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Globalization and Labour Market Effects: Trade vs. Induced Technical Progress

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Globalization and Labour Market Effects:

Trade vs. Induced Technical Progress

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Summary

The pure „trade effects“ of globalization are not large enough to explain the high European unemployment (even when one admits inflexible wages). However, there is a „technology effect“ which has reduced – in all industries – the demand for unskilled labour. Furthermore, the portion of high-skilled labour has increased continuously in all industries, despite the increase in the „skill premium“. To solve these two puzzles, technical progress „induced“ by globalization must be of a certain kind.

I. Introduction: Setting of the Stage

At the outset there is a remarkable and „unexpected factor increase“ through the wider integration in the world trade of the transformation states. This phenomenon is normally described within a typical Heckscher-Ohlin-Stolper-Samuelson (HOSS) model[1]. See Figure 1. The „autarky equilibrium“ in quadrant I (GE) is disturbed by indroducing (or largely increasing) North-South trade. This shifts the demand curve to N'N‘ (and NN and N'N‘ cross at $[p_T/p_M]_s$, the autarky price of the South). The consequences can be easily seen: Because of the price increase (E $\rightarrow$ F), resulting in more production of the high-tech good (G $\rightarrow$ H), the relative wage of unskilled labour (in the North) is decreasing (C $\rightarrow$ D). This inturn results in a reduction of the „quality intensity“ (h), reducing the relative wages or increasing the „skill premium“.

When in the North, prices and relative wages are rigid (in particular downwards), this increases the structural change (G $\rightarrow$ K) and North-South trade (because consumption in the North has not changed). Since rigid relative wages imply that factor intensities are fixed, the amount of unskilled labour set free in the low-tech sector is larger than the amount of new employment in the high-tech sector.

This means, the „globalization shock“ is accompanied (as Krugman [1995] told us) by a reduction in demand, employment and income! Either unskilled labour accepts the decrease in its real wage position or there is higher unemployment of unskilled labour (A $\rightarrow$ B, with given H implies less L). However, as the empirical literature tells us, the increase in world trade can account for only a small part of the registered unemployment. Further, it is interesting to note that the reduced demand for unskilled labour also appeared in the non-trade sector. Insofar technical progress must be invoked which reduces **in all** industries the demand for unskilled labour (see Haskel and Slaughter [EER 2002]). This can be shown by looking at eq. (4) in Appendix A. There, besides skill-biased technical progress (sbtp), also sector-biased technical progress is considered. First, skill-biased technical progress raises the skill premium. Second, changes in relative labour supply also alter the skill premium, where the magnitude of the wage effect varies with the elasticity of subsitution (σ). Third, suppose technical progress is sector-specific, then the impact of technical progress on the skill premium depends **un**ambiguously on which sector experiences the technical progress: Any sector-specific technical progress in the high-tech sector (a rise in the parameters A_T or δ_T) raises the skill premium (see e.g. Jones [JEP 1965]). Fourth, however, if technical progress appears in both sectors (i.e. technical progress is sector-pervasive) but is biased in favour of the high-tech sector (i.e. δ_T rises by more than δ_M), then the change in relative costs and thus in the skill-premium also depends on the magnitudes of the skilled labour's share of the two sectors wage bill, on the resp. distribution parameter as well as on the elasticity of substitution in the two sectors. Or put it otherwise: Rising skill premia are caused by more extensive skill-biased technical progress in skill-intensive sectors.

[1] There are 2 countries (N=North, S=South), 2 goods (T=high-tech, M=low-tech good), and 2 factors of production (H=skilled, L=unskilled labour). Mostly, capital is not taken into account (but two types of labour, skilled and unskilled), because the high capital mobility – brought about by the internationalization of capital markets – does not allow for interest rates differences (see e.g. Krugman, BPEA 1995).

This leads then to a further important question: How can we explain what is happening in different countries in different times[2]? One explanation is, that different countries experience different technical progress, i.e. the countries do not share identical production technologies. Here, the best way is by modelling technical progress as induced along the so called „Kennedy-Weizsaecker-lines“: Not only is technical progress introduced when it is cost-reducing, but out of the „sea of inventions“ entrepreneurs seek those technical progresses (or innovations) which are more cost-reducing than others (and these may very well be related to production factors). Or we can still go one step further down to look at inventions, and to argue that „profit incentives determine the amount of research and development directed at different factors and sectors“ of the economy (Acemoglu [RES 2002], 781).

These questions were of great interest in the end of the sixties and beginning of the seventies of the last century (maybe ending with Nordhaus‘ „Skeptical Thoughts an the Theory of Induced Innovations“ [QJE 1973])[3]. Today, however, there is relatively little research on biased technical progress. Therefore, to combine the literature about new growth theory with endogenous technical progress and these older ideas is a good starting point[4].

The paper is, therefore, organized in the following way: Part II the traditional literature on induced technical progress is introduced using the innovation possibility frontier (IPF). In part III, the IPF is combined with some new approaches in New Growth Theory. In part IV, the model is enlarged to take into account labor market regidities to explain increasing skill-premia as well as unemployment. Part V summarizes the results and gives some hints for future research.

[about here Figure 1]

[2] Results show that in the seventies of the last century all countries show a decreasing skill premium, while in the eighties almost all countries show an increasing skill premium; see Haskel and Slaughter, 2002, p. 1721; and ... . Even when it is tempting to do so, I’ll not take the opportunity to combine these findings with other parts of economic and political history (e.g. oil price shocks etc.).

[3] See also Eisen (1971), (1976) and Nordhaus (1969).

[4] See e.g. Romer (Macro III).

II. Induced factor-specific technical progress (skill-biased tp)

In line with the old and the new traditions in induced technical progress, in this part first the Drandakis and Phelps (1966) model is briefly summarized and an enlargement – according to ideas of Uzawa (IER 1965) – is presented.

The Drandakis and Phelpsideas are combined with the ideas of the New Growth Theory. In particular, when firms choose (and invest in) technology in addition to capital and labour, the notion of competitive equilibrium has to be modified or refined, either by introducing technological externalities (see Romer, 1986) or monopolistic competition (Romer, 1990; Grossman/Helpman, 1991). Third, the extension of the Drandakis/Phelps model is then also applied to the New Growth Theory.

IIa. A simple (old) induced innovation model

The economy is populated by a mass of consumers with constant savings rate α. The firms have access to a ‚neoclassical' production function (with constant returns to scale) where technical progress is of the factor-augmenting type[5]:

(1) $$Q(t) = F[B(t) \cdot H(t), A(t) \cdot L(t)]$$

where B(t), H(t), A(t) and L(t) are steadily differentiable functions of time, and B (t) and A(t) denote (unskilled) labour and (skilled labour or human) capital-augmenting technology terms, H(t) is (human) capital and L(t) is (unskilled) labour. Although firms have profit-maximizing amounts of (unskilled) labour and (human) capital, they choose their technologies to maximize the current rate of cost reduction for given factor proportions (see Kennedy, 1964, 543, and Drandakis and Phelps, 1966, 824). This is equivalent to maximizing the instantaneous rate of output growth g, given H and L. Differentation of eq. (1) with respect to time, holding H and L constant gives

(2) $$g = s(\frac{\dot{A}}{A}) + (1-s)(\frac{\dot{B}}{B})$$

where s is the share of (simple) labour in GDP.

In maximizing g, firms face a constraint introduced by Kennedy (EJ, 1964)[6], which is here called „innovation possibility frontier"[7]. This frontier specifies the limited rate of technological progress, giving the maximum rate of labor-augmenting technical progress with given rate of (human) capital-augmenting technical progress:

(3) $$\frac{\dot{A}}{A} = \phi(\frac{\dot{B}}{B}),$$

where ϕ is a strictly decreasing, differentiable and concave function, shown in Figure 2.

[5] See Appendix B for a CES specification.
[6] See also Samuelson (REStat, 1965) and Weizsaecker (RES, 1966).
[7] For a discussion with respect to this notion see also Ahmad (EJ1966).

[About here Figure 2]

The solution to maximizing eq. (2) subject to eq. (3) takes a simple form satisfying the first-order condition

(4) $$(1-s)+s\phi'(\frac{\dot{B}}{B})=0.$$

Diagrammatically, this solution is drawn in Figure 2 as the tangency of the innovation possibility frontier (IPF) and the line representing the instantaneous growth rate of output (P_1). Comparative statics are straightforward. A greater share of labour in GDP, s, makes labour-augmenting technical progress more valuable and increases $\dot{A}/A$ and reduces $\dot{B}/B$. According to Hicks (and Karl Marx), technical progress tends to replace the (more) expensive production factor.

Total differentiation of eq. (1) leads, to

(5a) $$\dot{Q}=F_L(\dot{L}A+L\dot{A})+F_H(HB+\dot{B}H)$$ and

(5b) $$\dot{Q}/Q=\frac{F_L\cdot L\cdot A}{Q}\cdot(\frac{\dot{A}}{A}+\frac{\dot{L}}{L})+\frac{F_H\cdot B\cdot H}{Q}\cdot(\frac{\dot{B}}{B}+\frac{\dot{H}}{H}).$$

Setting $\frac{F_L\cdot L\cdot A}{Q}=s$ and $\frac{F_H\cdot B\cdot H}{Q}=1-s$, and choosing a balanced growth path (BGP), which satisfies the two Kaldorian „basic facts“ that the capital-output-ratio H/Q is constant as well as a constant interest rate, implies that $\dot{B}/B=0$ and $\dot{A}/A=a\cdot Y/H=\dot{Q}/Q$. Technical progress has to be purely labour-augmenting, or graphically, the tangency point has to be at P_2 as shown in Figure 2. Thus

(6) $$(1-s)+s\phi'(0)=0.$$

Therefore, in equilibrium (and along a BGP) all technical progress is labour augmenting, and together with (human) capital accumulation imply constant factor shares. Furthermore, Drandakis and Phelps (1966) show that if $\sigma<1$ (the elasticity of factor substitution is smaller than one), then the BGP is globally stable. Intuitively, a greater share of labour in GDP encourages more labour-augmenting technical progress as shown by eq. (4). If the elasticity of substitution is larger than 1, the labour-augmenting technical progress increases the share of labour even further, hence destabilizing the economy. If the elasticity of substitution is smaller than 1, the labour's share falls and the economy converges towards the steady state.

These important results rest upon many restrictive assumptions with respect to the production function and the decision rule of entrepreneurs (see eq. (2)) – and the stationary and autonomously given IPF which is also independent of variations of factor prices and factor shares.

IIb. A dynamized IPF

In order to dynamize the IPF, Uzawa (JER, 1965) has given some useful insights: the intensity of technical progress is determined by the share of labour in the R & D sector, i.e.

$$\dot{A}/A = f(L_F/L) \quad or \quad \dot{A} = A \cdot f(1-u) \text{ where}$$

$u = L_p/L$, and $1-u = L_F/L$ and $L_p + L_F = L$, and f is increasing in $(1-u): f'(1-u) > 0, f''(1-u) \leq 0$ for all $0 \leq u \leq 1$.

Talking the IPF into account, leads to the following model:

(7) $$Q(t) = F[B(t)H(t), A(t)L_p(t)]$$

(8) $$\dot{A}(t) = \phi(\dot{B}/B) f(1-n).$$

This model – to circumvent the problems of competition – can be analyzed in a „planning setting“, where a bureaucracy determines the factor bias of technical progress, $\dot{A}/A$, the share of labour in the R & D sector, u, as well as the (economy-wide) savings rate, α.

It can be shown (see Uzawa, 1965 and Eisen, 1971, Chapter IV, part B) that in equilibrium – and there is only one – technical progress is only labour – augmenting, if $\sigma \neq 1$.

However, as mentioned above, and critized by many, it is unsatisfactory to entrust the decision with respect to the factor bias of technical progress to a bureaucracy, which chooses a point on the IPF to maximize the rate of cost reduction. Furthermore, technical progress is treated as a pure public good (financed by a tax on output). However, most of technical progress is protected by patents and trade marks, so firms can control access to an invention and earn profits from it. How can this model be connected with R & D profit-maximizing individual firms?

In order to answer this question one has either to introduce technological externalities or spill-overs from private research efforts to the public stock of knowledge: Investments in physical (Arrow, 1962) or human capital (Lucas, 1988) increase the productivity of other firms in the economy (see in particular Romer, 1986). Individual firms do not internalize this effect, so they are subject to constant „private returns“, while there are increasing returns at the aggregate level, and a competitive equilibrium exists. The alternative is to introduce monopolistic competition and property rights so that profit-seeking investments in knowledge play the critical role: Final good producers (users of technology) are competitive, but suppliers of technology have market power (see Aghion and Howitt, 1999, as well as Grossman and Helpman, 1992). However, when these monopolistic firms double their inputs, total output increases more than twofold, but their profits only double because of the decline in their product prices. In the following, this second approach will be followed and extended to incorporate the central idea of the induced innovations literature (see in particular Acemoglu, 1998, 1999, 2001).

III. Skill-biased tp and trade between North and South

III. 1 The demand side

Consider – as in Part I – a world economy consisting of a large advanced country, called North, and a set of small countries, called South. The main difference between North and South is – despite their relative sizes – the relative factor proportions: The North has H^N skilled and L^N unskilled workers, while the South has H^S skilled and L^S unskilled workers, and $H^N/L^N > H^S/L^S$.

All consumers in all countries have idential constant relative risk aversion (CRRA) preferences

(1) $$\int_0^\infty \frac{C(t)^{1-\theta} - 1}{1-\theta} \exp(-\rho t) dt$$

where C(t) is consumption at time t, ρ is the discount rate and θ is the elasticity of marginal utility or the coefficient of relative risk aversion. For θ = 0, the utility function is linear, and the consumers are risk neutral; for θ → 1, the utility function becomes logarithmic.

The production technology is also common across countries. The budget constraint of the representative consumer is

(2) $$C + I + R \leq Y^i \equiv [\gamma Y_L^{i\frac{\epsilon-1}{\epsilon}} + (1-\gamma) Y_H^{i\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}},$$

where I denotes investment, and R is total R & D expenditure, ε denotes the elasticity of substitution between the unskilled-labour intensive good and skilled-labour-intensive good; i = N, S.

The labour-intensive and human-capital-intensive final goods are produced competitively from constant elasticity of substitution (CES) production functions of labour-intensive and human-capital-intensive intermediates („machines“), with elasticity v=1/(1-β):

(3a) $$Y_L^i = \int_0^1 \tilde{q}_l^i(i)^\beta x_l^i(i)^{1-\beta} (L^i)^\beta di$$

(3b) $$Y_H^i = \int_0^1 \tilde{q}_h^j(i)^\beta x_h^j(i)^{1-\beta} \cdot (H^j)^\beta di$$

where β ∈ (0, 1), so that v > 1 and different intermediate goods are gross substitutes. The first good uses unskilled labour (L^j) and a set of differentiated intermediate goods, whereas the second uses skilled labour (H^j) and a different set of machines. The key assumption here is – following Acemoglu (2001, 2003) – that certain „machines“ can only be handled by unskilled workers, while some machines can only be used by skilled workers. $x_L^j(i)$ is the quantity of machines of variety i used in sector (or country) j together with workers of skill level s and $\tilde{q}_L^j(i)$ represent the qualities or productivities of this type of machine. The range (number or measure) of machines that can be used with unskilled and skilled labour simplifies the analysis because technical progress can be non-stochastic.

Producers of the final goods are price takers, therefore, they maximize profits by solving the following problem:

(4) $$\max_{z,\{x_s^j(i)\}} p_s Y_s^i - w_s Z - \int_0^1 \chi_s(i) x_s^j(i) di$$

taking the price of their product, p_s, wage, w_s, the rental prize of all machines, χ_s (i), as well as the range of machines as given (s = L, H). The first-order conditions for this problem give machine demands as

(5a) $$x_L(i) = \left[p_L\left((1-\beta)p_L^j \cdot q_L^j(i)L^j\right)^\beta / \chi_L(i)\right]^{1/\beta}$$

(5b) $$x_H(i) = \left[p_H((1-\beta)p_H^j \cdot q_H^j(i)H^j)^\beta / \chi_H(i)\right]^{1/\beta}.$$

These equations imply that the demand for machines increases with increasing product prices (p_s) and firm's employment, L(j) or H(j), and with decreasing machine prices, χ_s (i). This latter characteric leads to **a market size effect:** There will be a greater demand for technologies complementing „the more abundant factor“ (Acemoglu, 2002, 789).

Each type of machine is produced by a monopolist who holds the relevant patent. Since the demands for machines implied by eq. (5a, b) are isoelastic, the profit-maximizing price for these machines is a constant markup over marginal costs ψ. Without loss of generality, one can normalize this marginal cost to $(1-\beta)$, so that $\chi_s(i) = 1$.

Substituting machine prices in (5a, 5b) and the production functions (3a, b) give outputs as

(6a) $$Y_L^j = p_L^{j(1-\beta)/\beta} \tilde{Q}_L^j L^j,$$

(6b) $$Y_H^i = p_H^{j(1-\beta)/\beta} \tilde{Q}_H^j H^j,$$

where $\tilde{Q}_s^j = \int_0^1 \tilde{q}_s^j(i) di$ for s =L, H is a measure of the aggregate productivity of machines.

The final product markets for the two goods are competitive, so market clearing (without international trade) implies that the relative price, p_j, has to satisfy

(7) $$p^j = \frac{p_H^j}{p_L^j} = \frac{1-\gamma}{\gamma}\left(\frac{Y_H^i}{Y_L^i}\right)^{-1/\epsilon}.$$

The greater the supply of Y_H relative to Y_L the lower its relative price, p. Substituting (6a, b) results in the relative price of the two goods as a function of relative productivity and relative factor supplies, H^j/L^j:

(8) $$p^j = [(\frac{1-\gamma}{\gamma})^{-\varepsilon} \frac{Q_H \cdot H^j}{Q_l \cdot L^j}]^{-\frac{\beta(\varepsilon-1)}{1+\beta(\varepsilon-1)}}.$$

An increase in H^j / L^j therefore increases the relative supply of skill-intensive goods and depresses p^j.

The productivity of labour is driven by two forces: the first is the state of technology and the second is product prices. The **skill-premium** in country j is therefore given as

(9) $$\frac{w_H^j}{w_L^j} = (p^j)^{1/\beta} \cdot \frac{Q_H}{Q_L} = (\frac{1-\gamma}{\gamma})^{\frac{\varepsilon}{\sigma}} (\frac{Q_H}{Q_L})^{\frac{\sigma-1}{\sigma}} (\frac{H^j}{L^j})^{-1/\sigma},$$

where ε is the elasticity of substitution between the two final goods, and σ is the (derived) elasticity of substitution between the two factors, H and L, defined as

$\sigma \equiv \varepsilon - (\varepsilon - 1)(1 - \beta).$

Equation (9) implies, first that for a given state of technology (skill-bias) as captured by Q_H/Q_L, the skill premium is **decreasing** in the supply of skills. Second, the relative factor award is *also* **decreasing** in the relative factor supply, the usual substitution effect: The more abundant factor is substituted for the less abundant one!

III. 2 The supply side: The innovation possibility frontier

While section III.1 outlined how the production side of the economy determines the return to different types of innovations, i.e. the demand for innovation, the analysis in this section focuses on the relative cost of innovation, or the innovation possibility frontier“ (IPF).

There are different ways to incorporate this idea of induced bias in technological progress. On the one hand, one can distinguish – as in Rivera-Batiz and Romer (1991) – between the „lab equipment specification“ or the „knowledge-based specification“. While the former involves only the final good being used in the production of new innovations, the latter uses the scarce (non-accumulated) factor such as labour or – more specifically – scientists to generate new innovations (see the model in Part II). Then, however, spill-overs from past research to current productivity are necessary to sustain growth.

On the other hand, the R & D process can be modelled as in Grossman and Helpman (1991) and Aghion and Howitt (1992): Here an innovation based on a machine of quality q creates a new vintage with quality λq where λ > 1. Then, one unit of the final good spend an R & D for a machine of quality q leads to an innovation at the flow rate zϕ (z), where z is the aggregate research effort devoted to the discovery of this machine. Research effort z on a machine of quality q costs Bzq units of the final good. It is assumed that ϕ‘(.) ≤ 0, but throughout it is assumed that zϕ (z) is increasing z, so that – despite decreasing returns within a given period – greater research effort leads to faster innovations. As Acemoglu does (2003, 208) set $B = \beta(1-\beta)\lambda$ to simplify notation.

Free entry into the R & D sector implies that an additional euro spent for research must yield a return equal to cost – here it is asumed that the individual monopolistic R & D firm does not take into account the impact on the aggregate innovation possibilities:

$$\phi(z_S(q_S(i)))V_S(\lambda q_S(i)) = \beta(1-\beta)\lambda \cdot q_S(i).$$

Using the machine prices and demands above (see eq. 5a,b), flow profits of technology monopolists are

$$\pi_S^j = \beta p_s^{1/\beta} \cdot x_s^j(q_s^j(i)) \text{ for s = L, H.}$$

However, monopolists are interested in the net present value of profits (V_s) i.e. in the long-run profitability. Using a standard Bellman equation, this leads to

$$rV_L - \dot{V}_L = \pi_L \text{ and } rV_H - \dot{V}_H = \pi_H,$$

or given the costs of producing new innovations

$$rV_S(\lambda_S(i)) = \pi_s^j(\lambda q_S(i)) - z_S(\lambda_S(i))\phi(z_S(\lambda_S(i)))V_S(\lambda q_S(i)) + \dot{V}_S(\lambda q_S(i)).$$

where r is the (potentially time varying) interest rate. In a steady state (along a BGP), the $\dot{V}$ terms are 0 (i.e. profits and the interest rate are constant in the future) this yields[8]

$$V_L = \frac{\beta p_L^{1/\beta} x_L(q_L(i))}{r + z_L(q_L(i))\phi(z_L(q_L(i)))} \text{ and } V_H = \frac{\beta p_H^{1/\beta} x_H(q_H(i))}{r + z_H(q_H(i))\phi(z_H(q_H(i)))}.$$

The greater V_H is relative to V_L, the greater are the incentives to develop H-complementary machines, Q_H, rather than labour-complementary machines, Q_L. Combining with the price eq. (8) yields

$$\text{(10)} \qquad \frac{V_H}{V_L} = p^{1/\beta} \cdot \frac{x_H(q_H(i))[r + z_L\phi(z_L)]}{x_L(q_L(i))[r + z_H\phi(z_H)]} = \left(\frac{1-\gamma}{\gamma}\right)^{\frac{\epsilon}{\sigma}} \cdot \left(\frac{Q_H}{Q_L}\right)^{-\frac{1}{\sigma}} \cdot \left(\frac{H}{L}\right)^{\frac{\sigma-1}{\sigma}} \cdot \frac{[r + z_L\phi(z_L)]}{[r + z_H\phi(z_H)]}.$$

This expression shows that the relative profitability of the two types of innovation are determined by the **price** and the **market size effect**: An increase in the relative factor supply, H/L, will decrease V_H/V_L if $\sigma < 1$. When the factors are cross substitutes ($\sigma > 1$), the market size effect dominates. When they are gross complements, the price effect dominates.

The demand functions for machines, the price equations and the value functions ensure that there is an equilibrium where firms choose profit-maximizing technology, rent the profit-maximizing amounts of inputs; and monopolists follow their profit-maximizing pricing policy, and all markets clear.

To highlight the forces shaping the skill bias of technology, only balanced growth paths (BGP) are considered, where $\dot{V} = 0$ and prices are constant. Hence,

$$\text{(11)} \qquad \pi_s(\lambda q_s(i)) = \beta(1-\beta)\lambda \frac{r + z_s(q_s(i))\phi(z_s(q_s(i)))}{\phi(z_S(q_S(i)))} \cdot q_S(i)$$

for any machine i and s = L or H. The fact that $\phi(z)$ is decreasing and $z\phi(z)$ is increasing in z ensures that the R. H. S. of eq. (11) is increasing in $z_s(q_s(i))$, i.e. „a greater profitability translates into greater research effort“ (Acemoglu, 2003, 210).

Taking the BGP with $\dot{V}_S = 0$, then $z_H = z_L$ and eq. (10) reduces to

$$\text{(12)} \qquad p^j = \left(\frac{x_H^j(q_H(i))}{x_L^j(q_L(i))}\right)^{-\beta}.$$

noting that technical progress is dominated by the relative supply. Because of $z_H = z_L$, the demand for skill-complementary technology relative to labour-complementary technology should be independent of H/L, and the price and market-size effect should balance – and this secures eq. (12). Using eq. (8) and (10) shows, that on the BGP relative productivity of skilled workers satisfies

$$\text{(13)} \qquad \frac{Q_H^j}{Q_L^j} = \left(\frac{1-\gamma}{\gamma}\right)^{\varepsilon} \left(\frac{H^j}{L^j}\right)^{\beta(\varepsilon-1)}.$$

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[8] Since one can alternatively express V_S also in terms of wages, i.e. $V_L = (1-\beta)w_L L / rQ_L$ and $V_H = (1-\beta)w_H H / rQ_H$, one sees, as conjectured by the induced innovation literature, that there will be more innovations directed at factors that are more expensive (cf. Acemoglu, 2002, 790, n. 10).

This eq. shows, that the equilibrium skill-bias is determined by the relativ supply of skills, while the parameter β(ε-1) determines the power and the sign of this „directional effect". Because of ε > 1, an increase in H/L makes innovations and R & D in the skill-intensive sector more profitable, hence Q_H/Q_L increases.

The skill premium is along BGP (Q_H/Q_L is given by eq. 13)

$$\frac{w_H^j}{w_L^j} = \left(\frac{1-\gamma}{\gamma}\right)^{\varepsilon} \left(\frac{H^J}{L^j}\right)^{\sigma-2}. \tag{14}$$

III.3 The effects of international trade on skill-biased technical progress

Now suppose that there is opening to international trade. This will generate a single world relative price of skill-intensive goods, p^w. Total supply of skill-intensive goods will be – supposing that the opening of international trade does not change the property rights structure –

$$Y_H^j = (p_H^w)^{(1-\beta)/\beta} \cdot Q_H^W (H^N + \kappa H^S)/(1-\beta) \tag{15a}$$

and the total supply of labour-intensive goods will be

$$Y_L^j = (p_L^W)^{(1-\beta)/\beta} \cdot Q_L^W (L^N + \kappa L^S)/(1-\beta). \tag{15b}$$

Using these eq. and eq. (7), the relative world price is given as

$$p^W = (\frac{1-\gamma}{\gamma})^{\frac{\beta\in}{\sigma}} (\frac{Q_H^W (H^N + \kappa H^S)}{Q_L^W (L^N + \kappa L^S)})^{-\beta/\sigma} = (\frac{1-\gamma}{\gamma})^{\beta\in/\sigma} (\delta^{-1} \frac{Q_H^W H^N}{Q_L^W L^N})^{-\beta/\sigma} \tag{16}$$

where $\delta \equiv (H^N/L^N)((H^N + \kappa H^s)/(L^N + \kappa L^S)) > 1$, this follows from $H^S/L^S < H^N/L^N$. κ denotes the „cost difference" between North and South: despite free copying of new machines, the price in the South is not 1 but $\kappa^{-\beta/(1-\beta)}$. And – as in Acemoglu (2002, 801) – Q_H^W and Q_L^W emphasize „that world technologies may change from their pre-trade levels in the North as a result of international trade."

Furthermore, skills are (relatively) scarcer in the world economy than in the North alone, trade opening will increase the relative price of skill-intensive goods in the North, i.e. $p^W > p$. And this change in product prices will affect the direction of technological progress. And since the price effect „encourages innovations for the scarce factor, international trade, by making skills more scarce in the North, will induce more innovations directed at skilled workers" (Acemoglu, 2002, 801/2).

Now look at the effect of this induced change in technology on factor prices. Eq. (16) implies that – **without a change in technology** – trade opening will increase the skill premium in the North to

$$\frac{w_H}{w_L} = (p^W)^{1/\beta} \frac{Q_H}{Q_L} = (\frac{1-\gamma}{\gamma})^{\in/\sigma} \delta^{1/\sigma} (\frac{Q_H}{Q_L})^{(\sigma-1)/\sigma} (\frac{H^N}{L^N})^{-1/\sigma}. \tag{17}$$

Comparing with eq. (9), one sees that **trade opening** necessarily **increases the skill premium** – a simple application of trade theory.

However, **with directed technical progress**, the skill-premium in the North changes to

(18) $$\frac{w_H}{w_L} = (p^W)^{1/\beta} \frac{Q_H^W}{Q_L^W} = (\frac{1-\gamma}{\gamma})^{\epsilon} \cdot \delta \cdot (\frac{H}{L})^{\sigma-2} .$$

Comparing the new post-trade skill-premium (18) with the pre-trade skill premium (eq. 14), one sees that, irrespective whether $\sigma \gtreqless 1$, **trade opening increases the skill-premium**. However, comparing (18) and (14) shows that „the trade induced technical progress“ will increase the skill-premium by more than predicted by standard trade theory only when $\sigma > 1$. Therefore, one obtains the result that – as conjectured by Wood (1994) – „trade opening could induce skill-biased technical change and increase wage inequality more than predicted by standard trade theory. Yet, this conclusion is obtained only when skilled and unskilled workers are gross substitutes“ (Acemoglu, 2002, 802).

Appendix A:

In mathematical terms this follows easily from a CES production function with elasticity of substitution σ (0<σ<∞):

(1) $$Y = A(\delta H^{1-\frac{1}{\sigma}} + (1-\delta)L^{1-\frac{1}{\sigma}})^{\sigma/(\sigma-1)}.$$

It is assumed that there is perfect interindustry factor mobility so there is one equilibrium (national) wage for H and L, w and l resp. Each sector chooses employment of H and L to maximize profits subject to exogenous factor prices (and given production technology). First-order conditions imply that optimal labour demand is

(2a) $$\frac{MP_H}{MP_L} = (\frac{1-\delta}{\delta})^{\frac{\sigma-1}{\sigma}}(\frac{H}{L})^{-\frac{1}{\sigma}}$$ or

(2b) $$(\frac{H}{L}) \equiv h = (\frac{\delta}{1-\delta})^{\sigma}(\frac{w}{l})^{-\sigma}.$$

This model is closed by combining (2b) with an upward-sloping relative labour supply curve $(\frac{H}{L})^{Sup}$. In equilibrium, supply equals demand, therefore, the **change in the skill premium** is given by

(3) $$(\frac{\hat{w}}{l}) = (\frac{\hat{\delta}}{1-\delta}) - \frac{1}{\sigma}(\frac{\hat{H}}{L})^{Sup}.$$

Skill-brased technical change (here defined as a rise in (δ) raises (w/l).

To analyze this question in a two sector model, add i=1,2 in eq. (1), and then the sector(s) must be specified where the technical progress occurs. This maybe the **sector bias** of technical progress: Technical progress is **sector-specific** when it occurs in one sector only, and maybe called **sector-pervasive** when it occurs in both sectors.

Assume product prices as given (p_T and p_M). With zero profits in both sectors, the equilibrium skill premium can be written in the following way, where s_i is skilled labour's share of sector i's wage bill:

(4) $$\left(\frac{\hat{w}}{l}\right) = \frac{1}{s_T - s_M}[\left(\frac{\hat{p}_T}{p_M}\right) + \left(\frac{\hat{A}_T}{A_M}\right) + \hat{\delta}_T(\frac{\sigma}{\sigma-1})(\frac{s_T-\delta_T}{1-\delta_T}) - \hat{\delta}_M(\frac{\sigma}{\sigma-1})(\frac{s_M-\delta_M}{1-\delta_M})].$$

Because of the assumption about skill intensities in the sectors (in the high-tech good sector more skilled labour is employed), $s_T > s_M$, and $[(\frac{\sigma}{\sigma-1})(\frac{s_i-\delta_i}{1-\delta_i})]$ is positive due to the assumption that firms implement skill-biased technical progress only when it reduces unit costs.

Thus eq. (4) shows the **two** standard outcomes of a two-sector HOSS model (mentioned in the Introduction):

a) A rise in p_T / p_M raises (w/l), a fall lowers it. This is the Stolper-Samuelson theorem in relative terms.

b) Assuming a fixed set of industries and fixed product prices, factor supplies do not affect factor prices. Instead of changing wages, changes in factor supplies are absorbed via Rybczynski effects, i.e. output changes in the two industries. Leamer and Levinsohn (1995) call this result the **factor-price-insensitivity theorem** (FPI).

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Figure 1: Globalisation in the HOSS Modell