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THE PRODUCT LIFE CYCLE AND NEW INTERNATIONAL DIVISION OF LABOR

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This paper develops a dynamic model of the product life cycle, which highlights the key factors of the ongoing 'new' international division of labor. The model depicts a world of three regions—the North, the Middle, and the South—in which the pattern of trade is continuously changing. New goods are continuously developed in the North, the developed countries of the OECD, while technology of producing some northern goods is being transferred to the Middle, the Newly Industrializing Countries (NICs). Production technology of some middle goods is also being diffused to the South, the Less Developed Countries (LDCs). This process of product cycle-type technological changes affects not only the number of goods produced in and exported from each region, but also the relative commodity prices, factor prices, and capital movement in the world. This helps us understand why the NICs face with growing protectionism in developed country markets.

I. INTRODUCTION

Traditional theories of international trade view the world as the two different regions in terms of climate, culture, resources, technology and so on. The two regions trade goods to benefit from their differences. A typical prediction is that developed countries export manufactures and less developed countries export raw materials. This kind of trade models based on simple comparative advantage has long been dominant in textbooks. The rapidly changing character of international trade, however, has required a reconsideration of traditional models of international trade for the following reasons.[1]

First, the world is no longer North-South divided one, as the Newly Industrializing Countries (NICs) have rapidly grown recently. And the trade-related behavior

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[1]For a detailed explanation on this, see Kim, Se Won, *International Trade Policy,* International Business Co., 1988, pp. 387-420.

of the NICs has been quite different from what a traditional trade model would predict. Second, not like the static trade pattern of traditional models, international trade has become a dynamic one in character. That is, in many instances, international trade does reflect only temporary advantages resulting from technological changes. Third, the factors of production are becoming more and more mobile across the countries, yet the traditional models assume the perfect international immobility of resources. Especially international capital movement has recently been very active due to development of multinational enterprises and international banking such as Eurodollar market. Forth, since 1970s neo-protectionism among the developed countries has expanded. This is different from the one of 19th century which attempted to protect infant industries. Neo-protectionism is to protect the industries in which the developed countries are losing their comparative advantages. The traditional models of international trade are silent on this.

Based on the above reasoning, this paper develops a mode of the product life cycle in a three-country setting, in which, I hope, we can understand more theoretically the onoging new international division of labor. The remainder of the paper is organized as follows. After a brief literature review of the product life cycle models in section II, suggested is a simplified pattern of the dynamics of the product cycle involving three regions—the developed OECD countries, the NICs, and the Less Developed Countries (LDCs). Along with the structure of the dynamics of the product cycle, the structure of the model is then laid out in section III. The analysis of the model is then carried out in section IV, using comparative statics. Finally, Section V summarizes the result of the paper.

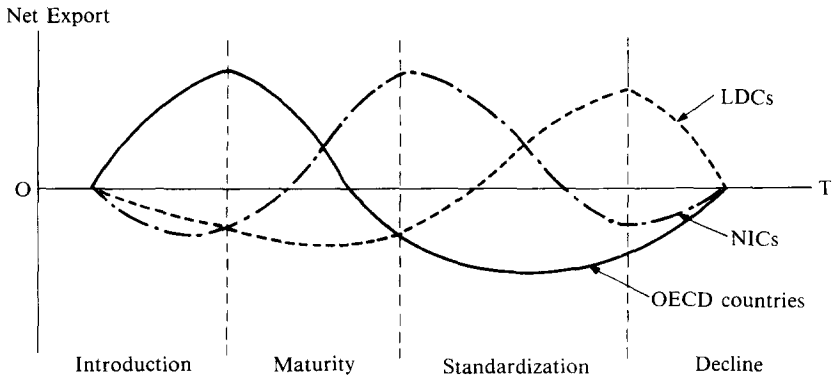
II. THE HYPOTHESIS OF THE PRODUCT LIFE CYCLE

Vernon (1966) was the first one who described the international trade in terms of a product life cycle. According to his hypothesis, a new product is developed in the United States because the country has a comparative advantage in research and development (R&D) and the new product requires close proximity to its markets. Accordingly the U.S. exports this product to the rest of the world for the first time. As the product becomes matured, however, the other advanced countries start producing and exporting this product. Only after the product becomes standardized is it produced in and exported from less developed countries. Eventually the product becomes obsolete and is no longer produced. Thus Vernon suggests that the product life cycle of four distinct phases—introduction, maturity, standardization, and decline—determines the trade pattern.

Since Vernon's hypothesis of the product life cycle first appeared, it has become widely accepted as an important explanation of the patterns of international trade. There have been, however, surprisingly few formal attempts to build theoretical models involving the hypothesis of the product life cycle.

Krugman (1979) took a first step toward constructing a formal model of the product cycle. In his model, new products are first produced in the developed region, the North. But simultaneously, the technology of producing older goods is diffused to the less developed region, the South. He shows that, with the rate of innovation and the rate of technology transfer exogenously given, the ratio of northern to southern wages, which is also the North's terms of trade, is an increasing function of the rate of innovation in the North and a decreasing function of the rate of technology transfer to the South. Since Krugman's pioneer work, many scholars attempted to extend his model. Dollar (1986) extended Krugman's model by relating the rate of technology transfer to differences in production costs in the two regions. Jensen and Thursby (1985, 1986) relate the rate of product innovation as a function of the amount of northern labor devoted to R&D. Segerstrom, Anant and Dinopolous (1987) assume the rate of innovation is endogenously determined based on the outcome of R&D races between firms. Butler (1988, 1989) assume that both regions can innovate new products and transfer technology to each other. Grossman and Helpman (1989) explicitly treat the private incentive for investment in R&D and the resource requirements of R&D activity. And Lee (1989) compares the effects of product-oriented technological changes and process-oriented technological changes in a model of the product cycle. He also shows that the product cycle can lead to intraindustry trade between the developed countries and the less developed countries.

All of the models above, however, are basically two-country models which do not seem proper in explaining the new international division of labor. As mentioned above, Vernon divides the world into three regions, the U.S., the other advanced countries, and the less developed countries. This distinction is no longer quite right either, as the U.S has become relatively weaker and the NICs have emerged.



[**Figure**] The Life Cycle and Trade Pattern of a Product

It would be more proper to assume that the world is divided into the developed countries of the OECD, the NICs and the LDCs. And the trade pattern would be as follows. A product is first introduced in the OECD countries and is exported to the other two regions. As the product becomes matured, the production technology is transferred to the NICs and the product is exported from the NICs to the OECD countries and the LDCs. After some time, when the product becomes standardized, the LDCs take turn producing and exporting the product until the product finally becomes obsolete. The figure below illustrates how each region's net export of a product changes along with the life cycle of the product.

A theoretical model illustrating the above pattern of international trade is build in the following section.

III. THE MOEL

Assume that the world has three regions, the North, the Middle, and the South. The North represents the developed countries of the OECD, the Middle the Newly Industrializing Countries (NICs), and the South the Less Developed Countries (LDCs). There is a large number of goods. But there are only three types of goods: new goods, matured goods, and old goods. New goods are recently developed goods that can only be produced in the North; matured goods can be produced in the North and in the Middle; old goods in all three regions. Each region has two factors of production, capital and labor, both homogeneous in each region. It is assumed that the total amounts of labor and capital in the world are fixed and capital is only the factor which is freely mobile between regions so that it moves from one region to another in response to differences in the return to capital in each region. All goods are produced with the same production process. However, only northern labor has the ability to develop new goods. Only after some time, can middle labor learn how to produce a good previously produced in the North. Southern labor is the least skilled labor so that it can learn how to produce a good previously produced only in the Middle.

Thus innovation is defined as the introduction of new products in the North, and technology transfer as the process that allows the Middle to produce a good formerly produced only in the North and the process that allows the South to produce a good formerly produced only in the Middle. If the North produces all types of goods, the prices of all goods must always be the same: with the same cost of producing all goods in the North, the prices of all goods will be the same under the perfect competition. If, on the other hand, there is complete specialization in each region, the relative price of new goods and matrued goods, that of new goods and old goods, and that of matured goods and old goods will be greater than one respectively and will be demand determined.[2] Complete specialization

[2]For more discussion of the condition for complete specialization, the reader is referred to Dollar (1986).

is assumed so that we can identify the number of goods produced in each region, n_N, n_M and n_S, the number of new, matured and old goods, respectively. That is, the North's resources are limited so that it can produce only new goods whose prices are higher than those of matured and old goods; the Middle's resources are also limited so that it can produce only matured goods.[3]

1. Product Innovation, Product Technology Transfer and Obsolescence of Products

Product innovation takes the form of adding new products in the North, while product technology transer enables the Middle to produce goods previously produced only in the North so that new goods are transformed into matured goods, or the South to produce goods previously produced only in the Middle so that matured goods are transformed into old goods. I take it as given that there is continuous introduction of new products in the North and continuous technological diffusion from the North to the Middle and from the Middle to the South.

We can then define the rate of change of the number of new goods as the difference between the rate of innovation and the rate of technology transfer in the North:

$$(1)\quad \dot{n}_N = dn_N/dt = gn_N - t_N n_N,\ 0<g<1,\ 0<t_N<1$$

where g and t_N are coefficients of innovation in the North and technology transfer from the North to the Middle respectively.[4] That is, the rate of product innovation in the North and the rate of product technology transfer from the North to the South are proportional to the number of new goods currently being produced in the North.[5]

The rate of change of the number of matured goods is the difference between the rate of technology transfer from the North to the Middle and the rate of technology transfer from the Middle to the South:

$$(2)\quad \dot{n}_M = t_N n_N - t_M n_N,\ 0<t_M<1$$

where t_M is coefficient of technology transfer from the Middle to the South. Note

[3]As mentioned earlier, the middle labor cannot produce the new goods whose prices are higher than middle goods because of its technology limitation.

[4]Even though n, n_N, and n_S can take only integer values, they are treated as differentiable continuous variables without loss of generality.

[5]Krugman (1979) assumes that the rate of product innovation is proportional to the number of products already developed, arguing "the more you know, the more you can learn". Dollar (1986), instead, assumes that the rate of product innovation is proportional to the number of new goods currently being produced in the North, arguing that product innovation should be related to the size of the North's economy as relfected in n_N. Here I follow Dollar.

that the rate of technology transfer from the Middle to the South is proportional to the number of new goods, not matured goods.[6]

Contrary to the assumptions of the Krugman and Dollar models, however, products eventually become obsolete. This allows the model to have a steady-state in the long-run.[7] Accordingly I assume that there is continuous extinction of old goods in the South at a rate proportionate to the number of old goods produced in the South. Thus, the rate of change of the number of old goods is the rate of technology transfer from the Middle to the South, less the rate of obsolescence:

$$(3)\quad \dot{n}_S = t_M n_N - q n_S, \quad 0<q<1$$

where q is coefficient of obsolescence.

Finally, the rate of change of the number of total goods must be the difference between the rate of product innovation and the rate of obsolescence:

$$(4)\quad \dot{n} = g n_N - q n_S,$$

which is the sum of Eqs. (1), (2) and (3).

The composition of the number of goods will always tend toward a stable mix. Defining $d_{NM} = n_N/n_M$, the time derivative of the ratio of the number of new goods to the number of matured goods is

$$(5)\quad \dot{d}_{NM} = (\dot{n}_N n_M - n_N \dot{n}_M) \,/\, \dot{n}_M^2$$
$$= (g - t_N) d_{NM} - (t_N - t_M)\, d_{NM}^2.$$

Hence, the ratio of the number of new goods to the number of matured goods will tend toward an equilibrium at $d_{NM} = (g - t_N)/(t_N - t_M)$. The composition of the number of goods is stable: any (positive) d_{NM} at any moment in time tends to move toward $d_{NM}^* = (g - t_N)/(t_N - t_M)$. The necessary condition is $g>t_N$ and $t_N>t_M$, or $g<t_N$ and $t_N<t_M$. This implies that the number of new goods relative to the number of matured goods increases as g and t_M increase, and t_N decreases.

By the same token, the ratio of the number of new goods to the number of old goods ($d_{NS} = n_N/n_S$) will tend toward a stable equilibrium at $d_{NS}^* = (g - t_N + q)/t_M$ because

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[6]The rate of technology transfer from the Middle to the South is assumed to be proportional to the number of new goods instead of matured goods because the number of matured goods depends upon the number of new goods by Eq.(1).

[7]Intuitively, Krugman and Dollar models are expansionary as, without the rate of product obsolescence, the number of total goods in the world increases over time. For more discussions on this, the reader is referred to Lee (1988).

$$(6)\quad \dot{d}_{NS} = (g - t_N + q)\, d_{NS} - t_M\, d_{NS}^2.$$

Necessary condition here is $g + q > t_N$. The ratio of the number of matured goods to the number of old goods ($d_{MS} = n_M/n_S$) will tend toward a stable equilibrium at $d_{MS}^* = (t_N - t_M)(g - t_N + q)/\{t_M(g - t_N)\}$ because

$$(7)\quad \dot{d}_{MS} = (t_N - t_M)(g - t_N + q)/t_M - (g - t_N)d_{MS}.$$

Necessary condition here is $t_N > t_M$ and $g > t_N$, or $t_N < t_M$ and $g < t_N < g + q$.

2. The Demand Side

As in Krugman (1979) and Dollar (1986), the utility function held by all individuals in all regions is assumed to be of the form:

$$(8)\quad U = \left(\sum_{i=1}^{n} C_i^{\theta}\right)^{1/\theta},\ 0 < \theta < 1,$$

where C_i is the consumption of the ith good, n is the number of all goods existed in all regions and θ is the demand parameter, which must be less than one for concavity. Therefore, for a given income, a consumer's utility will be improved if the number of available products increases. The utility function also implies that any two goods with the same price will be consumed in the same quantity by all consumers.[8]

Maximizing this specific form of utility function subject to the standard budget constraint implies that the relative demands (the demand for a representative new good relative to the demand for a representative matured good, the demand for a representative new good relative to the demand for a representative old good, and the demand for a representative matured good relative to the demand for a representative old good) will depend only on the relative prices of the corresponding two goods:

$$(9)\quad \begin{aligned} C_N/C_M &= (P_N/P_M)^{-(1/1-\theta)}, \\ C_N/C_S &= (P_N/P_S)^{-(1/1-\theta)}, \\ C_M/C_S &= (P_M/P_S)^{-(1/1-\theta)}, \end{aligned}$$

where C_N is consumption of a representative northern good, C_M is consumption of a representative matured good and C_S is consumption of a representative southern good.

[8]Originated by Avinash Dixit and Joseph Stiglitz E. (1977), this is a very restrictive utility function which is clearly unrealistic. As Krugman (1979) stressed, the only justification for the assumption is its simplifying power which allows us to speak of representative northern and southern goods since relative prices will not change within each region.

3. The Production Side

As mentioned in the above, capital is assumed to be freely mobile between regions, but labor is perfectly immobile. Within each region, however, there is assumed to be perfect competition and perfect mobility of capital and labor. With capital and labor as the inputs, the technology of producing all goods in each region is represented by a neoclassical production function exhibiting constant returns to scale, so that for given factor prices the capital-labor ratio will be the same between goods in a region. We can thus treat old goods, matured goods and new goods as three different composite commodities.

The assumptions of perfect competition and linearly homogenous production functions assure that factory prices will adjust so as to bring about full employment of resources in each region:

$$(10)\quad L_j = a_{Lj}(w_j/r_j)C_jn_j$$
$$K_j = a_{Kj}(w_j/r_j)C_jn_j$$

where L_j and K_j are the supplies of labor and capital in region j ($j=N,M,S$), a_{ij} denotes factor i ($i=L,K$) requirement per unit of output in region j, w_j is the rate of return on labor in region j, and r_j is the rate of return on capital in region j.[9] That is, demand for factor i in each region will equal the amount of factor used per unit of output with given factor prices times the total output of a representative good in the region times the number of such goods. The assumption of perfect competition also assures that profits are driven to zero:

$$(11)\quad P_j = a_{Lj}w_j + a_{Kj}r_j$$

where $j=N,M,S$. Note here that in the long run, the rate of return on capital becomes the same in the three regions. Then because the price of northern goods is higher than the prices of middle goods or southern goods, with the same rate of return on capital in the three regions, the real wage of northern workers is higher than that of middle workers or southern workers. Then it is obvious that with the same production technology the North will use more capital per worker than the other two regions. Therefore North's exporting products are more capital intensive than the other two regions' exporting products. By the same reason the real wage of middle workers is less than that of northern workers and higher than that of southern workers. And the matured goods are labor intensive compared with the new goods, but capital intensive compared with the old goods.

[9]The input coefficients, a_{iN}, a_{iM} and a_{iS}, where $i=K,L$, are different because, even though the three regions use the same process technology (i.e., the same production function), relative factor prices are different in the three regions. Obviously the derivatives of a_{Lj}, where $j=N,M,S$, with respect to the relative factor prices are negative and the derivatives of a_{Kj} with respect to the relative factor prices are positive.

IV. COMPARATIVE STATICS

From Eqs. (9) and (10) the relative demand for labor and the relative demand for capital can be written as

$$
\begin{aligned}
(12)\quad L_N/L_M &= (a_{LN}/a_{LM})(P_N/P_M)^{-(1/1-e)}(n_N/n_M)\\
L_N/L_S &= (a_{LN}/a_{LS})(P_N/P_S)^{-(1/1-e)}(n_N/n_S)\\
L_M/L_S &= (a_{LM}/a_{LS})(P_M/P_S)^{-(1/1-e)}(n_M/n_S)\\
K_N/K_M &= (a_{KN}/a_{KM})(P_N/P_M)^{-(1/1-e)}(n_N/n_M)\\
K_N/K_S &= (a_{KN}/a_{KS})(P_N/P_S)^{-(1/1-e)}(n_N/n_S)\\
K_M/K_S &= (a_{KM}/a_{KS})(P_M/P_S)^{-(1/1-e)}(n_M/n_S).
\end{aligned}
$$

Then relative prices can be expressed either as a function of the relative labor requirement per unit of output, the relative labor demand, and the relative number of goods; or as a function of the relative capital requirement per unit of output, relative capital demand, and the relative number of goods:

$$
\begin{aligned}
(13)\quad P_N/P_M &= (a_{LN}/a_{LM})^{1-e}(L_N/L_M)^{-(1-e)}(n_N/n_M)^{1-e}\\
&= (a_{KN}/a_{KM})^{1-e}(K_N/K_M)^{-(1-e)}(n_N/n_M)^{1-e}\\
P_N/P_S &= (a_{LN}/a_{LS})^{1-e}(L_N/L_S)^{-(1-e)}(n_N/n_S)^{1-e}\\
&= (a_{KN}/a_{KS})^{1-e}(K_N/K_S)^{-(1-e)}(n_N/n_S)^{1-e}\\
P_M/P_S &= (a_{LM}/a_{LS})^{1-e}(L_M/L_S)^{-(1-e)}(n_M/n_S)^{1-e}\\
&= (a_{KM}/a_{KS})^{1-e}(K_M/K_S)^{-(1-e)}(n_M/n_S)^{1-e}.
\end{aligned}
$$

And the relative demand for capital can be rewritten as

$$
\begin{aligned}
(14)\quad K_N/K_M &= (a_{KN}/a_{LN})(a_{KM}/a_{LM})^{-1}(L_N/L_M)\\
K_N/K_S &= (a_{KN}/a_{LN})(a_{KS}/a_{LS})^{-1}(L_N/L_S)\\
K_M/K_S &= (a_{KM}/a_{LM})(a_{KS}/a_{LS})^{-1}(L_M/L_S).
\end{aligned}
$$

Eqs. (13) and (14) can be mobilized to illustrate the effects of product-oriented technological change on the terms of trade, factor prices and relative distribution of world capital.

We can illustrate that when d_{NM} $(=n_N/n_M)$ rises, for example, the price of northern good relative to the price of middle good increases, northern factor prices relative to middle factor prices rise, and capital moves from the Middle to the North. To illustrate this, defining $p_{NM} = P_N/P_M$, from Eq. (13) we have

$$(15)\quad \partial p_{NM}/\partial d_{NM} = [(1\text{-}\theta)\ p_{NM}] \ /\ [d_{NM}\ (1+x+y)]$$

where $x = -(1\text{-}\theta)\ p_{NM}\ a_{LN}^{-1}[\partial a_{LN}/\partial(w_N/r_N)]\ [\partial(w_N/r_N)/\partial p_{NM}]$,

$y = +(1\text{-}\theta)\ p_{NM}\ a_{LM}^{-1}[\partial a_{LM}/\partial(w_M/r_M)]\ [\partial(w_M/r_M)/\partial p_{NM}]$.

Because θ, p_{NM}, and d_{NM} are positive numbers, the sign of Eq.(15) depends upon the sign of $(1+x+y)$, i.e., the signs of x and y. Because the derivatives of a_{Li} with respect to the relative factor prices, $\partial a_{Lj}/\partial(w_j/r_j)$, (where $j = N, M$), are negative, the signs of x and y are, in turn, determined by the signs of the partial derivatives of relative factor prices with respect to relative commodity prices. $\partial(w_N/r_N)/\partial p_{NM}$ is positive, and $\partial(w_M/r_M)/\partial p_{NM}$ is negative, so that the signs of x and y positive, and the sign of Eq.(15) is positive. That is, as p_{NM} rises (say, as P_N rises or/and P_M declines) the rates of return on northern industry factors increase and the rates of return on middle industry factors decrease. This, in turn, causes the freely mobile factor, capital, to move toward the North to equalize the return to capital in both regions, causing the increase in the rate of return on labor proportionally larger than the increase in the rate of return on capital in the North (i.e., $\partial(w_N/r_N)/\partial p_{NM} > 0$) and the decrease in the rate of return on labor proportionally larger than the decrease in the rate of return on capital in the Middle (i.e., $\partial(w_M/r_M)/\partial p_{NM} < 0$).

Intuitively, if n_N increases relative to n_M, there is excess demand for the North's output ($C_N n_N$) relative to the Middle's output ($C_M n_M$) because of the special form of the utility function, and p_{NM} must rise to equilibrate the system.

Then, with relatively more expensive labor than capital in the North, a_{LN} declines and a_{KN} rises: the northern capital-labor ratio increases. With relatively less expensive labor than capital in the Middle, a_{LM} rises and a_{KM} declines: the middle capital-labor ratio decreases. That is, the northern product becomes more capital intensive against the middle product, and the middle product becomes more labor intensive against the northern product. This is illustrated by Eq.(14).

By the same token, the signs of $\partial p_{NS}/\partial d_{NS}$ and $\partial p_{MS}/\partial d_{MS}$ are positive, where $p_{NS} = p_N/p_S$, $p_{MS} = p_M/p_S$.

1. Product Innovation

If, other things being equal, g, and hence the rate innovation in the North rises, the number of new goods relative to the number of other goods increases (because $n_N/n_M = (g-t_N)/(t_N-t_M)$ and $n_N/n_S = (g-t_N+q)/t_M$, the northern terms of trade improve, the absolute and relative northern wage rate increases, the world capital moves toward the North from the other two regions. Therefore northern product becomes more capital intensive and the other regions' products become more labor intensive. The effect on the number of matured goods relative to the number of old goods is ambiquous because $n_M/n_S = (t_N-t_M)(g-t_N+q)/\{t_M(g-t_N)\}$.

2. Technology Transfer

If, other things being equal, t_N, and hence the rate of technological transfer from the North to the Middle increases, the number of matured goods relative to the number of new goods (n_M/n_N) increases, the relative price of middle goods

to northern goods increases and the absolute and relative middle wage rate increases, and the world capital moves toward the Middle from the North. Therefore the middle product becomes less labor intensive against the northern product, and more capital intensive against the southern product. The effect on the number of matured goods relative to the number of old goods (n_M/n_S) is ambiguous. But this also causes the number of new goods relative to the number of old goods (n_N/n_S) to decline so that the North becomes the region which suffers the most severe negative effects.

If, other things being equal, t_M, and hence the rate of technological transfer from the Middle to the South increases, the number of old goods relative to the number of matured goods (n_S/n_M) increases, and the price of southern goods increases relative to middle goods, and the absolute and relative southern wage rate increases, and the world capital moves toward the South from the Middle. On the other hand, the number of new goods relative to the number of old goods (n_N/n_S) decreases and the number of new goods relative to the number of matured goods (n_N/n_M) increases. So there is no qualitative change on the part of the North.

3. Product Obsolescence

If, other things being equal, q, and hence the rate of product obsolescence in the South increases, the number of old goods relative to the number of new goods (n_S/n_N) and the number of old goods relative to the number of matured goods (n_S/n_M) decrease, the price of southern goods relative to either northern goods or middle goods decreases, and the absolute and relative southern wage rate decreases, and the world capital flows out of the South to the other two regions. This does not affect the number of new goods relative to the number of matured goods (n_N/n_M).

V. CONCLUDING REMARKS

The purpose of this paper is to provide a dynamic model of the product life cycle, which highlights the key factors of new international division of labor. The model depicts a world of three regions-the North, the Middle, and the South-in which the pattern of trade is continuously changing. New goods are continuously developed in the North, the developed countries of the OECD, while technology of producing some northern goods is being transferred to the Middle, the NICs. Production technology of some middle goods is also diffused to the South, the LDCs.

This process of product cycle-type technological change affects not only the number of goods produced in and exported from each region, but also the relative commodity prices, factor prices, and capital movement in the world. In order to

maintain the current gap between regions at least, the North must constantly innovate, the Middle and the South must keep learning technology from the North and the Middle respectively.

For example, if the North's innovation activities become sluggish or the NICs' technology learning becomes faster, the developed countries face the most severe negative effects. That is, their terms of trade will deteriorate, real wages will decline, and capital will move out from the developed countries. And hence the developed countries would try to protect their comparative advantage-losing industries. This helps us understand why the NICs currently face with growing protectionism in developed country markets.

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