A Note on the Product Cycles and the World Income Distribution

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1 Introduction

That the world generates a greater output level with international trade than with autarky is a commonplace. However, the benefits from trade may not be equally distributed among the trading partners. Since income level and income distribution within a country are very important to its economic growth,[1] the distribution of world income may have a profound effect on relative performances of economic growth among countries and therefore on world income inequality.

Trade liberalization in developing countries has been dramatic in the past few decades. Developing countries are moving towards less restrictive trade arrangements with developed countries. Meanwhile, many developing countries abandon the import substitution paradigm and participate more actively in the world "product cycle". These countries actively pursue a policy of industrialization through imitation to acquire more advanced technologies, raising their competitive edges in the world market.

These observations motivate us to study the impact of trade between developed and less-developed countries on the world income distribution. There are various approaches to tackle this problem.[2] In particular, the product-cycle models, which focuses on the effects of dynamic technological changes on the pattern of trade between a developing country and a developed country, seems to fit our purpose here.

2 Literature Review

Pioneered by Vernon (1966), innovation and imitation of technology had been incorporated in trade theories in the light of the concept of product cycle. Papers by Krugman (1979), Grossman and Help (1991a, b), Lai (1995) and many others have also contributed to this line of literature. These models generally assume that there is an innovating Northern country and a non-innovating but imitating Southern country.

A key feature of these models is that the North invents new types of goods so that

[1] See Aghion et .al. (1999) for a survey.

[2] For exanmple, Flam and Helpman (1987), and Matsuyama (2000) construct Ricardian models of trade. On the other hand, Krugman and Venables (1995) developes a geographic model of trade.

the varieties of goods available for consumption increase over time, while the South is able to produce these goods by imitation with a time lag. This feature can be found in Krugman (1979), Grossman and Helpman (1991a) and Lai (1995).[3] The other feature is that the North invents new technologies to improve the qualities of certain existing goods. Once the state-of-the-art technology embodied in a good is imitated by the South, the production of this good is then shifted to the South. Grossman and Help (1991b) construct this kind of quality ladder model.[4] In general, these features affect the relative wages between North and South through changes in the rates of innovation and imitation. Subsidizing R&D in a country either has a positive effect or no effect on its relative wage. Moreover, labor in the two countries is equally productive in comparable occupations, but the wage rate in the North is higher due to its technological advantage in innovation. However, an increase in the relative supply of labor has an ambiguous effect on relative wages.

In the following, we briefly review the setups and the key results of the models mentioned above.

2.1 Imitating New Varieties of Goods

In the model of Krugman (1979), all individuals share the same utility function

$$U = \left[\sum_{i=1}^{n} c(i)^{\theta}\right]^{1/\theta}, \ 0 < \theta < 1,$$

where $c(i)$ is the consumption of the good i, and n is the total number of products available. Consumers are love-of-variety. That is, for a given income and prices, a consumer will become better off if she is offered a wider selection of goods.

All goods share the same production technology. One unit of labor produces one unit of good. All goods are produced under conditions of perfect competition. Thus,

$$P_i = w_i, \ i = S, N,$$

[3]Krugman's work has been extended by Dollar (1986) and Jensen and Thursby (1986, 1987).

[4]Segerstrom et al. (1990), Glass and Saggi (1998), and Glass (1997) also employ a quality ladders product cycles model. But they do not focus on the issue of income distribution.

where w_i and P_i are the wage rate and the price of goods produced in country i, respectively. Let n_i and L_i denote the number of goods produced and the labor endowment in country i, respectively. $n = n_N + n_S$. The equilibrium relative wage is thus derived as

$$\frac{w_N}{w_S} = \left(\frac{n_N}{n_S}\right)^{1-\theta} \left(\frac{L_N}{L_S}\right)^{\theta-1}.$$

Thus, a realization of innovation which increases the relative importance of newly developed products, n_N/n_S, will raise the relative wage of the North. In Krugman's model, innovation and imitation are exogenous which leads n_N/n_S to equal to the ratio i/t, that is the ratio of the arrival rate of new products in the North to the rate of technology transfer to the South, t,

$$\frac{n_N}{n_S} = \frac{i}{t}.$$

Because northern wages reflect in part a rent on North's monopoly of new goods, a slowdown in innovation or an acceleration of technology transfer narrows the wage differential and may even lead to an absolute decline in living standards of workers in North. A decline in relative labor supply in the less advanced country, L_S/L_N, will also lower the relative wage of the North.

Grossman and Helpman (1991a) endogenizes the rate of innovation and imitation by assuming that an upfront R&D cost is required in order to conduct an innovative or an imitating activity. R&D activities use labor as input. There is a credit market in which the rate of interest is endogenously determined. Due to the R&D cost, the market structure of goods exhibits monopolistic competition. The producers behave as Bertrand competitors. A firm maximizes profits by setting a price that is a fixed mark-up over marginal cost and the expected present value of the profit streams equals its upfront cost in equilibrium.

The upfront cost for an innovative and an imitating activity is a_n/n and a_m/n_S units of labor, respectively. The a_n and a_m are fixed productivity parameters. Employment in R&D sector of the North is L_n, and that of the South is L_m. It can be derived that

$$\frac{\dot{n}}{n} = i = \frac{L_n}{a_n} \text{ and } \frac{\dot{n_S}}{n_S} = t\frac{n_N}{n_S} = \frac{L_m}{a_m}.$$

In the long run, if $w_N/w_S > 1/\alpha$, $0 < \alpha < 1$, a Southern imitator charges the monopoly price without the fear of competition from the original Northern developer of that variety.

In this wide-gap case, the relative northern wage is determined by

$$\left(\frac{w_N}{w_S}\right)^{\varepsilon} = \left(\frac{L_N - a_n i}{L_S - a_m i}\right)\left(\frac{t}{i}\right), \varepsilon > 1.$$

When i and t are taken as exogenous, increase in the relative supply of labor in the South raise the relative wage of the North. This is the same as in Krugman. However, when i and t are endogenous, then the conclusion is reversed and is exactly the opposite of that predicted by Krugman. The reversal stems ultimately from the increasing-returns nature of technologies for production of goods and knowledge.

An extension by Lai (1995) shows that even if there are skilled and unskilled labor the main results hold. An increase in the supply of unskilled (skilled) labor in a country lowers (raises) its relative wage. This is mainly because that skilled labor is required for R&D. The output of R&D made from one unit of labor is more valuable than goods made from one unit of labor. If $w_N/w_S < 1/\alpha$, which is so called the narrow-gap case, the relative wage of a region also increases with the relative size of that region's labor force.

In addition, Grossman and Helpman show that to subsidize R&D in a country has a positive effect on its relative wage. A subsidy on R&D is equivalent to an improvement in productivity in R&D. Put it in another way, it is like that each unit of labor generates more than one units of effective labor. Therefore, a subsidy on R&D has the same effect on the relative wages as an increase in relative labor supply does.

2.2 Imitating State-of-the-Art Technology

Grossman and Helpman (1991b) assume that a consumer maximizes utility

$$U = \int_0^{\infty} e^{-\rho t} \int_0^1 \log\left[\sum_j q_j(\omega) x_{jt}(\omega)\right] d\omega dt,$$

where $x_{jt}(\omega)$denotes consumption of quality j of good ω at time t. After j improvement of product ω, its highest available quality is given by $q_j(\omega) = \lambda^j$, $\lambda > 1$. For every ω, the consumer chooses one with the lowest quality adjusted price. In equilibrium it is always the highest available quality that provides the lowest quality adjusted price. The market structure of goods also exhibits monopolistic competition. The producers behave as Bertrand competitors. There are two kinds of innovators in North, the leaders

who owned the state-of-the-art technologies, and the followers who have the second-to-top technologies. Followers are called efficient if they may replace leaders by innovation. Otherwise, followers are inefficient. Let a_{nl} and a_{nf} denote the units of labor required per unit of time to undertake one R&D activity for a leader and a follower, respectively.

In the efficient-follower case, the relative wage is determined by

$$\frac{(1-\delta\frac{w_N}{w_S})}{(1-\delta)} = \frac{a_{nl}}{a_{nf}}$$

The relative wage of the North is higher when a_{nl}/a_{nf} is smaller, that is, when leaders are more efficient at R&D relative to followers. In this case, any subsidy to innovation or to imitation has no effect on relative wages. When followers are inefficient a subsidy to imitation expands the share of products manufactured in the North (because the South employs more resources in imitation and thereby contracts manufacturing employment) and reduced the North's relative wage. A subsidy to innovation has the opposite effects.

In the quality-ladder models, in contrast, country size is a less important factor in determining the relative wage. The relative wage that prevails in the regime with efficient followers does not vary with the sizes of the two countries. When followers are inefficient, the effects of labor supply on relative wages are ambiguous. An increase in a country's relative labor share increases the share of products manufactured in that country. At the same time, this county's relative labor share in R&D may decline. If less labor is employed in the R&D sector then its relative wage may decrease.

3 Vertical Division of Production and Product Cycles

This above branch of literature has focused on the trading in final goods. In these models, a successful innovation or imitation drives the incumbent good out of the market. Thus, innovation and imitation mainly reflect competition between North and South. Also, the effects of country size and industrial policies on relative wages differ across models.

Another important feature of international division of production is that countries may trade in intermediate goods. A finished product takes multiple stages at different

locations to complete. However, this vertical specialization (VS) feature have not yet been investigated in the product-cycle framework.

Hummel et al. (2001) document a deeper dimension to international integration involving the interconnection of production processes in a vertical trading chain that stretched across many countries. In a vertical trading chain, each country specializes in particular stages of a good's production sequence. Specifically speaking, countries use imported inputs to produce goods that are exported, which is defined as vertical specialization. They focus on this particular sequential linkage in international trade and suggest VS has risen dramatically. Their calculations, using input-output tables and maquiladoras, show that, as of 1990, the VS share of exports in ten OECD countries and Ireland, Korea, Taiwan and Mexico was 0.21, up almost 30% from 0.165 in 1970. Also, the growth in VS exports accounts for 30% or more of the growth in overall exports between 1970 and 1990. They suggest that there are two possible forces which explain the growth in vertical specialization and the changing nature of trade. One is technological shocks which have led to the fragmentation of production across different locations. The other is reductions in the cost of moving goods which have driven the increase in vertical specialization.

In the following, we propose a setup of product cycles in a two-stage production.

3.1 A Case of Two-Stage Production

There are two production sectors: an upstream sector and a downstream sector. The former produces a good y which is an input in the latter. Both sectors are monopolistically competitive. The downstream sector combines the good y and a home-made semi-finished good x to produce a capital good K. Both of the good y and good x have a unit variable cost w, i.e., one unit of labor.

The qualities of the semi-finished goods x and y can be raised through innovative activities. The increments to quality for both semi-finished products are exogenously given by a parameter η, $\eta > 1$. Initially, semi-finished products x and y have a quality level $q_{x0}$and q_{y0}, respectively. If a good ω, $\omega \in \{x, y\}$, experiences j times of successful improvements in quality, its quality becomes $q_{\omega 0}\eta^j$. Innovative activities have uncertain prospects. A firm that undertakes innovative activities at an intensity ϕ for an interval of

time of length dt succeeds in developing the next generation of the targeted product with a probability ϕdt. An innovative activity that might upgrade the quality of good ω from η^{j-1} to η^j need to pay an up-front cost of $aq_{\omega j}$ units of labor. That the up-front cost is an increasing function in quality reflects the fact that it is more difficult to invent a higher quality as the quality advances over time.

The production function of capital goods K_{ij} is assumed to take one unit of good x and one unit of good y

$$K_{ij} = \min\{x_i, y_j\},$$

where x_i and y_j denote quantities of good x and good y with quality η^i and η^j, respectively. The quality of the capital good K_{ij} is determined by the qualities of inputs,

$$Q_{ij} = \sqrt{q_{xi}q_{yj}},$$

where $q_{\omega h}$ is quality of the employed input good ω after h times of successful innovations, $\omega \in \{x, y\}$, $h \in 0 \cup N$. Define $\lambda \equiv \sqrt{\eta}$, $\lambda > 1$. Other things being held constant, each upgrade in quality can drive the unit price of capital goods up by a factor of λ.

It is assumed that firms proceed Bertrand competition and every firm takes the prices of other goods as given when making its pricing decision. Notations referring quality are omitted hereafter because only the state-of-the-art quality survives. The downstream firm sets a price

$$p = \lambda(w + p_y),$$

because its competitor would have driven the price down to $w + p_y$ and an improvement in quality of good x can raise p up by a factor of λ. Let π_x denote the instantaneous profit of a downstream firm producing capital goods,

$$\pi_x = (\lambda w + \lambda p_y - w - p_y) K,$$

where $(\lambda w + \lambda p_y - w - p_y)$ is the unit profit and K is quantity of sales. Define p_x to be the difference between the price of capital good K and the price of good y,

$$p_x = p - p_y,$$

which can be interpreted as the price of the semi-finished good x.

A downstream firm can choose to buy good y_j with the state-of-the-art quality η^j or good y_{j-1} with second-to-top quality η_{j-1}. Due to competition, $p_{y_{j-1}}$ will be equal to w and p_{y_j} will be set so that its second-to-top-quality competitor is driven out of the market. The firm seeks to maximize p_y subject to $p_x + p_y \leq \lambda (p_x + w)$. Thus,

$$p_y = \lambda (p_x + w) - p_x.$$

The instantaneous profit in the good y sector is

$$\pi_y = (\lambda w + \lambda p_x - p_x - w) K.$$

Consider a firm that enters the market at time s. The firm earns a profit $\pi_\omega(\tau)$ for $\tau \geq s$, $\omega \in \{x, y\}$, till the next quality upgrading occurs in its sector. The stream of these profits constitutes the value of this firm, v_ω. Given the monopolistically competitive market structure, free entry ensures that the value of this firm is equal to its up-front cost. If v_ω is less than the up-front cost then the firm will not enter the market in the first place. In general,

$$v_\omega \leq a q_\omega w, \text{ with equality for } \phi > 0.$$

3.2 Results and Conjectures

The multi-stage production setup outlined above may yield considerably different predictions on the relative wages from the previous models.

Firstly, technological races may be complementary instead of being competitive between countries. In the model proposed above, an increase in p_x (p_y) results in a higher level of p_y (p_x). Thus, a country will be able to benefit from the other country's efforts in raising quality. The benefit comes from a higher price level of goods which is produced domestically. Therefore, it may be in a country's interest to encourage technological progress in the other country.

Secondly, product cycles *within* a country may now play a more important role in raising the qualities of goods and/or the number of variety of goods. The reason is that a firm will be able to employ fewer resources in those R&D activities which are meant to take over the other country's incumbent technologies. On the other hand, a country can

make better use of its expenditure of R&D on a narrower range of goods, in particular, on those goods produced domestically.

Thirdly, following from the above result, a Southern country may also undertake innovative activities in spite of its less advanced technology. This says that a country can take advantage of its comparative advantage in R&D.[5] This is exactly what we have observed in the real world.

[5]Chu and Chen (2000) discussed the international division of innovations in an endogenous growth model, where countries may engage in vertical and/or horizontal innovation. The policy environment affects the international division of innovations and also has an effect on the rates of growth across countries.

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