Trade Liberalization and Specific Human Capital Accumulation

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Abstract

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Abstract: We develop a new framework for the analysis of the impact of trade liberalization on the wage structure. Our model focuses on the decision of workers to accumulate firm-specific skills, knowing that this means their future wages will have to be negotiated, and that the outcome of negotiation will depend on the profitability prospect of firms operating in a new trading environment.(THIS PAPER IS ONLY A FIRST DRAFT. PLEASE DO NOT QUOTE.)

1 Introduction

The effects of trade liberalization on wage structure and employment have been a continuing topic of debate. (See, for example, Freeman (1995), Wood (1994), Davis (1998), Falvey (1998), Tyers and Yang (1999).) Economists participating in this debate typically use a modified version of the Heckscher-Ohlin model, with fixed endowments of skilled and unskilled workers. While that framework is a useful starting point, it neglects an important aspect: the acquisition of skill in response to expected changes in trade regime is not modelled.

On the other hand, in the endogenous growth literature, human capital accumulation has received a great deal of attention. See Lucas (1988), Young (1991), Stokey (1991), and, for a survey of the trade and growth literature, see Long and Wong (1996). These authors however focused on long run considerations, and did not consider short-run issues such as the accumulation of industry-specific and firm-specific human capital, in response to trade liberalization. In this paper, we seek to fill that gap.

This paper presents a simple model of firm-specific human capital accumulation in a small open economy. We want to find out if trade liberalization will (a) increase or decrease firm-specific human capital accumulation, (b) widen the wage gap between skilled and unskilled workers. Implications for trade pattern between LDCs and DCs will be explored. We develop a new framework for the analysis of the impact of trade liberalization on the wage structure. Our model focuses on the decision of workers to accumulate firm-specific skills, knowing that this means their future wages will have to be negotiated, and that the outcome of negotiation will depend on the profitability prospect of firms operating in a new trading environment.

We show that, for a developing economy, expectation of trade liberalization may lead to a reduction in the supply of skilled workers in the high-tech industry. In the absence of perfectly competitive labor markets (recall that wages are negotiated between management and workers with firm-specific skills), this effect of free trade on the supply of skills may well be welfare-worsening. This argument has received some support from some section of the profession. In fact, the following quotation from Hirschman (1965, p 5) is quite relevant:

"The opponents of free trade have often pointed out that for a variety of reasons it is imprudent and harmful for a country to become specialized along certain product lines in accordance with the dictates of comparative advantage. Whatever the merits of these critical arguments, they would certainly acquire overwhelming weight if the question arose whether a country should allow itself to become specialized not just along certain commodity lines, but along factor-of-production lines. Very few country would ever consciously wish to specialize in unskilled labor, while foreigners with a comparative advantage in entrepreneurship, management, skilled labor and capital took over these functions, replacing inferior "local talents."

In Section 2, we consider a model of a single country. Later, we extend the model to deal with the two-country case, and offer interpretations (e.g., North-South trade). Policy implications will also be discussed.

Other issues that can be considered within the framework of our model are: (i) wage dispersion(Wood, 1994), (ii) gains from trade (Kemp, 1962,1995), (iii) comparative advantage, (iv) factor price non-equalisation (recall that wages are negotiated), (v) political economy e.g., gainers and losers, (vi) migration e.g., since it is cheaper to accumulate high-tech human capital in advanced countries, there is an incentive to migrate to these countries.

2 A Basic Model of Human Capital Accumulation

2.1 Assumptions and Notation

We assume that there are two periods only. As a first step, let us consider a small open economy, consisting of three sectors, denoted by G, S_{H} and S_{L}. (G and S stand for general and specific human capital respectively, and H and L refer to high-tech and low-tech respectively.) Each individual in this economy possesses one unit of general human capital, and can accumulate firm-specific human capital. Sector G produces the numeraire good, which is exported (or imported) at the price $P_G = 1$. The only factor of production in this sector is general human capital. Production in sector G is under constant returns to scale: one unit of general human capital produces W_G units of good G. Thus the wage rate in this sector is W_G in both periods.

Sector S_i produces an output Q_i $(i = H, L)$. The low-tech sector's output Q_L represents goods such as textile and clothing, and the high-tech sector's output Q_H represents goods such as pharmaceuticals, software, computers, etc. Assume that there are N_i firms in sector S_i and that each firm is endowed with one unit of industry-specific physical capital. N_i is exogenously given. For the time being, the price of good S_i in period t, denoted by P_{it} , is exogenously given. We assume that, in sector S_i, to produce a positive output, a firm must have one unit of industry-specific physical capital, and exactly one worker: a second worker would add nothing to output. If the worker (who works with one unit of industry-specific physical capital) has only one unit of general human capital, then the output is 1 unit of good S_i. If he has in addition h_i units of firm-specific human capital, then the output is $1 + \mu_i h_i$, where μ_i is a positive parameter representing the productivity of firm-specific human capital in sector S_i.

Initially,workers in sector S_i have no firm-specific human capital. In period one each sector S_i worker decides whether or not to invest in acquiring firm-specific human capital. If the worker decides to acquire human capital he acquires it by using $C_i(h_i)$ units of learning effort while he is working for a firm in sector S_i. Workers who acquire firm-specific human capital end up with h_i units of firm-specific human capital of type i, $(i = H, L)$.[1]We assume for simplicity that for the worker, the disutility of learning effort can be measured in terms of a reduction in his consumption of good G.[2] Let N be the number of individuals in this economy. We assume that $N > N_H + N_L$, so that when each firm in sectors S_L and S_H employs one worker, there are enough workers left to produce good G.

At the beginning of period two, a firm in sector S_i can rehire its period-one worker, who has acquired $h_i \geq 0$ units of firm-specific human capital, at a wage W_{i2} (which is an outcome of a bargaining process between the firm and the worker, to be discussed below), or it can dismiss that worker, and employ a new worker, who, of course, does not have firm-specific human

[1]Thus, it is implicitly assumed that, without the firm's unit of physical capital, the worker cannot acquire firm-specific knowledge.

[2]Alternatively, we can interpret $C_i(h_i)$ as the cost of education, which uses up real resources, identified as good G.

capital. If it takes the latter course of action, its profit is $\pi_{iR} = P_{i2} - W_G$. This is the firm's reservation level of profit in its bargaining with its worker. The experienced worker, on the other hand, can work in sector G in period two, at the wage W_G. This is his reservation level of wage in his bargaining with his existing employer.

2.2 Analysis of Wage Profiles

We now turn to the question of how bargaining determines the wage of the skilled worker in period two, given that the worker has acquired h_i units of firm-specific human capital. To do this, we adopt the theory of Nash cooperative bargaining, according to which the bargaining outcome is a pair (W_{i2}, π_i) that maximizes the so-called Nash product, $(\pi_i - \pi_{iR})^{\beta}(W_{i2} - W_G)^{1-\beta}$ subject to the constraint that $\pi_i + W_{i2} = (1 + \mu_i h_i)P_{i2}$. The parameter β represents the relative bargaining power of the firm, where $0 < \beta < 1$. This maximization yields the Nash-bargaining solution

$$W_{i2} = W_G + (1 - \beta)\mu_i h_i P_{i2} \tag{1}$$

and

$$\pi_i = (P_{i2} - W_G) + \beta \mu_i h_i P_{i2} \tag{2}$$

Equation (1) says that the skilled worker's wage consists of two components: a wage that he would earn elsewhere, plus a share of the surplus that his skills (together with the firm's capital stock) generate. Equation (2) indicates that firm profits equals the profit it would earn if it were to employ a worker without firm-specific skills, plus its share of the surplus generated by the skilled worker.

We now show how h_i is determined in period one. Assume for the time being that there is no uncertainty, and that individuals can borrow and lend at a constant[3] rate of interest r. Then in period one, the representative worker in sector S_i chooses h_i to maximize his lifetime wage income, net of effort cost:

$$W_{i1} - C_i(h_i) + \frac{1}{(1+r)}\left(W_G + (1-\beta)\mu_i h_i P_{i2}\right)$$

[3] The question of how r is determined should also be addressed. This can be done most simply by assuming that individuals maximize life-time utility $U_1 + \delta U_2$ where U_t is quasi-linear $U_t = \phi(X_{Ht}, X_{Lt}) + X_{Gt}$, and δ is a constant, $0 < \delta < 1$. (X_{it} represents the amount of good i consumed in period t.) Then, in equilibrium, $1/(1+r) = \delta$.

where he takes the first period wage, $W_{i1,}$ as given. This yields the first order condition

$$\frac{(1-\beta)\mu_i P_{i2}}{(1+r)} - C_i'(h_i) = 0 \tag{3}$$

and the second order condition

$$-C_i''(h_i) < 0.$$

Condition (3) says that the marginal gain in wage income in period two is equated to the marginal effort cost. Hence h_i is a function of P_{i2}, and, from (3) we obtain

$$\frac{\partial h_i}{\partial P_{i2}} = \frac{(1-\beta)\mu_i}{(1+r)C_i''(h_i)} > 0 \tag{4}$$

Thus a higher period-two price induces more investment in firm-specific human capital. If we parametrize the cost function by $C_i(h_i) = \gamma c_i(h_i)$, where $\gamma > 0$, then we obtain the following result

$$\frac{\partial h_i}{\partial \gamma} = \frac{c_i'(h_i)}{-\gamma c_i''(h_i)} < 0 \tag{5}$$

i.e., higher learning cost reduces investment in firm-specific human capital.

Next we determine the wage of this worker in period one. We assume that prior to period 1 all workers are mobile. This means that in equilibrium the expected lifetime income must be equal in all sectors. Thus, even though in period 1 he can earn W_G elsewhere, in equilibrium, his wage W_{i1} in sector S_i must be such that his life-time income (net of learning-effort cost) in sector S_i equals the life-time income of a worker in sector G:

$$W_G[1 + \frac{1}{1+r}] = W_{i1} - \gamma c_i(h_i(\gamma, P_{i2})) + \frac{1}{1+r}(W_G + (1-\beta)\mu_i h_i P_{i2}) \tag{6}$$

This simplifies to

$$W_{i1} = W_G + \gamma c_i(h_i(\gamma, P_{i2})) - \frac{1}{1+r}(1-\beta)h_i(\gamma, P_{i2})P_{i2} \tag{7}$$

This equation says that in period 1, the employer pays the employee his outside wage, plus the cost of firm-specific education, minus the surplus[4]

[4]This equation reflects the theory of on-the-job training, developed by Gary Becker.

that the employee can expect to capture in period 2. Differentiating (7), and using the envelope theorem, we get

$$\frac{\partial W_{i1}}{\partial P_{i2}} = -\frac{1}{1+r}(1-\beta)\mu_i h_i < 0$$

and

$$\frac{\partial W_{i1}}{\partial \gamma} = c_i(h_i(\gamma, P_{i2})) > 0$$

where we have made use of (3). Thus W_{i1} is a decreasing function of P_{i2}. The intuition behind this result is that if the worker expects to gain more in period 2 due to a higher period 2 price, then the employer can extract this gain from him by offering him a lower wage in period 1. Similarly, if the cost of acquiring skill increases, then the employer compensates for this by increasing W_{i1}. So far, we have not explained how the human capital in the two sectors H and L differ from each other. We deal with this next.

2.3 Cost and productivity

Think of sector S_L as a sector that produces clothing and textiles, and sector S_H as a sector that produces communication equipment, software, or pharmaceutical products. Recall that if h_H (respectively h_L) increases from zero to one, then the worker's output of good S_H (respectively S_L) increases by μ_H (respectively μ_L). It seems reasonable to assume that $\mu_H > \mu_L$. Thus, we may want to postulate that the costs of obtaining h_L and h_H are the same, i.e., $C(h_L) = C(h_H)$ if $h_L = h_H$, but h_H is more productive, i.e., $\mu_H > \mu_L$. In the remaining sections, we adopt this assumption for simplicity.

2.4 Autarkic Equilibrium

To solve for an autarkic equilibrium, we must specify the demand side, and be more specific on the supply side. The question of how r is determined should also be addressed. This can be done most simply by assuming that individuals maximize life-time utility $U_1 + \delta U_2$ where U_t is quasi-linear, i.e., $U_t = \phi(X_{Ht}, X_{Lt}) + X_{Gt}$, and δ is a constant, $0 < \delta < 1$. Then, in equilibrium, $1/(1+r) = \delta$. We assume that positive amounts of each good are consumed in each period. All individuals in this economy are workers, and own equal amount of shares in each sector. This assumption allows us to talk about the representative consumer.

To the assumption that U_t is quasi-linear, let us add the assumption that $\phi(X_{Ht}, X_{Lt})$ is homothetic, increasing, and displaying diminishing marginal rate of substitution. It follows that $\phi(X_{Ht}, X_{Lt})$ can be represented in the form

$$\phi(X_{Ht}, X_{Lt}) = g(f(X_{Ht}, X_{Lt}))$$

where $f(X_{Ht}, X_{Lt})$ is homogenous of degree one, and $g(.)$ is a monotone increasing function. Let E_t be the amount of income to be spent on goods X_{Ht} and X_{Lt} in period t. Then, from standard duality theory, the indirect utility derived from the consumption of these goods is[5]

$$v_t(P_{Ht}, P_{Lt}, E_t) = g\left(\frac{E_t}{I(P_{Ht}, P_{Lt})}\right), \qquad t = 1, 2 \tag{8}$$

where $I(P_{Ht}, P_{Lt})$ is the solution of the standard Hicksian cost minimization problem

$$\min_{X_{jt}} P_{Lt}X_{Lt} + P_{Ht}X_{Ht}$$

subject to the consumption point (X_{Ht}, X_{Lt}) being on the curve:

$$f(X_{Ht}, X_{Lt}) = 1$$

We next consider a simple example, let

$$\phi(X_{Ht}, X_{Lt}) = [X_{Ht}^{\alpha} X_{Lt}^{1-\alpha}]^{\lambda}$$

then

$$I(P_{Ht}, P_{Lt}) = 2P_{Ht}^{\alpha} P_{Lt}^{1-\alpha}.$$

The representative consumer solves the following intertemporal maximization problem

$$\max_{E_t; X_{Gt}} X_{G1} + g\left(\frac{E_1}{I(P_{H1}, P_{L1})}\right) + \delta X_{G2} + \delta g\left(\frac{E_2}{I(P_{H2}, P_{L2})}\right) \tag{9}$$

subject to

$$E_1 + X_{G1} + \frac{1}{1+r}(E_1 + X_{G1}) = M \tag{10}$$

[5] See the Appendix for a proof of this result.

where M is his life-time disposable income (net of learning effort cost). This problem has an interior solution (i.e., $E_t > 0$ and $X_{Gt} > 0$ for $t = 1, 2$) only if $1/(1+r) = \delta$ and

$$g^0 \left(\frac{E_1}{I(P_{H1}, P_{L1})} \right) \frac{1}{I(P_{H1}, P_{L1})} = 1 \tag{11}$$

$$g^0 \left(\frac{E_1}{I(P_{H2}, P_{L2})} \right) \frac{1}{I(P_{H2}, P_{L2})} = 1. \tag{12}$$

If $g(.)$ is linear, then an interior solution exists only if $1/(1+r) = \delta$ and

$$I(P_{H2}, P_{L2}) = I(P_{H1}, P_{L1}) = 1. \tag{13}$$

For the economy as a whole, demand for each good must equal its supply. We list below 19 unknowns and 19 equations that determine them. The 19 unknowns are output levels Q_{Gt}, Q_{Lt}, Q_{Ht}, consumption levels, X_{Gt}, X_{Lt}, X_{Ht}, prices P_{Lt}, P_{Ht}, life-time income M, and expenditures on non-numeraire goods, E_t. (Recall that $P_{G1} = P_{G2} = 1$, $h_i = h_i(P_{i2})$, while W_{i2} and W_{i1} are given by (1) and (7) respectively.) The 19 equations are:

(i) six supply equations:

$$Q_{Gt} = (N - N_L - N_H) W_G \qquad t = 1, 2 \tag{14}$$

$$Q_{L1} = N_L \tag{15}$$

$$Q_{H1} = N_H \tag{16}$$

$$Q_{L2} = N_L (1 + \mu_L h_L(P_{L2})) \tag{17}$$

$$Q_{H2} = N_H (1 + \mu_H h_H(P_{H2})) \tag{18}$$

(ii) from the consumer's maximization problem (9), we have seven equations, namely equations (10), (11), (12) and the following Roy's identities:

$$X_{Lt} = -\frac{(\partial v_t / \partial P_{Lt})}{(\partial v_t / \partial E_t)}, \qquad t = 1, 2 \tag{19}$$

$$X_{Ht} = -\frac{(\partial v_t / \partial P_{Ht})}{(\partial v_t / \partial E_t)}, \qquad t = 1, 2 \tag{20}$$

(iii) five out of six market clearing conditions (only five are needed due to Walras law):

$$NX_{\mathsf{G1}} = Q_{\mathsf{G1}} \tag{21}$$

$$NX_{\mathsf{G2}} = Q_{\mathsf{G2}} \tag{22}$$

$$NX_{\mathsf{Ht}} = Q_{\mathsf{Ht}}, \qquad t = 1, 2 \tag{23}$$

$$NX_{\mathsf{Lt}} = Q_{\mathsf{Lt}}, \qquad t = 1, 2 \tag{24}$$

(iv) the sum of life-time incomes (net of learning-effort cost) of all individuals equals the value of aggregate output net of learning-effort cost

$$NM = \sum_{\mathsf{t=1}}^{2}(Q_{\mathsf{Gt}} + P_{\mathsf{Lt}}Q_{\mathsf{Lt}} + P_{\mathsf{Ht}}Q_{\mathsf{Ht}}) - N_{\mathsf{L}}C_{\mathsf{L}}(h_{\mathsf{L}}) - N_{\mathsf{H}}C_{\mathsf{H}}(h_{\mathsf{H}}) \tag{25}$$

Remark:

To understand (25) recall that profits are distributed to individuals equally. Let Π denote the discounted sum of profits of all firms. Then the life-time income of a worker in sector G is

$$M_{\mathsf{G}} = \left(1 + \frac{1}{1+r}\right) W_{\mathsf{G}} + \frac{1}{N}\Pi \tag{26}$$

The life-time income of a worker in sector H is

$$M_{\mathsf{H}} = M_{\mathsf{G}} + C_{\mathsf{H}}(h_{\mathsf{H}}) = W_{\mathsf{1H}} + \frac{1}{1+r}W_{\mathsf{2H}} + \frac{1}{N}\Pi \tag{27}$$

because his life-time wage income is higher than $W_{\mathsf{G}}(1 + \frac{1}{1+r})$ by an amount which simply reflects his learning-effort cost. His *life-time income net of his learning-effort, which we denote by* M, is thus equal to M_{G}. Similarly, the life-time income of a worker in sector L is

$$M_{\mathsf{L}} = M_{\mathsf{G}} + C_{\mathsf{L}}(h_{\mathsf{L}}) = W_{\mathsf{1L}} + \frac{1}{1+r}W_{\mathsf{2L}} + \frac{1}{N}\Pi \tag{28}$$

Multiplying (26) by N_{G}, (27) by N_{H} and (28) by N_{L} , then adding them up, we get

$$NM + N_{\mathsf{L}}C_{\mathsf{L}}(h_{\mathsf{L}}) + N_{\mathsf{H}}C_{\mathsf{H}}(h_{\mathsf{H}}) = \text{ all wages+profits}$$

Then, using the national income identity, all wages+profits$=\sum_{\mathsf{t=1}}^{2}(Q_{\mathsf{Gt}} + P_{\mathsf{Lt}}Q_{\mathsf{Lt}} + P_{\mathsf{Ht}}Q_{\mathsf{Ht}})$. This gives equation (25).

EXAMPLE:

Let us consider a specific example.

Assume $\phi(X_{Ht}, X_{Lt}) = [X_{Ht}^{\alpha} X_{Lt}^{1-\alpha}]^{\lambda}$ with $\alpha = \lambda = 1/2$. Then

$$E_t = \frac{1}{8P_{Lt}^{1/2} P_{Ht}^{1/2}} \tag{29}$$

If there were **no** human capital accumulation (which would be the case if $\mu_L = \mu_H = 0$), then $Q_{it} = N_i$ for $i = H, L$ and $t = 1, 2$. Then, due to the symmetric Cobb-Douglas assumption, which implies equal budget share, we would have, for both $t = 1, 2$,

$$\frac{P_{Ht}}{P_{Lt}} = \frac{Q_{Lt}}{Q_{Ht}} = \frac{N_L}{N_H} \tag{30}$$

From (30) and (29), and letting the superscript n denote NO HUMAN CAPITAL ACCUMULATION, we have

$$P_{Ht}^{n} = \frac{(N_L/N_H)^{1/4}}{\sqrt{16 N_H}},\ P_{Lt}^{n} = \frac{(N_H/N_L)^{1/4}}{\sqrt{16 N_L}} \tag{31}$$

or

$$(P_{Ht}^{n})^4 = \frac{1}{(16)^2} \frac{N_L}{N_H^3} \tag{32}$$

Now consider the case where **there is** human capital accumulation. Then (30) and (31) apply only for $t = 1$. To find the prices in period 2, a further assumption is needed.

Assume

$$C_i(h_i) = \frac{1}{2} h_i^2$$

so that workers will choose

$$h_i = \rho \mu_i P_{i2}$$

where we define $\rho = (1 - \beta)/(1 + r)$. For period 2, we have

$$\frac{P_{H2}}{P_{L2}} = \frac{Q_{Lt}}{Q_{Ht}} = \frac{N_L\,(1 + \rho \mu_L^2 P_{L2})}{N_H\,(1 + \rho \mu_H^2 P_{H2})} \tag{33}$$

On the other hand, in view of the equal expenditure share, equation (29) gives

$$2P_{H2} Q_{H2} = 2P_{H2} N_H \left(1 + \rho \mu_H^2 P_{H2}\right) = \frac{1}{8P_{L2}^{1/2} P_{H2}^{1/2}} \tag{34}$$

From (34) we get

$$(16)^2 \left(P_{\mathsf{H}2} N_{\mathsf{H}} \left(1+\rho\mu_{\mathsf{H}}^2 P_{\mathsf{H}2}\right)\right)^2 = \frac{1}{P_{\mathsf{L}2} P_{\mathsf{H}2}} \tag{35}$$

Hence

$$P_{\mathsf{L}2} = \frac{1}{(16)^2 \left(P_{\mathsf{H}2}\right)^3 \left(N_{\mathsf{H}} \left(1+\rho\mu_{\mathsf{H}}^2 P_{\mathsf{H}2}\right)\right)^2} \tag{36}$$

From (36) it is clear that $P_{\mathsf{H}2}$ and $P_{\mathsf{L}2}$ are negatively related.

Let Δ denote the right-hand side of (36). Substitute (36) into (33) to get

$$P_{\mathsf{H}2} N_{\mathsf{H}} \left(1+\rho\mu_{\mathsf{H}}^2 P_{\mathsf{H}2}\right) = \frac{N_{\mathsf{L}} \left(1+\rho\mu_{\mathsf{L}}^2 \Delta\right)}{(16)^2 \left(P_{\mathsf{H}2}\right)^3 \left(N_{\mathsf{H}} \left(1+\rho\mu_{\mathsf{H}}^2 P_{\mathsf{H}2}\right)\right)^2} \tag{37}$$

Equation (37) shows that the price $P_{\mathsf{H}2}$ is a function of μ_{L}, μ_{H}, N_{L}, N_{H} and ρ. It is a complicated expression.

To simplify, let us consider first a special case. Let μ_{L} tends to zero, so that

$$P_{\mathsf{H}2}^4 \left(1+\rho\mu_{\mathsf{H}}^2 P_{\mathsf{H}2}\right)^3 - \frac{1}{(16)^2} \frac{N_{\mathsf{L}}}{N_{\mathsf{H}}^3} = 0 \tag{38}$$

Comparing (38) with (32), we see that $P_{\mathsf{H}2}$ is lower (compared with $P_{\mathsf{H}2}^{\mathsf{n}}$), when there is human capital accumulation in sector S_{H}. Furthermore, letting $F\left(P_{\mathsf{H}2}, N_{\mathsf{L}}, N_{\mathsf{H}}, \mu_{\mathsf{H}}, \rho\right)$ denote the left-hand side of (38), we obtain the following comparative statics results:

$$\frac{\partial P_{\mathsf{H}2}}{\partial \mu_{\mathsf{H}}} = -\frac{\left(\partial F/\partial \mu_{\mathsf{H}}\right)}{\left(\partial F/\partial P_{\mathsf{H}2}\right)} < 0$$

$$\frac{\partial P_{\mathsf{H}2}}{\partial N_{\mathsf{H}}} = -\frac{\left(\partial F/\partial N_{\mathsf{H}}\right)}{\left(\partial F/\partial P_{\mathsf{H}2}\right)} < 0$$

$$\frac{\partial P_{\mathsf{H}2}}{\partial N_{\mathsf{L}}} = -\frac{\left(\partial F/\partial N_{\mathsf{L}}\right)}{\left(\partial F/\partial P_{\mathsf{H}2}\right)} > 0$$

$$\frac{\partial P_{\mathsf{H}2}}{\partial \rho} = -\frac{\left(\partial F/\partial \rho\right)}{\left(\partial F/\partial P_{\mathsf{H}2}\right)} < 0$$

These results are intuitively plausible: the more productive the specific human capital in sector H is (i.e., the greater is μ_{H}), the greater will be its rate of accumulation, leading to an increase in the supply of Q_{H} , and hence a fall in its price; the greater the bargaining power of the worker (i.e., the greater is $(1-\beta)$ and hence ρ), the greater will be the rate of accumulation of h_{H}, leading to an increase in the supply of Q_{H} , and hence a fall in its price; the greater is the supply of physical capital in sector S_{H}, the greater will be the output $Q_{\mathsf{H}2}$ and hence the lower will be its price, etc.

Now consider the case where both μ_{L} and μ_{H} are positive. Then, instead of (38), we get

$$\left((16)^2 (P_{\mathsf{H}2})^3 \left(N_{\mathsf{H}} \left(1+\rho\mu_{\mathsf{H}}^2 P_{\mathsf{H}2}\right)\right)^2\right) F - \frac{N_{\mathsf{L}}\rho\mu_{\mathsf{L}}^2}{(16)^2 N_{\mathsf{H}}^3} = 0 \tag{39}$$

where F stands for the right-hand side of (38), which must now be positive for equation (39) to hold. Let $\Omega\left(P_{\mathsf{H}2}, N_{\mathsf{L}}, N_{\mathsf{H}}, \mu_{\mathsf{H}}, \mu_{\mathsf{L}}, \rho\right)$ stand for the right-hand side of (39). Then we obtain the following comparative static results, which are basically the same as in the special case where $\mu_{\mathsf{L}} = 0$:

$$\frac{\partial P_{\mathsf{H}2}}{\partial \mu_{\mathsf{H}}} = -\frac{(\partial\Omega/\partial\mu_{\mathsf{H}})}{(\partial\Omega/\partial P_{\mathsf{H}2})} < 0$$

$$\frac{\partial P_{\mathsf{H}2}}{\partial \mu_{\mathsf{L}}} = -\frac{(\partial\Omega/\partial\mu_{\mathsf{L}})}{(\partial\Omega/\partial P_{\mathsf{H}2})} > 0$$

$$\frac{\partial P_{\mathsf{H}2}}{\partial N_{\mathsf{H}}} = -\frac{(\partial\Omega/\partial N_{\mathsf{H}})}{(\partial\Omega/\partial P_{\mathsf{H}2})} < 0$$

$$\frac{\partial P_{\mathsf{H}2}}{\partial N_{\mathsf{L}}} = -\frac{(\partial\Omega/\partial N_{\mathsf{L}})}{(\partial\Omega/\partial P_{\mathsf{H}2})} > 0$$

3 The Pattern of Trade

Using our analysis of autarky equilibrium, we can now determine the effect of the opening of trade between two autarkic economies. Based on our analysis there are **three bases** for comparative advantage; factor endowments, differences in the productivity of firm specific human capital and differences in the bargaining power of labor. We will assume that there are no differences in preferences. We first consider differences in endowments. In this section, the asterisk $(*)$ denotes variables in the foreign country. Variables without the asterisk are those of the home country.

Explaining trade in terms of endowments:

Assume that the only difference between the two countries is that the ratio $N_{\mathsf{H}}/N_{\mathsf{L}}$ in the home country is higher than the corresponding ratio $N^{*}_{\mathsf{H}}/N^{*}_{\mathsf{L}}$ in the foreign country. To be more specific, assume

$$\frac{N_{\mathsf{H}}}{N_{\mathsf{L}}} > 1 > \frac{N^{*}_{\mathsf{H}}}{N^{*}_{\mathsf{L}}} \tag{40}$$

This means that the home country is relatively well endowed with specific capital in the high tech sector. Using the analysis of the example in the subsection on autarkic equilibrium we see that the home country's period-one autarkic price for good H is lower than that of the foreign country. Since we have three traded goods we need a further assumption to determine the pattern of trade. We assume that initial parameter values are such that

$$P_{\mathsf{H1}} < P_{\mathsf{G1}} = 1 < P_{\mathsf{L1}} \tag{41}$$

and that

$$P^{*}_{\mathsf{H1}} > P^{*}_{\mathsf{G1}} = 1 > P^{*}_{\mathsf{L1}} \tag{42}$$

Thus the opening of trade will result in the home country exporting good H and importing good L in period two. Which country exports G is indeterminate. Trade could also arise because of differences in technology or bargaining power of labor. They work in a similar way to endowment differences.

Explaining trade in terms of technological differences

Suppose that the productivity of human capital investment differs across countries. In particular, suppose $\mu_{\mathsf{H}} > \mu^{*}_{\mathsf{H}}$, then in the home country there is higher productivity in high tech human capital investment. From the results of the previous section, the home country will have lower period- one autarky price for good H and hence have the comparative advantage in the high-tech good. Accordingly, given (41) and (42) then it follows that the home country will export H and import L.

Explaining trade in terms of the bargaining power of labor

Suppose that workers in the home country have more bargaining power than workers in the foreign country, $\beta > \beta^{*}$. It then follows that the high tech good, H has a lower autarky price in the home country indicating comparative advantage in H for the home country. Again given (41) and (42) then it follows that the home country will export H and import L.

In the next section we compare two scenarios. In the first scenario, both countries are under autarky in both periods. In the second scenario, at the beginning of period one, it is announced that free trade will be allowed in period two. We want to know how prices and wages differ in the two scenarios?

4 Effects of Trade Liberalization

Our model can be used to shed light on the effects of trade liberalization.

We will first analyze the case in which inital endowments differ across countries. Consider the case of a less developed country, or *LDC* for short. Assume that this economy is relatively well endowed with low-tech specific capital. Then, it follows from the above analysis that this economy imports good H and exports good L When trade is liberalized the price of the imported good falls and the price of the export increases. We want to compare two scenarios: under scenario 1, which is the reference scenario, the import competing sector S_{H} is protected in both periods, while under scenario 2, protection is removed in period 2, and that removal is fully anticipated at the beginning of period 1. The sector G is not subject to any trade tax or subsidy in both scenarios. Thus trade liberalization will result in a lower domestic price$P_{\mathsf{H}2}$ as compared with the domestic price $P_{\mathsf{H}2}^{\mathsf{R}}$ in the reference scenario. From the analysis in the preceding sections, it follows that the lower $P_{\mathsf{H}2}$ implies a smaller rate of accumulation of firm-specific human capital in sector S_{H}. From (1), and (4), when $P_{\mathsf{H}2}$ is lower, then h_{H} also **decreases** in response, causing the wage of skilled workers in sector S_{H} to be lower (as compared with the reference scenario). Thus, **for the** *LDC* that exports the low-tech good and imports the high-tech good, **trade liberalization reduces the wage gap** $W_{\mathsf{H}2} - W_{\mathsf{G}}$, where $W_{\mathsf{H}2}$ is the wage received by a skilled worker in sector S_{H}. The wage premium per-unit of skill in sector S_{H}, defined as

$$w_{\mathsf{H}2} = \frac{W_{\mathsf{H}2} - W_{\mathsf{G}}}{h_{\mathsf{H}}} \tag{43}$$

also falls when there is trade liberalization, as can be inferred from (1).

Thus, it may be argued that trade liberalization could be harmful in the sense that it reduces the incentive to accumulate skills in the high-tech sector. Our result seems to lend support to the following view, quoted from Hirschman (1969, p. 5):

"The opponents of free trade have often pointed out that for a variety of reasons it is imprudent and harmful for a country to become specialized along certain product lines in accordance with the dictates of comparative advantage. Whatever the merits of these critical arguments, they would certainly acquire overwhelming weight if the question arose whether a country should allow itself to become specialized not just along certain commodity lines, but along factor-of-production lines. Very few country would ever consciously wish to specialize in unskilled labor, while foreigners with a comparative advantage in entrepreneurship, management, skilled labor and capital took over these functions, replacing inferior "local talents."

However, that is not the complete story. Trade liberalization also leads to an increase in P_{L2}, an increase in h_{L} and an increase in the wage gap $W_{\mathsf{L2}} - W_{\mathsf{G}}$ between workers in the low tech sector and workers with no firm specific human capital. Define S_{L} as

$$w_{\mathsf{L2}} = \frac{W_{\mathsf{L2}} - W_{\mathsf{G}}}{h_{\mathsf{L}}} \tag{44}$$

It follows then that the higher P_{L2} implies a larger rate of accumulation of firm-specific human capital in sector S_{L}. From (1), and (4), when P_{L2} is higher, then h_{L} **increases** in response, causing the wage of skilled workers in sector S_{L} to be higher (as compared with the reference scenario). Thus, for the LDC that exports the low-tech good and imports the high-tech good, trade liberalization leads to less human capital accumulation in sector H and reduces the wage gap $W_{\mathsf{H2}} - W_{\mathsf{G}}$, but increases human capital accumulation in sector L and the wage gap between the workers who only have general human capital and the low tech sector workers, $W_{\mathsf{L2}} - W_{\mathsf{G}}$.

There are two important implications of these results. First, to the extent that wages reflect human capital acquisition one should be careful about making normative statements about the desirability or undesirability of increasing wage gaps. If the a larger wage gap also means more skill acquisition it may be a good thing. Second, even in a simple model such as ours there is no obvious definition of a "wage gap." Actually, here there are three different wage rates and hence, two different wage gaps. In the example of an LDC, trade liberalization reduces the wage gap between the high tech sector workers and the workers with only general human capital, but increases the wage gap between low tech sector workers and general human capital types.

Next, consider an advanced industrialized country AIC. This country exports the high-tech goods, and imports the low-tech goods. The analysis for the effects of trade liberalization on the AIC are similar to the analysis for the LDC. What will happen is that trade liberalization will reduce the protective tariffs on low-tech goods leading to a fall in the price of these goods. This results in less accumulation of firm-specific human capital in the low tech sector S_{L}. Then, from (1) and (4), the wage gap $W_{\mathsf{L2}} - W_{\mathsf{G}}$ will fall. In the high tech sector the opposite will happen. Trade liberalization leads to higher prices for good H, more human capital accumulation in that sector and higher wages W_{H2}. The wage gap $W_{\mathsf{H2}} - W_{\mathsf{G}}$ will rise. So, in the case of the AIC, trade liberalization leads to a larger high tech wage gap, but a lower low tech wage gap.

By endogenizing human capital formation we gain some insights into the effects of trade liberalization on the "wage gap." First, our model demonstrates that there is a relationship between wages and human capital formation. This means that the normative implications of increasing wage gaps are unclear. While larger wage gaps may lead to a more unequal distribution of income which may be bad, the higher wages induce more human capital formation which is good. Second, even in our very simple model it is clear that there is not one wage gap. In fact, in our model there are two wage gaps. Furthermore, trade liberalization has opposite effects on the two wage gaps. Looking at the gap between the highest and lowest paid workers is only part of the story. The "wage gap" needs to be defined using a more informative measure, such as the dispersion of wages, and the effect of trade liberalization on that measure should be analyzed.

5 Uncertainty and Risk Aversion

Now we introduce uncertainty and risk aversion into the model. We restrict attention to a small open economy. We now assume that period-two price P_{H2} for good S_{H} is a random variable, and trade liberalization for country LDC will be represented by a fall in the mean of P_{H2}, accompanied by an increase in its variance. To justify this view, we propose to think of sector S_{H} as consisting of a large number of firms each producing a different high-tech product. Exposure to freer trade means that each of these producers faces a more volatile price for his output. (One may assume that before the freeing up of trade, the government of LDC was committed to a tariff or subsidy policy that minimizes variations in domestic prices of goods produced by import-competing firms). The liberalization of trade can be expected to bring about a fall in the average price of high-tech products, but the price of a given high-tech product may rise or fall relative to its price under the protection regime.

Since P_{H2} is random, the period-two negotiated wage is also random:

$$\widetilde{W_{H2}} = W_G + \mu_H(1-\beta)\widetilde{P_{H2}}h_H \tag{45}$$

We assume that under free trade

$$\widetilde{P_{H2}} = \theta\overline{P_{H2}} + \varepsilon$$

where θ is a shift parameter, and ε is a random variable with mean 0 and variance σ^2. (We may have to assume that ε has a specific distribution, such as the uniform distribution, or the normal distribution.) We assume that $\overline{P_{H2}}$ is a known constant. Under the protection regime, $P_{H2} = \overline{P_{H2}} + \varepsilon^R$ where ε^R has a smaller variance than σ^2.

In this section, we do not assume that individual workers can borrow or lend. For the time being, let us consider the simplest case: we assume that workers consume only the numeraire good. Then, for a representative worker in sector S_H, his utility in period one is $U_1(W_{1H} - \gamma c(h_H))$, and discounted utility in period two is $\delta U_2(W_G + \mu_H(1-\beta)\widetilde{P_2}h_H)$. (Here $\delta < 1$ is the discount factor.) Taking W_{1H} as given, the worker chooses h_H to maximize

$$V = U_1(W_{1H} - \gamma c(h_H)) + \delta E U_2(W_G + \mu_H(1-\beta)\widetilde{P_{H2}}h_H) \tag{46}$$

Note that if the utility function is linear, i.e., $U_t(X_t) = AX_t + D$, and if $\delta = 1/(1+r)$, then this model reduces to a special case of the basic model in Section 2, with $g(.) = 0$ identically.

The first order condition is

$$\frac{\partial V}{\partial h_H} = -\gamma c'(h)U_1' + (1-\beta)\mu_H \delta E\widetilde{P_{H2}}U_2' = 0 \tag{47}$$

and the second order condition is

$$\frac{\partial^2 V}{\partial h_H^2} = -\gamma c''(h_H)U_1' + (\gamma c'(h_H))^2 U_1'' + (1-\beta)^2\mu_H^2\delta E\left(\widetilde{P_{H2}}\right)^2 U_2'' < 0$$

From (47) we get the result that, *given* W_{1H},

$$\frac{\partial h_H}{\partial \theta} = \frac{1}{-V_{hh}}\mu_H\delta(1-\beta)\overline{P_{H2}}E\left(U_2' + (1-\beta)\mu_H\widetilde{P_{H2}}h_H U_2''\right) \tag{48}$$

which is positive if and only if

$$E\left(U_2' + (1-\beta)\mu_{\mathrm{H}}\widetilde{P_{\mathrm{H}2}}h_{\mathrm{H}}U_2''\right) > 0 \tag{49}$$

A sufficient condition for (49) to hold is that

$$\frac{-\mu_{\mathrm{H}}(1-\beta)\widetilde{P_{\mathrm{H}2}}h_{\mathrm{H}}U_2''\left(W_{\mathrm{G}} + (1-\beta)\mu_{\mathrm{H}}\widetilde{P_{\mathrm{H}2}}h_{\mathrm{H}}\right)}{U_2'\left(W_{\mathrm{G}} + (1-\beta)\mu_{\mathrm{H}}\widetilde{P_{\mathrm{H}2}}h_{\mathrm{H}}\right)} < 1 \tag{50}$$

and a sufficient condition for (50) is that the relative risk aversion coefficient is not greater than unity: $1 \geq -XU_2''(X)/U_2'(X) = \rho$.

It is important to note that the result (48) is based on a given $W_{1\mathrm{H}}$.To find the general equilibrium effect of an increase in θ on h_{H}, we must determine the equilibrium value of the pair $(W_{1\mathrm{H}}, h_{\mathrm{H}})$ simultaneously. In principle, this pair can be obtained from two equilibrium conditions, namely (47) and

$$U_1(W_{1\mathrm{H}} - \gamma c(h_{\mathrm{H}})) + \delta E U_2(W_{\mathrm{G}} + \mu_{\mathrm{H}}(1-\beta)\widetilde{P_{\mathrm{H}2}}h_{\mathrm{H}}) = U_1(W_{\mathrm{G}}) + \delta U_2(W_{\mathrm{G}}) \tag{51}$$

REMARK: In the case of linear utility, this model reduces to the model in Section 2. In that case, the variance σ^2 of the distribution of ε plays no role.

A NUMERICAL EXAMPLE: Assume that $U(X) = AX - (B/2)X^2$. Then conditions (47) and (51)become

$$\gamma c'(h_{\mathrm{H}})[A - B\,(W_{1\mathrm{H}} - \gamma c(h_{\mathrm{H}}))] =$$

$$\delta(1-\beta)\mu_{\mathrm{H}}E\widetilde{P_2}[A - B(W_{\mathrm{G}} + \mu_{\mathrm{H}}(1-\beta)\widetilde{P_2}h_{\mathrm{H}})] \tag{52}$$

and

$$A(W_{1\mathrm{H}} - \gamma c(h_{\mathrm{H}})) - (B/2)(W_{1\mathrm{H}} - \gamma c(h_{\mathrm{H}}))^2 +$$

$$\delta E\left(A(W_{\mathrm{G}} + (1-\beta)\widetilde{P_2}h_{\mathrm{H}}\mu_{\mathrm{H}}) - (B/2)(W_{\mathrm{G}} + (1-\beta)\widetilde{P_2}h_{\mathrm{H}}\mu_{\mathrm{H}})^2\right) =$$

$$(1+\delta)\left(AW_{\mathrm{G}} + (B/2)W_{\mathrm{G}}^2\right) \tag{53}$$

Substitute the right-hand side of (52) into (53) we obtain an equation to determine the equilibrium h_{H} in terms of $\overline{P_{\mathrm{H}2}}$, θ, and σ. In particular, if $c(h_{\mathrm{H}}) = (1/2)h_{\mathrm{H}}^2$ then substituting (52) into (53) gives a simple equation in h_{H}. The effect of an increase in the variance σ on the accumulation of h_{H} can then be analyzed.

6 Concluding Remarks

We have developed a model of firm-specific human capital accumulation and explored some of its implications. The model indicates that there are a lot of work to be done before we can predict the effects of trade liberalization on wage dispersion.(To be completed.)

APPENDIX

Derivation of equation (8)

If $\phi(X_{Lt}, X_{Ht})$ is homothetic then it must be true that there exists a function $f(X_{Lt}, X_{Ht})$ which is homogenous of degree one, and a monotone increasing function $g(.)$ such that $\phi(X_{Lt}, X_{Ht}) = g[f(X_{Lt}, X_{Ht})]$ .For any number $v_t > 0$, we define the expenditure function $E(P_{Lt}, P_{Ht}, v_t)$ by

$$E(P_{Lt}, P_{Ht}, v_t) = \min_{X_{Lt}, X_{Ht}} (P_{Lt}X_{Lt} + P_{Ht}X_{Ht})$$

subject to

$$g[f(X_{Lt}, X_{Ht})] = v_t$$

Clearly,

$$E(P_{Lt}, P_{Ht}, v_t) = \min_{X_{Lt}, X_{Ht}} (P_{Lt}X_{Lt} + P_{Ht}X_{Ht}), \text{s.t. } f(X_{Lt}, X_{Ht}) = g^{-1}(v_t)$$

Hence, letting $Y = X_{Lt}/g^{-1}(v_t)$ and $Z = X_{Ht}/g^{-1}(v_t)$, then

$$E(P_{Lt}, P_{Ht}, v_t) = g^{-1}(v_t) \min_{Z, Y} (P_{Lt}Y + P_{Ht}Z), \text{s.t. } f(Y, Z) = 1$$

Therefore

$$E(P_{Lt}, P_{Ht}, v_t) = g^{-1}(v_t) I(P_{Lt}, P_{Ht}) \tag{54}$$

where

$$I(P_{Lt}, P_{Ht}) = \min_{Z, Y} (P_{Lt}Y + P_{Ht}Z), \text{s.t. } f(Y, Z) = 1$$

Inverting the expenditure function (54), we get the indirect utility function

$$v(P_{Lt}, P_{Ht}, E_t) = g\left(\frac{E_t}{I(P_{Lt}, P_{Ht})}\right)$$

This completes the proof.

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