APPENDIX

A. Computation of the instantaneous Equilibrium in the open Economy

A good can be produced by a monopoly or a duopoly when imitated. Hereafter, we detail the different cases.

case 1: Imitated goods (only in South). This case concerns a share $(I/\theta + I)$ of goods produced in South.

When a good of technology (u, s) is imitated, sector is under a duopolistic competition à la Bertrand where both competitors use the same technology (u, s). The price is then equal to unit cost and factor demand in skilled and unskilled labor are given by:

$$d^h_{imit.}(t) = \frac{1}{\left[w^s_t \cdot \left(\frac{q^s_t}{w^s_t}\right)^{+\sigma}\left(\frac{s(t)}{u(t)}\right)^{-1+\sigma} + q^s_t\right]} \text{ and } d^U_{imit.}(t) = \frac{1}{\left[w^s_t + q^s_t \cdot \left(\frac{q^s_t}{w^s_t}\right)^{-\sigma}\left(\frac{s(t)}{u(t)}\right)^{1-\sigma}\right]}$$

case 2: Non imitated goods produced after a choice of neutral progress (South and North). This case concerns a share $(\theta/\theta + I)$ of goods produced in South and almost all goods produced in North. Each of these goods is produced by a monopoly with technology (u, s) whereas its competitor uses a technology $(\delta^{-1}u, \delta^{-1}s)$. This case is similar to the case in autarky and we get easily demand of skilled and unskilled labor (with $j \in \{North, South\}$):

$$d^h(t) = \frac{\delta}{\left[w^j_t \cdot \left(\frac{q^j_t}{w^j_t}\right)^{+\sigma}\left(\frac{s(t)}{u(t)}\right)^{-1+\sigma} + q^j_t\right]}; \; d^U(t) = \frac{\delta}{\left[w^j_t + q^j_t \cdot \left(\frac{q^j_t}{w^j_t}\right)^{-\sigma}\left(\frac{s(t)}{u(t)}\right)^{1-\sigma}\right]}$$

case 3: Non imitated goods produced after a choice of biased technical progress (South and North). This case concerns a share M_t of the continuum of goods. The dynamics of M_t are given by: $\dot{M}_t = \theta \int_{f^*_t}^{f_t} \alpha_t(x)dx - \theta M_t$ where the first term corresponds to the number of goods which are innovated whith a bias and the second term corresponds to the number of goods of M_t which are innovated. From this law of motion, we obtain that , at each date t, $M_t \leq \int_{f^*_t}^{f_t} \alpha_t(x)dx$: thus M_t is inferior to the number of goods on interface $[\delta f_t, f_t]$. But, from assumption 1 ($i.e$ δ close to 1), we know that the size of interface is quite "small" compared to the total amount of goods. Consequently M_t represents only a small share of goods.

In the case 3, the monopolistic firm produces with a technology (u, s) whereas its competitor uses a technology $(\delta^{-1}u, s)$: hence, this case is an intermediate case between case 1 and case 2 (and, here, both competitors may be located in different countries). In order to limit the analytical complexity of general equilibrium equations , we use the assumption 1 which says that δ is close to 1, to argue that competitor's technology is quite close (as a first approximation) to $(\delta^{-1}u, \delta^{-1}s)$: consequently, case 3 can be reasonably approximated by case 2 and factor demands are thus similar. This approximation concerns in fact a very small amount of goods (because M_t is very low) that is why we are sure, when aggregating on the continuum of goods, that this approximation do not alter the aggregated factor demands and general equilibrium equations.

Aggregated factor demands are easily derivated from the good factor demands by suming over the continuum of goods.

B. Some results on relative demand

The relative skilled-unskilled labor demand functions in South and North are equal to

$$D^s_{H/L}(q/w) = \left(\frac{q}{w}\right)^{-\sigma} \int_0^f \frac{\alpha_t(x)dx}{[x^{-(1-\sigma)} + (q/w)^{1-\sigma}]} / \int_0^f \frac{\alpha_t(x)dx}{[1 + x^{1-\sigma}.(q/w)^{1-\sigma}]} \quad \text{(B.1)}$$

$$D^n_{H/L}(q/w) = \left(\frac{q}{w}\right)^{-\sigma} \int_f^{+\infty} \frac{\alpha_t(x)dx}{[x^{-(1-\sigma)} + (q/w)^{1-\sigma}]} / \int_f^{+\infty} \frac{\alpha_t(x)dx}{[1 + x^{1-\sigma}.(q/w)^{1-\sigma}]} \quad \text{(B.2)}$$

Using Lemma 1 of Feenstra-Hanson (1995) and a basic variables change in (B.1-B.2), we can show that $\partial D^j_{H/L}/\partial(q/w) < 0$ for $j \in \{n, s\}$: clearly, an increase of skilled labor relative wage decreases the relative demand. We have also the other following results: $D^s_{H/L}(0) = D^n_{H/L}(0) = +\infty$ and $D^s_{H/L}(+\infty) = D^n_{H/L}(+\infty) = 0$. These two conditions, and the monotonicity of relative demands allow us to conclude that general equilibrium exists and is unique in autarky. Noting $\varepsilon^{1j}_t = [(q/w)/D^j_{H/L}][\partial D^j_{H/L}/\partial(q/w)]$ the price elasticity of relative demand, we can show, using Feenstra-Hanson (1995), that $\varepsilon^{1j}_t = -\sigma + (1-\sigma)\varepsilon_{fh}$ where ε_{fh} is the (negative) price elasticity of relative demand in Feenstra-Hanson. In their model, sectoral production functions are Leontieff, such we deduce that $-1 < \varepsilon_{fh} < 0$. This last result allows to show that:

$$\frac{\partial \left|\varepsilon^{1j}_t\right|}{\partial \sigma} > 0$$

The price elasticity of relative demand increases, ceteris paribus, when the elasticity of substitution between skilled and unskilled labor σ increases.

C. Dynamic General Equilibrium.

After basic rearrangements of equations (5.1-5.2-5.3), the international equilibrium with trade is characterized by the following set of equations:

$$\begin{cases} H^s/L^s = D^s_{H/L} & (e_1) \\ H^n/L^n = D^n_{H/L} & (e_2) \\ L^s = D^s_L & (e_3) \\ L^n = D^n_L & (e_4) \\ (w^n_t)^{1-\sigma}(1 + (q^n_t/w^n_t)^{1-\sigma} f_t^{1-\sigma}) = (w^s_t)^{1-\sigma}(1 + (q^s_t/w^s_t)^{1-\sigma} f_t^{1-\sigma}) & (e_5) \end{cases} \quad \text{(C.1)}$$

where demands have the following expressions:

$$\begin{aligned}
D^s_{H/L} &= \left(\frac{q^s_t}{w^s_t}\right)^{-\sigma} \int_0^{f_t} \frac{\alpha_t(x)dx}{[x^{-(1-\sigma)} + (q^s_t/w^s_t)^{1-\sigma}]} / \int_0^{f_t} \frac{\alpha_t(x)dx}{[1 + x^{1-\sigma}.(q^s_t/w^s_t)^{1-\sigma}]} \\
D^n_{H/L} &= \left(\frac{q^n_t}{w^n_t}\right)^{-\sigma} \int_{f_t}^{+\infty} \frac{\alpha_t(x)dx}{[x^{-(1-\sigma)} + (q^n_t/w^n_t)^{1-\sigma}]} / \int_{f_t}^{+\infty} \frac{\alpha_t(x)dx}{[1 + x^{1-\sigma}.(q^n_t/w^n_t)^{1-\sigma}]} \\
D^s_L &= \frac{\beta}{w^s_t}. \int_0^{f_t} \frac{\alpha_t(x)dx}{[1 + x^{1-\sigma}.(q^s_t/w^s_t)^{1-\sigma}]} \\
D^n_L &= \frac{\delta}{w^n_t} \int_{f_t}^{+\infty} \frac{\alpha_t(x)dx}{[1 + x^{1-\sigma}.(q^n_t/w^n_t)^{1-\sigma}]}
\end{aligned}$$

C.1. Differenciation of Equilibrium

By differentiating the system (C.1), we get:

$$\begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ 0 \end{bmatrix} dt = \begin{bmatrix} a_{11} & -a_{12} & 0 & 0 & 0 \\ a_{21} & 0 & -a_{23} & 0 & 0 \\ a_{31} & -a_{32} & 0 & -a_{34} & 0 \\ a_{41} & 0 & a_{43} & 0 & a_{45} \\ a_{51} & a_{52} & -a_{53} & a_{54} & -a_{55} \end{bmatrix} \begin{bmatrix} df \\ d(\frac{q^s}{w^s}) \\ d(\frac{q^n}{w^n}) \\ dw^s \\ dw^n \end{bmatrix} \tag{C.2}$$

Lemma 1 $\forall(i,j)$, $a_{ij} > 0$ and $\beta_i > 0$.

After some computations, we can prove that the coefficient $a_{11} = \frac{\partial D^s_{H/L}}{\partial f}$ has the sign of

$$Sg(a_{11}) = Sg[\frac{\frac{\alpha_t(f)}{[f^{-(1-\sigma)}+(q^s_t/w^s_t)^{1-\sigma}]}}{\frac{\alpha_t(f)}{[1+f^{1-\sigma}.(q^s_t/w^s_t)^{1-\sigma}]}} - \frac{\int_0^f \frac{\alpha(x)dx}{[x^{-(1-\sigma)}+(q^s_t/w^s_t)^{1-\sigma}]}}{\int_0^{f_t} \frac{\alpha(x)dx}{[1+x^{1-\sigma}.(q^s_t/w^s_t)^{1-\sigma}]}}]$$

The coefficient a_{11} is then positive: a move toward more skill intensive areas of the frontier f_t indeed increases the South relative demand.

Now we compute the partial derivative of South relative demand according to time: this corresponds to the consequences of spread of $\alpha_t(.)$ over time on the relative demands. In order to adress this point, we use the law of motion given by system (5.4): $-\beta_1 = \frac{\partial D^s_{H/L}}{\partial t}$ and we can prove:

$$Sg(-\beta_1) = Sg[\frac{\int_0^{f_t} \frac{\alpha_t(x)dx}{[x^{-(1-\sigma)}+(q^s_t/w^s_t)^{1-\sigma}]}}{\int_0^{f_t} \frac{\alpha_t(x)dx}{[1+x^{1-\sigma}.(q^s_t/w^s_t)^{1-\sigma}]}} - \frac{\int_{f^*_t}^{f_t} \frac{\alpha_t(x)dx}{[x^{-(1-\sigma)}+(q^s_t/w^s_t)^{1-\sigma}]}}{\int_{f^*_t}^{f_t} \frac{\alpha_t(x)dx}{[1+x^{1-\sigma}.(q^s_t/w^s_t)^{1-\sigma}]}}]$$

which is negative. The reason is that technical bias concerns the most skill intensive goods produced in South: consequently, the direct effect of $\alpha(.)$ dynamic is to lower the South relative demand.

Now we compute the symmetric coefficient for North. Coefficient signs can be explained by similar arguments as for South. We have $a_{21} = \frac{\partial D^N_{H/L}}{\partial f}$ and $-\beta_2 = \frac{\partial D^N_{H/L}}{\partial t}$ and we can prove, using (5.4) and assumption 1:

$$Sg(a_{21}) = Sg[\frac{\frac{\alpha_t(f)}{[1+f_t^{1-\sigma}.(q_t^n/w_t^n)^{1-\sigma}}}{\frac{\alpha_t(f)}{[f^{-(1-\sigma)}+(q_t^n/w_t^n)^{1-\sigma}]}} - \frac{\int_{f_t}^{+\infty}\frac{\alpha_t(x)dx}{[1+x^{1-\sigma}.(q_t^n/w_t^n)^{1-\sigma}]}}{\int_{f_t}^{+\infty}\frac{\alpha_t(x)dx}{[x^{-(1-\sigma)}+(q_t^n/w_t^n)^{1-\sigma}]}} \text{which is positive.}$$

After a variable change $y = \delta x$ we get:

$$Sg(-\beta_2) = Sg[\delta^{-1}.\frac{\int_{f_t^*}^{f_t}\frac{\alpha_t(y)dy}{[y^{-(1-\sigma)}+(q_t^n/\delta w_t^n)^{1-\sigma}]}}{\int_{f_t^*}^{f_t}\frac{\alpha_t(y)dy}{[1+y^{1-\sigma}.(q_t^n/\delta w_t^n)^{1-\sigma}]}} - \frac{\int_{f_t}^{+\infty}\frac{\alpha_t(x)dx}{[x^{-(1-\sigma)}+(q_t^n/w_t^n)^{1-\sigma}]}}{\int_{f_t}^{+\infty}\frac{\alpha_t(x)dx}{[1+x^{1-\sigma}.(q_t^n/w_t^n)^{1-\sigma}]}}]$$

which, by assumption 1 is negative.

Finally, coefficient a_{51} is obtained through the differentiation of the "frontier condition":

$$a_{51} = [(q^s)^{1-\sigma} - (q^n)^{1-\sigma}].(1-\sigma).f^{-\sigma} > 0$$

The sign of the other coefficients are straightforward to obtain by simple differentiation. ■

Lemma 2 Frontier f_t is increasing through time

This result is obtained by solving system (C.2) for df, and after computations, we get the following relation:

$$df = \frac{c_4 + c_5\Sigma_2 + c_6\Sigma_1}{c_1 + c_2\Sigma_2 + c_3\Sigma_1}dt \tag{C.3}$$

where: $c_1 = a_{51} + a_{54}\frac{a_{31}}{a_{34}} + a_{55}\frac{a_{41}}{a_{45}}$; $c_2 = \frac{a_{21}}{a_{23}a_{45}}$; $c_3 = \frac{a_{11}}{a_{12}a_{34}}$; $c_4 = \frac{a_{54}}{a_{34}}\beta_3 + \frac{a_{55}}{a_{45}}\beta_4$, $c_5 = \frac{\beta_2}{a_{45}a_{23}}$ and $c_6 = \frac{\beta_1}{a_{21}a_{34}}$.

From lemma 1, we know that $c_i > 0$ for all i. But expressions of Σ_1 and Σ_2 are more complicated:

$$\begin{aligned}\Sigma_1 &= (a_{52}a_{34} - a_{32}a_{54}) \\ &= \delta(1-\sigma)(w^s)^{-(1+\sigma)}f^{1-\sigma}\left(\frac{q^s}{w^s}\right)^{-\sigma} \\ &\quad \times\left[\int_0^f \frac{\alpha_t(x)dx}{[1+(\frac{q^s}{w^s}x)^{1-\sigma}]} - \int_0^f \frac{(\frac{x}{f})^{1-\sigma}.(1-\sigma)\alpha_t(x)dx}{[1+(\frac{q^s}{w^s}x)^{1-\sigma}]^2}.(1+(\frac{q^s}{w^s}f)^{1-\sigma}\right]\end{aligned}$$

So we obtain that: $Sg(\Sigma_1) = Sg([\frac{1}{x^{1-\sigma}} + (\frac{q^s}{w^s})^{1-\sigma}] - (1-\sigma)[\frac{1}{f^{1-\sigma}} + (\frac{q^s}{w^s})^{1-\sigma})])$ which is positive for all $x < f$.

$$\Sigma_2 = (a_{43}a_{55} - a_{45}a_{53})$$
$$= \delta(1-\sigma)(w^n)^{-(1+\sigma)} f^{1-\sigma} \left(\frac{q^n}{w^n}\right)^{-\sigma} \times$$
$$\times \underbrace{\left[\int_f^\infty \frac{(\frac{x}{f})^{1-\sigma}.(1-\sigma)\alpha_t(x)dx}{[1+(\frac{q^n}{w^n}x)^{1-\sigma}]^2}.(1+(\frac{q^n}{w^n}f)^{1-\sigma}) - \int_f^\infty \frac{\alpha_t(x)dx}{[1+(\frac{q^n}{w^n}x)^{1-\sigma}]}\right]}_{\Phi(\sigma)}$$

Coefficient $\Phi(\sigma)$, with $0 < \sigma < 1$, has an ambiguous sign; for σ close to 0, $\phi(\sigma)$ is positive, which means that $\Sigma_2 > 0$. For σ close to 1, $(1-\sigma)$ is close to 0 and it is easy to show that Σ_2 is negative but is very small compared to other terms in equation (C.3). For intermediate values of σ, we conjecture that potential negative effect of Σ_2 do not dominate the positive contribution of other terms in equation (C.3) (and this conjecture will always be true in our simulations). ■

Lemma 3 The system converges towards a steady state with no trade induced technical bias.

Steady state is reached as soon as there is no spread of $\alpha_t(.)$. This arises if $\alpha_t(x) = 0$ on $[f_t^*, f_t]$, or if firms do not choose technical bias ($f_t^* = f_t$). There is induced technical bias as long as condition (4.5) is satisfied for f_t, which gives, after some computations:

$$\left(\frac{B-\delta^{1-\sigma}}{1-B}\right).\frac{w_t^n}{q_t^n} \geq f_t \tag{C.4}$$

with $B = \frac{I+\delta(r+\theta)}{I+r+\theta} < 1$. Moreover, on the transition path, (q_t^n/w_t^n) is bounded from below (cf.lemma 4) and $\min_t (q_t^n/w_t^n) = A$. Setting $f_{\max} = \left(\frac{B-\delta^{1-\sigma}}{1-B}\right).A^{-1}$, we know that, as long as $f_t \leq f_{\max}$, it is profitable to bias the direction of technical change for goods in the neighborhood of f_t. As the sequence f_t is increasing and bounded from above, it converges towards a limit f_∞. At the limit, steady state is reached $f_t = f_\infty$ and one of the following situations necessary emerges: either condition (C.4) is not satisfied or there are no more technics on which to apply an induced technical bias (ie. $\alpha_\infty(x) = 0$ on $[f_\infty^*, f_\infty]$. ■

C.2. Proof of relation (5.5)

From rank 1 and rank 2 of system (C.2), we get $\beta_1 = a_{11}df - a_{12}d(q^s/w^s)$ and $\beta_2 = a_{21}df - a_{23}d(q^n/w^n)$ which can be rewritten:

$$\frac{d(\frac{q^j}{w^j})}{dt} = \frac{-\partial D^j_{H/L}/\partial t}{\partial D^j_{H/L}/\partial(q^j/w^j)} + \frac{-\partial D^j_{H/L}/\partial f}{\partial D^j_{H/L}/\partial(q^j/w^j)}.\dot{f} \text{ with } j \in \{n, s\} \tag{C.5}$$

After some basic computations this relation is equivalent to $\Gamma_t^j = \frac{1}{-\varepsilon_t^{1j}}.[\varepsilon_t^{2j} + \varepsilon_t^{3j}.\frac{\dot{f}_t}{f_t}]$ where:

$$\begin{cases} \varepsilon_t^{1j} = \frac{q^j/w^j}{D^j_{H/L}}.\frac{\partial D^j_{H/L}}{\partial(q^j/w^j)} < 0. \text{ is the price elasticity of relative demand} \\ \varepsilon_t^{2j} = \frac{1}{D^j_{H/L}}.\frac{\partial D^j_{H/L}}{\partial t} < 0. \text{ is the "sensitivity" of the relative demand to the spread of } \alpha_t(.) \\ \varepsilon_t^{1j} = \frac{f}{D^j_{H/L}}.\frac{\partial D^j_{H/L}}{\partial f} > 0. \text{ is the elasticity of relative demand to a move of the frontier } f \end{cases} \quad (C.6)$$

C.3. Existence and uniqueness of general equilibrium

We demonstrate, in this section, that at each date t, instantaneous general equilibrium exists and is unique. We omit the time index. Let f be given. We give hereafter a demonstration based on property of relative separability of general equilibrium system (C.1). Equations (e_1) and (e_2) of general equilibrium system (C.1) can be rewritten as follow: $H^s/L^s = D^s_f(q/w)$ and $H^n/L^n = D^n_f(q/w)$. From appendix (B), we know that these two implicit equations have unique positive solutions $(\frac{q^s}{w^s}(f), \frac{q^n}{w^n}(f))$. Plunging f and the associated values $\frac{q^s}{w^s}(f)$ and $\frac{q^n}{w^n}(f)$ in (e_3) and (e_4) we immediatly get $w^s(f)$ and $w^n(f)$. Then, plunging $(f, \frac{q^s}{w^s}(f), \frac{q^n}{w^n}(f), w^s(f), w^n(f))$ in (e_5) we can define $LHS(f)$ and $RHS(f)$ as respectively the left hand side and the right hand side of (e_5). Noting $\Delta(f) = LHS(f) - RHS(f)$, tedious but straightforward computations give:

$$\Delta(f) = \frac{\sigma}{L^s}\int_0^f \alpha(x)\frac{1+(q^s/w^s).f}{1+(q^s/w^s).x} - \frac{\delta}{L^n}\int_f^0 \alpha(x)\frac{1+(q^n/w^n).f}{1+(q^n/w^n).x} \quad (C.7)$$

Equilibrium corresponds to the set $\{f^* \in \mathbb{R}^+$ such that $\Delta(f^*) = 0\}$. We can differentiate $\Delta(.)$:

$$\Delta'(f) = (q^s - q^n) + \frac{a_{54}.a_{31}}{a_{34}} + \frac{a_{11}}{a_{12}.a_{34}}.\Sigma_2 + \frac{a_{55}.a_{41}}{a_{45}} + \frac{a_{21}}{a_{23}.a_{45}}.\Sigma_1$$

Using appendix (C.1), we know that $\Delta'(f) > 0$. Furthermore, it is easy to show that $\Delta(0) < 0$ and $\Delta(+\infty) > 0$. This last property and the monotonicity of $\Delta(.)$ implies that the set $\{f^* \in \mathbb{R}^+$ such that $\Delta(f^*) = 0\}$ is reduced to one and only one point f.

D. Inferior bound of q^n/w^n and q^s/w^s

To make the point, we have to keep in mind the two following facts. First, the spread of $\alpha(.)$ resulting from induced technical change always decreases wage inequalities in both regions (coefficient β_1 and β_2 in appendix C.1). Secondly, when f_t increases, wage inequalities increase in both regions (coefficient a_{11} and a_{21}). The question is what is the lowest value northern wage inequalities can take along the transition path? This value corresponds to a particular shape of $\alpha_t(.)$. As we have proved, f_t is increasing through time. Thus, it is clear that the lowest value of northern wage premium corresponds to a case where $f_t = f_0$ and the shape of α_t corresponds to a spread of α_0 where all goods on $[\delta f_0, f_0]$ are moved on $[f_0, \delta^{-1} f_0]$. Hence, this setup gives the lower bound of q^n/w^n on transition path. Similarly we get the inferior bound of q^s/w^s.

[Figure VIII]

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Authors

Mathias Thoenig
Affiliation:
Crest and EUREQua (Université Panthéon- Sorbonne)
address:
Laboratoire de macroéconomie du CREST
Timbre J360
15 boulevard Gabriel Péri
92245 Malakoff Cedex
France
phone number : 33 1 41 17 77 91
Fax number : 33 1 41 17 76 66
email : thoenig@ensae.fr

Thierry Verdier
Affiliation:
Ceras, Delta and CEPR
address:
Delta
Ecole Normale Supérieure
48 boulevard Jourdan
75014 Paris
France
phone number : 33 1 43 13 63 08
Fax number : 33 1 43 13 63 10
email : tv@delta.ens.fr

Tables

Table I : value of parameters

H^n/L^n	H^s/L^s	North relative size	σ	θ	δ	rate of growth	I
1	0.1	1/6	0.5	0.25	0.9	2.6%	1

Table II : comparative statics of elasticity of substitution σ

elasticity	$\sigma = 0.4$	$\boldsymbol{\sigma} = \mathbf{0.5}$	$\sigma = 0.6$	$\sigma = 0.7$
Premium in North	3.7%	**3.0%**	2.8%	2.2%
Premium in South	5.5%	**2.5%**	1.2%	0.6%

Table III : comparative statics of growth rate

rate of growth	1%	2%	**2.6%**	4%
Premium in North	1.0%	2.8%	**3.0%**	6.0%
Premium in South	1.4%	2.3%	**2.5%**	3.5%

Table IV : comparative statics of technical increment

Increment	$\delta = 0.7$	$\delta = 0.8$	$\boldsymbol{\delta} = \mathbf{0.9}$
Premium in North	8.7%	7.3%	**3.0%**
Premium in South	12%	11%	**2.5%**