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The product cycle and the world distribution of income
A reformulation

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Abstract

This paper uses a North–South trade model with skilled and unskilled labor to study the effect of labor supply on the world distribution of income. The world rate of innovation is endogenized. An increase in the supply of unskilled labor in a country lowers its steady-state relative wage (which is consistent with Krugman's result), while an increase in supply of skilled labor in a country raises its steady-state relative wage (which is consistent with Grossman–Helpman's result) when the elasticity of substitution between goods is sufficiently large. Both Krugman's and Grossman–Helpman's models are special cases of this unified model.

Key words: Product cycles; Innovation; Imitation; Growth

JEL classification: F43; O31; F12

1. Introduction

Since Raymond Vernon (1966) published his celebrated product cycle theory, there have been several attempts to formalize the international product cycle in a dynamic framework. The notable examples are Krugman (1979), Jensen and Thursby (1986), Dollar (1986), Flam and Helpman (1987), Sergerstrom et al. (1990) and more recently, Grossman and Helpman (1991a, 1991b). Each of these papers has its own focus on

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particular aspects of the product cycle (e.g. Dollar focused on capital movement, Flam and Helpman focused on endogenous product quality changes and Grossman and Helpman (1991b) focused on the endogenous rates of innovation and imitation). None of these papers, however, study specifically the long-run world distribution of income when there are both skilled and unskilled labor. In this paper, we shall focus on the effects of changes in the supply of skilled and unskilled labor in the North and South on the long-run world distribution of income when growth is endogenous. This question becomes more interesting in the past decade as developing countries abandon the import substitution paradigm and participate more actively in the world 'product cycle'. For example, the case of China actively integrating with the North in the last decade through imitation of and exporting to the rest of the world deserves particular attention. With its huge labor force (China has about one fifth of the world's population), the effect of this increase in labor supply in the 'South' on the world distribution of income can be very great.

In Krugman's (1979) seminal article, he assumed there exists an exogenously determined number of goods in the world at any moment. A fraction of the goods is produced solely by the North and the rest are produced solely by the South following imitation. This fraction is constant in steady state given the exogenous rates of product innovation by the North and the exogenous rate of imitation by the South. Since goods and labor markets are competitive and each good has a downward-sloping demand curve, the ratio of the demands for labor between two countries is a negative function of the relative wage between the two countries. As a result, an increase in the supply of labor in a country lowers the relative wage of that country.

In contrast, Grossman and Helpman (1991a, hereinafter referred to as G–H, 1991a) developed a model in which an increase in a country's labor supply increased the wage relative to that of the other country. They assume that the rate of innovation and rate of imitation are both endogenous, and hence the steady-state fraction of goods produced by the North is endogenous. Labor is needed for both manufacturing and R&D. Therefore, in addition to the Krugman effect (that an increase of the supply of labor in a country lowers the relative wage of labor for a given fraction of goods produced by the country), an increase of supply of labor has an additional effect: it increases the fraction of goods produced by the country and raises the demand for labor in the manufacturing sector. It turns out that the latter effect always dominates the former given their specific way of modeling innovation and imitation. Referring back to the question of China's integration with the rest of the world, according to Krugman, an increase in supply of labor from China (which can be considered part of the South) will depress the relative wage of the South and the real wage of Southern labor. According to G–H (1991a), however, an increase in the supply of labor from China will increase the relative wage of the South, provided that labor can be used in both production and R&D.

This paper develops a model that encompasses the Krugman and G–H models. The key innovation is the introduction of both skilled and unskilled labor in production. In our model, if one varies the supply of unskilled labor, which is needed only in production, then Krugman's result obtains. If one varies the supply of human capital (i.e. skilled labor), which is needed for both production and R&D, then the G–H (1991a) result holds when the elasticity of substitution between goods is sufficiently small. Both Krugman's and G–H's results are obtained as special cases of our model.

This paper proceeds as follows. Section 2 sets up the model. Section 3 studies the effects of changes in labor supply on the relative income of labor in the North and the South. Section 4 concludes.

2. The model

2.1. General features

This paper modifies the Grossman–Helpman model by assuming there are two types of labor: human capital (used interchangeably with 'skilled labor') and unskilled labor. The two types of labor are not perfectly substitutable for one another.

We define engineers and researchers as suppliers of human capital H, and unskilled workers as suppliers of unskilled labor L. We assume that R&D can only be done by H, while manufacturing has to be undertaken by both H and L, which enter into a CES production function. All other features of the model follow that in G–H (1991a).

A representative consumer in the world (which consists of the North and the South) maximizes intertemporal utility

$$W_t = \int_t^{\infty} e^{-\rho(\tau - t)} \log[u(\tau)] \, \mathrm{d}\tau$$

subject to intertemporal budget constraint

$$\int_t^{\infty} e^{-r(\tau - t)} E(\tau) \, \mathrm{d}\tau = \int_t^{\infty} e^{-r(\tau - t)} Y(\tau) \, \mathrm{d}\tau + A(t) \, ,$$

where instantaneous utility $u(\tau) = [\int_0^{n(\tau)} x(j)^{\alpha} \, \mathrm{d}j]^{1/\alpha}$. The variables $x(j)$, E, Y, A represent the consumption of good j, total expenditure, total income and value of assets in each period, respectively. Therefore spending evolves according to $\dot{E}/E = r - \rho$. Imposing the normalization $E(t)/n(t) = 1$ for all t, we find the interest rate $r = \rho + g$, where $g = \dot{n}/n$ by definition.

Maximization of utility $u(t)$ subject to budget constraint $\int_0^n p(j)x(j)\,\mathrm{d}j = E$ in each period leads to the demand function

$$x(j) = \frac{Ep(j)^{-\epsilon}}{\int_0^n p(\xi)^{1-\epsilon}\,\mathrm{d}\xi}, \quad \text{where } \epsilon = \frac{1}{1-\alpha}. \tag{1}$$

In steady state equilibrium, goods 0 to n_s (on a continuous spectrum) have been imitated and produced by Southern firms (where each good is produced by a different firm); goods n_s to n are produced by Northern firms. Because goods enter symmetrically into the instantaneous utility function $u(\tau)$, consumption $x(j)$ is the same for all goods j produced in the same country. In fact firms in the same country will behave identically.

Assuming free trade, and price competition between firms, it can be shown that the Northern price is $p_N = c_N/\alpha$. Hence, instantaneous profit of a Northern firm is

$$\pi_N = \left(\frac{1-\alpha}{\alpha}\right)c_N x_N \tag{2}$$

where c_N is the Northern unit cost of production.

Southern firms set their price similarly as long as $p_s < c_N$. A Southern firm, however, cannot set a price above c_N, since it will then be undercut by the original innovator which it imitates. Therefore, when $c_s < \alpha c_N$ (wide cost-gap case), $p_s = c_s/\alpha$ so that $\pi_s = [(1-\alpha)/\alpha]c_s x_s$. But when $c_s \geqslant \alpha c_N$ (narrow cost-gap case), $p_s = c_N$ so that $\pi_s = (c_N - c_s)x_s$.

In the discussion that follows, we focus on only the wide gap case and on steady-state equilibrium, at which $\dot{n}/n = \dot{n}_s/n_s = g$ (which is constant over time) and $E/n = 1$ so that $\dot{E}/E = \dot{w}_b^a/w_b^a = \dot{n}/n$ ($a = N$, S and $b = H$, L) where w_b^a is the wage of labor type b in country a. We have empirical evidence to support our focus on the wide gap case only. In the real world, we have reason to believe that w_L^S/w_L^N is in the order of 0.1 or less, while a reasonable value of α is much higher than 0.1.[1] In any case, we conjecture that the qualitative results in the narrow gap case are similar to those in the wide gap case, as is true in G–H (1991a).

The manufacturing production function (for both the North and the South) of good i is a CES function:

$$x(i) = A[\beta h(i)^\gamma + (1-\beta)l(i)^\gamma]^{\frac{1}{\gamma}}$$

where $\gamma \leqslant 0$; $0 < \beta < 1$; $h(i)$ and $l(i)$ are the quantity of human capital and labor devoted to production of good i, and $\sigma = 1/(1-\gamma)$ is the elasticity of

[1] For example, the average wage of Chinese unskilled labor is no more than \$500 per year, which is no more than \$0.25 per hour, while the average wage of unskilled labor is greater than \$5 per hour in the United States.

substitution between the two factors. When $\gamma > 0$, the manufacturing production isoquants will intersect the axes. This implies that manufacturing can be carried out with only one factor. Since we want to consider the case where both types of labor are used in manufacturing, we shall only consider the case when $\gamma \leq 0$ ($\sigma \leq 1$), i.e. when skilled and unskilled labor are sufficiently complementary to each other. This includes Cobb–Douglas ($\gamma = 0$) and Leontief ($\gamma = -\infty$) functions.

Following G–H (1991a), it is assumed that the cost of producing a blueprint in the North is dependent on n, which is a proxy for knowledge in the North: $w_H^N a_d / n$ where a_d is a parameter for labor requirement in innovation in the North. Similarly, the cost of imitation of a good by a Southern firm is $w_H^S a_i / n_s$ where a_i is a parameter for the labor requirement in imitation in the South. Therefore, the total demand for H for R&D in the North and South in steady state is $\dot{n} a_d / n$ ($= a_d g$) and $\dot{n}_s a_i / n_s$ ($= a_i g$) respectively, where g is defined as the steady-state rate of innovation.

The labor market clearing conditions in the North therefore become

$$a_d g + H_N^p = H_N \quad \text{and} \quad L_N^p = L_N \,, \tag{3}$$

where H_b, L_b ($b = N, S$) are the inelastic supply of skilled labor and unskilled labor in country b, and H_b^p ($b = N, S$) are the skilled labor and unskilled labor engaged in manufacturing in country b.

The labor market clearing conditions in the South similarly become

$$a_i g + H_s^p = H_s \quad \text{and} \quad L_s^p = L_s \,. \tag{4}$$

2.2. The Northern equilibrium condition

The Northern 'no-arbitrage condition' (or zero profit condition) requires that in equilibrium, the instantaneous profit rate, which is instantaneous profit divided by initial investment in blueprint development, must be equal to the interest rate plus the risk premium, as in Grossman–Helpman:

$$\frac{\pi_N}{\left(\frac{a_d w_H^N}{n}\right)} = \rho + g + \mu \tag{5}$$

where $\mu = \dot{n}/(n - n_s) = \dot{n}_s / n_N$ is called the rate of imitation, which is also the 'hazard rate' at which a Northern product will be imitated at any moment. It represents the risk premium to be paid to shareholders of Northern firms. Note that in steady state $\mu / g = n_s / n_N$.

Let ϕ_N be the factor cost share of skilled labor in manufacturing in the North. Then the wage bill of skilled workers in the manufacturing sector is a fraction ϕ_N of the total wage bill of all workers in the manufacturing sector. This implies that $c_N x_N = w_H^N H_N^p / [\phi_N (n - n_s)]$. Since $n_s / n = \mu / (g + \mu)$ in steady state, this equation implies that $c_N x_N = [(\mu + g)/g)]\ w_H^N H_N^p / n\phi_N$. Moreover, since the CES production function is homothetic, ϕ_N depends only on the relative quantity of skilled and unskilled labor used in manufacturing. It is straightforward to show that $\phi_N = \beta(H_N - a_d g)^\gamma / [\beta(H_N - a_d g)^\gamma + (1-\beta)L_N^\gamma]$. Substituting this expression into the last one, then substituting the resulting expression into (2), and invoking the labor market clearing condition (3), we can rewrite the Northern no-arbitrage condition (5) as a reduced form equation relating μ and g:

$$\frac{g+\mu}{g}\left(\frac{1-\alpha}{\alpha}\right)[\beta(H_N - a_d g)^\gamma + (1-\beta)L_N^\gamma](H_N - a_d g)^{1-\gamma} = a_d(\rho + g + \mu)\beta \ . \tag{6}$$

Notice that w_H^N/n has been canceled on both sides of the equation. The above equation is the *NN* curve shown in Fig. 1. It represents the combination of g and μ consistent with labor market, goods market and capital market equilibria in the North. Notice that it is affected by both H_N and L_N. Also note that this equation reduces to the *NN* curve in Grossman and Helpman (1991a) when $\beta = 1$ (their equation (21)). The *NN* curve is upward-sloping, meaning that a higher rate of imitation is consistent with a higher rate of innovation in the North. A higher μ shortens the average duration for which an innovator enjoys monopoly profits. However, for given g and n, it also reduces the number of firms competing for production resources in the North, leading to higher profits for the firm while the

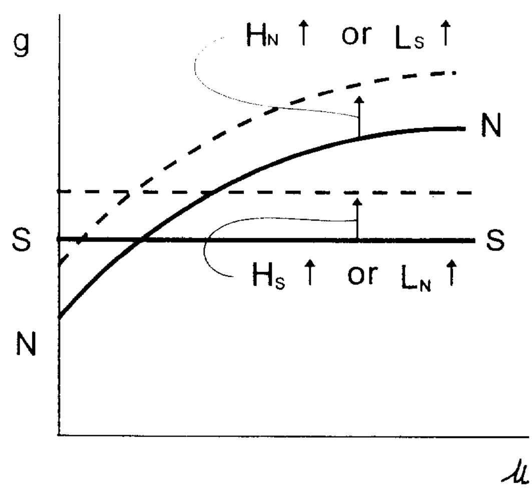

Fig. 1.

monopoly position lasts. Given the functional forms assumed, the latter effect dominates, leading to higher g.

2.3. The Southern equilibrium condition

The Southern equilibrium condition can be derived similarly. The Southern 'no-arbitrage condition' is

$$\frac{\pi_s}{\left(\frac{a_i w_H^S}{n_s}\right)} = \rho + g\,, \tag{7}$$

which implies (from (2)) that $((1-\alpha)/\alpha)c_s x_s = (\rho + g)a_i w_H^S / n_s$. If ϕ_s is the factor cost share of skilled labor in manufacturing in South, then $c_s x_s = w_H^S H_s^p / n_s \phi_s$, i.e. the wage bill of skilled workers in the Southern manufacturing sector is a fraction ϕ_s of the total wage bill of all workers in the manufacturing sector. Note that $\phi_s = \beta(H_s - a_i g)^\gamma / [\beta(H_s - a_i g)\gamma + (1-\beta)L_s^\gamma]$. Using this expression and the previous two, and invoking the labor market clearing condition (4), the no-arbitrage condition (7) can be rewritten as

$$\left(\frac{1-\alpha}{\alpha}\right)[\beta(H_s - a_i g)^\gamma + (1-\beta)L_s^\gamma](H_s - a_i g)^{1-\gamma} = a_i(\rho + g)\beta\,. \tag{8}$$

Notice that w_H^S / n_s has been canceled from both sides of the equation. This is the *SS* curve shown in Fig. 1. Again, it is affected by both H_s and L_s. Notice that this equation is reduced to the *SS* curve in the wide gap case of Grossman–Helpman (1991a) when $\beta = 1$ (their equation (23)). Recall that $\mu / g = n_s / n_N$ in steady state. The *SS* curve is horizontal, meaning that changes in μ do not affect the steady-state rate of innovation consistent with Southern equilibrium. The intuition is: for given g and n, an increase in μ increases the share of goods manufactured in the South, lowering the profits per firm. However, it lowers the cost of imitation equi-proportionately (due to knowledge expansion), resulting in exactly the same profit rate as before.

3. Comparative steady states analyses

To reiterate, the following analyses assume we are in the wide cost-gap regime, i.e. $c_s / c_N < \alpha$. Any change that causes w_L^S / w_L^N or w_H^S / w_H^N to increase can lead to an increase in c_S / c_N.[2] To the extent that c_s / c_N increases, we assume in the following analyses that the exogenous changes are sufficiently

[2] This is seen from the following equation: $c_s / c_N = \{[(w_L^S)^{\gamma/(\gamma-1)}(1-\beta)^{1/(1-\gamma)} + (w_H^S)^{\gamma/(\gamma-1)}\beta^{1/(1-\gamma)}]^{(\gamma-1)/\gamma}\} / \{[(w_L^N)^{\gamma/(\gamma-1)}(1-\beta)^{1/(1-\gamma)} + (w_H^N)^{\gamma/(\gamma-1)}\beta^{1/(1-\gamma)}]^{(\gamma-1)/\gamma}\}$

small that c_s/c_N does not exceed α after the changes, so that we stay in the wide gap regime.

3.1. Effect of changes in labor supply on g, μ and μ/g

As shown by Eq. (8) and Fig. 1, an increase in H_s shifts the SS curve up, leading to an increase in g, μ and μ/g. From Eq. (8), it is seen that $H_s^p = H_s - a_i g$ increases as well. Similarly, Eq. (6) and Fig. 1 show that an increase in H_N shifts the NN curve up, leaving g unchanged, μ decreased and μ/g decreased. Eq. (6) also shows that $H_N^p = H_N - a_d g$ increases.

When $\gamma < 0$, Eq. (8) and Fig. 1 show that an increase in L_s shifts the SS curve down, leading to a decrease in g, μ and μ/g. If we divide both sides of (8) by $H_s - a_i g$, it is not hard to see that $L_s/(H_s - a_i g)$ increases as L_s increases. Eq. (6) shows that an increase in L_N shifts the NN curve down, increasing μ and μ/g but leaving g unchanged.[3] When $\gamma = 0$ (Cobb–Douglas production function), L_s and L_N have no effects on g, μ and μ/g.

These results are shown in Table 1. They will be found useful in the following analyses concerning relative wages, etc. In the following subsections, we investigate the effect of L_s and L_N on w_L^S/w_L^N, which is studied by Krugman (1979) and the effect of H_s and H_N on w_H^S/w_H^N, which is studied by Grossman and Helpman (1991a). We shall also analyze the other effects of L_b and H_b $(b = N, S)$ on the relative wages.

3.2. Effects of changes in labor supply on w_L^S/w_L^N

The wage of Southern unskilled labor is equal to the value of its marginal product:

Table 1
Comparative steady states results (wide cost-gap case)

	w_L^S/w_H^S	w_L^N/w_H^N	w_L^S/w_L^N	w_H^S/w_H^N	μ	g	μ/g
$L_s\uparrow$	↓	↑	↓	↓[a]	↓	↓	↓
$L_N\uparrow$	nil[b]	↓	↑	↑[a]	↑	nil[b]	↑
$H_s\uparrow$	↑	↓	↑	↑[c]	↑	↑	↑
$H_N\uparrow$	nil[b]	↑	↓	↓[c]	↓	nil[b]	↓

[a] True when α is sufficiently small and the absolute value of γ is sufficiently large, given H_s/a_i and ρ.
[b] 'nil' means 'no effect'.
[c] True when α is sufficiently small, given H_s/a_i and ρ.

[3] It should be noted that L_N and H_N have no effects on g only because of the specific way imitation is modeled here.

$$w_L^S = VMP_L^S = c_s(1-\beta)A\left[(1-\beta) + \beta\left(\frac{H_s - a_i g}{L_s}\right)^{\gamma}\right]^{(1-\gamma)/\gamma} . \tag{9}$$

Similarly, the wage of Northern unskilled labor is equal to the value of its marginal product:

$$w_L^N = VMP_L^N = c_N(1-\beta)A\left[(1-\beta) + \beta\left(\frac{H_N - a_i g}{L_N}\right)^{\gamma}\right]^{(1-\gamma)/\gamma} . \tag{10}$$

From Eqs. (1) and (2), we see that π_b $(b = N, S)$ is proportional to $(c_b)^{1-\epsilon}$, given the prices of other firms. Therefore,

$$\frac{\pi_S}{\pi_N} = \left(\frac{c_S}{c_N}\right)^{1-\epsilon} . \tag{11}$$

Moreover, the instantaneous profit of a Southern (or Northern) firm is proportional to the total cost of production of the firm:

$$\pi_s = \left(\frac{1-\alpha}{\alpha}\right)c_s x_s = \left(\frac{1-\alpha}{\alpha}\right)\frac{w_L^S L_s}{n_s(1-\phi_s)} ; \tag{12}$$

$$\pi_N = \left(\frac{1-\alpha}{\alpha}\right)c_N x_N = \left(\frac{1-\alpha}{\alpha}\right)\frac{w_L^N L_N}{n_N(1-\phi_N)} . \tag{13}$$

Dividing (12) by (13), then substituting the resulting equation into (11), we obtain an expression for c_s/c_N. Substituting this expression into an equation formed by dividing (9) by (10), and recalling that $n_s/n_N = \mu/g$, we obtain

$$\omega_L^{1/\alpha} = \left(\frac{w_L^S}{w_L^N}\right)^{1/\alpha} = \left(\frac{\mu}{g}\right)^{(1-\alpha)/\alpha}\left(\frac{L_N}{L_s}\right)^{(1-\alpha)/\alpha} \times \left[\frac{1-\beta+\beta\left(\frac{H_s - a_i g}{L_s}\right)^{\gamma}}{1-\beta+\beta\left(\frac{H_N - a_d g}{L_N}\right)^{\gamma}}\right]^{(1-\gamma)/\gamma-(1-\alpha)/\alpha} \tag{14}$$

On the RHS, the first term is positively related to the fraction of goods produced by the South; the second term is negatively related to the supply of labor in the South relative to that of the North; the third term is positively related to the marginal product of labor of the South relative to that of the North.

From the results in Section 3.1 and (14), w_L^S/w_L^N increases with H_s, since $H_s - a_i g$ increases, $H_N - a_d g$ decreases and μ/g increases. On the other hand w_L^S/w_L^N decreases with H_N, since $H_N - a_d g$ increases, $H_s - a_i g$ is unchanged, and μ/g decreases. In other words, an increase in the supply of skilled labor in a country increases the relative wage paid to its unskilled labor. The intuition: an increase in the supply of skilled labor in the South increases the marginal product of the unskilled workers and also the fraction of goods produced by the South n_s/n_N $(=\mu/g)$. Since both effects increase the demand for unskilled labor in the South, the relative wage of Southern unskilled workers increases.

From the results in Section 3.1 and (14), it can be seen that as long as $\gamma \leqslant 0$ (i.e. $\sigma \leqslant 1$), w_L^S/w_L^N increases with L_N but decreases with L_s, in agreement with Krugman (1979). Notice that when $\beta = 0$, Eq. (14) is identical to the corresponding expression in Krugman (1979), since L_b becomes the only factor in the production sector of country b. In general, when β is not equal to 0, the manufacturing sector exhibits diminishing returns to unskilled labor. An increase in supply of unskilled labor L_s decreases the 'real wage' of unskilled workers (wage/price of its own country's good), w_L^S/c_s, relative to that of the North, w_L^N/c_N. When $\gamma \leqslant 0$, an increase in L_s decreases the fraction of goods produced by the South.[4] An increase in total output and a decrease in fraction of goods produced by the South means an increase in output per variety in the South relative to the North. Hence, the effect on the terms of trade c_s/c_N is negative (since each firm is faced with a downward sloping demand curve for its good, according to (1)), which further reinforces the decrease in relative wage. Similar arguments apply to an increase in L_N.

3.3. *Effects of changes in labor supply on* w_H^S/w_H^N

Because L_b and H_b^p $(b = N, S)$ enter in a similar fashion into the production function in the manufacturing sector, we can obtain an expression for w_H^S/w_H^N very easily: from Eq. (14), we exchange the roles of L_N and $H_N - a_d g$ $(=H_N^p)$, and those of L_s and $H_s - a_i g$ $(=H_s^p)$, then replace β by $1-\beta$. Hence, the relative wage of skilled labor is:

$$\omega_H^{1/\alpha} = \left(\frac{w_H^S}{w_H^N}\right)^{1/\alpha} = \left(\frac{\mu}{g}\right)^{(1-\alpha)/\alpha} \left(\frac{H_N - a_d g}{H_s - a_d g}\right)^{(1-\alpha)/\alpha} \times \left[\frac{\beta + (1-\beta)\left(\dfrac{L_s}{H_s - a_i g}\right)^{\gamma}}{\beta + (1-\beta)\left(\dfrac{L_N}{H_N - a_d g}\right)\gamma}\right]^{(1-\gamma)/\gamma-(1-\alpha)/\alpha} \quad (15)$$

On the RHS, the first term is positively related to the fraction of goods

[4] When unskilled and skilled labor are sufficiently complementary to each other, an increase in L_s sufficiently increases the marginal product of skilled labor in manufacturing that skilled labor is drawn from the Southern R&D sector to the manufacturing sector.

produced by the South; the second term is negatively related to the supply of manufacturing skilled labor in the South relative to the North; the third term is positively related to the marginal product of skilled labor in manufacturing in the South relative to the North. Note that the above equation is reduced to that of G–H when $\beta = 1$, that is, when skilled labor is the only factor of production in manufacturing.

The effects of H_s and H_N can be decomposed into two: (1) keeping μ/g unchanged, the direct effects of H_s (H_N) on w_H is negative (positive); (2) the effect of a change in μ/g, which tends to make w_H increase with H_s and decrease with H_N. The two effects tend to counteract each other. Therefore, in general, the effects of H_s and H_N are ambiguous. However, in an appendix which is available from the author upon request, it is shown that if α is sufficiently small, then the same comparative steady-states results as in G–H (1991a) obtain, i.e. an increase in H_s (H_N) raises (lowers) the relative wage of Southern skilled labor.[5] The intuition for the effect of α is: as α gets smaller, products are less substitutable for each other, so that the value of each blueprint is higher. An increase in H_s increases the fraction of goods produced by the South n_s/n_N ($=\mu/g$). As the value of each blueprint gets higher, the impact of an increase in n_s/n_N ($=\mu/g$) on the marginal product of skilled labor in the Southern R&D and manufacturing sector gets larger, boosting the relative wage of the Southern skilled labor. When $\beta = 1$, H is the only factor of production in manufacturing, and the expression is reduced to that in G–H (1991a).

The effects of L_s can be decomposed into three: (1) keeping μ/g unchanged, increases in L_s will raise the marginal product of skilled labor in the South, which tends to increase w_H; (2) the effect of a change in μ/g, which tends to make w_H decrease with L_s; (3) the effect of g on the demand for labor in the manufacturing sector in the South relative to that of the North. The first two effects tend to counteract each other. Therefore, in general, the effects of L_s are ambiguous. However, we show that if α is sufficiently small, and $|\gamma|$ is sufficiently large (H and L sufficiently complementary to each other) then an increase in L_s lowers the relative wage of Southern skilled labor. The proof is contained in the appendix available from the author upon request.[6] The intuition of the effect of α is similar to that in the last paragraph. The effects of L_N are just opposite to that of L_s.

The results in the last two subsections are listed in Table 1.

[5] Note that μ/g increases with H_s. The appendix shows that w_H is positively related to $(\mu/g)^{(1-\alpha)/\alpha}$ and other terms that increase with H_s. Therefore, the effect of μ/g on w_H increases as α gets smaller. In fact, the condition for the Grossman–Helpman result to hold is estimated to be approximately $\alpha < 0.65$, which corresponds to a labor cost mark-up of about 50%. This condition is not too stringent since the initial investment cost has not been taken into account.

[6] Note that μ/g decreases with L_s. The appendix shows that w_H is positively related to $(\mu/g)^{\theta'}$ and other terms that decrease with L_s, where $\theta' = [(1-\alpha)/\alpha]/[(\gamma-1)/\gamma + (1-\alpha)/\alpha]$. Hence, the effect of μ/g on w_H increases as α gets smaller and $|\gamma|$ gets larger.

3.4. Increase in both H_s and L_s

When $\gamma < 0$, increases in H_s and L_s have countervailing effects on g and relative wages in the South, and the total effect is rather intractable. Hence, we consider only the simple case where increases in H_s and L_s result in unchanged g, μ and μ/g. If we divide both sides of (8) by $H_s - a_i g$, we can easily see that increases in H_s and L_s that leave g unchanged lead to a decrease in $(H_s - a_i g)/L_s$. Since μ/g is also unchanged, and L_s increases, we conclude from (14) that w_L^S/w_L^N decreases as a result. To evaluate the effect on w_H^S/w_H^N, we rewrite (15), using the *SS* and *NN* curves:

$$\omega_H^{1/\alpha} = \left(\frac{w_H^S}{w_H^N}\right)^{1/\alpha} = \left(\frac{\mu}{g}\right)^{(1-\alpha)/\alpha}\left[\frac{a_d(\rho+g+\mu)g}{a_i(\rho+g)(\mu+g)}\right]^{1/\alpha} \times \left\{\frac{[\beta(H_s - a_i g)^\gamma + (1-\beta)L_s^\gamma]^{1/\gamma}}{[\beta(H_N - a_d g)^\gamma + (1-\beta)L_N^\gamma]^{1/\gamma}}\right\}. \quad (16)$$

It is obvious from (16) that w_H^S/w_H^N increases, since $H_s - a_i g$ and L_s both increase.

The results in the last three subsections give us a way of thinking about the effects of the integration of a huge country like China into the international product cycle. First, an increase in unskilled labor supply will decrease the long-run rate of innovation in the advanced countries, which cannot be predicted by G–H (1991a). Second, an increase in skilled labor supply will increase the rate of innovation, which is consistent with G–H. Finally, to the extent that the integration leaves the rates of innovation and imitation basically unchanged, the relative wage of Southern unskilled labor decreases, but that of skilled labor increases in the long run.

3.5. Effects on real wage

Using the results in Table 1, it can be shown that an increase in supply of skilled labor (unskilled labor) in a country increases (decreases) the wage of unskilled labor in the same country relative to all other wages in the world when α is sufficiently small (different varieties of goods are sufficiently differentiated from each other) and $|\gamma|$ is sufficiently large (factors are sufficiently complementary to each other).[7] Thus, an increase in supply of skilled labor (unskilled labor) raises (lowers) the real wage of unskilled labor

[7] A proof of this is contained in the appendix that is available from the author upon request. Essentially, the proof shows that w_L^S (w_L^N) increases relative to all other wages as H_s (H_N) increases when α is sufficiently small. Moreover, w_L^S (w_L^N) decreases relative to all other wages as L_s (L_N) increases when α is sufficiently small and $|\gamma|$ is sufficiently large.

in the same country. These results are qualitatively the same as obtained from the factor proportions model of neoclassical trade theory. For example, according to the Heckscher–Ohlin model, an increase in supply of capital (labor) in a country will raise (lower) the real return to labor in the same country.

The intuition for the result is straightforward: an increase in supply of skilled labor (unskilled labor) in a country, say the South, lowers (raises) the marginal product of skilled labor but raises (lowers) the marginal product of unskilled labor L_s in the same country. This raises (lowers) both w_L^S/w_H^S and w_L^S/w_L^N. As long as this change has positive (negative) or no effect on the wage of Southern skilled labor relative to that of the North, w_H^S/w_H^N, the wage of L_s relative to all other wages rises (falls).

4. Conclusion

Krugman (1979) found that the long-run relative wage of a region varies inversely with the size of that region in the product cycle where the rate of innovation and rate of imitation are exogenous. Grossman and Helpman (1991a) found that this relative wage varies directly with the size of the region if labor is required for both manufacturing and R&D, and the long-run rates of innovation and imitation are determined endogenously. By assuming that the rates of innovation and imitation are endogenized in a similar fashion as in Grossman and Helpman, we find that an increase in the size of unskilled labor in a region will decrease its relative wage, consistent with Krugman's finding. An increase in the size of skilled labor in a region, which is required for both manufacturing and R&D, will increase its relative wage only when the elasticity of substitution between goods is sufficiently large (so that each blueprint is sufficiently valuable relative to the prices of goods.)

The integration of a large country like China into the international product cycle increases the supply of both skilled and unskilled labor in the South. To the extent that such integration basically leaves the long-run world rate of innovation and rate of imitation unchanged, we find that the relative wage of Southern unskilled labor will decrease whereas the relative wage of Southern skilled labor will rise in the long run.

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