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Trade, Human Capital and Labour Market Adjustment

by

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GEP Leverhulme Centre for Research on Globalisation and Economic Policy

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Abstract

This paper highlights the way in which workers of different age and ability are affected by trade liberalisation. A general-equilibrium model of trade and human-capital is constructed. Individuals differ not only in their endogenous education-level but also in their exogenous age. They can, at any point in their lives, skill-upgrade through (costly) schooling. Trade-adjustment is analyzed as a problem in investment-theory. We find that adjustment can take a long time and older-workers differ from younger-workers in the proportion of population negatively affected and severity of losses. Results suggest that trade-adjustment-assistance should focus on older-unskilled-workers in skilled-abundant-countries and younger-skilled-workers in unskilled-labour-abundant-countries.

JEL classification: F11, F16, J31, J62.

Keywords: International Trade, Factor Mobility, Labour market adjustment.

Outline

Non-Technical Summary

Labour market consequences of globalisation are controversial. Fears that the process implies increasing job losses and downward pressure on wages are widespread often resulting in demands for import protection. Growing concerns about the importance of such adjustment costs in the policy community is evident. This is not an inconsequential debate: there have been recent reforms of the USA's compensation scheme for trade-displaced workers and new EU proposals to set up a *Globalisation Adjustment Fund*.

Academic economists typically respond to public and policy makers concerns by explaining that, in the long-run, there are aggregate gains from freer trade. Until recent years, while understanding the long-run consequences of increased globalisation has had a central role in the theoretical literature, the transitional dynamics - short and medium run disturbances - had received less focused treatment. However, to realise potential long-run gains, trade-displaced workers must become re-employed. The historical record seems to suggest that this may take some time and entail earnings losses, especially for workers with characteristics associated with greater adjustment difficulties. However there will also be gains for some types of workers. A widely held perception is that both adjustment costs and benefits should depend on workers' age, experience and ability in some way. This paper models adjustment as a dynamic process and exposes workers' earning gains and losses with an explicit time dimension. Particular attention is given to the role that training may play in helping the economy respond to a trade shock and to the incidence and magnitude of trade-related adjustment costs and benefits by workers' age, skill and level of ability.

The main novelty of the paper is an exploration of a new mechanism: the interplay between trade liberalisation, adult training and worker's age. Moreover, rather than imposing an ad hoc adjustment mechanism, the adjustment process is analysed as a problem in investment theory; workers balance the costs of human capital formation with expected future benefits. Individuals differ not only in their education-level but also in their exogenous age and ability. They can, at any point in their lives, skill-upgrade through (costly) schooling. Trade liberalisation, by affecting wages, will also affect both the incentive to acquire education and returns to it. We show that adjustment can take a long time and expose its dynamics.

We find that workers of different age and ability profiles are differently affected. Older workers differ from younger workers in the proportion of population negatively affected and severity of losses. We also find that in skilled labour abundant countries, trade liberalisation leads to progressive skill upgrading, changing specialisation to the skill intensive good and increases wage dispersion among skilled workers. Until the new steady-state is achieved, skilled labour abundant countries will have a skill endowment below the steady-state equilibrium; the converse holds for unskilled abundant countries. Our results seem to suggest that adjustment assistance should focus on older unskilled workers in skilled labour abundant countries and younger skilled workers in unskilled labour abundant countries.

1. INTRODUCTION

Adjustment costs borne by workers are traditionally viewed as transitory and small relative to the benefits of trade liberalisation: This, for example, is the conclusion reached by Matusz and Tarr (2002) in a recent survey of evidence. A widely held perception is that both should depend on age. However, by treating workers within each skill group as homogeneous, most trade models implicitly assume all skilled and unskilled workers are affected equally. Another commonly held view is that education plays a role in facilitating adjustment to external shocks. Labour can increase its productivity by investing in human capital and whether to remain unskilled is an investment decision that can be reversed in the future through (costly) education/retraining. Again however, trade models do not allow for displaced workers' retraining.

This paper integrates these features into a Heckscher-Ohlin framework. Most trade models that analyse the relationship between trade expansion and labour market adjustment, focus on the rise in wage inequality associated with labour reallocation between contracting and expanding industries. We argue that the existing literature underestimates the impact of trade liberalisation for two reasons: first, by affecting relative wages trade liberalisation causes capital losses, via changes in the returns to education; second, by treating workers within each skill group as homogeneous, most models implicitly assume all workers in a particular group (independent of their age, experience and ability) are equally affected by liberalisation. That, however, is not consistent with the labour economics literature which concludes that earning profiles depend not only on education but also on these other individual characteristics.

Our paper highlights the way in which workers of different age and ability are affected by an unexpected trade expansion. We consider two small economies where each consists of two manufacturing and one educational sector. The manufacturing sectors are Low-Tech and High-Tech. Each uses skilled and unskilled labour (neither being sector specific) and has flexible technology[1]. Following Becker (1964 and 1993), Becker-Chiswick (1966) and Mincer (1974 and 1993) we model educational investments accounting for the relationship between earning profiles, ability and age. Being unskilled or becoming skilled is an investment decision. Unskilled workers enter the labour force without training. Education transforms individuals with general skills into skilled workers

[1] Each industry can adjust the skilled and unskilled labour usage per unit of output, in absolute and relative terms, in response to an exogenous change in input prices.

after an exogenous lapse of time, but is not costless. Moreover, we allow individuals to change labour status at any time in their lives. In contrast to previous models [e.g. Borsook (1986), Findlay and Kierzkowski (1983)] the decision to enter the labour market as unskilled can be reversed through schooling. The existence of constraints on skill upgrading (in the form of training costs) is the only rigidity we impose in the labour market. Furthermore, we assume individuals differ not only in their endogenous education level but also in exogenous ability level and age. The return to higher education is an increasing function of ability and decreasing function of age. Adjustment is modelled as a dynamic process.

How does the current population (students, unskilled and skilled workers) react to trade liberalisation? Both the incentive to acquire education and returns to it change. Within each group, gains or losses differ, depending, among other things, on age. At the time of first entry to the labour market, an individual has to decide between entering unskilled or engaging in training and entering later as skilled. For individuals that are not at the beginning of their working life, liberalisation occurs after they have committed to a course of action based on their expectations of future prices and labour market conditions. Given the new circumstances, these individuals will observe returns to education different from expected.

The remainder of the paper is organised as follows: section 2 presents the model and section 3 characterizes the (steady-state) equilibrium of the economy. The trade driving forces are discussed in section 4. Adjustment costs and benefits placed on workers by trade liberalisation in skilled and unskilled abundant countries are described in section 5. Section 6 discusses the dynamic evolution of the skilled and unskilled labour supply to reach the new equilibrium steady-state and Section 7 concludes.

2. THE MODEL

Technology

Consider an economy producing two goods, low-tech (1) and high-tech (2), using two factors, unskilled (L) and skilled labour (S)[2] measured in efficiency units. The quantity of skilled labour services available for use in manufacturing (S_M) depends on the quantity

[2] To keep the analysis direct and focused on the dynamics of labour adjustment process, we will abstract from the consideration of physical capital as a third factor.

of skilled labour services allocated to education (S_E) which, in turn, depends on the number of students. Factors are immobile between countries, but mobile between sectors.

The production function is assumed to be neoclassical and is given by

$$X_j = F_j(L_j, S_j) \tag{1}$$

in which X_j is the output of the commodity produced in industry *j* and L_j and S_j are, respectively, the amount of unskilled and skilled labour employed with constant returns to scale and convex production technology,

$$x_j = f_j(l_j),\ \frac{\partial x_j}{\partial l_j} > 0,\ \frac{\partial^2 x_j}{\partial l_j^{\,2}} < 0 \tag{2}$$

where $x_j = X_j/S_j$ and $l_j = L_j / S_j$.

With perfectly competitive markets for goods and factors and assuming incomplete specialization, in equilibrium,

$$P_j = a_{Lj} W_{Lj} + a_{Sj} W_{Sj} \tag{3}$$

where P_j is the price of output *j* (*j=1, 2*); a_{Lj} and a_{Sj} are, respectively, the equilibrium requirement of unskilled and skilled labour per-unit of output *j*; and W_{Lj} and W_{Sj} the returns to unskilled and skilled labour per efficiency unit.

Profit maximization leads to the condition that in each sector, each efficiency unit of each type of labour must be paid the marginal value product

$$W_{Lj} = P_j * \frac{\partial X_j}{\partial L_j} \tag{4a}$$

$$W_{Sj} = P_j * \frac{\partial X_j}{\partial S_j} \tag{4b}$$

Since, in the long run, factors are homogeneous and costlessly mobile between industries, W_{Lj} and W_{Sj} are common across industries ($W_{Lj} = W_L$ and $W_{Sj} = W_S$, $\forall j$). Hence, for given output prices, national income is maximized when factors are allocated to equate their marginal value product across industries and this depends on the intensity of usage of the production factor.

If we assume full employment:

$$L = L_1 + L_2 = a_{L1} X_1 + a_{L2} X_2 \tag{5a}$$

$$S = S_M + S_E = (S_1 + S_2) + S_E = (a_{S1} X_1 + a_{S2} X_2) + a_{SE} * X_E \tag{5b}$$

where L and S denote, respectively, the stock of each factor. a_{SE} is the equilibrium requirement skilled labour per student and X_E the output of the education sector.

In contrast to unskilled labour, not all the stock of skilled labour is available for goods manufacturing. Education can transform individuals with ordinary and general skills into skilled workers after an exogenous lapse of time. Educational services are provided to students by skilled labour (S_E) and only after each spends E time with $\beta \in]0,1]$ efficiency units of skilled labour can he/she work as skilled. X_E (new skilled workers) equals the number of students and a_{SE} equals β. At any time, the amount of skilled labour allocated to education equals β times the number of students. This parameter is a measure of efficiency of the educational sector. The lower it is, the higher the productivity of one efficiency unit of skill employed in the educational sector.

Finally, assume that at any common factor prices,

$$\frac{S_2}{L_2} > \frac{S_1}{L_1} \tag{6}$$

that is, there are no factor intensity reversals, with the high-tech sector always being skill intensive.

Individual Investment behaviour and Human Capital Acquisition

Investment in Formal Education

Assume individuals are heterogeneous with respect to their ability. Ability is a combination of ordinary and general knowledge that is innate and acquired prior to working age[3]. Individuals are indexed by their ability (α) which is uniformly distributed among the population and varies along the unit interval: $\alpha \in [0,1]$. Before entering the labour market, each faces a choice between investing in formal education for a period or entering immediately: schooling choice determines labour market status. Only by spending extra time at school (that we consider to be a fixed length of time E) can an individual be employed as a skilled worker.

If each individual's working lifetime is finite and exogenously given by time T, the working lifetime of a skilled worker is $T - E$ and of an unskilled worker T. Suppose that

[3] Note that we can interpret this background period, for example, as the compulsory stages of education.

gross working earnings, per unit of time, of an unskilled worker do not depend on ability and are equal to W_L. Gross working earnings of a skilled worker depend on the number of efficiency units of skill he/she possesses[4] and are equal to αW_S. In doing this we depart from the assumption that skilled labour is homogeneous: skilled workers differ in the supplied level of ability and, therefore, in their net earnings. Moreover, net earnings of skilled workers differ from gross earnings: formal education is both time and resource consuming. During the schooling period the individual earns no income and incurs costs. Each person who wants additional school training has to rent β efficiency units of skilled labour, with $\beta \in]0,1]$. Therefore, in each of the E periods that education takes, its direct cost will be equal to the reward of one efficiency unit of skill times β. In addition to the direct cost of schooling, there is an indirect cost: forgone working earnings as an unskilled worker.

Thus, becoming skilled involves an investment in formal education. The net present value of this is the difference between discounted benefits and discounted costs[5]:

$$R(\alpha) = \int_{E}^{T} (\alpha W_S - W_L) e^{-rz} \mathrm{dz} - \int_{0}^{E} (\beta W_S + W_L) e^{-rz} dz \qquad (7)$$

where r is the interest rate in a perfect capital market. The higher $R(\alpha)$, the better the investment. We assume all individuals that expect positive net returns to schooling will undertake the investment. Therefore, solving for $R(\alpha) = 0$ we get the level of ability from which individuals choose to engage in education ($\tilde{\alpha}$):

$$\tilde{\alpha} = \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}\beta + \frac{e^{rE}(e^{rT}-1)}{e^{rT}-e^{rE}}\frac{W_L}{W_S} = \Gamma\beta + (1+\Gamma)w = w + \Gamma(\beta + w) \qquad (8)$$

with $\Gamma = \dfrac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}$ and $w = \dfrac{W_L}{W_S}$.

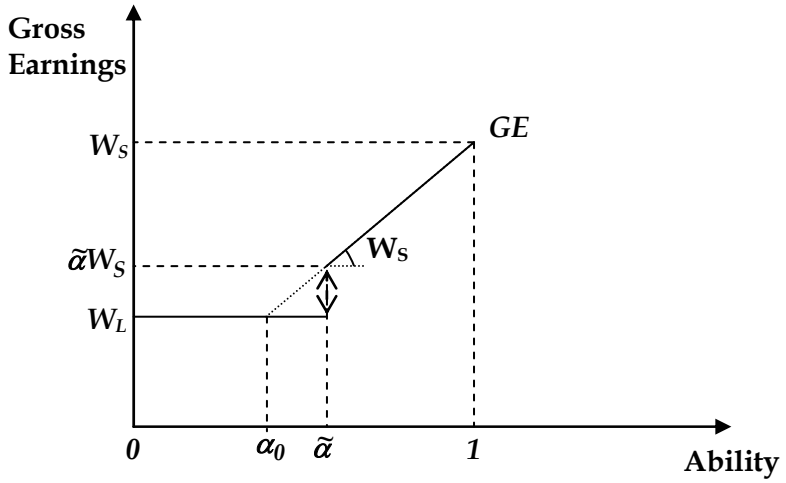
[4] This assumption is based on the idea that unskilled workers jobs involve more trivial tasks, on which the worker either succeeds or fails, while skilled workers job involves more complex tasks on which the degree of performance can differ – the time taken depends on the workers ability.

[5] Note that we are assuming that education is undertaken before starting to work. To the extent that the investment is profitable, its postponement would reduce the discounted net returns. Under our framework, in equilibrium it would not be sensible for any individual to work first as unskilled and only undertake schooling afterwards. The rationale lies in the fact that the individual would earn the unskilled wage during an extra time when he could be earning the skilled wage rate.

Therefore, an individual with $\alpha > \tilde{\alpha}$ decides to become skilled and an individual with $\alpha \leq \tilde{\alpha}$ enters the labour market immediately as unskilled. As $\Gamma > 0$, $\beta > 0$ and $w > 0$, the critical level of ability ($\tilde{\alpha}$) is always higher than zero. Note that if becoming skilled was instantaneous ($E = 0$), $\tilde{\alpha}$ would simply equal the relative wage ($\Gamma = 0$). The existence of a costly schooling period to became skilled ($E > 0, \beta > 0$) implies a decrease in the number of skilled workers and an increase in the average level of ability of the skilled labour force.

Figure 1 illustrates the relationship between ability level and gross earnings (*GE*). In equilibrium, individuals with ability in the interval $[0, \tilde{\alpha}]$ do not to acquire skills and spend their entire working life earning W_L (*per* unit of time. The gross earnings of unskilled workers do not depend on ability level so *GE* is horizontal in this interval. Individuals with higher ability become skilled and spend their post-educational work life earning αW_S (*per* unit of time). Gross earnings of skilled workers depend positively on ability. They vary along the interval $[\tilde{\alpha} W_S, W_S]$, with positive slope α. In the absence of an educational period, *GE* would be continuous. Individuals with ability in the interval $[\alpha_0, \tilde{\alpha}]$ would decide to become skilled. In this setting that is not the case. For $\alpha = \tilde{\alpha}$, with $E > 0$ and $\beta > 0$, $W_L \neq \tilde{\alpha} W_S$.

Figure 1 – Ability and Gross Earnings



The defined equilibrium can change as a consequence of a change in relative wages:

$$\frac{\partial \tilde{\alpha}}{\partial w} = 1 + \Gamma > 0 \qquad (9a)$$

$$\varepsilon_{\tilde{\alpha},w} = \frac{1}{\frac{e^{rT}(e^{rE}-1)}{e^{rE}(e^{rT}-1)}\frac{\beta}{w}+1} = \frac{1}{\frac{\Gamma}{1+\Gamma}\frac{\beta}{w}+1} < 1 \qquad (9b)$$

where $\varepsilon_{\tilde{\alpha},w}$ is the elasticity of the critical level of ability to the relative wage (W_L / W_S).

Eq. 9a shows that an increase in the relative wage of unskilled workers increases the incentive to stay unskilled. Eq. 9b shows that this change is less than proportional to the change in the relative wage: the elasticity of the critical level of ability in relation to the relative wage of unskilled workers is less than 1.

By specifying the rate of return to investment in education [$r_E(\alpha)$], the relationship between discounted benefits and costs can be derived in a different way from computing the net income gains from education [$R(\alpha)$]. Defining $r_E(\alpha)$ as discounted benefits relative to discounted costs[6], we get the following expression:

$$r_E(\alpha) = \frac{\int_E^T (\alpha W_S - W_L)e^{-rz}dz}{\int_0^E (\beta W_S + W_L)e^{-rz}dz} = \frac{e^{rT}-e^{rE}}{e^{rT}(e^{rE}-1)}\frac{\alpha - w}{\beta + w} = \frac{1}{\Gamma}\frac{\alpha - w}{\beta + w} = \frac{\alpha - w}{\tilde{\alpha} - w} \qquad (10)$$

$r_E(\alpha)$ is higher than one for all skilled workers. Among individuals belonging to this skill group there will be differences in this rate. Eq. 11 shows that the higher the level of ability, the higher the rate of return to the investment in education.

$$\frac{\partial r_E(\alpha)}{\partial \alpha} = \frac{1}{\Gamma(\beta + w)} = \frac{1}{\tilde{\alpha} - w} > 0 \qquad (11)$$

$$\varepsilon_{r_E,\alpha} = \frac{\alpha}{\alpha - w} > 1 \qquad (12)$$

Changes in the relative wage will affect returns to investment in education.

$$\frac{\partial r_E(\alpha)}{\partial w} = -\frac{1}{\Gamma}\frac{\alpha + \beta}{(\beta + w)^2} = -\frac{\tilde{\alpha} - \alpha}{(\tilde{\alpha} - w)^2} < 0 \qquad (13)$$

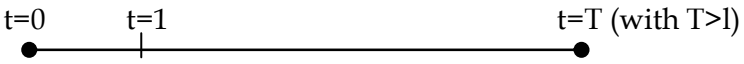
Eq. 12 shows that the rate of return to education is a decreasing function of the relative wage of unskilled workers.

[6] We define the rate of return to the investment in education as the wage gains (working earnings as high skilled minus working earning as low-skilled for $T - E$ periods) relative to education (direct and indirect) costs for E periods.

Investment in Formal Education and Age

All individuals with time T to go until the end of their working life and a level of ability higher than $\tilde{\alpha}(t=0)$, will invest in education immediately. It is not rational to postpone this investment. However, an exogenous change in relative wages or in the efficiency of the educational sector will change the returns to schooling. This will affect not only those at the beginning of their career but also those already working as unskilled. Therefore we need to model the possibility of reversing an earlier decision to stay unskilled.

If we consider *t* to be the age of an individual at a particular point in time (the beginning of working life has been normalised to *t=0*), in the population there will be people aged between *0* and *T*. If age is uniformly distributed within the population, we will have the same number of individuals at each point of the following segment



We assume that at any time an individual can reverse his/her initial decision of not becoming skilled.

For any combination of t and α, the expected net returns to education are $R(\alpha,t)$:

$$R(\alpha,t)=\int_{t+E}^{T}(\alpha W_S - W_L)e^{-r(z-t)}dz-\int_{t}^{t+E}(\beta W_S + W_L)e^{-r(z-t)}dz \qquad (14)$$

They are positive for

$$\alpha > \tilde{\alpha}(t)=\frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{r(t+E)}}\beta+\frac{e^{rE}(e^{rT}-e^{rt})}{e^{rT}-e^{r(t+E)}}\frac{W_L}{W_S}=\Lambda\beta+(1+\Lambda)w \qquad (15)$$

with $t \neq T-E$ and $\Lambda=\frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{r(t+E)}}$ [7]. Note that, for $t<T-E$, $\Lambda>0$. Moreover, for $\tilde{\alpha}(t)>0$ and $t>0$, $\Lambda>\Gamma$ thus $\tilde{\alpha}(t)>\tilde{\alpha}$.

Accounting for age, the critical level of ability will differ between individuals. $\tilde{\alpha}(t)$ is a positive function of t.

$$\frac{\partial\tilde{\alpha}(t)}{\partial t}=\frac{e^{r(E+t+T)}(e^{rE}-1)r(\beta+w)}{(e^{rT}-e^{r(t+E)})^2}>0 \qquad (16)$$

[7] Note that for t=0, $\Lambda=\Gamma$.

Thus, the older the individual, the higher the minimum level of ability necessary for positive net returns to education.

As for $E > 0, \Lambda > 0$, changes in relative wages of unskilled labour will positively affect the equilibrium level of the critical level of ability:

$$\frac{\partial \tilde{\alpha}(t)}{\partial w} = 1 + \Lambda > 0 \text{ for } t < T - E \tag{17a}$$

$$\varepsilon_{\tilde{\alpha}(t),w} = \frac{1}{\frac{\Lambda}{1+\Lambda}\frac{\beta}{w} + 1} < 1 \tag{17b}$$

Eq. 17a shows that the lower the relative wage of low skilled-labour (*w*), the lower the ability level at which workers are indifferent between entering the labour market immediately or engaging in education. Conversely, the higher the relative wage of low skilled-labour, the higher the number of low-skill workers in each age group that decide not to acquire human capital through additional schooling.

From Eq. 17a combined with Eq. 17b, we can conclude that, everything else being equal, an increase in the relative wage of unskilled labour will increase $\tilde{\alpha}(t)$ but less than proportionally. Furthermore, it is important to notice that $\varepsilon_{\tilde{\alpha}(t),w} < \varepsilon_{\tilde{\alpha},w}$ [see Eq. 17b and Eq. 9b]. The impact of the same change in relative wages on the decision to become a skilled worker varies across age profiles. Fewer individuals belonging to older generations will have an incentive to reverse their prior decision as a consequence of a change in relative wages.

By computing $\tilde{\alpha}(t)$ it is possible to distinguish individuals of different age profiles that have an incentive to become skilled from those that stay unskilled. Allowing individuals to reverse their decision, the question of how big the relative earnings of those that became skilled at $t \neq 0$ are arises. By computing $r_E(\alpha, t)$ [Eq. 18] it is possible to address this.

$$r_E(\alpha,t) = \frac{\int_{t+E}^{T} (\alpha W_S - W_L) e^{-r(z-t)} dz}{\int_{t}^{t+E} (\beta W_S + W_L) e^{-r(z-t)} dz} = \frac{e^{rT} - e^{r(t+E)}}{e^{rT}(e^{rE} - 1)} \frac{\alpha - w}{\beta + w} = \frac{1}{\Lambda} \frac{\alpha - w}{\beta + w} \tag{18}$$

with

$$\frac{\partial r_E(\alpha,t)}{\partial \alpha} = \frac{1}{\Lambda} \frac{1}{\beta + w} > 0 \tag{19}$$

$$\frac{\partial r_E(\alpha,t)}{\partial t} = \frac{e^{r(t+E)}}{e^{rT}(e^{rE}-1)}\frac{w-\alpha}{w+\beta}r < 0 \text{ for } \alpha > \tilde{\alpha} \qquad (20)$$

Eq. 19 shows that among skilled workers of the same age, the higher the level of ability, the higher the rate of return to education. More importantly, among equally able skilled workers, the higher the age at which they decide to invest in education, the lower the rate of return [Eq. 20].

3. FACTOR ENDOWMENTS IN STEADY-STATE

We assume that at each point in time an exogenous number of individuals N_0 are born and die (the country's population level is stationary). Thus the population level at t is equal to $TN_0 = N$. Furthermore, we also assume each individual is replaced by an identical one in terms of ability upon death (the number of individuals with the same level of ability in the population is also stationary). Thus, $\tilde{\alpha}N$ individuals constitute the supply of unskilled labour. The remaining $(1-\tilde{\alpha})N$ are either:

- Skilled: $(1-\tilde{\alpha})(T-E)N_0 = (1-\tilde{\alpha})(1-\frac{E}{T})N$

- In education to became skilled: $(1-\tilde{\alpha})EN_0 = (1-\tilde{\alpha})\frac{E}{T}N$.

The average level of ability of individuals that decide to became skilled is $\tilde{\alpha} + \frac{1-\tilde{\alpha}}{2} = \frac{1+\tilde{\alpha}}{2}$. Therefore, the supply of unskilled and skilled labour are, respectively:

$$L = \tilde{\alpha}N \qquad (21)$$

$$S = \frac{1}{2}(1+\tilde{\alpha})(1-\tilde{\alpha})(1-\frac{E}{T})N = \frac{1}{2}(1-\tilde{\alpha}^2)(1-\frac{E}{T})N \qquad (22)$$

Not all skilled labour services will be used in production of goods. β units of skilled labour are allocated to each student. Therefore, the number of units of skill allocated to education is $S_E = \beta(1-\tilde{\alpha})\frac{E}{T}N$. The number of units of skill diverted to production is $S_M = S - S_E = \frac{1}{2}(1-\tilde{\alpha}^2)\left[1-\frac{E}{T}(1+\frac{2\beta}{1-\tilde{\alpha}})\right]N$.

4. TRADE DRIVING FORCES

In this model trade is motivated by differences in relative factor endowments: S_M / L. These are endogenous and can be affected by: differences in life expectancies and birth rates; differences in the efficiency of the educational sector; differences in the duration of the additional schooling period needed to become skilled.

Consider the first. Assume that both countries are similar in population size but differ both in terms of life expectancy and birth rate[8]. In country *A* life expectancy is higher and birth rate lower than in *B* ($T_A > T_B$ and $(N_0)_A < (N_0)_B$ with $T_A*(N_0)_A = T_B*(N_0)_B = N$). As, $\partial\tilde{\alpha}/\partial T < 0$[9] the difference in life expectancy will imply differences in the critical level of ability between countries: $\tilde{\alpha}_A < \tilde{\alpha}_B$. Thus, the supply of unskilled labour is lower in country A than in B and the supply of skilled labour for use in manufacturing (negative function of $\tilde{\alpha}$ and a positive function of T[10]) is higher in A than B.

In steady state differences in endowments will exist between countries:

	L	**S_M**
Country A	$\tilde{\alpha}_A N$	$\frac{1}{2}(1-\tilde{\alpha}_A^{\,2})\left[1-\frac{E}{T}(1+\frac{2\beta}{1-\tilde{\alpha}_A})\right]N$
Country A	$\tilde{\alpha}_B N$	$\frac{1}{2}(1-\tilde{\alpha}_B^{\,2})\left[1-\frac{E}{T}(1+\frac{2\beta}{1-\tilde{\alpha}_B})\right]N$

Country A will be the skill abundant country and country B the unskilled abundant, $(S_M / L)_A > (S_M / l)_B$.

In the second case, where the only difference between countries is in the efficiency of the educational sector (higher A than in B) as, $\partial\tilde{\alpha}/\partial\beta > 0$[11], the difference in the

[8] Note that in the context of this model birth rate equals death rate.

[9] Note that $\frac{\partial\tilde{\alpha}}{\partial T} = -\frac{e^{r(t+T+E)}(e^{rE}-1)}{(e^{rT}-e^{rE})^2} r(w+\beta)$.

[10] Note that $\frac{\partial S_M}{\partial\tilde{\alpha}} = -\frac{\alpha(T-E)+\beta E}{T} N < 0$ and $\frac{\partial S_M}{\partial T} = \frac{N(1+\alpha)[1-(\alpha-2\beta)]E}{2T^2} > 0$.

[11] Note that $\frac{\partial\tilde{\alpha}}{\partial\beta} = \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}$.

efficiency will imply differences in the critical level of ability between countries: $\tilde{\alpha}_A < \tilde{\alpha}_B$. Therefore, as in the previous case $(S_M / L)_A > (S_M / L)_B$ [12].

Finally, in the third case, where the only difference between countries is in the duration of the educational process (longer in B than in A) as, $\partial\tilde{\alpha}(t)/\partial E > 0$ [13], like in the two previous cases $\tilde{\alpha}_A < \tilde{\alpha}_B$. Therefore, again country A will be the skill abundant country and country B the unskilled labour abundant country[14], $(S_M / L)_A > (S_M / L)_B$.

5. TRADE LIBERALISATION

Given two countries that only differ in the ratio: S_M / L, by the Heckscher-Ohlin and Stolper-Samuelson theorems, trade will induce a decrease in the relative price of the skill-intensive good in the low-skill abundant country (in the other, the opposite occurs). Furthermore, if changes in prices induce changes in factor supplies, the combined price elasticity of supply will be made higher (Rybczynski effect).

Skill Abundant Country

In the skill abundant country, liberalisation induces an increase in the relative price of the skill intensive good. Hence, by the Stolper-Samuelson theorem, liberalisation reduces W_L and increases W_S, and the wage for skilled workers in the post-liberalisation steady-state (W_S') will be higher than the pre-liberalisation steady-state (W_S): $W_S' > W_S$. Conversely, for unskilled workers $W_L' < W_L$. Thus, the relative wage rate of unskilled labour will decrease [$W_L'/W_S' = w' < w = W_L/W_S$].

At the time of liberalisation there are three types of individuals in the working age population: unskilled workers, students, and skilled workers.

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[12] Note that $\frac{\partial S_M}{\partial \beta} = -\frac{(1+\alpha)E}{T} N < 0$

[13] Note that $\frac{\partial\tilde{\alpha}(t)}{\partial E} = \frac{e^{r(T+E)}(e^{rT} - e^{rt})}{\left[e^{rT} - e^{r(t+E)}\right]^2} r(w+\beta)$, with t=0: $\frac{\partial\tilde{\alpha}}{\partial E} = \frac{e^{r(T+E)}(e^{rT} - 1)}{(e^{rT} - e^{rE})^2} r(w+\beta)$.

(i) Unskilled Workers

All unskilled workers have time *T-t* to go until the end of their career but *t* differs among them. We distinguish two groups: first, individuals that have just finished the compulsory stages of education (*t=0*) and, therefore, have *T* working time to go until the end of their working life. Second, individuals working as unskilled that have time *T-t* left.

Unskilled workers at the beginning of their career

With time T to go, these workers decide whether to enter the labour market unskilled or engage in further education. Their decision is based on post-trade prices. As shown in Eq. 9a the critical level of ability is a positive function of the relative wage of unskilled labour. By increasing the returns to education, trade creates an additional incentive to become skilled. More individuals at the beginning of their career will opt for education than in previous generations.

Under pre-trade prices the present value of net returns to education is positive for all individuals with ability in the interval $]\tilde{\alpha},1]$; under post-liberalisation prices the present value of net returns is positive for all individuals with ability in the interval $]\tilde{\alpha}_{t=0}',1]$ with $\tilde{\alpha}_{t=0}' = \Gamma\beta + (1+\Gamma)w' < \tilde{\alpha} = \Gamma\beta + (1+\Gamma)w$. Therefore, trade induces individuals with ability in the interval $]\tilde{\alpha}_{t=0}',\tilde{\alpha}]$ to become skilled.

All individuals with ability in the interval $]\tilde{\alpha},1]$ benefit from liberalisation for two reasons. First, their rate of return on education is higher than it would have been in the absence of liberalisation (see Eq. 13). Second, lifetime earnings are higher than they would have been in the absence of liberalisation. Eq. 23 for $\alpha > \tilde{\alpha}$ and $W_S' > W_S$,

$$LE' - LE > \frac{e^{rE}(e^{rT}-1)}{e^{r(T+E)}}\frac{W_L(W_S'-W_S)}{rW_S} > 0$$

$$LE' - LE = \left(\int_E^T \alpha W_S' e^{-rz}\mathrm{d}z - \int_0^E \beta W_S' e^{-rz}dz\right) - \left(\int_E^T \alpha W_S' e^{-rz}\mathrm{d}z - \int_0^E \beta W_S' e^{-rz}dz\right) =$$

$$= \int_E^T \alpha(W_S'-W_S)e^{-rz}\mathrm{d}z - \int_0^E \beta(W_S'-W_S)e^{-rz}dz = \left[\frac{(e^{rT}-e^{rE})\alpha - e^{rT}(e^{rE}-1)\beta}{e^{r(T+E)}}\right]\frac{W_S'-W_S}{r} \qquad (23)$$

where LE and LE' and are, respectively, the life-time earnings pre- and post-liberalisation.

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[14] Note that $\frac{\partial S_M}{\partial E} = -\frac{(1+\alpha)[1-(\alpha-2\beta)]}{2T}N < 0$

Those with an ability level in the interval $]\tilde{\alpha}_{t=0}', \tilde{\alpha}]$ in the absence of liberalisation would have remained unskilled.

$$LE'-LE = \left(\int_E^T \alpha W_S' e^{-rz}\mathrm{d}z - \int_0^E \beta W_S' e^{-rz} dz\right) - \int_0^T W_L e^{-rz}\mathrm{d}z =$$

$$= \frac{(e^{rT} - e^{rE})W_S'\alpha - e^{rT}(e^{rE} - 1)W_S'\beta - e^{rE}(e^{rT} - 1)W_L}{e^{r(T+E)}r} \qquad (24)$$

$$LE'-LE = 0 \text{ when } \alpha = \tilde{\alpha} + (1+\Gamma)w(\frac{W_S}{W_S'} - 1) = \tilde{\alpha}' + (1+\Gamma)w'(\frac{W_L}{W_L'} - 1)$$

$$and \ \frac{\partial(LE'-LE)}{\partial\alpha} > 0$$

Eq. 24 suggests that in this country, although these workers prefer to become skilled, only the more able will benefit from liberalisation. For those, not only are post-trade life-time earnings as skilled higher as unskilled, but also, higher than pre-trade lifetime earnings as unskilled.

Individuals working as unskilled

For the second type of individual, the situation is different. They observe liberalisation after having decided not to invest in education at the beginning of their career. Traditional analysis concludes that this type of worker loses as a consequence of liberalisation due to the lower wage rate of unskilled labour. However, this does not allow for reversal of the decision not to become skilled. This new feature of our framework brings interesting additional insights.

Had an unskilled worker decided to become skilled at the beginning of his/her career, net discounted benefits of the investment in education, under the post trade prices after *t*, would have been[15]:

$$R(\alpha)' = \left[\int_E^t (\alpha W_S - W_L)e^{-rz}dz + \int_t^T (\alpha W_S' - W_L')e^{-rz}dz\right] - \int_0^E (\beta W_S + W_L)e^{-rz}dz \qquad (25)$$

They are positive for $\alpha > \tilde{\alpha}'$ with

$$\tilde{\alpha}' = \frac{e^{r(t+T)}(e^{rE} - 1)W_S}{e^{rT}(e^{rt} - e^{rE})W_S + e^{rE}(e^{rT} - e^{rt})W_S'}\beta + \\ + \frac{e^{r(E+T)}(e^{rt} - 1)W_L + e^{rE}(e^{rT} - e^{rt})W_L'}{e^{rT}(e^{rt} - e^{rE})W_S + e^{rE}(e^{rT} - e^{rt})W_S'} \qquad (26)$$

[15] Note that we are considering that all unskilled workers have more than *E* years of experience. To see what the particular case of those with a level of experience lower than *E* go to appendix 1.

As $R(\alpha)' > R(\alpha)$ [16], $\tilde{\alpha}' < \tilde{\alpha}$. Thus, in every generation, unskilled workers with a level of ability in the interval $]\tilde{\alpha}', \tilde{\alpha}]$ have lower working earnings than those they could have given their ability level.

The fact that unskilled workers with ability in the interval $]\tilde{\alpha}', \tilde{\alpha}]$ regret their decision of not becoming skilled, is not in itself an adjustment cost. These workers can reverse their previous decision and invest in education. However, only those that expect net benefits from investing on education at *t* will do so given a worker's age, he/she will engage in further education at age *t* if $R(\alpha, t)'$ [given by Eq. 14 with $W_L = W_L'$ and $W_S = W_S'$ [17]] is higher than *0*. Therefore, if he/she has a level of ability within the interval $]\tilde{\alpha}(t)', \tilde{\alpha}[$, with $\tilde{\alpha}(t)' = \Lambda\beta + (1+\Lambda)\frac{W_L'}{W_S'}$; he/she will decide to change occupation through education[18]. $\tilde{\alpha}(t)'$ is always lower than $\tilde{\alpha}$ for $t < T + \frac{1}{r}\ln[Z]$ with

$$Z = \frac{W_L - W_L'}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-1}{e^{rT}}\right) + \frac{W_S' - W_S}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-e^{rE}}{e^{r(E+T)}}\alpha - \frac{e^{rE}-1}{e^{rE}}\beta\right) + \frac{1}{e^{rT}}$$ [19].

Thus, in all generations until $t = T + \frac{1}{r}\ln[Z]$ there will be unskilled workers that change occupation in this way. There are three cases to be considered. Either $\tilde{\alpha}' < \tilde{\alpha}(t)' < \tilde{\alpha}$, $\tilde{\alpha}(t)' < \tilde{\alpha}' < \tilde{\alpha}$ and $\tilde{\alpha}' < \tilde{\alpha} \le \tilde{\alpha}(t)'$ with the ordering depending upon the underlying parameters of the model.

Consider the first case (illustrated in figures 2). Given their level of ability, unskilled workers aged $t \neq 0$ can be in one of the following situations. First, those with

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[16] Note that $R(\alpha)' = R(\alpha) + \int_t^T [(W_L - W_L') - (W_S - W_s')\alpha]e^{-rz}dz$.

Moreover, $\forall \alpha, \int_t^T [(W_L - W_L') - (W_S - W_s')\alpha]e^{-rz}dz = \frac{(e^{rT} - e^{rt})[(W_L - W_L') - (W_S - W_S')\alpha]}{e^{r(t+T)}r} > 0$ for $W_L > W_L'$ and $W_S < W_S'$. Thus, $\forall \alpha, R(\alpha)' > R(\alpha)$ in the skill abundant country.

[17] $R(\alpha, t)' = \int_{t+E}^{T} (\alpha W_S' - W_L')e^{-r(z-t)}dz - \int_t^{t+E} (\beta W_S' + W_L')e^{-r(z-t)}dz < R(\alpha)'_{t<E} < R(\alpha)'_{t>E}$

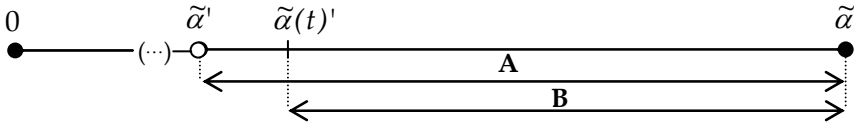
[18] Note that for $t \ge T - E$ it is never rational to change occupation because there wouldn't be returns to the investment needed.

[19] To see the mathematical proof go to Appendix 2.

ability in the interval $[0, \tilde{\alpha}']$ choose to remain unskilled. They lose from liberalisation. Their lifetime discounted (to *t=0*) earnings will equal $\left(\int_0^t W_L e^{-rt} + \int_t^T W_L' e^{-rt} \right)$, lower than $\int_0^T W_L e^{-rt}$.

All remaining unskilled workers regret the initial decision of not becoming skilled [segment A]. However, only the more able will reverse it [segment B]. Thus, individuals with ability in the interval $[\tilde{\alpha}', \tilde{\alpha}(t)']$ will suffer two types of losses from liberalisation: a cost in terms of resources: lower lifetime discounted earnings as unskilled workers; and , a psychological cost, earnings below their potential level given their level of ability. They have to cope with regretting the decision made when younger, knowing it is too late to reverse it. Third, individuals with a level of ability in the interval $]\tilde{\alpha}(t)', \tilde{\alpha}]$ will decide to change occupation through education from age *t* until *t+E*.

Figure 2 – Unskilled labour: Regrets versus Reversals



However, note that they will have rates of return on education lower than their potential level (given their ability). Given the post-trade prices, schooling early in their lives would yield a higher return on the investment. In fact, the period of return to the investment in education is shorter if it just occurs after liberalisation. Later investments produce returns over a shorter period, thus postponement of the investment reduces the present value of net gains. Moreover, direct education costs will be higher after liberalisation. For these workers the actual rate of return on education [$r_E(\alpha, t)'$ given by Eq. 18 with $W_L = W_L'$ and $W_S = W_S'$] is lower than if they had decided to become skilled workers at the beginning of their careers [$r_E(\alpha)'$].

$$r_E(\alpha)' = \frac{\int_E^t (\alpha W_S - W_L) e^{-rz} dz + \int_t^T (\alpha W_S' - W_L') e^{-rz} dz}{\int_0^E (\beta W_S + W_L) e^{-rz} dz} \qquad (27a)$$

$$r_E(\alpha,t)' = \frac{\int_{t+E}^{T}(\alpha W_S' - W_L')e^{-r(z-t)}dz}{\int_{t}^{t+E}(\beta W_S' + W_L')e^{-r(z-t)}dz} \tag{27b}$$

with $\alpha \in]\tilde{\alpha}', \tilde{\alpha}(t)'[$, $r_E(\alpha)' > 1$ and $r_E(\alpha,t)' < 1$ therefore we have $r_E(\alpha,t)' < r_E(\alpha)$.

Moreover, even though all the more able unskilled workers (individuals with ability in the interval $]\tilde{\alpha}(t)', \tilde{\alpha}]$), have positive net returns to education, not all will benefit from liberalisation.

$$LE' - LE = \left(\int_{t+E}^{T}\alpha W_S' e^{-rz}\mathrm{d}z - \int_{t}^{t+E}\beta W_S' e^{-rz}dz\right) - \int_{t}^{T} W_L e^{-rz}\mathrm{d}z =$$

$$= \frac{(e^{rT} - e^{r(t+E)})W_S'\alpha - e^{rT}(e^{rE}-1)W_S'\beta - e^{rE}(e^{rT}-e^{rt})W_L}{e^{r(T+t+E)}r}$$

$$LE' - LE = 0 \text{ when } \alpha = \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{r(t+E)}}\beta + \frac{e^{rE}(e^{rT}-e^{rt})}{e^{rT}-e^{r(t+E)}}\frac{W_L}{W_S'} = \tag{28}$$

$$= \underbrace{\tilde{\alpha}(t)' + (1+\Lambda)w'\underbrace{(\frac{W_L}{W_L'} - 1)}_{>0}}_{>\tilde{\alpha}(t)'} \quad \underbrace{(1+\Lambda)w\underbrace{(\frac{W_S}{W_S'} - 1)}_{<0}}_{<\tilde{\alpha}(t)} = \tilde{\alpha}(t)$$

$$and \ \frac{\partial(LE' - LE)}{\partial\alpha} > 0$$

For workers with ability equal to $\tilde{\alpha}(t)'$, life-time earnings post-liberalisation are lower than pre-liberalisation. Moreover, if

$$\beta > \left(\frac{1+\Gamma}{W_S} - \frac{1+\Lambda}{W_S'}\right)\frac{W_L}{\Lambda - \Gamma} = \left(\frac{(e^{rT}-1)(e^{rT}-e^{r(t+E)})}{W_S} - \frac{(e^{rT}-e^{rt})(e^{rT}-e^{rE})}{W_S'}\right)\frac{W_L}{e^{rT}(e^{rt}-1)(e^{rE}-1)}$$

then, all unskilled workers that decide to change their course of action through education will be losers ($\forall\alpha, \alpha \in]\tilde{\alpha}(t)', \tilde{\alpha}]$, $LE' - LE < 0$). Otherwise, the more able, and only those, may gain from liberalisation as for $\tilde{\alpha}$, $LE' - LE > 0$. Note that, in any case, those who lose, lose less than any worker with an ability level lower than theirs.

Our framework also allows us to analyse whether there are inter-generational differences in the number of unskilled workers in each of the situations. $\tilde{\alpha}$ does not depend on age. However, $\tilde{\alpha}'$ and $\tilde{\alpha}(t)'$ do.

$$\frac{\partial\tilde{\alpha}'}{\partial t} = \frac{r(W_L - W_L')\left[(e^{-rE}-e^{-rt})W_S + (e^{-rt}-e^{-rT})W_S'\right]}{e^{rt}\left[(e^{-rE}-e^{-rt})W_S + (e^{-rt}-e^{-rT})W_S'\right]^2} -$$

$$- \frac{r(W_S - W_S')\left[(e^{-rE}-e^{-rt})W_L + (e^{-rt}-e^{-rT})W_L' + (1-e^{-rE})(W_L + W_S\beta)\right]}{e^{rt}\left[(e^{-rE}-e^{-rt})W_S + (e^{-rt}-e^{-rT})W_S'\right]^2} < \frac{\partial\tilde{\alpha}'(t)}{\partial t} \tag{29a}$$

$$\frac{\partial \tilde{\alpha}'(t)}{\partial t} = \frac{e^{r(E+t+T)}(e^{rE}-1)r(W_S'\beta + W_L')}{(e^{rT}+e^{r(t+E)})^2} > 0$$

$$\frac{\partial\left[\frac{\partial \tilde{\alpha}'}{\partial t}\right]}{\partial t} < 0 \text{ with } \frac{\partial\left[\frac{\partial \tilde{\alpha}'(t)}{\partial t}\right]}{\partial t} = \frac{e^{r(t+T+E)}(e^{rT}-e^{r(T+E)})r^2(W_L'+W_S'\beta)}{(e^{rT}+e^{r(t+E)})^3} > 0 \qquad (29b)$$

Eq. 29a shows that $\tilde{\alpha}(t)'$ is always a positive function of age and, in the skill abundant country, $\tilde{\alpha}'$ is also a positive function of *t.* Therefore, the higher the age profile, the larger the number of individuals that cannot escape wage losses due to liberalisation through occupational change. Eq. 29b shows that $\tilde{\alpha}(t)'$is concave while $\tilde{\alpha}'$ is convex. Therefore, until a certain age each additional year has a bigger impact on $\tilde{\alpha}(t)'$ than on $\tilde{\alpha}'$ after which the opposite happens. Under this setting, in younger generations, the higher the age profile, the larger the number of individuals that although regretting their previous decision regarding education, know it is too late to reverse it.

The second possibility is that $\tilde{\alpha}(t)' < \tilde{\alpha}' < \tilde{\alpha}$. In this case although liberalisation does not induce regrets, there will be reversals. Unskilled workers with ability in the interval $]\tilde{\alpha}(t)', \tilde{\alpha}]$ change their labour status through education. Moreover, as $\tilde{\alpha}(t)'$ is a positive function of age, the number of workers that do so is lower in older generations. Therefore, the severity of losses induced by trade is higher for older generations.

Finally, if $\tilde{\alpha}' < \tilde{\alpha} \leq \tilde{\alpha}(t)'$, liberalisation does not induce regrets nor does it lead to moves between occupations. Therefore, all unskilled workers will face wage losses as a consequence. Note that this can only be the case of workers that at the time of trade are aged

$$T + \frac{1}{r}\ln[Z] \text{ with } Z = \frac{W_L - W_L'}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-1}{e^{rT}}\right) + \frac{W_S' - W_S}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-e^{rE}}{e^{r(E+T)}}\alpha - \frac{e^{rE}-1}{e^{rE}}\beta\right) + \frac{1}{e^{rT}}.$$

or more years as it is only possible for those to have $\tilde{\alpha} \leq \tilde{\alpha}(t)'$.

(ii) Students

As a consequence of liberalisation discounted benefits of investment in education increase: the difference between earnings of skilled and unskilled workers. The effect on discounted costs is less clear. Higher tuition fees these costs higher, lower forgone earnings make them lower. The actual discounted value of net returns of students [$R(\alpha)'_{t<E}$] (discounted for *t=0*) is

$$R(\alpha)_{t<E}^{'} = \int_{E}^{T}(\alpha W_S'-W_L')e^{-rz}dz - \left[\int_{0}^{t}(\beta W_S + W_L)e^{-rz}dz + \int_{t}^{E}(\beta W_S'+W_L')e^{-rz}dz\right] \quad (30)$$

where *t* is age at the time of liberalisation.

Eq. 31 gives the difference between actual and expected discounted value of the net returns [$R(\alpha)$ was defined in Eq. 7][20]:

$$\begin{aligned} &R(\alpha)_{t<E}^{'} - R(\alpha) = \\ &= \int_{E}^{T}\left[\alpha(W_S'-W_S) - (W_L'-W_L)\right]e^{-rz}\mathrm{dz} - \int_{t}^{E}\left[\beta(W_S'-W_S) + (W_L'-W_L)\right]e^{-rz}dz = \\ &= \int_{t}^{T}(W_L - W_L')e^{-rz}dz + (W_S'-W_S)\left(\int_{E}^{T}\alpha e^{-rz}\mathrm{dz} - \int_{t}^{E}\beta\, e^{-rz}\mathrm{dz}\right) \end{aligned} \quad (31)$$

In the skill abundant country $R(\alpha)_{t<E}^{'} > R(\alpha)$ for all students (for proof see Appendix 3). Thus, the increase in future benefits of being skilled more than compensates the increase in tuition fees whilst a student. As a consequence of liberalisation students do not regret their decision to invest in education, the associated returns turned out to be higher than expected. The increase in the returns to education is the benefit of liberalisation for these individuals[21].

One important result is that not all students have equal benefits. They differ on the remaining time they have to spent in the educational system to became skilled and, therefore, on the actual of rate of return on investment in education [$r_E(\alpha)_{t<E}^{'}$].

$$\begin{aligned} r_E(\alpha)_{t<E}' &= \frac{\int_{E}^{T}(\alpha W_S'-W_L')e^{-rz}dz}{\int_{0}^{t}(\beta W_S + W_L)e^{-rz}dz + \int_{t}^{E}(\beta W_S'+W_L')e^{-rz}dz} = \\ &= \frac{e^{rt}(e^{rT}-e^{rE})(W_S'\alpha - W_L')}{e^{r(T+E)}(e^{rt}-1)(W_L+W_S\beta) + e^{rT}(e^{rE}-e^{rt})(W_L'+W_S^{'}\beta)} = \\ &= \frac{(W_S'\alpha - W_L')}{\frac{(e^{r(t+T+E)}-e^{r(T+E)})}{(e^{r(T+t)}-e^{r(E+t)})}(W_L+W_S\beta) + \frac{(e^{r(E+T)}-e^{r(t+T)})}{(e^{r(T+t)}-e^{r(E+t)})}(W_L'+W_S^{'}\beta)} = \\ &= \frac{e^{-rT}(e^{r(T+t)}-e^{r(E+t)})(W_S'\alpha - W_L')}{\left[e^{rt}(e^{rE}W_S - W_S^{'}) + e^{rE}(W_S^{'}-W_S)\right]\beta + \left[(e^{rE}e^{rt}-e^{rE})W_L+(e^{rE}-e^{rt})W_L'\right]} \end{aligned} \quad (32)$$

[20] Note that all students have $\alpha > \tilde{\alpha}$ thus $R(\alpha) > 0$. Thus if we have $R(\alpha)_{t<E}'-R(\alpha) > 0$ for all $\alpha > \tilde{\alpha}$, it must be the case that $R(\alpha)_{t<E}^{'} > R(\alpha)$.

[21] It equals the increase in student's life-time earnings.

$$\frac{\partial r_E(\alpha)'_{t<E}}{\partial t} =$$

$$\underbrace{\frac{re^{r(t+E)}(e^{rT}-e^{rE})}{e^{rT}}}_{>0} \frac{(W_S'\alpha - W_L')\left[(W_L'-W_L)+(W_S'-W_S)\beta\right]}{\left[e^{rE}(1-e^{rt})(W_L+W_S\beta)+(e^{rt}-e^{rE})(W_L'+W_S'\beta)\right]^2} \tag{33}$$

As $\alpha > \tilde{\alpha} > W_L/W_S > W_L'/W_S'$ for all the students, $(W_S'\alpha - W_L') > 0$. Thus, the actual rate of return to education is a positive function of *t* for $\beta > -\Delta W_L/\Delta W_S = (W_L'-W_L)/(W_S - W_S')$ [22]. In this case, students closer to the end of the educational process will have a higher benefit from liberalisation than their younger counterparts as the positive difference between the post- and the pre-trade trade rate of return to education is larger. The converse holds for $\beta < -\Delta W_L/\Delta W_S$.

(iii) Skilled Workers

This type of worker has capital gains as a consequence of liberalisation. By increasing the wage rate of skilled labour and decreasing that of unskilled labour, liberalisation increases the discounted benefits of investment in education. In contrast to students, it does not affect the costs of schooling, only the benefits. The actual rate of return to education [$r_E(\alpha)'$: see Eq. 27a] is higher than it would otherwise have been:

$$r_E(\alpha)' - r_E(\alpha) = \frac{(e^{rT}-e^{rt})}{e^{r(T+t-E)}(e^{rE}-1)} \frac{(W_L - W_L') + (W_S'-W_S)\alpha}{(W_L + W_S\beta)} > 0 \tag{34}$$

However, not all skilled workers have equal benefits. They differ on the length of their remaining working life and therefore on the actual return to education. Eq. 35 shows that older workers gain less from liberalisation.

$$\frac{\partial\left[r_E(\alpha)' - r_E(\alpha)\right]}{\partial t} = \frac{\partial r_E(\alpha)'}{\partial t} = -\frac{r(W_L - W_L') + (W_S'-W_S)\alpha}{e^{r(t-E)}(e^{rE}-1)(W_L+W_S\beta)} < 0 \tag{35}$$

Unskilled Labour Abundant Country

In the unskilled labour abundant country, liberalisation induces a decrease in the relative price of the skill intensive good. Hence, by the Stolper-Samuelson theorem, reduces

[22] $\lim_{t\to 0} r_E(\alpha)' = \frac{1}{\Gamma}\frac{W_S'\alpha - W_L'}{W_S'\beta + W_L'} = \frac{1}{\Gamma}\frac{\alpha - w'}{\beta + w'} > r_E(\alpha)$ and

W_S (the return of skill) and increases W_L. Therefore, the wage rate for skilled workers in the post-liberalisation steady-state (W_S') will be lower than that in the initial steady-state (W_S): $W_S' < W_S$. The wage rate for unskilled workers in the post-liberalisation steady-state (W_L') will be higher than that in the initial steady-state (W_L): $W_L' > W_L$. As a consequence the relative wage rate of unskilled labour increases [$W_L'/W_S' = w' > w = W_L/W_S$], which affects returns to education.

(i) Unskilled Workers

As in the skill abundant country unskilled workers that have just finished the background schooling period and have time *T* to go until the end of their working life are in a different situation from those that at time of liberalisation have already worked as unskilled. The first, observe liberalisation and decide their course of action considering post-trade prices and labour market conditions. Thus, as the critical level of ability is a positive function of the relative wage of unskilled workers [see Eq. 9a], fewer individuals at the beginning of their career opt to became skilled compared to previous generations. For all individuals with ability in the interval $]\tilde{\alpha}_{t=0}', 1]$ returns to education are positive under post-trade and pre-trade prices. They are losers from liberalisation since, by Eq. 13, their actual return to education decreases and, by Eq. 23, their lifetime earnings will also be lower.

The second group observe liberalisation after having decided not to invest in education at the beginning of their career. As staying unskilled becomes more attractive, they will not have an incentive to change. They gain from liberalisation. Their expected lifetime earnings increase as depicted in Eq. 36.

$$\int_t^T W_L' > \int_t^T W_L \qquad (36)$$

(ii) Students

As a consequence of liberalisation, on the one hand, due to lower discounted benefits and higher forgone earnings, the discounted value of net returns to education decrease. On the other hand, due to lower tuition fees during the remaining schooling

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$\lim_{t \to E} r_E(\alpha)_{t<E}' = \frac{1}{\Gamma} \frac{W_S'\alpha - W_L'}{W_S\beta + W_L} = \frac{1}{\Gamma} \frac{\alpha - w'}{\beta + w'} \frac{W_S'\beta + W_L'}{W_S\beta + W_L}$.

period it increases. The actual discounted value of net returns of students [$R(\alpha)'_{t<E}$ given by Eq. 30], will differ from its expected value [$R(\alpha)$ given by Eq. 7]. For students, the difference between $R(\alpha)$ and $R(\alpha)'_{t<E}$ [given by Eq. 31] is always negative[23]. Thus students have returns to education lower than expected. Moreover, $R(\alpha)'_{t<E}$ is equal to zero for

$$\tilde{\alpha}'_{t<E} = \frac{e^{r(E+T)}(e^{rt}-1)W_S + e^{rT}(e^{rE}-e^{rt})W_S'}{e^{rt}(e^{rT}-e^{rE})W_S'}\beta + \\ + \frac{e^{r(E+T)}(e^{rt}-1)W_L + e^{rE}(e^{rT}-e^{rt})W_L'}{e^{rt}(e^{rT}-e^{rE})W_S'} \tag{37}$$

Therefore, those with ability in the interval $]\tilde{\alpha}, \tilde{\alpha}'_{t<E}[$ have negative returns to education.

All students therefore have returns to education lower than expected. The most severe situation is those of students with ability in the interval $]\tilde{\alpha}, \tilde{\alpha}'_{t<E}[$ who have the additional psychological cost of knowing that had they decided to remain unskilled at the start of their working life, lifetime earnings would have been higher.

Would they be better off dropping school and starting to work as unskilled? If the expected earnings from working as unskilled exceed those of remaining a student, the rational decision will be to drop school. The right and left hand side of Eq. 38, respectively, depict lifetime earnings in each of these situations:

$$\int_E^T \alpha W_S' e^{-rz}dz - \int_t^E \beta W_S' e^{-rz}dz > \int_t^T W_L' e^{-rz}dz \\ \alpha > \frac{e^{rT}(e^{rE}-e^{rt})}{e^{rt}(e^{rT}-e^{rE})}\beta + \frac{e^{rE}(e^{rT}-e^{rt})}{e^{rt}(e^{rT}-e^{rE})}w' = \tilde{\alpha}^* \tag{38}$$

Note that $\tilde{\alpha} < \tilde{\alpha}^* < \tilde{\alpha}'_{t<E}$ thus, students with ability in the interval $]\tilde{\alpha}, \tilde{\alpha}^*]$ will drop out of the education system losing resources already invested in education[24]. Students with ability in the interval $]\tilde{\alpha}^*, \tilde{\alpha}'_{t<E}[$, although regretting their previous decision, will stick to it, facing lifetime earnings below their potential level. The remaining, students with ability in

[23] Note that all students have $\alpha > \tilde{\alpha}$ thus $R(\alpha) > 0$. Accordingly, if $R(\alpha) - R(\alpha)'_{t<E} > 0$ for all $\alpha > \tilde{\alpha}$, it must be the case that $R(\alpha)'_{t<E} < R(\alpha)$.

[24] Note that under this framework the education costs are sunk.

the interval $\left[\tilde{\alpha}'_{t<E},1\right]$, have positive returns to education but lower than expected when they committed to their course of action.

	Life-time earnings	***LE'-LE***
Without liberalisation (LE')	$\int_E^T \alpha W_S e^{-rz} dz - \int_0^E \beta W_S e^{-rz} dz$	
With liberalisation at *t* for those who drop formal education	$-\int_0^t \beta W_S e^{-rz} dz + \int_t^T W_L' e^{-rz} dz$	$\int_t^E \beta W_S e^{-rz} dz + \int_t^T W_L' e^{-rz} dz - \int_E^T \alpha W_S dz$ equal to zero for $\alpha = \alpha^* + \frac{e^{rE}(e^{rT}-e^{rt})}{e^{rt}(e^{rT}-e^{rE})} w'(\underbrace{\frac{W_S'}{W_S}}_{<0} - 1) < \alpha^*$ and $\alpha < \tilde{\alpha}$ for $t > \frac{Log\left[\frac{e^{rT}(W_L'+W_S\beta)}{(e^{rT}-1)W_L + W_L' + e^{rT}W_S\beta}\right]}{r}$
With liberalisation at *t* for those who continue their formal education	$-\left[\int_0^t \beta W_S e^{-rz} dz + \int_t^E \beta W_S' e^{-rz}\right] + \int_E^T \alpha W_S' e^{-rz} dz$	$\int_E^T \alpha(W_S' - W_S) e^{-rz} dz + \int_t^E \beta(W_S - W_S') e^{-rz} dz$ equal to zero for $\alpha = \frac{e^{rE}(e^{rT}-e^{rt})}{e^{rt}(e^{rT}-e^{rE})}\beta < \alpha^*$

We can conclude that the negative effects of liberalisation differ among students of the same age but different levels of ability: higher ability means lower losses. Moreover there will also be differences in trade effects between younger and older workers and depend on the number of individuals of the same age in each situation. Eq. 39 and 40 show the relationship between ability cut offs and age:

$$\frac{\partial \tilde{\alpha}^*}{\partial t} = -\frac{e^{r(E+T)} r(W_L' + W_S'\beta)}{(e^{rT} - e^{rE}) W_S'} \tag{39}$$

$$\frac{\partial \tilde{\alpha}'_{t<E}}{\partial t} = -\frac{e^{r(E+T)} r(W_L' + W_S'\beta)}{(e^{rT} - e^{rE}) W_S'} + \frac{e^{r(E+T)} r(W_L + W_S\beta)}{(e^{rT} - e^{rE}) W_S'} = \frac{\partial \tilde{\alpha}^*}{\partial t} + \frac{e^{r(E+T)} r(W_L + W_S\beta)}{(e^{rT} - e^{rE}) W_S'} \tag{40}$$

The number of people with ability in the interval $]\tilde{\alpha}^*, \tilde{\alpha}'_{t<E}[$ is higher in older than in younger generations, specially if $\beta > -\Delta W_L / \Delta W_S$ because in this situation an increase in age leads to a decrease in $\tilde{\alpha}^*$ but an increase in $\tilde{\alpha}'_{t<E}$. Thus, it is not only in older generations that there will be fewer people deciding to drop school and fewer people facing post-liberalisation positive returns to their investment in education.

In addition, among those with positive returns to education and the same level of ability, the older they are the higher the losses if $\beta < -\Delta W_L / \Delta W_S = (W_L' - W_L)/(W_S - W_S')$. The converse is valid for $\beta > -\Delta W_L / \Delta W_S$.

(iii) Skilled Workers

Traditional analysis concludes that this type of worker loses from liberalisation due to a lower wage rate. Here we argue that, by not considering the change to the returns to acquired education implied by liberalisation, they underestimate their loses. Moreover, we allow for changes in labour status. Despite their qualifications, skilled workers can opt to work as unskilled. As a consequence of liberalisation all skilled workers face a lower rate of return on education. The actual rate of return to education is $r_E(\alpha)'$ [defined on Eq. 27a] which is lower than $r_E(\alpha)$ [defined on Eq. 10]. Moreover, since all individuals that expect a positive return decide to become skilled, some iwill regret this decision. This will be especially true for those that face negative net returns to education. The actual net discounted benefits of the investment in education will be lower than zero for $\alpha < \tilde{\alpha}'$. However, all individuals with ability higher than $\tilde{\alpha}$ decided to became skilled. As $R(\alpha)'$ is negative for $\alpha \in [\tilde{\alpha}, \tilde{\alpha}'[$ [25], the less able skilled workers face capital losses in the form of negative returns to education.

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[25] Note that $R(\alpha)' = R(\alpha) + \int_t^T [(W_L - W_L') - (W_S - W_s')\alpha] e^{-rz} dz$. Moreover, in the unskilled labour abundant country,

$$\forall \alpha, \int_t^T [(W_L - W_L') - (W_S - W_s')\alpha] e^{-rz} dz = \frac{(e^{rT} - e^{rt})[(W_L - W_L') - (W_S - W_S')\alpha]}{e^{r(t+T)} r} < 0 .$$

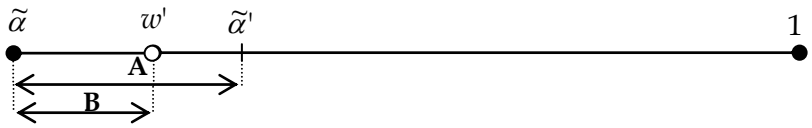
However, they can reverse their decision and change occupation. If expected earnings from working as unskilled exceed expected earnings of remaining skilled, the rational decision will be to work as unskilled, even after having invested in education. The right and left hand side of Eq. 41, respectively, depicts lifetime earnings in each of these situations:

$$\int_t^T W_L' e^{-rz} dz > \int_t^T \alpha W_S' e^{-rz} dz \qquad (41)$$

Thus, if the change in prices is high enough, $\tilde{\alpha} < w' < \tilde{\alpha}'$ [26], individuals with a level of ability in the interval $]\tilde{\alpha}, w'[$ [27] will decide to work as unskilled. For them, the transition involves a change of occupation.

Figure 3 illustrates the three possible situations for skilled workers in the unskilled labour abundant country. Following liberalisation, all skilled workers face lower than expected returns to education. Those with ability in the segment A regret their decision to become skilled, a proportion decide to reverse it [segment B].

Figure 3 – Skilled labour: Regrets versus Reversals



The dimensions of each segment varies across generations. $\tilde{\alpha}$ does not depend on age however, $\tilde{\alpha}'$ does: it is a negative function of age [for $W_L' > W_L$ and $W_S' < W_S$, by Eq. 29 $\partial\tilde{\alpha}'/\partial t < 0$] Thus, segment A is lower for older than younger generations. Accordingly,

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Accordingly, $\forall \alpha, R(\alpha) > R(\alpha)'$. For $\alpha = \tilde{\alpha}, R(\alpha) = 0 \text{ and } R(\alpha)' = \int_t^T [(W_L - W_L') - (W_S - W_S')\alpha] e^{-rz} dz < 0$. For $\tilde{\alpha} < \alpha < \tilde{\alpha}', R(\alpha) > 0 \text{ and } R(\alpha)' < 0$. For $\alpha = \tilde{\alpha}', R(\alpha) > 0 \text{ and } R(\alpha)' = 0$.

Finally, for $\alpha > \tilde{\alpha}', R(\alpha) > R(\alpha)' > 0$.

[26] Note that $\tilde{\alpha}'$ is always higher than w' and $\tilde{\alpha}$ is always higher than w but not necessarily higher than w' as in this country $w' > w$.

[27] Note that $w' > \tilde{a} \Leftrightarrow w' > \underbrace{\frac{1-e^{-rE}}{e^{-rS}-e^{-rT}}}_{>0}\beta + \underbrace{\frac{1-e^{-rT}}{e^{-rS}-e^{-rT}}}_{>1} * w$ which is possible.

the proportion of the population (in absolute and relative terms) in each generation that faces negative returns to their investment on education is higher in younger generations. In older generations, fewer skilled workers face negative returns to this investment and more face returns that, in spite of being positive, are lower than expected. Note that, as $\tilde{\alpha}'$ is a negative function of age, in older generations we can have $\tilde{\alpha} < \tilde{\alpha}' < w'$. In these circumstances, although these workers do not regret the decision made when younger, they would be better off changing occupation after liberalisation.

For all skilled workers that change occupation, the trade induced change on life-time earnings equals $LE' - LE = \int_t^T (W_L' - \alpha W_S) e^{-rz} dz = (W_L' - \alpha W_S) \frac{e^{rT} - e^{rt}}{e^{r(T+t)} r}$. Trade induces losses to the more able of those that change labour status and gains to the remaining. Across individuals with the same ability but different ages, younger individuals suffer higher losses. Conversely, among the winners, the younger have higher benefits.

For all skilled workers that remain the same occupation, the losses in life-time earnings equal $\alpha \int_t^T (W_S' - W_S) e^{rz} dz$. As in the previous case, younger individuals suffer higher losses. Moreover, if the level of ability lies in the interval $]w', \tilde{\alpha}'[$, younger individuals' suffer higher capital losses[28]. If ability lies in the interval $]\tilde{\alpha}', 1[$, younger individuals suffer higher negative differences between expected and effective rates of returns to education[29].

6. DYNAMIC LABOUR SUPPLY

Skill Abundant country

In our framework, trade leads to an increase in the return to education in the skill abundant country. As a consequence the equilibrium level of the critical level of ability decreases leading to an increase in the number of skilled workers and fall in the number of unskilled

[28] Note that $\frac{\partial [R(\alpha) - R(\alpha)']}{\partial t} = -\frac{\partial [R(\alpha)']}{\partial t} = -\frac{(W_L' - W_L) + (W_S - W_S')\alpha}{e^{rt}} < 0$

[29] Note that $\frac{\partial [r_E - r_E']}{\partial t} = -\frac{\partial [r_E']}{\partial t} = -\frac{r[(W_L' - W_L) + (W_S - W_S')\alpha]}{e^{r(t-E)}(e^{rE} - 1)(W_L + W_S \beta)} < 0$

workers. The new equilibrium supply of skilled and unskilled labour is given by Eqs. 21 and 22 with $\tilde{\alpha} = \tilde{\alpha}_{t=0}'$, where $\tilde{\alpha}_{t=0}'$ is the critical level of ability in the new steady state [Eq. 8 with $W_S = W_S'$ and $W_L = W_L'$: $\tilde{\alpha}_{t=0}' = \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}\beta + \frac{e^{rE}(e^{rT}-1)}{e^{rT}-e^{rE}}\frac{W_L}{W_S}$].

Thus, changes in the supply of skilled and unskilled labour are, respectively:

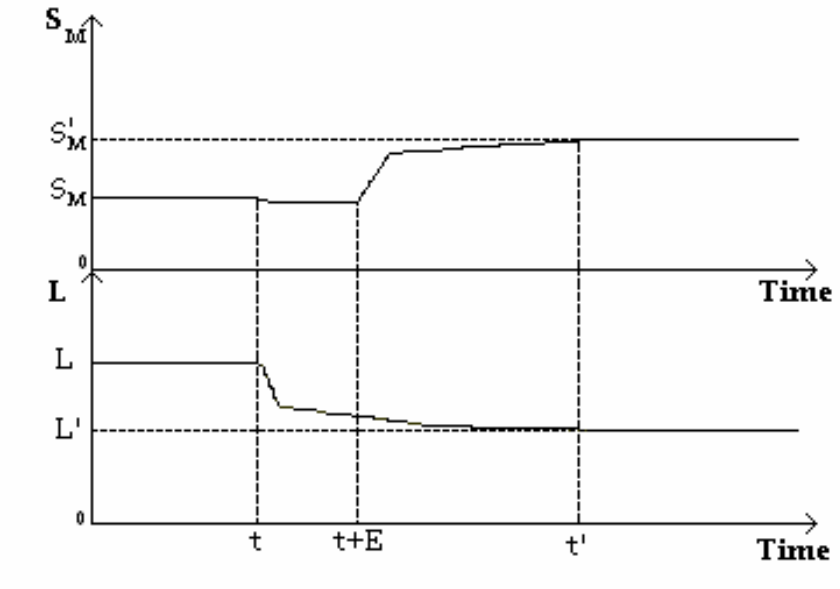
$$L'-L = (\tilde{\alpha}_{t=0}'-\tilde{\alpha})N \tag{42}$$

$$S'-S = \frac{1}{2}\left[(1-\tilde{\alpha}_{t=0}'^{2}) - (1-\tilde{\alpha}^{2})\right](1-\frac{E}{T})N = \\ = (\tilde{\alpha}-\tilde{\alpha}')N\left[\frac{1}{2}(\tilde{\alpha}+\tilde{\alpha}_{t=0}')(1-\frac{E}{T})\right] \tag{43}$$

Note that more students with the same number of teachers *per* student implies that more units of skill are diverted to education. There is a positive change in the number of units of skilled labour allocated to education equal to: $S_E'-S_E = \beta(E/T)N(\tilde{\alpha}-\tilde{\alpha}_{t=0}') > 0$. The variation in the number of units of skill allocated to production is: $S_M'-S_M = (\tilde{\alpha}-\tilde{\alpha}_{t=0}')\left(0.5(\tilde{\alpha}+\tilde{\alpha}_{t=0}') - \left[0.5(\tilde{\alpha}+\tilde{\alpha}_{t=0}')+\beta\right](E/T)\right)N$.

Figure 4 depicts the dynamics of unskilled and skilled labour supply for use in manufacturing between the two steady-states in the skilled labour abundant country.

Figure 4 – Dynamics of labour supply skill abundant country



Immediately after liberalisation the number of unskilled workers decreases for two reasons. First, more individuals at the beginning of their working life choose to engage in further education. Second, some unskilled workers change occupation. This change implies

an increase in the number of students and, consequently, on the skilled labour services drawn into the education system. However, the total stock of skilled labour remains at its initial level until *t*+*E*. Notwithstanding this, during this period less skilled labour services are available for use in production due to the growth in the educational sector. Note that as for $t > T - E$, $\tilde{\alpha}(t)'$ is negative, no unskilled worker with less than time *E* to go until the end of his career invests in education. Therefore, the number of students and, demand for education services will increase until *t*+*E*: the number of unskilled workers leaving the labour market surpasses the number of unskilled workers arriving.

At *t*+*E*, the unskilled workers that have decided to change occupation re-enter the labour market as skilled. The increase in the number of students at *t* equals the increase in skilled workers at *t*+*E*. Note that the increase in the skilled labour supply to the manufacturing sector will be higher as the needs for educational services decrease.

Since not all individuals with ability higher than $\tilde{\alpha}_{t=0}'$ become skilled, the transition between the pre- and post-trade steady-state can take some time. By assuming that each individual is replaced by an identical one in terms of ability upon death, the transition will take *T* minus the age of the younger unskilled worker with ability in the interval $]\tilde{\alpha}_{t=0}', \tilde{\alpha}(t)']$. During this time, considering the result that $\tilde{\alpha}(t)'$ is a positive function of age at the time of liberalisation (*t*) and that $\tilde{\alpha}_{t=0}'$ does not depend on *t*, the decrease/increase in the supply of unskilled/skilled labour will be increasingly smaller until at *t'* the new steady-state levels of supply of skilled and unskilled labour and students are achieved.

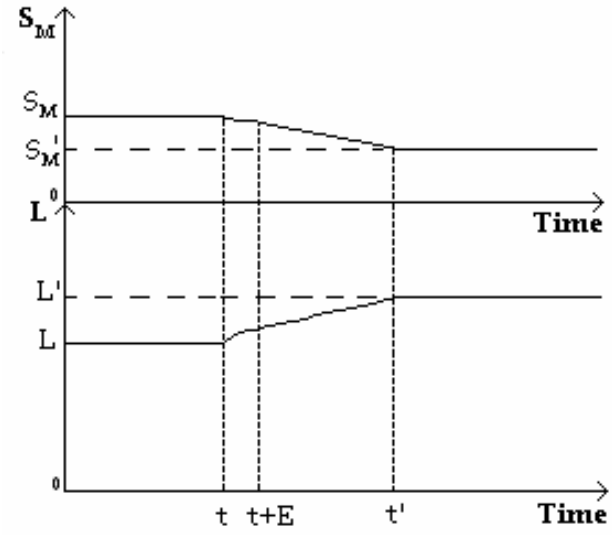
According to theory on variable factor supplies in a H-O-S setting (e.g. Martin, 1976; Neary, 1978, Woodland, 1982), provided that factor supplies are not backward-bending and there is incomplete specialisation, there will be a shift to specialisation in the skill-intensive good (X_2) in the skill abundant country. This result is consistent with the findings of Borsook (1987) and Findlay and Kierzkowski (1983). By modelling adjustment, we present new results. In particular, we find that this shift is progressive and has the following dynamics: immediately following liberalisation, both *L* and S_M fall but in different proportions, $|\Delta L| > |\Delta S_M|$, producing a negative Rybczynski effect on X_1 and positive effect on X_2. After the initial impact, and until *t*+*E*, the supply of skilled labour for use in manufacturing remains constant while that of unskilled labour falls. This induces a negative effect on X_1 and positive effect on X_2. After *t*+*E*, with S_M in variable supply as

well, and a further decrease in L, there will be a further shift to specialisation in the skill-intensive good. Note that both the rise in S_M and fall in L produce positive Rybcsynski effects on X_2 and negative effects on X_1. This pattern of evolution continues at a decreasing rate until the new steady-state levels of skilled and unskilled labour supplies are achieved.

Unskilled Labour Abundant country

In our framework, trade in the unskilled labour abundant country leads to a decrease in the return to education. As a consequence the equilibrium critical level of ability decreases leading to an increase in the number of unskilled workers and a fall in the number of skilled workers. The new equilibrium supply of skilled and unskilled labour is given by Eq. 21 and Eq. 22 with $\tilde{\alpha} = \tilde{\alpha}_{t=0}'$ where $\tilde{\alpha}_{t=0}'$ is the new steady state ability cut-off. Thus, the changes in supply of skilled and unskilled labour reflect those in the skill abundant country but with opposite sign [see Eq. 33 and 34]. Additionally, in the presence of fewer students, less units of skill will be allocated to education and more to production. Figure 5 depicts the dynamics between the two steady-states.

Figure 5 – Dynamics of labour supply in the unskilled labour abundant country



Immediately after liberalisation, the supply of unskilled workers increases for two reasons. First, more individuals at the beginning of their working life choose to remain unskilled. Second, in the presence of occupation reversal, some skilled workers change occupation and some students drop out of education. However, the immediate negative effect on S_M will be less pronounced, partly because with fewer students, less educational

services are needed and more units of skill are available; partly because not all students with an ability level lower than the new steady state cut-off drop out of the education system.

Until t+E, the number of students continues to decrease - more students finish than enter education. The positive change in the supply of unskilled labour equals the sum of the negative change on the number of students and on the supply of skilled labour.

At *t+E* the number of students and skill units allocated to education will stabilise. However, since not all individuals with ability lower than the new steady-state cut off [$\tilde{\alpha}_{t=0}'$] will change occupation, the full adjustment the new equilibrium will be convergent, but will take time. By assuming each individual is replaced by an identical one in terms of ability upon death, the transition will take *T* minus the age of the younger skilled worker with ability in the interval $[w', \tilde{\alpha}_{t=0}']$ [30]. As for any *t*, $\tilde{\alpha}_{t=0}' > w'$ the transition will take T-E.

Variable factor supplies theory (e.g. Martin, 1976; Neary, 1978, Woodland, 1982) predicts a shift to specialisation in the unskilled labour intensive good (X_1) in the unskill abundant country as both the rise in *L* and fall in S_M produce positive Rybczynski effects on X_1 and negative effects on X_2. By explicitly modelling adjustment, we present new results. In particular, we find that this shift is progressive and the full effect of trade on specialisation will only occur at time *t+(T-E).*

1. SUMMARY AND CONCLUSIONS

This paper highlights how workers of different age and ability are affected by an unexpected trade liberalisation in two types of countries: skilled and unskilled labour abundant. It models adjustment as a dynamic process and exposes losses induced by trade liberalisation. It also allows for displaced workers' retraining.

Two small economies are considered where each consists of two manufacturing and one educational sector. The manufacturing sectors (low-tech and high-tech) use skilled and unskilled labour and, at any common factor prices, the high-tech sector is relatively skill-intensive. Markets are competitive and undistorted. Hence, factor returns are uniquely determined by product prices. An increase (decrease) in the relative price of the skill-

[30] In the absence of occupation reversals, ie if $w' < \tilde{\alpha}$, the interval of the level of ability is not $[w', \tilde{\alpha}']$ but $[\tilde{\alpha}, \tilde{\alpha}']$.

intensive-good increases the real return to skilled (unskilled) labour and reduces that to unskilled (skilled) labour. Human capital acquisition is endogenous. Unskilled workers are those who enter the labour force without training and education is an activity that transforms unskilled into skilled workers. It is both time- and resource-consuming and it entails opportunity costs (forgone earnings as an unskilled worker) as well as direct costs (tuition fees). The more efficient the educational sector of a country, the lower its tuition fees.

Individuals differ not only in their endogenous education level but also in exogenous ability and age. Ability is uniformly distributed among the population. The productivity, and gross working earnings of unskilled workers do not depend on their ability, but those of skilled workers do. The benefits of education (the skill premium) depend on workers' individual characteristics; the costs on the efficiency of the educational sector and duration of the additional schooling period needed to become skilled. The return to education is an increasing function of ability and decreasing function of age. For any given product (hence factor) prices there is a critical level of ability above which the present value of net returns to education is positive. An increase in the cost of schooling implies a decrease in the number of skilled workers and an increase in the average level of ability of the skilled labour force.

Trade is motivated by differences between countries in relative factor endowments, which are endogenous. They can be affected by differences in life expectancies and birth rates, and by differences in the efficiency of the education sector.

The model brings additional insights in two domains: dynamics of labour supply during the transition and trade-induced gains and losses. We find that trade leads to progressive skill upgrading in skill abundant country; while the converse holds for the unskilled labour abundant country. Adjustment is a dynamic process that may take longer than suggested by traditional analysis. Until the new steady-state is achieved, the skilled (unskilled) labour abundant country will have a skill endowment below (above) the steady-state equilibrium level, because, although all individuals could reverse their previous educational/occupational decisions, for older workers it may be too late to do so. Since skill acquisition is costly, not all unskilled workers with an ability level higher than the new steady state cut-off will invest in human capital. Nor will all skilled workers with an ability level lower than the new steady state cut-off reverse their labour status. The dynamics of labour supply have effects on specialisation. In particular, in skilled labour abundant

countries trade liberalisation leads to a progressive shift to specialisation in the skill intensive good.

In the skill abundant country, skilled workers and students are the winners from liberalisation. They have capital gains in the form of higher than expected returns to education. Among skilled workers with the same level of ability, the older the worker the lower the gains. Conversely, among students, gains are lower for younger individuals that will have to pay tuition fees for longer. By contrast, unskilled workers are losers. More workers choose to become skilled at the beginning of their work life. However, only the more able switchers actually benefit from liberalisation (in the sense that they have higher post-trade earnings as skilled, than pre-trade earnings as unskilled). Some experienced unskilled workers will find they regret their decision to stay uneducated. However, only a proportion of those reverse it. The transition will involve skill acquisition/retraining whose costs are higher as a consequence of liberalisation. This is particularly harmful to older workers since they have a shorter period of return to the investment in education. Those that remain unskilled suffer wage losses. The proportion of the population negatively affected by liberalisation and the severity of the losses are higher in older age cohorts.

In the unskilled-labour-abundant country, unskilled workers gain from liberalisation. Students and skilled workers lose, since they face returns to education that are lower than expected. The less able experience capital losses in the form of negative returns to education. These losses are especially high for those who, under the new factor prices, would rather work as unskilled. The transition may involve costly occupational change for these workers. In this case, liberalisation is more penalising for younger than older generations. In younger generations there will be more skilled workers facing negative returns to past investments on education and more students deciding to drop school. Across individuals with the same level of ability, younger individuals suffer higher capital losses on their investment in education.

These results suggest that trade adjustment assistance should focus on older unskilled workers in skilled labour abundant countries and younger skilled workers in unskilled labour abundant countries.

APPENDIX 1

For unskilled workers with $t \le E$, the actual discounted value of net returns of education (discounted for t=0) accounting for trade liberalisation at t is equal to $R(\alpha)'_{t\le E}$ [defined in Eq. 30]. Solving for $R(\alpha)'_{t\le E} = 0$ we get the level of ability starting from which, accounting for trade liberalisation at *t*, investing in education at *t=0* would have had positive net returns[31]:

$$\tilde{\alpha}'_{t<E} = \frac{e^{r(T+E)}(e^{rt}-1)W_S + e^{rT}(e^{rE}-e^{rt})W_S'}{e^{rt}(e^{rT}-e^{rE})W_S'}\beta + \\ + \frac{e^{r(T+E)}(e^{rt}-1)W_L + e^{rE}(e^{rT}-e^{rt})W_L'}{e^{rt}(e^{rT}-e^{rE})W_S'}$$

In this situation, unskilled workers, aged at the time of trade liberalisation $t<E$, with ability in the interval $\left]\tilde{\alpha}'_{t<E}, \tilde{\alpha}\right]$ have lower working earnings than those they could have had given their ability level. They regret their decision of not becoming skilled. Note that if trade liberalisation at *t* had been anticipated at *t=0*, the rational decision for these workers would have been to invest in education immediately. Postponing the investment would have meant lower discounted net returns. However, if trade liberalisation (at $t<E$) had been anticipated only at t_0, with $0<t_0<t$, just those with $R(\alpha, t_0)'_{t<E} > 0$ have working earnings below their possibilities.

$$R(\alpha, t_0)'_{t<E} = \int_{t_0+E}^{T} (\alpha W_S' - W_L')e^{-r(z-t_0)}dz - \\ - \left[\int_{t_0}^{t_0+t} (\beta W_S + W_L)e^{-r(z-t_0)}dz + \int_{t}^{t+E} (\beta W_S' + W_L')e^{-r(z-t_0)}dz\right]$$

As $R(\alpha, t_0)'_{t<E}$ is lower than $R(\alpha)'_{t<E}$, the associated critical level of ability is higher. Thus, as a consequence of trade liberalisation, fewer unskilled workers aged $t<E$ would regret their previous decision.

[31] Note that for t=E, $\tilde{\alpha}_{t=E}' = \frac{e^{rT}(e^{rt}-1)(W_s\beta + W_L) + (e^{rT}-e^{rt})W_L'}{(e^{rT}-e^{rt})W_S'}$.

APPENDIX 2

$\tilde{\alpha}(t)' < \tilde{\alpha}$ for $\alpha > \tilde{\alpha}(t)'$ and

$$t < T + \frac{1}{r}\ln\left[\frac{W_L - W_L'}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-1}{e^{rT}}\right) + \frac{W_S' - W_S}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-e^{rE}}{e^{r(E+T)}}\alpha - \frac{e^{rE}-1}{e^{rE}}\beta\right) + \frac{1}{e^{rT}}\right]$$

Proof:

Given that $R(\alpha,t)' > R(\alpha) \Rightarrow \tilde{\alpha}(t)' < \tilde{\alpha}$. We are going to prove that $R(\alpha,t)' > R(\alpha)$ until certain age limit.

$$R(\alpha,t)' = \int_{t+E}^{T}(\alpha W_S' - W_L')e^{-r(z-t)}dz - \int_{t}^{t+E}(\beta W_S' + W_L')e^{-r(z-t)}dz \qquad R(\alpha) = \int_{E}^{T}(\alpha W_S - W_L)e^{-rz}\mathrm{d}z - \int_{0}^{E}(\beta W_S + W_L)e^{-rz}dz$$

$$R(\alpha,t)' > R(\alpha) \Leftrightarrow$$

$$\Leftrightarrow (\alpha W_S' - W_L')\frac{e^{-rE}-e^{-r(T-t)}}{r} - (\beta W_S' + W_L')\frac{1-e^{-rE}}{r} >$$

$$> (\alpha W_S - W_L)\frac{e^{-rE}-e^{-rT}}{r} - (\beta W_S + W_L)\frac{1-e^{-rE}}{r} \Leftrightarrow$$

$$\Leftrightarrow e^{-r(T-t)}(\alpha W_S' - W_L') <$$
$$\left[(W_L - W_L') - (W_S - W_S')\alpha\right](e^{-rE} - e^{-rT}) +$$
$$+\left[(W_L - W_L') + (W_S - W_S')\beta\right](1 - e^{-rE}) + (\alpha W_S' - W_L')e^{-rT} \Leftrightarrow$$

$$\Leftrightarrow e^{-r(T-t)} < Z \text{ with}$$

$$Z = \frac{\left[(W_L - W_L') + (W_S' - W_S)\alpha\right](e^{-rE} - e^{-rT}) + \left[(W_L - W_L') + (W_S - W_S')\beta\right](1 - e^{-rE}) + (\alpha W_S' - W_L')e^{-rT}}{(\alpha W_S' - W_L')}$$

$$\Leftrightarrow t < T + \frac{1}{r}\ln(Z) \Leftrightarrow$$

$$\Leftrightarrow t < T + \frac{1}{r}\ln(Z)$$

Condition : $Z > 0$

proof that *it* is always the case for $\alpha > \tilde{\alpha}(t)'$

$$Z = \frac{\left[(W_L - W_L') + (W_S' - W_S)\alpha\right](e^{-rE} - e^{-rT}) + \left[(W_L - W_L') + (W_S - W_S')\beta\right](1 - e^{-rE}) + (\alpha W_S' - W_L')e^{-rT}}{(\alpha W_S' - W_L')} =$$

$$= \frac{W_L - W_L'}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-1}{e^{rT}}\right) + \frac{1}{e^{rT}} + \frac{W_S' - W_S}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-e^{rE}}{e^{r(E+T)}}\alpha - \frac{e^{rE}-1}{e^{rE}}\beta\right)$$

As

$W_L' < W_L \Leftrightarrow W_L - W_L' > 0$

$\left(\frac{e^{rT}-1}{e^{rT}}\right) > 0, \frac{1}{e^{rT}} > 0$

For $\alpha > \tilde{\alpha}(t)'$, $\alpha W_S' - W_L' > 0$

Thus, for $\alpha > \tilde{\alpha}(t)'$, $\frac{W_L - W_L'}{\alpha W_S' - W_L'}\left(\frac{e^{rT}-1}{e^{rT}}\right) + \frac{1}{e^{rT}} > 0$

$W_S' > W_S \Leftrightarrow W_S' - W_S > 0$

$\frac{e^{rT}-e^{rE}}{e^{r(E+T)}}\alpha > \frac{e^{rE}-1}{e^{rE}}\beta \Leftrightarrow \alpha > \Gamma\beta$ which is always the case when $\alpha > \tilde{\alpha}(t)' = \Lambda\beta + (1+\Lambda)w$ with $\Lambda > \Gamma > 0$

APPENDIX 3

In the skill abundant country $R(\alpha)'_{t<E} > R(\alpha)$ for all students.

Proof

With $W_L > W_L'$ and $W_S < W_S'$ both $\int_t^T (W_L - W_L')e^{-rz}dz$ and $(W_S' - W_S)$ are positive.

Moreover, all students have $\alpha > \tilde{\alpha} = \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}\beta + \frac{e^{rE}(e^{rT}-1)}{e^{rT}-e^{rE}}\frac{W_L}{W_S}$.

Given that, if $\alpha > \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}\beta + \frac{e^{rE}(e^{rT}-1)}{e^{rT}-e^{rE}}\frac{W_L}{W_S}$, $\frac{e^{rE}(e^{rT}-1)}{e^{rT}-e^{rE}}\frac{W_L}{W_S} > 0$ then $\alpha > \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}\beta$. Multiplying both sides of the inequation by $(e^{rT}-e^{rE})e^{rt} > 0$ we get:

$$\alpha(e^{rT}-e^{rE})e^{rt} > \frac{e^{rT}(e^{rE}-1)}{e^{rT}-e^{rE}}(e^{rT}-e^{rE})e^{rt}\beta \Leftrightarrow \alpha(e^{rT}-e^{rE})e^{rt} > e^{r(T+t)}(e^{rE}-1)\beta.$$

Given that $e^{r(T+t)}(e^{rE}-1)\beta > e^{rT}(e^{rE}-e^{t})\beta$ then we can affirm that for all the students

$$\int_E^T \alpha e^{-rz}\mathrm{dz} - \int_t^E \beta\, e^{-rz}\mathrm{dz} = \frac{\alpha(e^{rT}-e^{rE})e^{rt} - \beta(e^{rE}-e^{rt})e^{rT}}{e^{r(T+t+E)}r} > 0.$$

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