect that foreign direct investments might be highly correlated with intra-industry trade in vertically differentiated products. Even if the impact of FDI is higher on intra- than on inter-industry trade, the literature finds no particular link between FDI and trade in vertically differentiated products. Second, we would expect vertical fragmentation to take place in sectors where multinational corporations are important since there is a large share of company-specific products in total parts and components trade. This would imply there exists a link between sectors where multinationals are important and the increase in trade in vertically differentiated products. This is not what the literature generally finds since the increase in the share of intra-industry trade in vertically differentiated products has occurred in *all* manufacturing sectors, irrespective of their market structure.

Clearly, more studies are needed on this topic to understand what could cause this change in the composition of trade. The implications for welfare or for policy are not the same if the underlying cause is a fundamental change in the production process or if, as we have argued, it can be explained by comparative advantage and asymmetric sectoral trade liberalization.

Appendix

This Appendix derives the equilibrium conditions for the limits of each trade configuration and thus describing the frontiers in Figure 5. Consider Region I first; along the frontier with Region IV, there is no trade and thus $N_t = 0$. With (20), this implies that $\tilde{\theta}_H = \bar{\theta}$ and thus, with (15),

$$\bar{\theta} = \frac{\alpha(t_N + t_M)}{\ln r}, \quad (\text{A.1})$$

while (17) and (18) become

$$\begin{aligned} K_H &= \frac{D_H}{2\alpha r_H}(\bar{\theta}^2 - \hat{\theta}_H^2); \\ K_F &= \frac{D_F}{2\alpha r_F}(\bar{\theta}^2 - \hat{\theta}_F^2). \end{aligned} \quad (\text{A.2})$$

The frontier between I and IV is determined by (16), (A.1) and (A.2). These five equations determine $\hat{\theta}_H$, $\hat{\theta}_F$, r_H , r_F and t_M for given values of t_N , K_H , K_F , D_H , D_F , α and $\bar{\theta}$.

The frontier between I and II defines the limit for intra-industry trade. Since this type of trade exists as soon as Country F's consumers buy quality products from Country H, then it must be true that along this frontier $\tilde{\theta}_F = \hat{\theta}_F$. Using (28),

$$\hat{\theta}_F = \frac{\alpha(t_N - t_M)}{\ln r}. \quad (\text{A.3})$$

Note that, since $\hat{\theta}_F > 0$ (see (16)), then $t_N > t_M$. The frontier between Regions I and II is then determined by (15), (16), (17), (18) and (A.3). They determine respectively $\tilde{\theta}_H$, $\hat{\theta}_H$, $\hat{\theta}_F$, r_H , r_F and t_M for given values of t_N , K_H , K_F , D_H , D_F , α and $\bar{\theta}$. Note that (20) also determine N_t residually.

The frontier between Regions II and III is characterized by $N_t = 0$ and the existence of intra-industry trade. Hence, using (30),

$$D_H \left[(1 + t_N)(\bar{\theta} - \tilde{\theta}_H) + \frac{1}{2\alpha}(\bar{\theta}^2 - \tilde{\theta}_H^2) \right] = D_F \left[(1 + t_M)(\tilde{\theta}_F - \hat{\theta}_F) + \frac{1}{2\alpha}(\tilde{\theta}_F^2 - \hat{\theta}_F^2) \right]. \quad (\text{A.4})$$

This also implies from (27) that $w_F = 1 + t_N$. Hence the frontier between II and III is determined by (23), (24), (25), (28) and (A.4). They determine $\hat{\theta}_H$, $\hat{\theta}_F$, r_H , r_F , $\tilde{\theta}_H$, $\tilde{\theta}_F$ and t_M .

Finally, the frontier between Regions III and IV has no intra-industry trade and thus is characterized by $\tilde{\theta}_H = \bar{\theta}$ and $\hat{\theta}_F = \tilde{\theta}_F$ since Country H's (respectively, Country F's) consumers import high (respectively, low) quality products. Using (21) and (22), this implies

$$\bar{\theta} = \frac{\alpha(w_F + t_M - 1)}{\ln r}, \quad (\text{A.5})$$

and

$$\hat{\theta}_F = \frac{\alpha(w_F - t_M - 1)}{\ln r}. \quad (\text{A.6})$$

This also means that the capital market condition reduces to (A.2). Hence, (16), (A.2), (A.5) and (A.6) determine respectively $\hat{\theta}_H$, r_H , r_F , w_F and t_M . Note that this system of equations is independent of t_N .

Finally, we show that the four frontiers intersect at the same point E in Figure 5. To see this, observe that, at E, $w_F = 1 + t_N$ so that (A.5) and (A.6) become equivalent to (A.1) and (A.3) respectively. Since $\bar{\theta} = \tilde{\theta}_H$ and $\tilde{\theta}_F = \hat{\theta}_F$, (25) becomes identical to (A.2). Hence, E is determined by (23), (24), (A.1), (A.2) and (A.3) and these 6 equations are consistent with the equilibrium in Regions I, II and III. They determine respectively $\hat{\theta}_H$, $\hat{\theta}_F$, t_N^p , r_H , r_F , t_M^p given K_H , K_F , D_H , D_F , α and $\bar{\theta}$.

Table 1: Equilibrium IIT and P ($K_F = 1.2, K_H = D_H = D_F$)

Region	t_N	t_M	IIT	P
II	.2	0	.967	.784
		.01	.964	.76
		.03	.924	.715
		.05	.387	.674
	.3	0	.975	.766
		.01	.976	.752
		.03	.971	.724
		.05	.939	.698
		.07	.708	.673
	.5	0	.99	.734
		.01	.994	.726
		.03	.997	.712
		.11	.994	.661
	III	.6	0	1.0
.04			1.0	.709
.08			1.0	.679
.12			1.0	.657

$\alpha = .35; t_M^p = .13; t_N^p = .537.$

Table 2: Equilibrium IIT and P ($K_F = 2$; $K_H = D_H = D_F = 1$)

Region	t_N	t_M	IIT	P	
II	1.5	0	.845	.5854	
		.1	.838	.5859	
		.2	.787	.586	
		.3	.436	.5863	
	2	0	.89	.541	
		.1	.91	.547	
		.2	.927	.553	
		.3	.933	.558	
		.4	.521	.563	
	2.5	0	.937	.504	
		.1	.976	.512	
	III	3	0	1.0	.463
			.1	1.0	.5
.2			1.0	.529	
.3			1.0	.549	
.4			1.0	.559	

$$\alpha = .35; t_M^p = .41; t_N^p = 2$$

Table 3: Equilibrium IIT and P ($D_H = 1.7, K_F = 1.2, D_F = K_1 = 1$)

Region	t_N	t_M	IIT	P
II	1.5	0	.798	.625
		.06	.775	.622
		.12	.716	.621
		.18	.537	.619
	2.0	0	.841	.575
		.06	.842	.577
		.12	.834	.579
		.18	.802	.581
		.24	.665	.582
	2.2	0	.887	.533
		.04	.899	.536
	III	3	0	1.0
.06			1.0	.486
.12			1.0	.511
.18			1.0	.533
.24			1.0	.549
.3			1.0	.561

$$\alpha = .35; t_M^p = .314; t_N^p = 2.36$$

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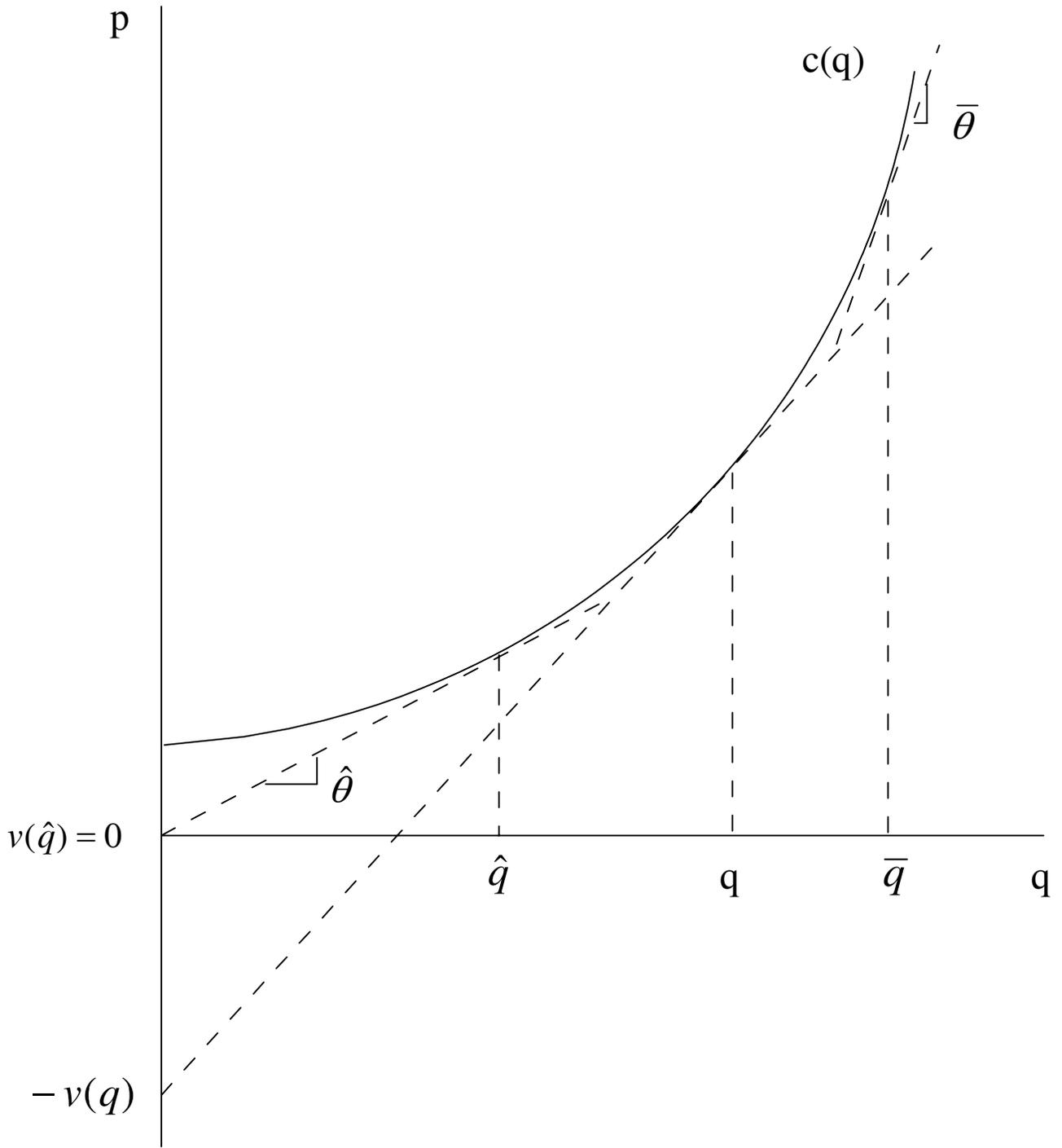


Figure 1: Basics

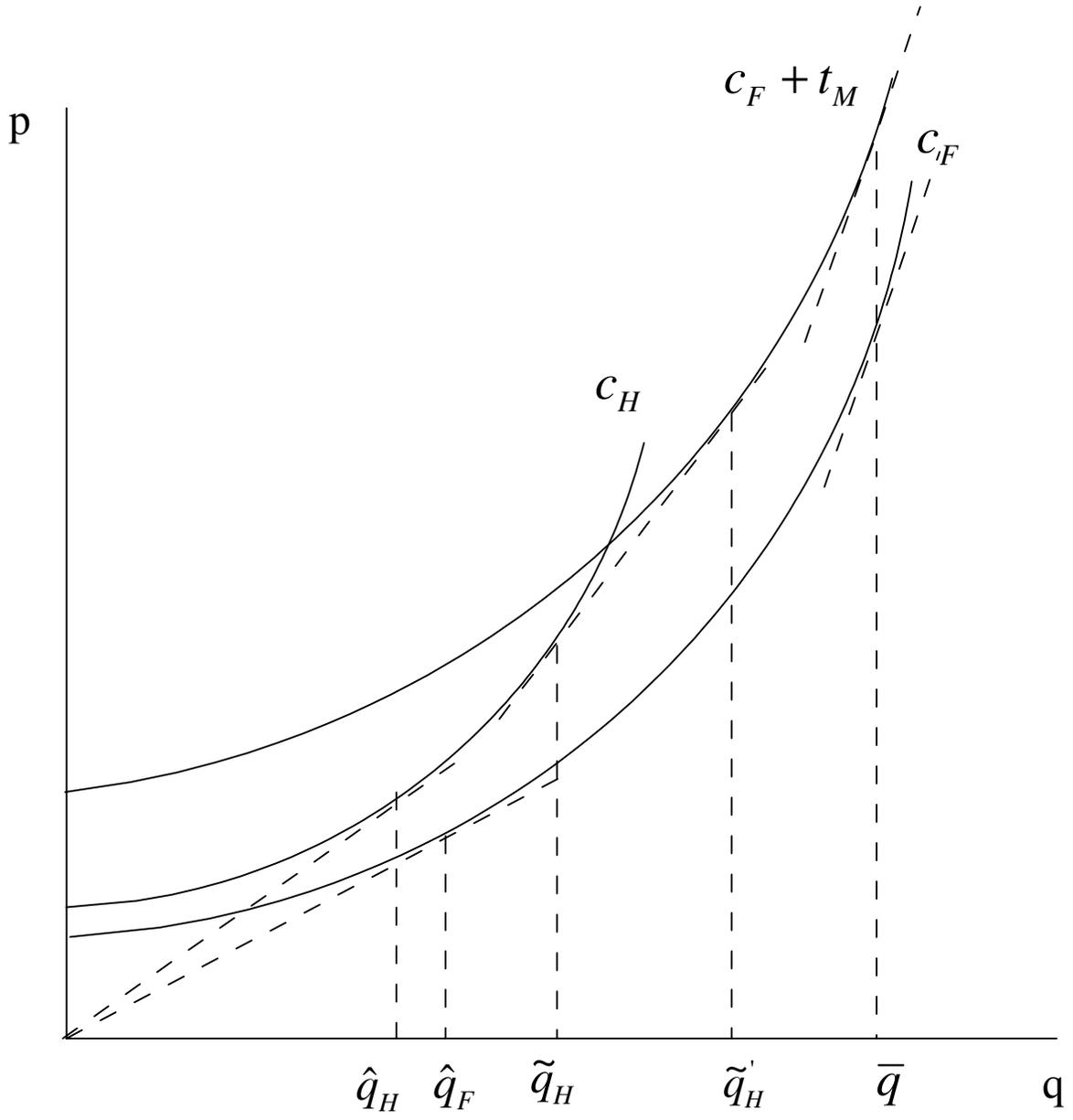


Figure 2: Barrier to Trade in Manufacturing

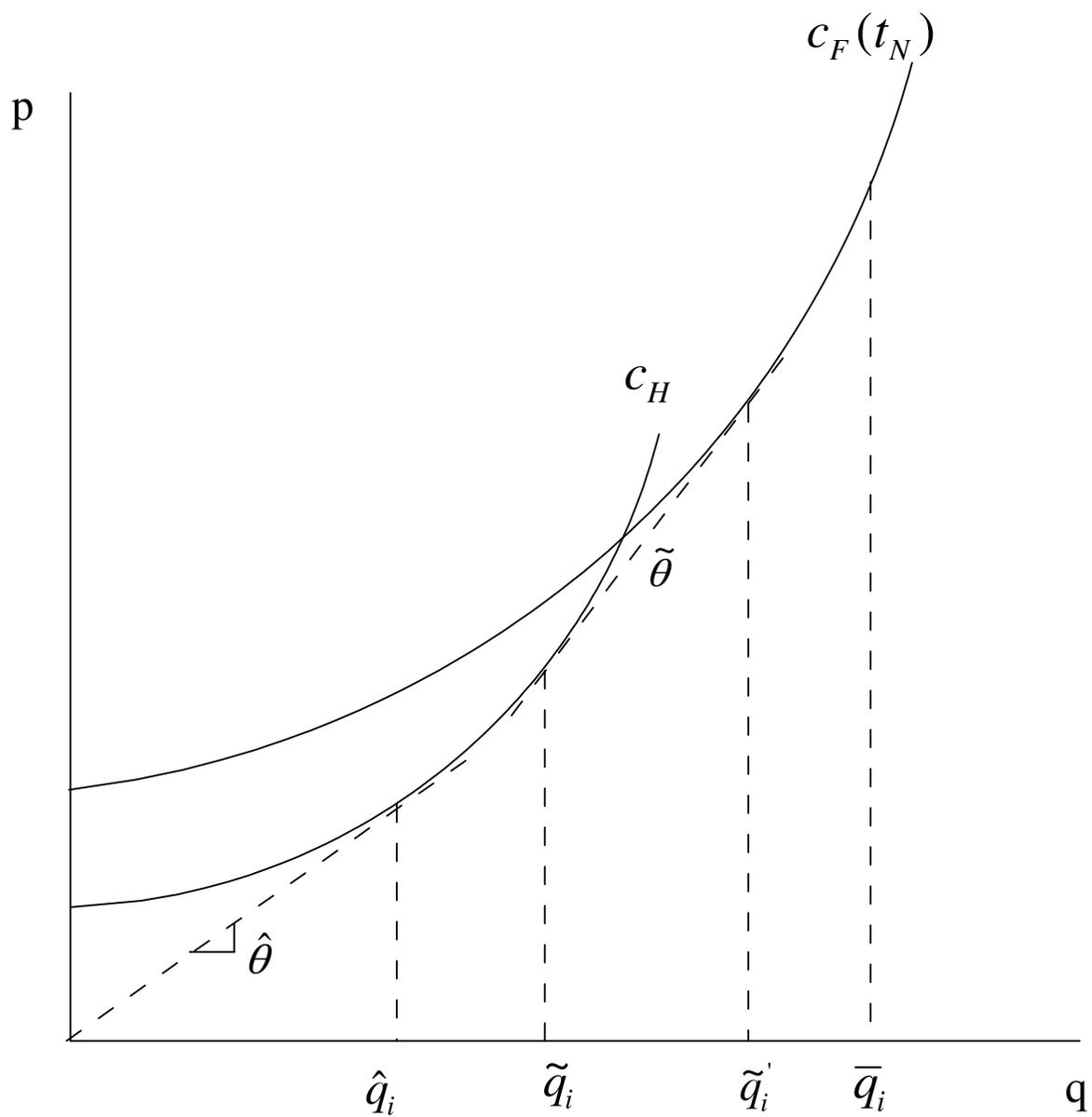


Figure 3: Barrier to Trade in Non-Manufacturing

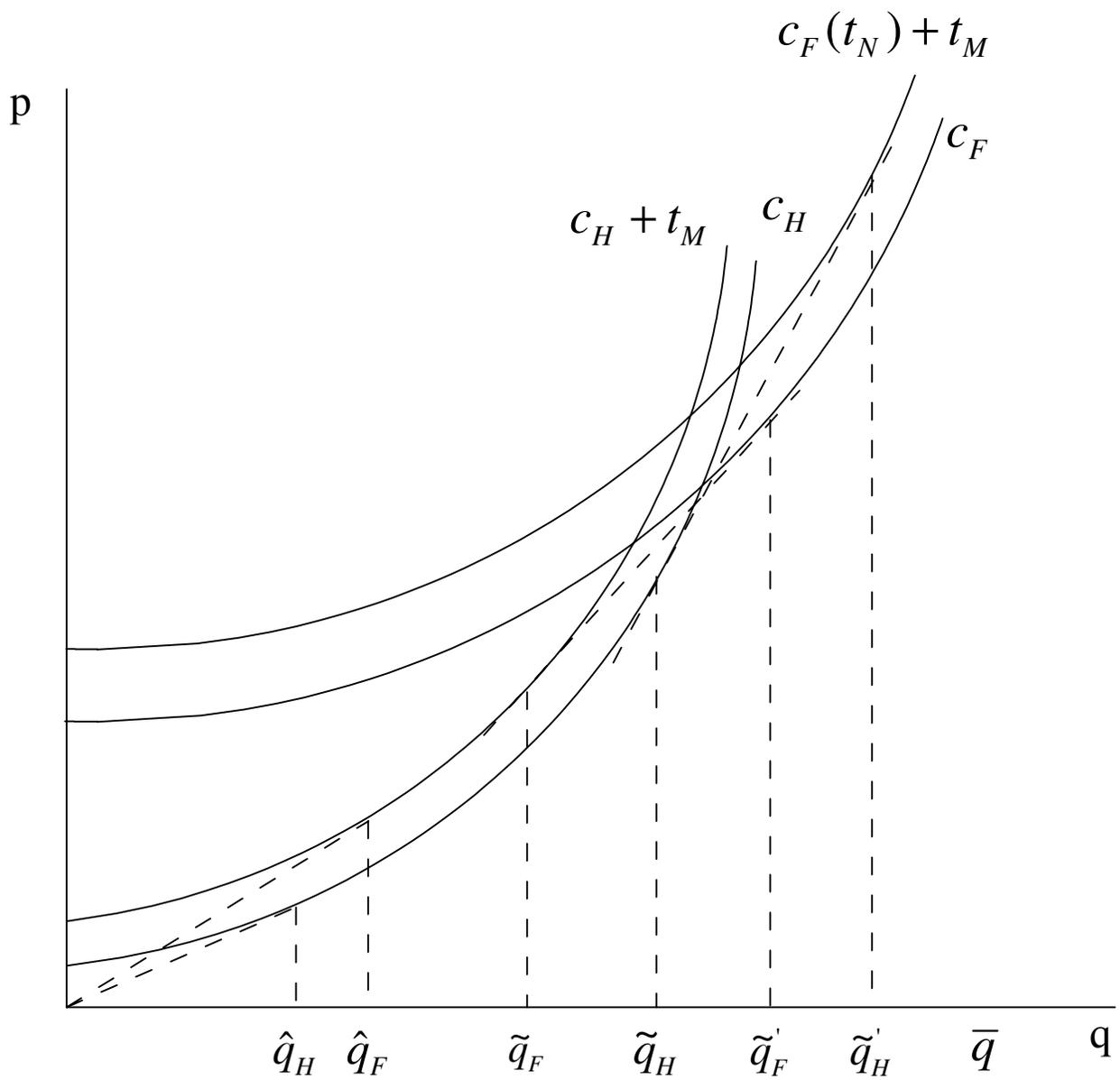


Figure 4: General Case

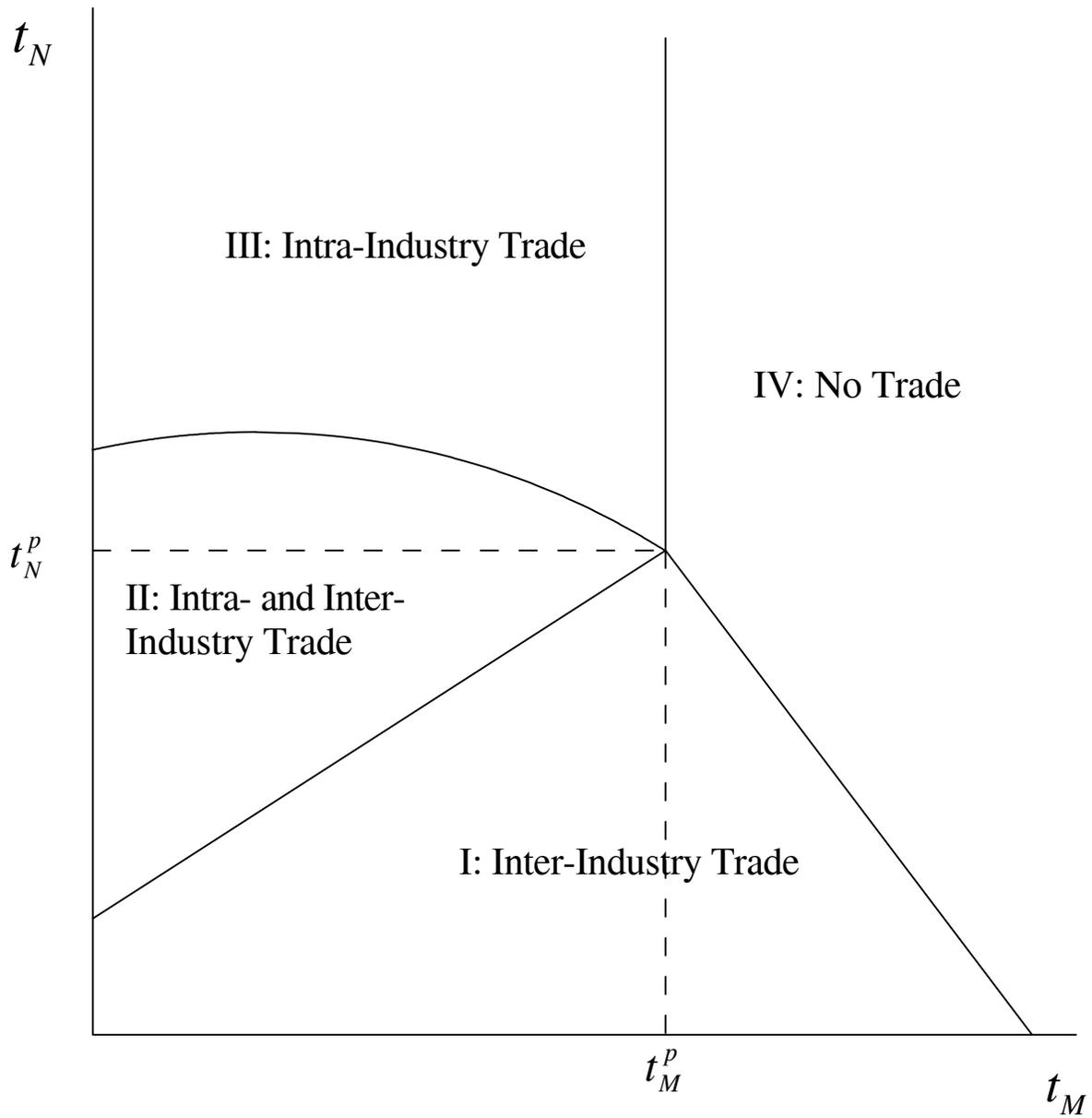


Figure 5: Equilibrium Types of Trade