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Product imitation and policies of a developing country

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Product imitation and policies of a developing country

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I. PRODUCT IMITATION AND POLICIES OF A DEVELOPING COUNTRY

A. Introduction

Although a large proportion of world trade occurs among the developed countries and the share of developing countries in international markets has been only around 20%, the structure of trade between the developed and the developing countries has been changing so that developing countries export more modern manufactures. The share of manufactures in exports of developing countries is growing rapidly. The driving force behind this gain is the application of "hand-me-down" technology with low cost labor, which is first described by Raymond Vernon and others more than twenty years ago. The developing countries sought the competitive advantage and profits starting in simple manufactures such as clothing, footwear, bicycles, toys, household electrical appliances and increasingly higher technology products. The strategy of these countries has been not only the adaptation of the technology learned from the developed countries but also literally copying their products and competing with them in the international market, taking advantage of their low labor costs. There are a few such countries that have been
successful in doing so, including Korea, Taiwan, Hongkong, Singapore and previously Japan, and now China, and there may be other less developed countries joining them in the future. This growth or development is a reflection of the product cycle. Although there are a number of studies on the subject of the product cycle, there are not many studies focusing on the policies by the South and their implication for the welfare of consumers in the South. My paper proposes to expand the analysis to consider southern strategies.

Two industrial policies, R&D subsidy and entry subsidy to imitators in the South, are considered here in a situation where the firms in the South can imitate the varieties that are currently produced in the North and can invest R & D labor to bring down the production cost so as to be able to compete in the market. We also assume there are a fixed number of varieties that are produced traditionally in the South. We assume that, where competition in varieties exists, it takes place as Bertrand competition. Within this context, the effects of the subsidy depend on the unit cost gap between the North and the South. In the case where the cost gap is narrow, the southern firms charge the price just under the competitor's unit cost of production. In this case, we show a zero R&D subsidy with a small subsidy to entry can raise the welfare of the southern consumers. The increased labor demand due to the subsidy raises the wage rate in the South, which
increase the price of the traditional varieties. The reduced demand and production of the traditional varieties free up the resources for more varieties to be available in the market. No R&D subsidy is optimal because the individual firms in the South are already efficiently allocating the labor between production and R&D, and the R&D subsidy would reallocate labor to a less efficient point. The entry subsidy reduces the consumption of traditional varieties and reallocates the released resource to produce additional varieties. If, however, there is no entry subsidy, then a small subsidy to R&D can raise welfare even if it leads to less efficient resource allocation. This could be the case if the welfare gain from having more varieties dominates the loss from less consumption plus the inefficient resource allocation.

In the case where the southern firms can charge the optimal unconstrained monopoly price which, given demand assumptions, is a fixed markup over the unit cost, the optimal R&D subsidy is positive. This subsidy raises the consumption of imitation varieties but reduces the number of the varieties. The optimal entry tax depends on the form of the R&D function.

Section 2 reviews the literature involving the imitation, the innovation, the technology transfer and the policies of North and South, including some empirical studies. The basic
The model is explained in Section 3. The trade equilibriums of the two cases are described in Section 4.

In the second chapter, the equilibrium is solved under the R&D subsidy and the entry tax to imitators in the South in Section 1. The welfare implications of those policies are studied in the second section. The results are summarized in the end of the chapter.

B. Literature Review

There have been numerous studies of the trade relationship between the South and the North, the exporters of primary products and exporters of manufactures respectively, but theoretical studies of trade dynamics due to product cycle between the two manufacturing groups are relatively recent. One group is the northern developed countries that specialize in the new or higher technology goods. The other is the southern developing countries that specialize in the old or lower technology goods. These papers try to find the factors that affect the terms of trade and the growth rates of these two groups where R&D generates a continuous introduction of new goods, and analyze the comparative dynamics on the growth rates of changes in the labor forces in either country and of various industrial and trade policies.
Krugman (1979) developed a model of Vernon's product cycle between North and South in the context of horizontally differentiated final goods. He tried to explain the ever changing trade patterns in which goods once exported by developed countries are exported back by the developing countries, amid the sustained higher wages in the northern countries, and he analyzed the effect of the technology transfer on the world distribution of income. The wage and the terms of trade of the North were sustained at a higher level because the North had exclusive knowledge of how to create new products. The North had to keep innovating to maintain their position. Labor increases in the South increased the demand for northern products, and hence raised the wage and terms of trade of the North.

Dollar (1986) finds slightly different results about the direction of the wage rate and terms of trade in a model where the rate of technology transfer is endogenously determined by the differences in production costs in the regions, although the innovation rate is still exogenous. Dollar's results differ from Krugman's in the long run context. As the wage rate and the terms of trade gap widens due to increases in labor supply in the South, the production cost in the North becomes increasingly unfavorable to the North, so the relocation of production facilities from the North to the South increases, which creates technology transfer. This trend
is reinforced by the capital flow out of the North to the South. The results are a lower equilibrium wage rate and terms of trade than the initial equilibrium points before the increase in labor supply in the South.

Jensen and Thursby (1986, 1987) assume a monopolist in the North and a social planner in the South. The monopolist allocates its resources to equate the marginal revenue product of labor between current production and R&D, given the rate of imitation of the South. The southern planner allocates resources to equate the marginal revenue product of labor between imitation and current production, given the rate of innovation in the North. Nash equilibrium determines the optimal level of imitation and innovation. Labor supply increases in the South will raise the marginal revenue product of labor in the activity of R&D and lower it in the current production. So the increase of innovation activity will be the response of the North to the labor increase in the South.

Grossman and Helpman (1989) build a product cycle model where the rates of innovation and imitation are endogenously determined. One of the key features in this model is that each northern oligopolist continuously faces the risk that its product will be copied by a southern imitator at which time its profit stream will come to an end. They study how these two rates are affected by the various industrial and trade policies of the North but leave out the welfare analysis.
Another paper by Grossman and Helpman (1989 b) considers the welfare of a small open economy which innovates through R&D and concludes that the market determined rate of innovation is not necessarily lower than the welfare maximizing rate of innovation.

In the papers by Segerstrom, Anant and Dinopoulos (1990) and Grossman and Helpman (1989c), the innovation takes the form of improvement in the quality of a fixed set of goods, rather than additional varieties of goods. In Sergerstrom et al, the R&D activities are "invention lotteries" in which the probability of winning the race is proportional to resources devoted to R&D by each firm. The R&D takes place in one industry at a time and the South is a passive player in that the technology is transferred to the South without any cost, after a specified patent period. The South does not have to devote any resources for imitation and the North does not have to face the risk of being imitated since they are protected by a patent. Instead, the R&D investment itself is a risky business due to its uncertain result and competition from other northern firms who are targeting the same product. In Grossman and Helpman, R&D and imitation activities are simultaneous in all industries and the firms in either place face continuous risk of being imitated by the South or having their products improved upon by northern competitors. In this setting, both papers perform comparative dynamics to see the
effects of an expansion of labor forces in either country and study the effects of trade and industrial policy on the growth rates of both innovation and technology transfer or imitation, but both papers leave out the welfare analysis. Stokey (1991) also developed a model of North-South trade based on vertical product differentiation using the Lancaster (1966) characteristics approach where goods are graded according to the number of characteristics that they provide. The results predict the phenomena that not all range of products will be produced, i.e., there is a gap between the highest quality produced by the South and the lowest produced by the North, and that free trade will speed up human capital accumulation in the North and slow it down in the South. Young (1991) provided a model that can analyze the effect of trade on growth which is represented by learning by doing. The results indicate that under free trade the LDC experiences rates of technical progress less than or equal to those under autarky.

All of these studies mentioned above are dynamic in nature and study the factors affecting the rate of imitation or innovation. Welfare analysis is avoided due to its complexity in a dynamic setting. There are a few static models that explicitly consider the welfare of the consumers. Pugel (1982) presents a theoretical analysis of endogenous technological change and the international transfer of technology in an Ricardian model of trade. The study shows
that the welfare of the North is lowest in a world of no transfer, improves with free transfer, improves with globally optimum royalties, and improves further with the nationally optimal foreign royalty. The welfare of the South is lowest in a world of no transfer, which is equivalent to the welfare achieved under the highest royalty paid to the North. Falvey (1983) ranks in terms of welfare cost, the possible policies which try to establish domestic production of a certain industry. However this study does not involve R&D, imitation and innovation. Feenstra and Judd (1982) also rank the welfare gain among the various policies of a northern country in a situation where R&D is done in the North and the production is done in the South. The result indicates that the welfare gain in the North is maximized for an export tariff on technology transfer, followed by an import tariff on goods, with an export tariff on goods the poorest policy alternative.

There are few empirical studies of the product cycle. Wells (1969) tried to test the hypothesis that United States exports of high income products would be growing compared with exports of low income products. He studied the export performance of consumer durables for the period 1952-63. The result seems to be consistent with the predictions of the product cycle model. Hirsch (1975) did a similiar study, but did a multi-country cross-sectional analysis. After dividing the industries into four categories according to technology
levels, he regressed the export performances of each group on income levels of countries. The results are also consistent with expectations derived from the product cycle model; a positive correlation between the export performance of high technology industry and income levels. Gagnon and Rose (1992) looked at multilateral American and Japanese trade time series data disaggregated to the four-digit SITC level. However little evidence is found of product cycle dynamics between 1962 and 1988. The goods that were in surplus(deficit) in the beginning of the period almost always remained in surplus(deficit) throughout the sample in both country.

C. The Basic Model

The basic model used here is a simple static North-South model modified from Grossman and Helpman (1989), which is a dynamic model. The main difference lies in the nature of the output of R&D. In Grossman and Helpman (1989), it takes the form of knowledge accumulation which will in turn influence the rate of innovation and imitation. In this model, the result of R&D is the reduction of the production cost in the South and the direct invention of new products in the North.

There are two countries in this world. One is the northern developed country, called North, the other the
southern newly industrializing country, called South. North can innovate new varieties whereas South can only imitate.

There exists an infinite number of symmetrically differentiated product varieties, among which only a subset of them is currently available in the market. All consumers have identical preference for the differentiated varieties. Each consumer maximizes a symmetric CES utility function

$$U = \frac{K}{\sum_{i=1}^{K} C_i^\alpha}, \quad 0 < \alpha < 1 \quad (1.1)$$

subject to budget constraint

$$E = \sum_{i=1}^{K} p_i C_i \quad (1.2)$$

$$C_i$$ is the amount of consumption of differentiated product variety $$i$$, $$p_i$$ is the price of the variety $$i$$, $$E$$ is expenditure and $$K$$ is the total number of varieties available on the market. The elasticity of demand for any variety is $$\sigma = 1/(1-\alpha)$$ which is constant for all prices, assuming $$K$$ is large. Resulting demand functions are

$$C_i = p_i^{-\sigma E} \sum_{j=1}^{K} p_j^{1-\sigma}, \quad i = 1,2,\ldots,K \quad (1.3)$$
Suppose labor is the only resource, used in both manufacturing and R&D sectors and perfectly substitutable between the two sectors. We assume that, without innovation in either country, the South could produce $n^M$ fixed number of "traditional" varieties, with their technologies inherited from the past, and the North would produce $n^O$ number of "old" varieties that were previously innovated.\(^1\) When southern entrepreneurs learn the technologies of northern varieties and recognize the profit opportunities, given low southern wages, they imitate some of the varieties produced in North. At the same time, northern firms also invest in R&D to innovate new varieties that southern firms can not imitate. After this imitation in South and innovation in North, the South now produces $n^S$ additional number of imitation varieties and North produces $n^N = n^O - n^S + n^N$ number of varieties, where $n^N$ is the number of newly innovated varieties. Southern firms can not imitate the new($n^N$) varieties since the technologies are not available in South. South may not be able to copy all the older($n^O$) varieties even if they knew the technologies because the production costs of adopting those varieties may be so high that they need to invest considerable resources in R&D to bring the production costs down to a marketable level.\(^2\)

\(^1\) $n^M$ is assumed to be fixed. The implicit assumption here is that its production cost is lower in the South.

\(^2\) The technology is transferred at no cost. But knowing the technology does not necessarily produces the marketable quality of products.
The production and R&D technologies for those varieties in each region are as follows. For the traditional varieties in South, they need $a_M$ amount of labor to produce a unit and do not require R&D. For the varieties $n_S$ that are recently imitated from North, they require $a_S$ amount of labor to produce a unit. The initial $a_S$ is assumed to be high but can be reduced through R&D. Assume $a_S$ is a monotonically decreasing function of $R_S$

$$a_S = a_S(R_S), \quad a'_S(R_S) < 0, \quad s \in n_S \quad (1.4)$$

where $R_S$ is the amount of labor devoted to cost reduction via R&D. This differs from other trade models that include varieties under monopolistic competition and assume fixed unit labor requirement for the varieties. Production technologies in the South are;

$$a(i) = \begin{cases} a_M & \text{for } i \in n_M \\ a_S(R_S) & \text{for } i \in n_S \end{cases} \quad (1.5)$$

In North, all old varieties $n_O-n_S$ take $a_N$ amount of labor to produce a unit and do not require R&D\(^3\). The newly developed varieties $n_N$ also need $a_N$ amount of labor to produce a unit, but these new varieties also require at least $\bar{R}_N$ amount of

\(^3\)The old varieties take $a_N$ but only non-imitated ones will be produced.
labor for R&D to be able to produce each new variety with \( a_n \) amount of labor per unit. Hence the production and R&D technology in North are

\[
a(i) = \begin{cases} 
a_N & i \in n_o - n_S \\
a_N & R_N \geq \tilde{R}_N \quad i \in n_p \\
\infty & R_N \leq \tilde{R}_N \quad i \in n_p \end{cases} \quad (1.6)
\]

where \( n_p \) is the set of potential products to be developed. Each variety for all \( i \) is produced by a monopolist. A monopolist producing variety \( i \) maximizes profit by setting optimal price given demand (1.3), wage rate \( w \) and production technology, taking as given prices of other goods

\[
\max_{p_i} \pi(i) = (p_i - a_i w_i) Q^T(p_i) - C(R_i)
\]

The first order condition is

\[
\frac{\partial Q^T(p_i)}{\partial p_i} [\alpha p_i - a_i w] = 0 \quad (1.7)
\]

The profit maximizing price is a fixed mark up over marginal cost if this variety does not face competition. The pricing decision does not depend on the quantity of its or
other varieties. Price change of a variety by a single firm does not affect other firms' production decisions and pricing policies of their varieties.\(^4\) All northern monopolists, those producing new or old varieties, assuming no competition, maximize their profit by charging a fixed markup over marginal cost

\[ \alpha P_N = w_N a_N \]  

(1.8)

Prices are the same for all \( i \) in North due to symmetric nature of demand and production technology in North.

In the South, it is assumed that the traditional varieties \( n_M \) are produced under perfect competition. The newly imitated varieties, \( n_S \), are under the Bertrand competition between the monopolists producing the same varieties in North and South. Therefore the prices of those varieties will depend on the gap between the unit production cost of North and of South. When the gap is small southern firms will only be able to charge a price just below the production costs in the North for that variety. If the gap is wide, then they would charge fixed markup over marginal cost of southern varieties. Therefore setting the wage rate in the North equal to one, the prices of the varieties from the South are

\(^4\)This is due to the assumption of a large number of varieties.
In addition, southern monopolists producing imitated varieties maximize profit by choosing optimal level of $R_S$, the amount of labor for the cost reduction research, given wage rate $w_S$, cost reduction technology (1.4), demands (1.3) and pricing policy

$$\max_{R_S} \pi(i) = p_SQ^T(p_S) - a_S(R_S)Q^T(p_S)w_S - C(R_S)$$

where $Q^T(i)$ denotes total demands from North and South for variety $i$. If $p_S = a_N$, $\partial p_S/\partial a_S = 0$. If $p_S = a_Sw_S/\alpha$, $\partial p_S - a_Sw_S = 0$.

Therefore the first term in the derivative goes to zero in either case. The first order condition becomes

$$-\frac{\partial a_S}{\partial R_S}Q^T - 1 = 0$$

(1.10)

and rearranged to get $-\partial R_S/\partial a_S = Q^T(S)$.

The total demand for a variety $Q^T(S)$ is the marginal amount of labor saved by cost reduction R & D. The first order condition states that

$^{5}$The invertible R&D function is assumed.
marginal research labor incurred to reduce a certain amount of ag should be equal to the marginal amount of production labor saved from reduced ag. The second order condition for interior solution is

\[-[\frac{\partial^2 a_S}{\partial R^2_S} Q^T + \frac{\partial Q}{\partial S} \frac{\partial^2 S}{\partial a_S} (\frac{\partial a_S}{\partial R_s})^2] < 0\]

If \( p_S = a_N \cdot \frac{\partial p_S}{\partial a_S} = 0 \). Hence \( a" \) has to be positive. If \( p_S = a_S^w/a \), then \( \alpha p_S - a_S^w = 0 \). Therefore the above expression becomes

\[a" - \frac{\sigma(a')^2}{a} > 0\]  \hspace{1cm} (1.11)

The change in unit cost has to be such that the R&D cost incurred is not dominated by the change in the demand for that variety to have an interior solution.

D. Trade Equilibrium

The southern firms would continue to imitate if there were a positive profit. They hire more R&D and production labors which would raise the wage in the South. But the imitation is possible only to the point where additional attempt to imitate would cause their costs to exceed the revenue. At this point
imitation stops and new equilibrium is achieved, assuming there are enough varieties to copy so that this equilibrium occurs before all \( n_0 \) varieties are imitated. Thus at equilibrium, profit for all \( n_S \) becomes zero.

\[
[p_S - a_S(R_S)w_S][C(S) + C^*(S)] - w_S R_S = 0 \tag{1.12}
\]

where \( C(i) \) and \( C^*(i) \) are southern and northern demand for the varieties. The number of traditional varieties are fixed, and those varieties are produced under perfect competition, thus

\[
[p_M - a_Mw_S][C(M) + C^*(M)] = 0 \tag{1.13}
\]

Similarly, due to free entry, the number of new varieties produced in the North will increase until profit becomes zero.

\[
[p_N - a_N][C(N) + C^*(N)] - R_N = 0 \tag{1.14}
\]

where \( w_N \) is set to 1 as numeraire. Since the firms producing the old varieties that are not imitated can also charge mark up monopoly price, by symmetry, they make \( R_N \) amount of profit, which equals the operating profit of innovating firms since the older varieties do not require current R&D.

Resource constraints in each region are
\[ n_s [a_s Q^T(s) + R_s] + n_m a_m Q^T(m) = L_s \]  \hfill (1.15)
\[ n_n [a_n Q^T(n) + R_n] - R_n (n_O - n_s) = L_n \]  \hfill (1.16)

\( L_s \) and \( L_n \) are labor forces in South and North and \( n_O \) is the number old variety that the North was producing. The demands for \( M, S \) and \( N \) in each region becomes

\[
C(S) = A \frac{1}{p_S} E_s \\
C^*(S) = A \frac{1}{p_S} E_N \\
C(N) = \left( \frac{p_N}{p_S} \right)^{-\sigma} C(S) \\
C^*(N) = \left( \frac{p_N}{p_S} \right)^{-\sigma} C^*(S) \tag{1.17}
\]

\[
C(M) = \left( \frac{p_M}{p_S} \right)^{-\sigma} C(S) \\
C^*(M) = \left( \frac{p_M}{p_S} \right)^{-\sigma} C^*(S)
\]

where \( A = [n_s + n_m p_M \left( \frac{p_M}{p_S} \right)^{1-\sigma} + n_n p_N \left( \frac{p_N}{p_S} \right)^{1-\sigma}]^{-1} \)

\[
E_s = w_s L_s \\
E_N = \pi_N (V - n_s) + L_N
\]

And trade is balanced at the equilibrium.

\[
p_S n_S C^*(S) + p_M n_M C^*(M) = p_N n_N C(N) \tag{1.18}
\]

Since the imitation varieties in the South are produced under Bertrand competition with the varieties in the North, the prices charged by each southern firm depend on the production cost gap between the regions, as mentioned earlier.
However the gap itself is endogenous. The optimal amount of research labor $R^S$, production labor $a^S$ and the relative wage rate are endogenously determined. Therefore it is not apparent at the outset whether the southern monopolists would charge maximum markup price or the price just under production cost of their competitors in the North. First I assume the size of the cost gap between the two regions to be wide or narrow and determine the parameter range that would satisfy the condition for each case. The condition is that the equilibrium $w^S$, $R^S$ and $a^S$ should satisfy (i) for the narrow gap case where the monopoly price of imitation varieties are constrained by the production cost of northern varieties, and (ii) for the wide case where unconstrained.

\[
\begin{align*}
\text{i) } & a^S(R^S)w^S / \alpha \geq a_N \geq a^S(R^S)w^S \\
\text{ii) } & a_N \geq a^S(R^S)w^S / \alpha \\
\text{iii) } & a_N \geq a^M w^S
\end{align*}
\]

(1.19)

In order for the South to be able to produce the traditional varieties $n^M$, the condition (iii) has to be satisfied. For simplicity let us assume $a_M$ is less than $a_S$ so that (iii) is satisfied since $a_N \geq a^S(R^S)w^S$ is always true.\(^6\)

\(^6\)This is true as long as there is positive amount of $R^S$. See Equ(1.26).
1. Narrow gap case

Southern imitators charge $p_S$ just below the production cost of their counterpart in the North, so that they could capture the entire market of the variety. Northern monopolists charge fixed markups over their production costs. Therefore pricing policies by the monopolists in North and South for varieties under Bertrand competition are

\[
\begin{cases}
p_N = \frac{a_N}{\alpha} \\
p_S = a_N
\end{cases}
\] (1.20)

Substituting these prices into zero profit conditions in each region

\[
\begin{align*}
[a_N - a_S(R_S)w_S][Q(S) + Q^*(S)] &= w_S R_S \\
[a_N/\alpha - a_N][Q(N) + Q^*(N)] &= R_N
\end{align*}
\] (1.21) (1.22)

From (1.22), equilibrium total demand for $n_N$ has to be

\[
C(N) + C^*(N) = \frac{R_N}{a_N} \frac{\alpha}{1-\alpha}
\] (1.23)

Since $C(S) = (p_N/p_S)^\alpha C(N)$, the equilibrium total demand for $S$ is fixed proportion to the equilibrium total demand for $N$.
\[ C(S) + C^*(S) = \left( \frac{1}{\alpha} \right) \sigma \frac{R_N}{a_N} \frac{a}{1-\alpha} \] (1.24)

This equilibrium \( Q^T(S) = C^T(S) \) is substituted in the first order condition (1.10) to get the optimal \( R_S \) and \( a_S \) from R & D technology (1.4). The total demand for \( n_S \) and zero profit condition in South (1.21) determine relative wage rate in South as

\[
w_S = \frac{a_N Q^T(S)}{a_S(R_S)Q^T(S) + R_S} \] (1.25)

This equilibrium wage rate and the optimal \( R_S \) and \( a_S \) should satisfy the conditions stated in (1.19) to be the narrow gap case. When the equilibrium wage rate is substituted the condition (i) \( a_N > a_S w_S \) becomes

\[ 1 > \frac{Q^T(S)}{Q^T(S) + R_S/a_S(R_S)} \] (1.26)

which is clearly satisfied, and \( a_S w_S / \alpha \geq a_N \) becomes

\[ R_N / a_N > \alpha^\sigma R_S / a_S(R_S) \] (1.27)
If the ratio of optimal $R_S$ to $a_S$ fell below $a^{-\sigma}R_N/a_N$, then southern monopolists would not be able to charge full mark up price.

From resource constraint of South, the equilibrium number of southern varieties $n_S$ is

$$n_S = \frac{L_S - n_M a_M Q^T(M)}{a_S Q^T(S) + R_S}$$  \hspace{1cm} (1.28)

Since $Q^T(M) = (p_M/p_N)^{-\sigma} Q^T(N) = (a_M w_S/a_N)^{-\sigma} Q^T(N)$ and with equilibrium wage rate (1.25), rewrite (1.28)

$$n_S = \frac{L_S}{a_S Q^T(S) + R_S} - n_M \left( \frac{a_M Q^T(S)}{a_S Q^T(S) + R_S} \right)^{1-\sigma}$$  \hspace{1cm} (1.29)

$$n_S + n_M \left( \frac{p_M}{p_S} \right)^{1-\sigma} = \frac{L_S}{a_S Q^T(S) + R_S}$$  \hspace{1cm} (1.30)

Combining resource constraint of North (1.16), the equilibrium total demands for $n_N$ (1.22) and $n_S$ (1.29)

$$n_N = (1-\alpha) \left[ \frac{L_N}{R_N} + V - n_S \right]$$  \hspace{1cm} (1.31)

The demands for $n_S$ and $n_N$ in each region derived from (1.17), the trade balance (1.18) and (1.22) are
\[ C(i) = \left[ n_S + n_M \left( \frac{a_M w_S}{a_N} \right)^{1-\sigma} \right] C_T(i) / A \quad (1.32) \]

\[ C^*(i) = n_N \left( \frac{1}{\alpha} \right)^{1-\sigma} C_T(i) / A \quad (1.33) \]

where \[ A = [n_S + n_M \left( \frac{a_M w_S}{a_N} \right)^{1-\sigma} + n_N \left( \frac{1}{\alpha} \right)^{1-\sigma}] \]

\[ i = M, S, N \]

The expressions above are not complete reduced form, but they give a more intuitive picture. The total demands for each variety are proportional to the total number of variety in each region.

2. Wide gap case

Monopolists in both the North and the South charge a fixed markup over their marginal cost if \( a_S w_S \) is low enough compared to the marginal cost of northern varieties

\[
\begin{align*}
    p_N &= a_N / \alpha \\
    p_S &= a_S w_S / \alpha
\end{align*}
\quad (1.34)
\]

The zero profit condition for the varieties \( n_S \) in South becomes

\[ (1/\alpha-1)w_S a_S [Q(S) + Q^*(S)] = w_S R_S \quad (1.35) \]
The total demand for $n_S$ becomes a function of the amount of research labor invested. Therefore the equilibrium $Q^T(S)$, $R_S$, and $a_S$ are simultaneously determined by

\[ Q^T(S) = \frac{R_S}{a_S(R_S)^{1-\alpha}} \]  

\[ -a'_S(R_S) = \frac{1}{Q^T(S)} \]  

\[ a_S = a_S(R_S) \]

the total demand for $n_S$, the first order condition for $R_S$ and the R & D technology. From (1.35) and resource constraint of South $n_S=[L_S-n_Ma_MQ^T(M)]/oR_S$ and $Q^T(M)=(\alpha a_M/a_S)^{-\sigma}[\alpha R_S/a_S(1-\alpha)]$, the equilibrium number of variety is

\[ n_S = \frac{L_S}{aR_S} - n_M(\frac{\alpha a_M}{a_S(R_S)})^{1-\sigma} \]  

With (1.21) and (1.31), the equilibrium number of new varieties in the North is

\[ n_N = (1 - \alpha)\left[\frac{L_N}{R_N} + V - n_S\right] \]

From trade balance condition (1.18) with demands and prices,
This equilibrium wage rate, $R_g$ and $a_g$ should satisfy the condition (ii) in (1.19). Substituting this wage rate, the condition translates to

$$\alpha^{-\sigma} \frac{R_N/\alpha_N}{a_N} \leq \frac{R_S}{a_S}(R_S)$$

(1.38)

It can be seen that the ranges of $R_S/a_S(R_S)$ are exhaustive and $\alpha^{-\sigma}R_N/a_N$ is the unique value that separates the narrow and wide case.

Total demands for $i_N$ and $i_S$ in each region can be obtained from demands (1.17), zero profit conditions (1.21) and (1.35), and trade balance condition (1.18). They are the same form as in the narrow case but the equilibrium $Q^T(i)$, the number of varieties and prices to be substituted are different.

\[
Q(i) = [n_S + n_M(\frac{\alpha a_M}{\alpha_S})^{1-\sigma}]Q^T(i)/A
\]

(1.39)

\[
Q^*(i) = n_N(\frac{a_N}{\alpha_S w_S})^{1-\sigma}Q^T(i)/A
\]

(1.40)

where \( A = [n_S + n_M(\frac{aa_M}{\alpha_N})^{1-\sigma} + n_N(\frac{a_N}{\alpha_S w_S})^{1-\sigma}] \)

\( i = M, S, N \)
II. POLICIES AND WELFARE OF A DEVELOPING COUNTRY

A. R&D and Entry Subsidy

In an effort to maximize the welfare of the consumers in the South, the southern government may try to subsidize imitation R&D or to control entry into the market. The effects of these policies under Bertrand competition will be different depending on whether the production cost gap is wide or narrow.

The imitators in the South choose the optimal amount of research labor to maximize profit in the presence of these policies:

\[
\max_{R_S} \pi(i) = p_S Q^T(p_S) - a_S(R_S) Q^T(p_S) w_S - R_S (1 - \eta) w_S - e
\]

\[
\frac{\partial \pi(i)}{\partial R_S} = \frac{\partial Q^T}{\partial p} \frac{\partial p}{\partial a_S} \frac{\partial a_S}{\partial R_S} [\alpha p - a_S w_S] - Q^T w_S \frac{\partial a_S}{\partial R_S} w_S (1 - \eta) = 0
\]

The government subsidizes \( \eta R_S \) amount of R&D labor to each firm entering into the market but charges \( e \) for an entry tax. The pricing policies of southern firms will not be affected by the R&D subsidy and the entry tax. The first term of the derivative goes to zero in either case. The first order condition becomes
\[-Q^T \frac{\partial a_S}{\partial R_S} - (1-\eta) = 0 \quad (2.1)\]

The profits of all firms in South are zero at an equilibrium.

\[\begin{align*}
[p_M a_Mw_S [C(M)+C^*(M)] &= 0 \quad (2.2) \\
[p_S - a_S(R_S)w_S [C(S)+C^*(S)] - w_S R_S (1-\eta) - \epsilon &= 0 \quad (2.3)
\end{align*}\]

The pricing policy of southern firms producing imitation varieties is

\[P_S = \begin{cases} a_N & \text{if } a_S w_S / \alpha > a_N > a_S w_S \\ a_S w_S / \alpha & \text{if } a_N > a_S w_S / \alpha \end{cases} \quad (2.4)\]

The total differentiation of (2.1), (2.3), (2.4), the demand function for imitation varieties and the resource constraint yields

\[\begin{align*}
a''_S Q_S dR_S + a'_S dQ_S &= d\eta \quad (2.5) \\
de &= R_S w_S d\eta - [a_S Q_S + R_S (1-\eta)] w_S \hat{w}_S \quad (2.6) \\
\hat{p}_S &= k \left[ \frac{a'_S}{a_S} dR_S + \hat{w}_S \right] \quad (2.7)
\end{align*}\]

where \[\begin{cases} k = 0 & \text{if } a_S w_S / \alpha > a_N > a_S w_S \\ k = 1/\alpha & \text{if } a_N > a_S w_S / \alpha \end{cases} \]

\[\hat{Q}_S = -\sigma \hat{p}_S \quad (2.8)\]

\[\begin{align*}
(a_S Q_S + R_S) d\hat{n}_S + n_S (a'_S Q_S + 1) dR_S + n_S a_S Q_S \hat{Q}_S + n_M a_M \hat{Q}_M &= 0 \quad (2.9)
\end{align*}\]
For the ease of analysis, \((w_S, \eta)\) are chosen as instruments making \(e\) endogenous, i.e., the government sets welfare maximizing wage rate and determines the entry tax supporting the wage rate. Solve the above equations for \(\hat{Q}_S, \hat{p}_S, \ dn^*_S,\) and \(dR^*_S\) in terms of \(\hat{w}\) and \(dn^*_\eta\)

\[
\hat{p}_S = k\left(\hat{w} - \frac{yd\eta}{\sigma(1-\eta)}\right)/(1-\eta) \\
\hat{Q}_S = k\left(-\sigma\hat{w} + \frac{yd\eta}{(1-\eta)}\right)/(1-\eta) \\
dR^*_S = \frac{-\sigma k(1-\eta)\hat{w} + d\eta}{a^*_S Q_S(1-\eta)} \\
\hat{n}_S = \sigma\left[\frac{ka^*_S Q_S}{(1-\eta)} + \frac{n_M a_M Q_M}{n_S} + \frac{\eta k(1-\eta)}{a^*_S Q_S(1-\eta)}\right]\hat{w} \\
- \left[\frac{ka^*_S Q_S y}{(1-\eta)(1-\eta)} + \frac{\eta}{a^*_S Q_S(1-\eta)}\right]dn^*_\eta
\]

In the narrow case \((k = 0)\) where the production costs of the two regions are close so that the full mark-up price of southern varieties exceeds the production cost of northern varieties, the prices of the varieties produced in the South will be set at the northern production cost, which is assumed to be constant. Hence the total demand for each variety does not depend upon either policy. The R&D subsidy raises the level of \(\hat{R}_S(\eta)\) leading to lower \(ag(\eta)\), since, \(-\partial R_S/\partial s_S = Q^T(S)/(1-\eta)\) from the first order condition, the marginal amount of labor saved by the R&D has increased by
$\eta Q^T(S)/(1-\eta)$. However the wage rate can not influence the level of $R_\Sigma(\eta)$ in the narrow case because the change in production cost does not move the price or the total demand, hence the level of $R_\Sigma$ remain the same. The higher wage rate(lower entry tax) raises the number of imitation varieties, since the higher wage rate makes the traditional varieties relatively expensive, leading to less production and consumption of those varieties, making more resources available to the sector of imitation varieties. The R&D subsidy, however, given total output, results in each firm using more resources, which reduces $R_\Sigma$.

In the wide gap case($k = 1/\alpha$), the southern monopolists set their maximum profit prices regardless of the northern production costs, and hence any policies that affects production cost would have an impact on the prices. The lower wage rate(higher entry tax) and higher R&D subsidy reduce the price and increase the demand and production of the southern varieties and the level of $R_\Sigma$, which reduces the number of varieties produced in the South.

B. Welfare Analysis

The southern government chooses $\eta$ and $w_\Sigma$ to maximize the welfare of its consumers.
\[ U = \sum C^\alpha(i) = n_S C^\alpha(S) + n_M C^\alpha(M) + n_N C^\alpha(N) \quad (2.13) \]

The equilibrium demands for each variety are

\[ C(i) = \frac{E p_i^{-\sigma}}{p} \quad (2.14) \]

where

\[ E = n_S p_S Q_S + n_M p_M Q_M \]
\[ p = \sum p_i^{1-\sigma} = n_M p_M^{1-\sigma} + n_S p_S^{1-\sigma} + n_N p_N^{1-\sigma} \]

Substitute the equilibrium demands into the utility function to get the indirect utility function.

\[ V = \left( E p^{\sigma-1} \right)^{\sigma^{-1}} \quad (2.15) \]

Total differentiation of the above indirect utility function yields

\[ dV = \frac{(\sigma^{-1}) V}{\sigma E} \left[ (n_S p_S X_S \hat{p}_S + n_M p_M X_M \hat{p}_M) \right. \]
\[ + (n_S p_S Q_S \hat{Q}_S + n_M p_M Q_M \hat{Q}_M + p_S Q_S d n_S) \]
\[ + \left. \left( \frac{1}{\sigma^{-1}} \right) (p_S C_S d n_S + p_N C_N d n_N) \right] \quad (2.16) \]

The first line in the bracket represents the terms of trade effects, where \( X_S \) and \( X_M \) stand for the amount of exports of each variety to the North. The welfare improvements due to the growth of total production is shown in the second line in the
bracket and the value of addition varieties in the last terms. Substitute the total differentiation of resource constraint (2.9) into the above (2.16), it becomes

\[
dV = \frac{\sigma - 1}{\sigma} \frac{V}{E} \left[ (n_sp_s X_sp_s + n_mp_M X_M \dot{p}_M) 
+ \left\{ n_s a_S \left( \frac{p_s}{a_S} - \frac{p_M}{a_M} \right) dQ_s + \left[ p_s Q_s - \frac{p_M}{a_M} (a_s Q_s + R_s) \right] d\dot{h}_s \right\} 
- \frac{p_M}{a_M} n_s (a_s Q_s + 1) dR_s 
+ \left( \frac{1}{\sigma - 1} \right) (p_s C_s d\dot{h}_N + p_N C_N d\dot{h}_N) \right] \tag{2.17}
\]

To interpret the above expression, set up the Lagrangian maximizing GNP subject to resource constraint.

\[
L = n_mp_M Q_M + n_sp_s Q_s + \lambda [L - n_m a_M Q_M - n_s (a_s Q_s + R_s)] \tag{2.18}
\]

\[
\frac{\partial L}{\partial Q_M} = n_m (p_M - \lambda a_M) \tag{2.19}
\]

\[
\frac{\partial L}{\partial Q_s} = n_s (p_s - \lambda a_s) \tag{2.20}
\]

\[
\frac{\partial L}{\partial n_s} = [p_s Q_s - \lambda (a_s Q_s + R_s)] \tag{2.21}
\]

\[
\frac{\partial L}{\partial R_s} = -\lambda n_s [a_s Q_s + 1] = 0 \tag{2.22}
\]

(2.19) and (2.20) indicate that GNP is maximized when

\[ p_M/a_M = p_s/a_s \]

However under laissez faire \[ p_s/a_s > \]
$w = p_M / a_M$. Therefore, given prices, the government can raise welfare by directing their policies to raise $Q_S$ and hence lower $Q_M$. Turning to the amount of R&D, since $a'_SS + l = 0$ from the first order condition of profit maximization of individual firms, the amount of R&D is at its optimal level under laissez faire. Hence, if the government were to use the R&D subsidy as a policy to improve welfare, the welfare gain from the increased GNP and the number of varieties should exceed the loss from the suboptimal R&D level due to the policy which moves the resource allocation away from the efficient point.

Regarding the optimal number of imitation varieties, two things should be considered. From (2.19) and (2.21)

$$\frac{p_S Q_S}{(a_S Q_S + R_S)} - \frac{p_M}{a_M}$$

(2.23)

This is $AVP_s^{L_s} - AVP_{M_s}^{L_s}$. If this is positive, there should be more imitation varieties. The other is the last term in (2.16)

$$\left(\frac{1}{\sigma - 1}\right)
[p_s C_s - p_N C_N / \sigma] d_{\sigma}$$

$$= \left(\frac{1}{\sigma - 1}\right) E \left[\frac{p_N}{p_s} \sigma - 1\right] > 0$$

(2.24)

taking into account that $\sigma d_n_N + d_{\sigma} S = 0$. This is the "price index" effect, i.e., as the number of imitation varieties
increases, the total number of varieties available in the market also increase, i.e., \((d_n N + d_n S)/d_n S > 0\) and also the varieties imitated become cheaper since \(p_S < p_N\).

Hence welfare changes if, first of all, given prices and the number of varieties, GNP changes; second, given prices, the real GNP adjusted for varieties changes; and third, if the terms of trade change.

Now substitute the solutions (2.10) - (2.14) into (2.16) to get the welfare maximizing combination of entry and R&D subsidy.

\[
dV = \left\{ \left( U_2 + \frac{k[U_1 + (1- \eta)\sigma U_3]}{(1-yk)} \right) \right\} \left\{ \frac{ykU_1}{\sigma(1-\eta)(1-yk)} + \frac{U_3}{1-yk} \right\} d\eta
\]

(2.25)

where

\[
U_1 = p_S n_S X_S + \frac{\alpha n_S Q_S}{(a_S Q_S + R_S)} (a_S A - p_S R_S)
\]

\[
U_2 = p_M n_M X_M + \frac{\alpha n_M a_M Q_M}{(a_S Q_S + R_S)} (A + e - w_S R_S \eta)
\]

\[
U_3 = \eta n_S (p_S Q_S + A)
\]

\[
A = \left( \frac{1}{\sigma - 1} \right) [p_S C_S - p_N C_N / \sigma]
\]

In the narrow case \((k = 0)\), the optimal entry and R&D subsidy is \((e^*, \eta^*)\) such that \(U_2\) and \(U_3\) becomes zero. \(U_3\) goes to zero when \(\eta = 0\) and \(e\) has to be negative to make \(U_2\) zero. Therefore no R&D subsidy is needed to maximize the welfare of southern consumers. The entry subsidy alone serves to reduce
the consumption of traditional varieties by raising the wage rate and hence the relative price of traditional varieties without disturbing the efficiency of resource allocation to R&D, so that more imitation varieties can be produced. To get the optimal entry subsidy, substitute $p_M^* = w_S d_M$ and $w_S (a_S Q_S + R_S) = p_S Q_S - e$, the zero profit condition for $U_2$ and rewrite

$$U_2 = X_M (p_S Q_S - e) + \sigma Q_M \left[ \left( \frac{\theta}{\sigma - 1} \right) (p_S Q_S - p_N Q_N / \sigma) + e \right] = 0 (2.26)$$

where $\theta = E/(E+E^*) = C_i/Q_i$, the domestic consumption over total production representing the relative size of the country. Hence the optimal entry subsidy is

$$e = -p_S Q_S \left( \frac{1}{\sigma - 1} \right) \left[ 1 - \left( \frac{\theta}{\sigma + \theta - 1} \right) \left( \frac{\sigma - 1}{\sigma} \right) \sigma - 1 \right] (2.27)$$

In the narrow case the total revenue in each firm does not change. The optimal entry subsidy becomes smaller as the $\theta$ is larger since the resource base that can be drawn upon is larger. If an entry subsidy/tax is not feasible, then a R&D subsidy alone can raise welfare even though it moves resource allocation to an inefficient point. The welfare losses from the inefficient use of labor and the reduced consumption of traditional varieties are dominated by the gain from the increase in the imitation varieties due to resources released.
from the traditional sector. But as the R&D subsidy increase
the loss becomes larger to the point where the welfare
decreases.

In the wide gap case (k = 1), the optimal combination of
entry and R&D subsidy (e*, η*) is such that

\[ yU_1 + \sigma(1-\eta)U_3 = 0 \]  
\[ U_1 + U_2 = 0 \]

Since \( e-w^S R_S \eta = p^S Q^S - w^S a^S Q^S - w^S R_S \) from the zero profit
condition

\[ U_1 = n^S Q^S p^S [(1-\theta-\sigma) + \frac{\sigma a^S}{p^S} X] \]  
\[ U_2 = n^M a^M Q^M w^S [(1-\theta-\sigma) + \frac{\sigma}{w^S} X] \]  
\[ U_3 = \left( \frac{\eta^S}{a^"Q^S} \right) X \]

where \( X = (A+p^S Q^S)/(a^S Q^S + R_S) \). Substitute these into (2.29)
and (2.30) to get

\[ y p^S n^S Q^S \left[ \frac{\sigma a^S}{p^S} X - (\sigma + \theta - 1) \right] + \frac{\sigma(1-\eta) \eta^S}{a^"Q^S} X = 0 \]
From the above two equations, the optimal wage rate and R&D subsidy can be obtained. Those are

\[ \eta^* = \frac{1}{z + \alpha + 1} \]  
\[ w_S^* = X \left( \frac{\sigma \alpha}{\sigma + \theta - 1} \right) \left( \frac{z + 1}{z + \alpha} \right) \]

where \( z = \frac{n_S a_S Q_S}{n_M a_M Q_M} \). The optimal R&D subsidy is positive. The subsidy raises the level of investment in R&D, which reduces the price of imitation varieties and increases the demand for the varieties. The increase in R&D investment and production reduces the number of imitation varieties as can be seen from (2.10) through (2.14). Hence the positive optimal R&D implies that there are too many varieties under Laissez-faire. The optimal entry tax is determined from the zero profit condition.

\[ e^* = w_S^* a_S Q_S \left( \frac{1}{\alpha} + \frac{a' R_S}{a_S} \right) \]

The sign of the entry tax depends on the two terms in the bracket in (2.37) which are the elasticity of substitution and the elasticity of unit cost with respect to the level of R&D.
The \((w, \eta)\) space is divided into two regions by an iso-cost line as seen in the Figure 2.1. If \(w'\) were the wage rate under Laissez faire, then the optimal wage rate would be higher wage rate \(w''\) by the entry subsidy without an R&D subsidy. However the solution is based on the assumption that it would stay in the narrow region. The analysis can not rule out the possibility that the point on the iso-cost line or in the wide region is the optimum. In the wide gap case, the optimal R&D subsidy turned out to be positive and the entry tax depended on the relative magnitude.

\[ a_S w_S = \alpha a_N \]

Figure 2.1 Division of narrow and wide region in wage and R&D subsidy space
of the elasticity of substitution and the elasticity of R&D function. Again we can not rule out the policy measures that drive cost gap to be narrow to be globally optimum.

C. Summary

In a situation where the southern firms imitate the products being produced in the North and enters the market with lower labor cost via R&D, the R&D and entry subsidy to imitators in the South can have different results on the number of varieties produced in the South and the welfare of the southern consumers depending on the unit cost gap of the varieties produced in North and South. In the case where the gap is narrow, the demand for the imitation varieties are independent of the policies since the price is fixed by the production cost of the northern varieties, which is a parameter in this model. In this case the welfare of the southern consumers is maximized when the number of imitation varieties is increased until its marginal benefit from the increase is equal to the marginal loss from the reduction in the consumption of traditional varieties. This can be achieved effectively by the subsidy to entry which will raise the wage rate and the price of the traditional variety and zero subsidy to R&D, where subsidy or tax to R&D will lead to inefficient
allocation of labor. The larger the country size is, the smaller the subsidy to entry they need.

In the wide gap case, the optimal subsidy to R&D is positive while the sign of the entry tax depends on the R&D function. The higher R&D subsidy and entry tax reduce the price of the imitation varieties, which increases the demand for the varieties and leads to a higher level of R&D investment. Therefore the number of imitation varieties decreases.

The main conclusion drawn from this analysis is that there is a room for a southern government to improve welfare of its consumers. This is in part due to the number of traditional varieties assumed fixed and in part due to monopoly power of the innovating and imitating firms. The improvement of welfare in this model comes from adjusting the amount of consumption of the traditional variety so that there are more varieties available, which leads to the terms of trade change such that larger proportion out of total production of a variety can be consumed in the South. The policy combination to improve welfare depends on the competitiveness or the cost gap between the competitors.

Throughout these chapters we have assumed only two countries and one type of resource in a static world. However it is true that this type of static analysis is not adequate to address the ever-changing trade patterns of those
developing countries due to the imitation and innovation. Hence the next step to extend this model is to include more than one point in time. One way to incorporate dynamics in this model is to consider the situation where the newly imitated varieties become traditional varieties in subsequent periods. It would also be interesting to include more than two countries; for example, multiple South and a North or multiple North.
III. TRADE FLOWS AND THE EXCHANGE RATE

A. Introduction

There have recently been a series of empirical studies to investigate the existence of a stable long run relationship between trade balance, exchange rate and incomes. Faced with the apparently persistent U.S trade deficit, these studies have reexamined the role of exchange rates and real incomes in restoring trade balances. Yellen and Rose (1989) examined bilateral trade flows between the United States and other G-7 countries but could not reject the hypothesis that the real exchange rate was statistically insignificant determinant of bilateral trade flows. Rose (1991) also found little evidence of any strong stable long run and short run relationship between the exchange rate and the bilateral trade balance between U.S. and U.K, Canada, Germany and Japan. However Peruga (1992) studied the same bilateral trade relationship and found the cointegrating relationships between the bilateral trade balances and the exchange rates in some of the bilateral trade in question, indicating the presence of stable long run trade balance equations between the countries and concluded that the traditional trade balance equations such as trade balance being a function of exchange rate and incomes
are sufficient to explain the long run behavior of the trade balance. One reason for the different conclusion is in the choice of techniques in testing for cointegration. Yellen and Rose (1989) and Rose (1991) used the Granger and Engle (1987) two step OLS procedure but Peruga (1992) employed the Maximum Likelihood approach suggested by Johansen (1988, 1991) and Johansen and Juselius (1990) to estimate and test for the existence of a cointegrating relationship among U.S. bilateral trade balances, exchange rates and incomes. These papers deal with aggregated trade balances to see if these balances respond to the fluctuation of exchange rates. However, there is no theoretical reason why a depreciation or appreciation need have any particular effect on the trade balances, as Rose (1991) acknowledges. Since the Marshall-Lerner condition does not have to be satisfied, and imports and exports tend to move together, the amount of import and export could be netted out leaving the trade balance stable. Or if there is a large deficit or surplus, the behavior of the trade balance upon the fluctuation of the exchange rate will depend on the import or the export. Hence we need to examine imports and exports as well as trade balances to see the changes of those trade flows in response to the fluctuation of exchange rates. Also the responses of these trade flows could be different among different product categories. In examining the bilateral trade
relationship, it is often important for a policy maker to know which industry is affected most or least in which direction.

In this chapter I also study the role of the exchange rate on the trade flows; import, export and trade balance, but use the data disaggregated into five "end-use" product categories. The primary question in this paper is whether the bilateral exchange rate and incomes can explain the bilateral trade flows in each product categories. Since most of the series turned out to be nonstationary from examining the plots of the series and the Dickey-Fuller unit root test, they are checked for the existence of the cointegration among the trade flow, the real exchange rate and the relative income. If those are cointegrated, the short run dynamics of the variables are estimated through the error correction model and the forecast error variances are decomposed into the portions for which each variable accounts. The responses of the trade flows to an innovation in the real exchange rate or the relative income are examined. This paper also tests the belief that the trade flows respond differently to the appreciation than to the depreciation. This could occur when export prices rise and import prices fall during appreciation, but import prices rise and export prices fail to decline during depreciation due to increase in production costs or vice versa.
B. Aggregate vs Disaggregate Trade Equation

In investigating whether the exchange rate plays any role in determining the amount of the aggregate trade flows with the aggregated data, it can be a problem since the exchange rate is endogenous at the aggregated level. The traditional aggregate trade balance equation has the form

\[ TB = f(e/p, p^*, Y/Y^*) \]  
(3.1)

where the \( e \) is the nominal exchange rate, \( p \) the general price level and \( Y \) the income used as a proxy for expenditure, and \( * \) represents the foreign variables. In this equation, not only is the endogenous exchange rate included as a regressor but also the general price level and the income are not independent of each other. Linkages between the price level and the real sector through monetary mechanisms are too well established to be ignored. Two endogenous variables in an equation with multicollinearity among regressors can not possibly yield any determinate result. Although they could be tested for cointegration when the series are non stationary, the two may move together by a change in an exogenous variable instead of exchange rate having any effect on the aggregated
trade balance. Hence it seems the aggregate trade equations can be meaningful only in a general equilibrium framework.

Since I do not intend to build the general equilibrium model, I tried to avoid those problems by disaggregating the aggregate data into five major categories. At a disaggregated level, the traditional ceteris paribus assumptions of the partial equilibrium analysis are more likely to hold and the trade flows of each category can be assumed to be exogenous to the exchange rate.

C. Data

The data used here are the quarterly bilateral trade flows between US and Canada from 1972 to 1987, disaggregated into five "end-use" categories (Table 3.1). The import and export unit value index of each category are used as proxy for the price of each category. These data are taken from Highlights of U.S Imports and Exports. The real GDP's are from International Financial Statistics. The trade amounts of each group are expressed in dollar and deflated by the price indices of each group. All variables are transformed into logs. The real exchange rates or the relative prices of each category are the export unit value index over the import unit value index for that category. Figure 3.1 plots these data. For each series, the data is subtracted from its mean and
Table 3.1. Five "End-Use" Categories

Group 1: Foods, Feeds and Beverages

- Cattle
- Meat products and poultry
- Fish and shellfish
- Vegetables and preparations
- Feedstuffs
- Coffee, beans and cane sugar
- Whiskey and other alcoholic beverages

Group 2: Industrial Supplies and Materials

- Fuels and lubricants
- Paper and paper base stocks
- Textile materials
- Ferroalloying and nonferrous metals

Group 3: Capital goods (Machinery, except consumer type)

- Electrical machinery
- Machine tools
- Construction, textile and other industry machines

Group 4: Automobiles

- Passenger, trucks, buses and parts

Group 5: Consumer goods
Figure 3.1 The trade flows between US and Canada and the relative prices
Figure 3.1 Continued
Figure 3.1 Continued
divided by its variance to be able to draw a trade flow and its price on the same graph.¹

D. Dickey-Fuller Unit root tests

Most economic time series exhibit upward trend over time, which is a sign of non stationarity. If a series is not stationary, then the mean and the variance are not well defined. Hence it is necessary to test for the existence of non stationarity.

If a variable $x$ has an autoregressive representation of the form

$$(1-L)x_t = \Phi_1(1-L)x_{t-1} + \ldots + \Phi_p(1-L)x_{t-p} + \varepsilon_t$$ \hspace{1cm} (3.2)

where $\varepsilon_t$ is a stationary stochastic process, $\sum \Phi_i < 1$ and $L^k X_t = x_{t-k}$, then the variable $x$ has a unit-root in its autoregressive process. The presence of unit root in a variable $x$ can be tested by estimating $\gamma$ in each alternative specification of the error correction form

$$\Delta x_t = \alpha + \beta t + \gamma x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-i} + \varepsilon_t$$ \hspace{1cm} (3.3)

¹This standardization is not done for analysis but only for plotting purpose.
\[ \Delta x_t = \alpha + \gamma x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-i} + \epsilon_t \]  \hspace{1cm} (3.4)

\[ \Delta x_t = \gamma x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-i} + \epsilon_t \]  \hspace{1cm} (3.5)

A large negative t-statistic of \( \gamma \) rejects the null hypothesis of a unit-root in \( x \). Since the result of this test is very sensitive to the specification of the equation, it is necessary to test specifically the presence of the trend and drift terms as well as the number of the lags to be included.

The statistics used to determine the lag length in (3.3) are from Ljung-Box Q test for the serial correlation and F test for the joint significance of the lags. Three choices of the lag length to be tested are 12, 8 and 4, considering the data used are quarterly. With each choice of the lag length, I obtained the statistics from F test of joint significance of the last four lags, i.e. 9 to 12 if length 12 or 5 to 8 if length 8, and Q test. The objective is to exclude the marginal four lags that are not jointly significant starting from the length 12, and to have the white noise error term that does not have serial correlation. Table 3.2 reports the statistics from Q and F test applied to the trade flows between US and Canada and Table 3.3 reports the results for relative prices and relative income. In Table 3.2, for the US imports and exports of group 1, the agricultural products, from Canada, the F test shows that only the lags from 1 to 8 are
<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>F</th>
<th></th>
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* significant at 5% level
Table 3.3. Determination of lag length for the unit root test of the relative prices and income

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</table>

* significant at 5% level.

significant. Although the Q statistic is the smallest at length 12, 9.21 is small enough to assume no serial correlation. Hence the proper length of the lags to be included in the unit root test is 8 which is indicated by the bold faced number. The lags of the trade balance of this group are not significant in any choices of the length, but if all lags excluded, there was serial correlation in the error term. Since the lag length of the import and export were 8, I chose
the same length for the trade balance, which shows small Q statistic. The F test statistic of the imports of group 2, the industrial supplies, shows that only the lags from 1 to 4 are significant at 5% level and also the Q statistics is smallest at lag length 4, hence the choice is length 4, and so on. The same method has been applied to the relative prices to determine the proper lag length in the unit root test.

Using the lags determined by the above tables, the unit root tests for the trade flows, the relative prices and income are done for each alternative specification. Equation (3.3) is the full specification which includes the drift and time trend terms. The second specification (3.4) excludes the time trend term. The third (3.5) excludes both the drift and trend. The procedure to choose the appropriate specification for the unit root test is as follows\(^2\). Starting from the full specification, the significance of the coefficient for \(x_{t-1}, y\), is tested using the Dickey-Fuller's \(\tau_t\) table, i.e., \(H_0 : \gamma = 0\). The rejection of this hypothesis means that there is no unit root in the series tested. If not rejected, however, we need to test the presence of the trend. This is done by testing the joint hypothesis of both \(\beta\) and \(\gamma\) equal to zero. If there is a significant trend, the t-statistic of \(\gamma\) in normal distribution determines the presence of the unit root. If no trend, the same procedure is applied to the second specification which

\(\text{---}\)

\(^2\text{This procedure is from Professor Enders's class materials.}\)
has no trend term. Test \( H_0 : \gamma = 0 \) using Dickey-Fuller's \( \tau_\mu \)
statistics. If not rejected, test the joint hypothesis of both \( \alpha \) and \( \gamma \) equal to zero which tests the presence of the drift
term. If there is a significant drift, the t-statistic of \( \gamma \) in
normal distribution determines the presence of the unit root.
If no trend and no drift, the test of the significance of \( \gamma \)
determines the presence of the unit root. The results of the
unit root tests are reported in Table 3.4 and 3.5. In Table
3.4 the real US imports of group 1, agricultural products,
from Canada rejects the joint hypothesis of both \( \beta \) and \( \gamma \) equal
to zero and \( \gamma \) in the series is significantly different from
zero using normal distribution meaning that this series is
trend stationary. The US exports, however, rejects the null
hypothesis \( \gamma \) equal to zero regardless of trend or drift. The
trade balance of group 3, the capital goods, could not reject
the joint hypothesis of both \( \alpha \) and \( \gamma \) equal to zero, however \( \gamma \)
is significantly different from zero in normal distribution,
which indicates it is stationary without trend or drift. All
other trade flows seemed to be nonstationary without trend and
drift. The relative prices and the relative income all turned
out to be nonstationary except the relative price of group 2
for which the statistic is just over the 5% critical value.
### Table 3.4 Unit root tests for the US-Canada trade flows

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<th>lags</th>
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<th>(a,0,r)</th>
<th>a=r=0</th>
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<td>7.578*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>exp 8</td>
<td>-3.608*</td>
<td></td>
<td></td>
<td></td>
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<td>5.594</td>
<td>-0.632</td>
<td>1.032</td>
</tr>
<tr>
<td></td>
<td>exp 12</td>
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<td>2.186</td>
<td>-1.882</td>
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<td>-1.028</td>
<td>3.519</td>
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<td>-1.996</td>
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<td>6.730</td>
<td>-2.930</td>
<td>5.130</td>
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* statistics larger than the critical value at 5% significance level.

### Table 3.5 Unit root tests for the relative prices and income

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<tr>
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<td>-3.500</td>
<td>6.730</td>
<td>-2.930</td>
<td>5.130</td>
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* statistics larger than the critical value at 5% significance level.
E. Co-integration Test

In order for the non stationary variable to have a stable linear relationship, a linear combination of the variables should be stationary. Since the equations of interest are

\[ I_i = I_i(\eta, Y^*, Y) \]  \hspace{1cm} (3.6)

\[ E_i = E_i(\eta, Y^*, Y) \]  \hspace{1cm} (3.7)

\[ B_i = B_i(\eta, Y^*, Y) \]  \hspace{1cm} (3.8)

where \( I_i, E_i \) and \( B_i \) are import, export and trade balance of each category \( i \), \( r_i \) is the real exchange rate or the relative price of each category, and \( Y^* \) and \( Y \) are the foreign and domestic income. The variables tested for cointegration, therefore, are a trade flow - import, export or trade balance - of a product group between U.S. and Canada, real exchange rate and relative income. In this paper, I adopted the maximum likelihood approach suggested by Johansen (1988, 1991) for the cointegration test.

Let \( X_t \) be a \( k \times 1 \) vector of \( I(1) \) variables whose dynamic behavior is captured by the following autoregressive model

\[ X_t = \sum_{i=1}^{k} \Pi_i X_{t-i} + \epsilon_t, \quad t=1, \ldots, T \]  \hspace{1cm} (3.9)
where the \(\varepsilon\)'s are \(IN_k(0, \Lambda)\). The above system can be rewritten in the error correction form

\[
\Delta X_t = \Pi X_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t
\] (3.10)

where \(\Pi = -I + \sum_1^k \Pi_j\) and \(\Gamma_i = -\sum_{i+1}^k \Pi_j\). The variables in \(X\) are said to be cointegrated if there is a linear combination of them, \(\beta X\) is \(I(0)\). \(\beta\) is known as the cointegrating vector. If the system \(X\) is cointegrated, then the rank(\(\Pi\)) = \(q < k\), and there exist \(k\times q\) matrices \(\alpha\) and \(\beta\) such that \(\Pi = \alpha \beta'\). \(q\) is the dimension of the space of cointegrating vectors \(\beta\), and the \(\alpha\)'s are the vectors of adjustment coefficients. The brief testing procedures which are given in Johansen (1991) are as follows. Set up the likelihood function

\[
L_{\text{max}}^{-2/T}(\alpha, \beta, \Lambda) = |\Lambda|\exp\left\{T^{-1}\sum_{t=1}^T (R_{o\ell} - \alpha \beta R_{kt})' \Lambda^{-1}(R_{o\ell} - \alpha \beta R_{kt})\right\}
\] (3.11)

where \(R_{o\ell}\) and \(R_{kt}\) are the residuals from regressing \(\Delta X_t\) and \(X_{t-k}\) respectively on the lagged variables. This is minimized with respect to \(\alpha\) and \(\Lambda\) for fixed \(\beta\), which gives

\[
\hat{\alpha}(\beta) = S_{ok}\beta(\beta S_{kk}\beta)^{-1}
\]

\[
\hat{\Lambda}(\beta) = S_{oo} - S_{ok}\beta(\beta S_{kk}\beta)^{-1}\beta S_{ko}
\]

\[
L_{\text{max}}^{-2/T}(\beta) = |S_{oo}|\left|\beta'(S_{kk} - S_{ko}S_{oo}^{-1}S_{ok})\beta\right|/|\beta'S_{kk}\beta|
\]

(3.12)  (3.13)  (3.14)
where \( S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R_{jt}', (i,j=0,k) \). The last equation is minimized with respect to \( \beta \), which are the eigenvectors associated with the largest eigenvalue from the equation \( \lambda S_{kk} - S_{ko} S_{ok}^{-1} S_{ko} = 0 \), which leads to

\[
L_{\text{max}}^{-2/2T}(r) = |S_{oo}| \prod_{i=1}^{r} (1 - \lambda_i)
\]

There are two test statistics which are available and have the following form

\[
\text{MAXEIG} = -T \ln(1 - \lambda_{r+1})
\]

\[
\text{TRACE} = -T \sum_{i=r+1}^{p} \ln(1 - \lambda_i)
\]

The first statistic, MAXEIG, tests the unconditional significance of individual eigenvalues whereas TRACE tests the conditional significance of the ordered eigenvalues, i.e. tests \( \lambda_r > 0 \), given smaller values are all zero.

Each series are tested for the cointegration with the real exchange rate and the relative income at two different lag length: 4 and 8. Table 3.6 through 3.9 reports Maxeig and trace statistics and their cointegrating vectors from Johansen's test for US-Canada series with the lag length 4 and 8. The cointegrated series at either lags are
Foods, Feeds, and Beverage: deficit
Industrial materials: import, export, deficit
Capital goods: export
Automobiles: deficit
Consumer goods: import, export, deficit

Most of the nonstationary trade flows seemed to be cointegrated with the real exchange rate and the relative income with lags 4 or 8 except the imports and exports of the group 4, the automobiles. There are more series with the multiple cointegrating vectors at lags 8. The cointegrating vectors are normalized such that the element of the vector corresponding to the trade volumes becomes 1. Hence in Table 3.7, the elements of the trade volumes in a vector are omitted since they are all ones. Other elements are reported such that, for example, in the trade balance of group 1, \( \text{vol} + 5.370\text{rp} + 5.576\text{ry} - 1.348 = 0 \) representing a equilibrium linear relationship among the trade volume, the relative price and relative income. The adjustment coefficients are normalized as to capture the per period percentage adjustment in each variable to the deviation from its long run value. The imports and exports of the group 5, the consumer goods, even have three cointegrating vectors. These cointegrating vectors can be thought of as representing constraints that impose on the movement of the variables to achieve the equilibrium.
Table 3.6 Cointegration tests of the trade flows with the relative price and income (US-Canada) (lags=4)

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<td>20.391*</td>
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C.V 5% 22.002 15.672 9.243 34.910 19.964 9.243
10% 19.766 13.752 7.525 32.003 17.852 7.525

* statistics larger than 10% critical value

Table 3.7 Cointegrating vectors and adjustment coefficients (l=4)

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Table 3.8 Cointegration tests of the trade flows with the relative price and income (US-Canada) (lags=8) maxeig trace

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</tbody>
</table>

5%  22.002 15.672 9.243  34.910 19.964  9.243
10% 19.766 13.752 7.525  32.003 17.852  7.525

* statistics higher than 5% critical value

Table 3.9 Cointegrating vectors and adjustment coefficients (lags=8)

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relationships among the variables. Hence the more cointegrating vectors there are, the more stable is the equilibrium relationship. Since the relative price is the export price over the import price and the relative income is the Canadian income over the US income, the sign of the element of the cointegrating vectors is expected to be negative for the relative prices and positive for the relative income if the trade flow is the import, the opposite if the export. The signs of the trade balances depend on the relative magnitudes of the import and the export of the group. The results show that the signs of the relative income are negative in most trade flows and the signs of the relative prices do not appear to have any patterns. The sign of the adjustment coefficient should be negative. A positive or insignificant adjustment coefficient indicates that the variable is weakly exogenous in the context of the relationship.

The likelihood ratio tests of the null hypothesis that the price elasticity is zero or the null of zero income elasticity indicate that the price elasticities and the income elasticities are all significant. A zero value for a particular coefficient in the cointegrating vector indicates that the corresponding variable does not belong in the cointegrating relationship.
Table 3.10 reports the shares(%) of the product categories of US-Canada trade in 1987. Most of US trade with Canada are comprised of the industrial materials and automobiles, where the automobiles are not cointegrated with the exchange rate. About half of US imports from Canada are cointegrated with the relative prices, which are the categories of industrial supplies and consumer goods while the categories of US exports of industrial supplies, capital goods and consumer goods are cointegrated with the real exchange rate. Although both the imports and exports of group 1 and 4 are not cointegrated with prices and income, their trade balances are cointegrated.

Table 3.10 The shares(%) of the product categories in US-Canada trade as of 1987

<table>
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<tr>
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<th>g5</th>
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<td>Export</td>
<td>4</td>
<td>24*</td>
<td>27*</td>
<td>39</td>
<td>6*</td>
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</table>

* represents the series that are cointegrated

A caution is needed in interpreting the result for the automobile categories since the automobile trade between United States and Canada has been under the Auto Pact from 1965. The Auto Pact requires that at least 50% of the contents of the automobiles has to be from North America to be exempt from the duty. Since the automobile assemblers in Canada were the subsidiaries of big auto makers in the United States,
mostly parts were exported and assembled cars were imported between the same firms.

F. Error Correction Model, Error Decomposition and Impulse Response

1. Error correction model

When there exists a cointegration among the trade flows, the real exchange rate and the relative income, those variables will not drift far away from their equilibrium relationship. The disequilibrium caused by a shock at a certain period to the variables should be corrected throughout the subsequent periods. This implies that the error measured from the equilibrium should have explanatory power of the movement of the variables. Hence if the variables are cointegrated, there should be an error correction representation of the form

\[ A(L)^*(1-L)X_t = \alpha E_{t-1} + \varepsilon_t \]  

where \( A(L)^* \) is a \( nxn \) polynomial matrix in the lag operator of order \( p \) with \( A(0)^* = I \), \( \alpha \) is the speed of adjustment, \( E_{t-1} = \beta'X_{t-1} \) which are the stationary error correction terms and \( \varepsilon_t \) is the white noise process. \( X_t = (VL(i)_t, XR_t, RY_t)' \), where
VL_t are the import, the export or the trade balance of each category, XR_t is the real exchange rate and RY_t is the relative income. The above system of equations is a little different than a standard VAR with differenced data. As Engle and Granger(1987) pointed out, a standard VAR in differences without the error correction terms will be misspecified if the variables are cointegrated, and will have omitted important constraints if the data are used in levels. So the system to be estimated is

\[
\Delta X_t = \sum_{i=1}^{p} B_i \Delta X_{t-i} + \alpha \epsilon_{t-1} + \epsilon_t \tag{3.19}
\]

B is the 3x(3x4 + 1) coefficient matrix to be estimated with lag length set to be 4 reflecting the quarterly data. The estimates of the equation where the trade flows become dependent variable are reported in Table 3.11. The individual coefficients of the system are not significant in most cases. The coefficients of the error correction terms are mostly significant and have correct signs.

2. Impulse responses

Another way to see the relationships among the variables in the system of VAR is to trace out the responses of the
Table 3.11 Estimates of VAR(US-Canada)

<table>
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<th>tbl</th>
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<td>-0.14</td>
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</table>
* Significant at 5% level

system to a shock in a particular variable.

A VAR(p) process of the type (3.19) can be shown to have a moving average representation

\[ \Delta X_t = \mu + \sum_{i=0}^{\infty} M_i \nu_{t-i} \]

(3.20)

where \( \mu = E[\Delta X_t] = (I - B_1 - B_2 - \ldots - B_p)^{-1} \) and \( M_i \), the coefficients of the error terms, are calculated using \( B_i \)'s. Since the error terms of the variables are contemporaneously correlated, assuming an innovation in one of the variable while forcing other error terms to be zero is unrealistic. Hence in order to have a covariance matrix such that there is
no instantaneous correlation among the components, triangularization of the matrix is needed. Since the covariance matrix $V$ is positive definite, there exists a nonsingular matrix $P$ such that $PVP' = I$. With this matrix the MA representation in (3.20) can be rewritten as

$$\Delta X_t = \mu + \sum_{i=0}^{\infty} Z_i w_{t-i}$$  \hspace{1cm} (3.21)

where $Z_i = M_i P^{-i}$ and $w_t = P v_t$. The components of $w_t$ now are uncorrelated and all have unit variance. Hence the responses of the variable $X$ to a one standard deviation shock, $w_0$, in one of the variables at period zero are

$$X_0 = Z_0 w_0, \quad X_1 = Z_1 w_0, \quad X_2 = Z_2 w_0, \quad \ldots$$

The Figure 3.2 plots the responses of the variables to a shock in the relative prices, i.e. the appreciation of the U.S. real exchange rate. The exports are supposed to be reduced and the imports to be increased in response to the appreciation. In the categories of the industrial supplies and the consumer goods, imports seem to move in the same direction as the price movement and exports in the opposite, which is consistent with the expectation. The responses of the income are relatively small in most of the categories.
Figure 3.2. Impulse Response of trade flows and the relative income to the Shock of the relative prices.
Figure 3.3 plots the responses of the variable to a shock in the relative income. The relative income is defined as Canadian income over US income. The import of the industrial supplies is relatively responsive to the income change compared to other categories of which trade volumes and the relative prices show small responses and become stable rather quickly.
Figure 3.3. Impulse Response of the Trade Flows and the relative prices to the shock of the relative income
Figure 3.3. Continued
3. Forecast error variance decomposition

The forecast error covariance matrix of an $h$-step forecast is

$$V(h) = V + \sum_{i=1}^{h-1} M_i V M_i'$$

$$= P^{-1}P V P' (P^{-1}) + \sum_{i=1}^{h-1} M_i P^{-1} P V P' (P^{-1}) M_i$$

$$= \sum_{i=0}^{h-1} Z_i Z_i'$$ \hspace{1cm} (3.22)

The sum of the $m$th diagonal elements of $Z_0 Z_0' Z_1 Z_1' \ldots Z_{h-1} Z_{h-1}'$ is the forecast error variance of the $h$-step forecast of variable $m$. The $m$th diagonal element of $Z_i Z_i'$ is the sum of the squares of the elements in the $m$th row of $Z_i$. Therefore the squares of each elements in the $m$th row of $Z_i$ is the contribution of innovations by each variable to the variable $m$ in the $i$th step forecast.

Table 3.12 reports the percentage of the 4, 12 and 24 period ahead forecast error variance of each variable caused by innovation in each variable where the Cholesky decomposition is done in the order of the relative income, the relative price and the trade flows. The relative income is largely negligible in explaining the variance of the trade
Table 3.12. Decomposition of the variances (ry-rp-vol)

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flows except in the case of the deficits of group 1, the agricultural products, where the relative income explains about 14% of the variance of the deficits. The relative price accounts for more than 40% of the variance of the imports of the group 2, the industrial supplies. In the cases of the trade balance of agricultural products and the imports of consumer goods, the relative prices are not important predicting the trade flows. Another decomposition of the different order is tried where the relative price comes first, the relative income second and the trade flows last (Table 3.13). In this order of decomposition, the relative prices became negligible in all trade flows except group 2 whereas the relative income explains a much larger percentage of the variances of the trade flows.

G. Asymmetric Response of Trade Flows to the Exchange Rate

It is believed that trade flows respond differently during depreciation than during appreciation. This could happen when export prices rise and import prices fall during appreciation but import price rise and export price fail to decline during depreciation due to increase in production costs or vice versa. If this is true, the low statistical significance of the exchange rate to the trade flows may be attributable to the asymmetry. This hypothesis is tested by
Table 3.13. Decomposition of the variances (rp-ry-vol)

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using dummy variables in one of the equations in the error correction model which has the trade flow as dependent variable. Since the depreciation and appreciation has to deal with the change in exchange rate, the error correction model had a suitable form. The equation to be estimated has the following form

\[
\Delta VL_t = f(p\Delta XR_{t-1}, n\Delta XR_{t-1}, p\Delta XR_{t-2}, n\Delta XR_{t-2}, p\Delta XR_{t-3}, n\Delta XR_{t-3},
\]
\[
p\Delta XR_{t-4}, n\Delta XR_{t-4}, \Delta VL_{t-1}, \Delta VL_{t-2}, \Delta VL_{t-3}, \Delta VL_{t-4},
\]
\[
\Delta RY_{t-1}, \Delta RY_{t-2}, \Delta RY_{t-3}, \Delta RY_{t-4}, X_{t-1}, \epsilon_t)
\]

\[
p = 1 \text{ if } \Delta XR_{t-1} > 0
\]
\[
where \quad 0 \text{ otherwise}
\]
\[
n = 1 - p
\]

Here VL is the trade volume of imports, exports or balance of trade for each product group. XR represents the real exchange rate, RY the relative income and \( E_{t-1} \) is the error correction term. Hence \( n\Delta XR(t-i) \) represents depreciation and \( p\Delta XR(t-i) \) appreciation. If there is no asymmetry in the response of the trade flows to the fluctuation of the exchange rate, the magnitudes of the coefficients should be the same. The signs of the depreciation and the appreciation are both supposed to be the same and positive if import and negative if export.
The sign of the trade balance depends upon the relative magnitude of the import and the export elasticities. The estimates of the above equation (3.23) by OLS are reported in Table 3.14. The signs of the coefficients of the appreciation and depreciation in import or export equations do not exhibit any pattern and the coefficients are mostly not significant. However asymmetry is detected in several cases. The F test checks the equality of coefficient of the depreciation and appreciation. The Hi is the hypothesis that the coefficients of \( p\Delta XR(t-i) \) and \( n\Delta XR(t-i) \) are the same where \( i = 1 \) through 4. The third and fourth lags of the real exchange rate were rejected for the equality of the coefficients of the depreciation and appreciation in the deficits of the agricultural goods. The exports and deficits of the industrial material(exp2), the deficits of automobiles and the exports of the consumer goods do not reject the hypothesis of symmetry. The exports of the capital goods indicates that the first two lags of the differenced exchange rate have asymmetric impact on the export where the depreciation(\( n\Delta XR(t-1) \)) in the t-1
Table 3.14 Asymmetric responses of trade flows to the exchange rate (US-Canada)

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<td>E(t-1)</td>
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* Significant at 5% level

...period led to the decrease in the exports but signs reversed in the next period. Hence the indications of the asymmetry are shown in the deficits of agricultural products and consumer goods, the imports of industrial supplies and consumer goods and the exports of capital goods. The error correction terms show all correct signs and significant in most of the categories.
H. Summary and Conclusion

This paper attempted to study if the real exchange rate plays any role in explaining the trade flows in major product categories between U.S. and Canada in long run and short run. Among the trade flows that are cointegrated, this paper checks the short run dynamics using error correction model and tested the hypothesis that the responses of the trade flows to the exchange rate can be asymmetric.

In terms of cointegration, the bilateral trade flows between U.S. and Canada in most categories were cointegrated with the real exchange rate and the relative income. The category of the automobiles is not cointegrated although the category has the largest share among the categories. The automobile trade were under the Auto Pact between the United States and Canada since 1965. Hence the flows could be subjected to the institutional arrangement rather than the fluctuation of exchange rate.

The analysis of the short run dynamics among the variables can be summarized as follows. From the impulse responses, the trade flows seemed to respond to the shock in the relative prices. There were a few cases in which appreciation reduces the amount of imports which improves the deficit for a few periods. This could be explained by the inelastic US demand for that category. However the variance
decomposition shows that even if the trade flows respond, the percentage of the variance that are explained by the exchange rate is small or even negligible.

As to the asymmetry of the responses of the trade flows, the deficits of agricultural products and consumer goods, the imports of industrial supplies and consumer goods and the exports of capital goods showed asymmetry, where the imports of the industrial materials has the largest share among the imports.

The results from this study indicate that the real exchange rate and the relative income are not suitable to explain the trade flows of automobiles which are a relatively important category among the flows between the two countries. This category may be better explained by the institutional arrangements such as the Auto Pact. The trade flows that are cointegrated take up about half of the total bilateral trade volumes. However the analysis of the short run dynamics indicates that even among the cointegrated series, the relative prices were not significant in explaining the variances of the trade flows. This means that the trade flows and the relative price and income do not drift far away from their long run relationships, but the responses of the trade flows to the movement of the exchange rate and income are not statistically significant. Or the traditional trade equations may be missing the important variables in explaining the
bilateral trade relationship between the exchange rate and the volumes. Those missing variables could be the factors that take the multilateral environment into account.
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