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NORTH-SOUTH KNOWLEDGE SPILLOVERS AND COMPETITION. CONVERGENCE VERSUS DIVERGENCE

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Abstract
Technology spillovers from high productivity countries in the North allow low productivity countries in the South to improve productivity in high-tech sectors at relatively low cost. However, the South's share in world goods markets for high-tech products is relatively low, which reduces the revenue base from which R&D activities have to be financed. Our simple Ricardian endogenous growth model shows how the balance between toughness of competition in trade and the strength of North-South spillovers determines whether productivity levels diverge, partially converge or fully converge in the long run. Under divergence, relative wages in the South steadily fall behind. If convergence prevails, the North is confronted with declining employment in high-tech sectors.

1. Introduction

Productivity levels differ widely across countries. Developing countries, or, more generally speaking, low productivity countries, lack the knowledge to produce goods according to the technology and quality that prevail in high productivity countries. Under suitable conditions, developing countries may gradually close the knowledge gap by assimilating the rich world's methods and standards. Firms in the relatively poor countries (the South) learn from firms in the relatively rich countries (the North). Suitable conditions refer to, among others, property rights, labour skills and macro-economic stability as emphasized by Abramovitz (1989).

The empirical literature (e.g. Baumol and Wolff, 1988; Soete and Verspagen, 1993) documents that low productivity countries may join the "club" of converging countries, catching up to the high productivity levels of the leader country. However, other countries are destined to join a club that steadily falls behind.

Catching-up is not a free lunch. Learning and the assimilation of techniques require investment efforts, although lower ones than the development of entirely new techniques at the technology frontier. A sufficient market share is needed to cover the cost of this R&D investment. This is why competition enters the story. High productivity firms in the North have a large market share on world markets. This provides the revenue base for R&D activities, which improve their competitiveness by shifting the technology frontier. Southern firms, in contrast, face a low market share for their products which either have lower quality or are expensive relative to the competing products of the North. If competition is tough, Southern firms have not sufficient revenues to finance the R&D activities that could close the technology gap. In that case, there is divergence rather than convergence in productivity levels, despite the presence of international knowledge spillovers.

When low productivity countries catch up (or fall behind), large shifts in the international division of labour and the economic structure within rich countries may occur. This is sometimes feared in rich countries. Developing countries have low wages which may threaten employment in high wages countries. However, wage differentials reflect productivity differentials and catching-up induces a relative wage increase in the South. Unless specific circumstances prevail, international competition and trade is beneficial to all trading partners. Another issue, not the focus of this paper, is that there may be unfavourable distributional effects, immiserizing the unskilled workers in the North as discussed in Bhagwati (1994). Furthermore, there may be problems on the sectoral level in the North in case of convergence, because firms in the high-tech sector are confronted with a fall in market share. Domestic markets have to be flexible enough to faciliate adjustment.

We analyse the dynamics of convergence and its consequences for domestic economic structure in the context of a simple two-sector two-country endogenous growth model. To delineate our model it is instructive to compare it with the hysteresis model by Grossman and Helpman (1991, Ch. 8). In the latter model, R&D feeds upon public knowledge. These spillover effects may be national in scope, which implies that the country with the highest public knowledge in R&D in the initial situation specializes partially in the generation of technological know-how. In our model there are no spillovers of this kind. Each firm builds upon its own experience and all knowledge is tacit or firm-specific. Therefore no country specializes in knowledge production. However, there is a spillover effect from the developed to the developing economy, which may lead to catching-up. In the terminology of Grossman and Helpman this may be seen as a global spillover effect, but in contrast with their analysis of global effects ours is one-sided and self-destructive. It ceases to be effective once catching-up is completed. The idea that the accumulation of knowledge is primarily an in-house activity of firms is supported by casual evidence (e.g. Pavitt, 1984; Dosi, 1988). If this is taken for granted the analysis can be enriched by assuming that in addition to the accumulation of firm-specific knowledge firms can learn from each other as we have shown elsewhere in the context of a fully symmetric model without one-sided catching-up possibilities (Smulders and Van de Klundert, 1994). For the present purpose there seems no need to complicate the analysis by introducing technological spillovers across firms in the same country.

The paper is organized as follows. In Section 2 the model is introduced and the possibilities for the international division of labour are presented. Temporary equilibrium solutions for different specializiation regimes are presented in Section 3 along with an analysis of their comparative statics. Dynamic issues come to the foreground in Section 4. It is shown under which conditions countries convergence or diverge. Starting from an initial situation with a relatively low productivity level in the high-tech sector of the developing economy, equilibrium trajectories for relative wages and relative productivity levels are derived analytically. The issue of strategic behaviour is touched upon and illustrated by means of a numerical example. The paper concludes with an evaluation of the results in Section 5.

2. A slightly asymmetric two-sector two-country model

There are two countries, which have the potentiality to produce traditional goods (y) or high-tech goods of specification i (x_i, with $i = 1....n$; the number of products n is constant). Consumers have Cobb-Douglas preferences over both categories and spend a fraction $1-\sigma$ of their income on traditional goods. There is only one factor of production, labour. Productivity in the traditional sector is constant and is set at unity for convenience. In contrast, labour productivity in producing high-tech goods (denoted by h) can be increased by spending on R&D. Expenditure on R&D is an investment, which could be modelled in a world of perfect foresight by standard optimization techniques. Here we take a short-cut by assuming that there is a fixed ratio between labour allocated to production and to R&D in each high-tech sector. Although this approach may seem rigid, it may be more realistic in a world of uncertainty and unpredictability. Preferences for high-tech goods are of the Dixit-Stiglitz type. Accordingly, each good i has its own niche and monopolistic competition between firms within and across national borders leaves each producer with a monopoly profit to cover R&D expenses and other fixed costs.

Countries are symmetric[1] apart from two exceptions. First, the developing economy (or the South, labeled country 2) has a substantial lower labour productivity in the high-tech sector compared with the developed economy (or the North, country 1). This type of backwardness is simply inherited from the past. Second, conditions have changed in a favourable way and country 2 is able to assimilate knowledge from the richer economy. This catch-up process by the developing economy is the only spillover effect in the model. Apart from this, each firm in the high-tech sector learns from its own past experience in performing R&D activities. Knowledge in each firm is completely tacit and therefore not public except for the one-sided spillover from the rich to the poor. Because all firms build upon accumulated knowledge, the model generates (endogenous) growth. It may converge to a steady state eventually, as catching-up is self-defeating and comes to a stop once both countries have the same productivity in producing high-tech goods. In a steady state growth pattern the traditional sector benefits from the dynamism in the high-tech sector by improving its terms of trade.

Production of traditional commodities follows from:

$$y = L_y \tag{2.1}$$

where L_y denotes the amount of labour allocated to the traditional sector. Time subscripts are omitted where this does not lead to confusion. If the equations for both countries are similar we present only one equation. Under the assumption of perfect competition, the price of these goods equals labour cost:

$$p_y = w \tag{2.2}$$

where w denotes the wage rate.

There are n firms in the high-tech sector of each country producing $2n$ varieties altogether. Denoting labour productivity in this sector by h and labour employed in production by L_x, we may write output x (measured in quality units) of variety i as:

$$x_i = h_i L_{xi} \tag{2.3}$$

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[1] Hence we assume the labour force, number of firms and fixed cost to be equal in both countries ($L^1 = L^2$, $n^1 = n^2$, and $f^1 = f^2$). In the appendix, we solve the model for asymmetry in these variables.

R&D-activity in each sub-sector i is related to the amount of labour allocated in production. Denoting labour employed in the R&D department by L_r, we have

$$L_{ri} = \beta L_{xi} \tag{2.4}$$

R&D generates an increase in labour productivity, depending on the amount of labour L_r and the level of knowledge firms have acquired in the past (h). The developing economy (country 2) may catch-up by learning from the experience in the developed economy (country 1). This spillover depends positively on the gap between the firms' productivity level and the technology frontier in the leading country (h^1). This gives rise to the following relations:

$$\begin{aligned} \dot{h}^1 &= \xi^1 h^1 L_r^1 \\ \dot{h}^2 &= \xi^2 h^2 L_r^2 \left(\frac{h^1}{h^2}\right)^{\alpha} \end{aligned} \tag{2.5}$$

where a dot over a variable indicates the time derivative. The parameter α measures the strenght of the spillover effect. It captures the institutional factors that determine the capacity to exploit knowledge spillovers.

As observed above, consumers spend a fraction $1\text{-}\sigma$ of their income on traditional goods and a fraction σ on high-tech goods. Equilibrium in the markets for traditional goods requires that the amount spent in the world economy on these goods must be equal to the value of traditional goods produced in the world as a whole. A similar relation holds for high-tech goods: the value spent must equal the value of production. Assuming symmetry with respect to the varieties of the high-tech sector in each country separately, we may write:

$$\frac{1-\sigma}{\sigma} = \frac{y^1 p_y^1 + y^2 p_y^2}{n^1 x^1 p^1 + n^2 x^2 p^2} \tag{2.6}$$

where p denotes the price of high-tech goods. Preferences are uniform across countries. Preferences over varieties are given by a CES function with an elasticity of substitution equal to $\varepsilon > 1$. As a result, demand for any variety of country 1 relative to demand for any variety of country 2 depends on the relative price of these varieties according to the formula:

$$\frac{x^1}{x^2} = \left(\frac{p^1}{p^2}\right)^{-\varepsilon} \tag{2.7}$$

Each firm faces a demand curve for its product with an own price elasticity equal to ε. We assume that n is sufficiently large so that profit-maximizing firms compete monopolistically. Accordingly, they set a mark-up on labour cost:

$$p = \frac{\varepsilon}{\varepsilon - 1} \frac{w}{h} \tag{2.8}$$

Labour market equilibrium implies that exogenous labour supply L equals labour demand. To complete the picture, it is assumed that firms in the high-tech sector incur fixed labour cost (f) of a traditional type. Equilibrium in the labour market then requires:

$$L_y + n(L_x + L_r + f) = L \tag{2.9}$$

Equations (2.1)-(2.4) and (2.6)-(2.9) determine temporary equilibrium by solving for the variables[2] y, L_y, x, L_x, L_r, p/w, p_y/w, and p^1/p^2, given labour productivity h which is predetermined by R&D activities in the past. Equation (2.5) then provides the dynamic part of the model, by determining how productivity evolves over time.

Since the product varieties produced in the high-tech sector in different countries are imperfect substitutes, consumers demand all varieties that originate from both countries, even if one country supplies varieties at a lower price. In contrast, traditional goods are perfect substitutes. Hence, only if the production cost for traditional goods is equal across countries, both countries will produce these goods. Otherwise, total production of traditional goods is located in the country with lowest price. As a result, two regimes are possible, characterized formally by:

$$\begin{aligned} &y^i \geq 0 \text{ and } y^j > 0 \quad \text{iff } p_y^i = p_y^j, \qquad i,j \in \{1,2\},\ i \neq j \qquad \text{(Equal wage regime)} \\ &y^i = L_y^i = 0 \qquad \text{iff } p_y^i > p_y^j, \qquad i,j \in \{1,2\},\ i \neq j \qquad \text{(Specialization regime)} \end{aligned} \tag{2.10}$$

In the next section we start with a static or temporary equilibrium solution for given h^1 and h^2 in case both countries are producing the traditional good. The solution with one country specializing in the production of traditional goods will be discussed subsequently.

3. Temporary equilibrium solutions and comparative statics

3.1. Equal wage regime

If traditional goods are produced in both regions, we have $p_y^1 = p_y^2 = p_y$. As appears from equation (2.2), this implies equality of wages $w^1 = w^2$. Taking account of wage equalization, substitution of equations (2.1), (2.2), (2.3), and (2.8) into (2.6) results after some manipulation in:

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[2] Note that there is one set of equations for each country, which results in 16 equations, solving the variables mentioned for each country. In fact only 15 variables need to be solved, since p^1/p^2 applies to both countries. Indeed, by Walras' law, one equation is redundant.

$$\left[L_y^1 + L_y^2\right] = \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)n\left[L_x^1 + L_x^2\right] \tag{3.1}$$

Adding the labour market equilibrium relations (2.9) for both countries and substituting (2.4), gives the aggregate resource constraint:

$$\left[L_y^1 + L_y^2\right] = 2(L-nf) - (1+\beta)n\left[L_x^1 + L_x^2\right] \tag{3.2}$$

Equations (3.1) and (3.2) determine worldwide allocation of labour over both sectors, characterized by $[L_y^1+L_y^2]$ and $[L_x^1+L_x^2]$. To find how the labour allocation of each country separately is related to worldwide allocation, we substitute (2.3) and (2.8) into (2.7), taking into account wage equalization, and rewrite the result in the following ways:

$$\left[L_x^1 + L_x^2\right] = \left(d^{\varepsilon-1}+1\right) L_x^1 \tag{3.3}$$

$$\left[L_x^1 + L_x^2\right] = \left(d^{-(\varepsilon-1)}+1\right) L_x^2 \tag{3.4}$$

where $d \equiv h^2/h^1$ denotes the productivity ratio in the high-tech sector.

Figure 1 characterizes this short-run equilibrium. The first quadrant depicts (3.1) and (3.2). The point of intersection S determines worldwide allocation of labour. The fourth quadrant depicts (3.3) and (3.4) to determine L_x^1 and L_x^2 respectively. Finally, the third quadrant shows the (uniform) labour market constraint (2.9) to determine L_y^1 and L_y^2.

Figure 1

Country 2 (the South) has low productivity ($d<1$). This implies that (3.3) lies below (3.4) so that $L_x^1 > L_x^2$ and $L_y^1 < L_y^2$. The higher productivity allows country 1 to produce high-tech goods at lower cost. It has a comparative advantage in high-tech goods and specializes relatively in these goods.

A shift in preferences towards high-tech goods, i.e. a rise in σ, rotates the curve for equation (3.1) to the right. Worldwide production shifts away from traditional goods towards high-tech goods. Both countries expand national production in this sector and withdraw labour from traditional production. If the preference shift is so large that (3.1) rotates to point Q, country 1 locates its total labour force L in the high-tech sector. At this point there is a regime switch in the specialization pattern.

A similar result may be obtained in case the relative productivity level in the high-tech sector changes in favour of country 1 (i.e. d declines). This change makes the line corresponding to (3.3) steeper and that to (3.4) flatter so that both lines diverge more. The productivity change increases the comparative advantage of country 1 and increases its degree of specialization in high-tech goods.

3.2 The partial specialization regime

The regime of partial specialization applies when traditional goods are produced in country 2 (the South) exclusively and country 1 (the North) produces high-tech goods only.[3] The relative price of goods is then determined by supply and demand. Substituting of eqs. (2.1) - (2.3), and (2.8) in (2.6), taking account of $y^1 = L_y^1 = 0$, and eliminating L_x using (2.3), (2.4), (2.7), and (2.9) for country 1, we find the semi-reduced demand equation:

$$L_y^2 = \frac{1-\sigma}{\sigma}\,\frac{\varepsilon}{\varepsilon-1}\,\frac{L-nf}{1+\beta}\left[\omega^{-1}+\omega^{-\varepsilon}d^{\varepsilon-1}\right], \tag{3.5}$$

where $\omega \equiv w^2/w^1$ denotes relative wages. Substitution of eqs. (2.3), (2.4), and (2.7) in the labour market equilibrium relation for country 2, eq. (2.9), results in the semi-reduced supply equation:

$$L_y^2 = (L-nf)\left[1-\omega^{-\varepsilon}d^{\varepsilon-1}\right]. \tag{3.6}$$

The equilibrium solution for relative wages and traditional sector employment is at the intersection of both curves as illustrated in Figure 2.

Figure 2

With the employment in the traditional goods sector determined, it is straightforward to find the amount of labour allocated in the high-tech sector L_x^2 as shown in the lower panel of Figure 2. The regime of partial specialization requires $\omega \equiv w^2/w^1 < 1$. A shift in preferences towards the traditional good, i.e. a fall in σ, shifts the demand curve (3.5) in an upward direction. The relative price of traditional goods rises and these goods need to be produced in both economies if the preference shift is large. Such a regime switch obtaines when supply and demand intersect at point *S'* in Figure 2. A similar result holds in case of catching-up. In particular, a rise in *d* shift both curves upward and the relative wage rises. Intuitively, country 1 looses some of its comparative advantage in high-tech goods so that its share in world-wide production of these goods falls. Worldwide, consumers devote a larger fraction of their high-tech expenditures on high-tech goods originating from country 2 so that relative (wage) income in this country rises.

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[3] The static equilibrium in case traditional goods are produced in country 1 exclusively ($L_y^2=0$) is symmetric to the case discussed. Note from figure 1 (and our discussion of a change in *d*) that the former case arises only if $d>1$. Hence, this case is not of interest, since we focus on the situation in which country 2 has lower productivity so that it faces catch-up opportunities, i.e. $d<1$.

3.3 Linking the two regimes

The productivity gap d determines which regime applies. If productivity levels differ substantially (i.e. d sufficiently small, say $d<d^*<1$) country 1 specializes in high-tech goods. If productivity differences narrow through a process of catching up (i.e. d rises so that $d^*<d<1$), the equal wage regime becomes relevant. If the catch-up process is completed (i.e. $d=1$), productivity differences are removed completely, and the structure of both economies is uniform. The positive relation between the catch-up variable d and the wage ratio ω in case of specialization can be found by equating eqs. (3.5) and (3.6). Within the equal wage regime, $\omega=1$ irrespective of the value of d. Hence, over the entire range $0<d<1$ where catch-up for the South is relevant, ω and d are related in general equilibrium according to:

$$d = \omega \left[\frac{\omega - \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1}{1+\beta}\right)}{1 + \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1}{1+\beta}\right)} \right]^{\frac{1}{\varepsilon-1}} \quad \text{for } 0<d\leq d^*$$

$$\text{(GE)} \qquad (3.7)$$

$$\omega = 1 \quad \text{for } d^*<d\leq 1$$

where d^* is the switching point between the two regimes. We can express d^* in terms of the parameters ε, σ, and β, by substituting $\omega = 1$ in the first equation in (3.7).
Figure 3a presents (3.7) as the general equilibrium (GE) locus. The allocation of labour in both countries is presented for $d \leq 1$ in Figure 3b with respect to the high-tech sector (L_x) and in Figure 3c with respect to the traditional sector (L_y)[4].

Figure 3

As long as the developed country produces high-tech goods only (i.e. when the specialization regime applies, $d<d^*$), there is no intersectoral reallocation in the developed economy, but labour moves away from the y-sector towards the x-sector in the developing country when that country catches up. The low productivity country improves its position on the world market for high-tech goods. At the same time, the position of the high productivity country on this market declines relatively. It can only maintain its high-tech production levels and employment by accepting a decline in wages relative to the low productivity country ($\omega \equiv w^2/w^1$ rises) so that wage cost decline.[5]

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[4] The analytical expressions for labour allocation in the equal wage regime follow in a straightforward way from (3.1)-(3.4). Equations (3.4), (3.5), (2.9) and the condition $L_y^1=0$ yield labour allocation in the specialization regime.

[5] Due to this change in relative wages, the world price index for high-tech goods declines relative to the price for traditional goods (which equals w^2), which explains the fall in world consumption and production of traditional goods (L_y^2 falls and $L_y^1=0$).

In the equal wage regime (where $d>d^*$), labour moves out of the high-tech sector into the traditional sector in the developed economy when this country looses comparative advantage in high-tech goods production. The reason is that it cannot any longer reduce wages relative to the low productivity country to maintain high-tech employment, since its wages are already as low as in the low productivity country. Lower wages would result in a reversal of the specialization pattern with the high productivity country producing for total world traditional goods demand. In the catching-up country, intersectoral labour reallocation away from the traditional sector occurs at a faster rate than in the specialization regime. This is possible because the developed country takes over a larger and larger part of world production of traditional goods.

The main question is of course whether there will be catching-up starting from an initial position with $d < 1$. To answer this question we now turn to the dynamics of the model.

4. To be or not to be: convergence or divergence

Firms in the high-tech sector apply resources to produce new technologies for the production of differentiated goods. The amount of labour in R&D is related to direct productive labour according to (2.4). Substituting this equation in (2.5), we can write the growth rate of labour productivity in the high-tech sector of country 1 as:

$$\dot{h}^1/h^1 = \xi\beta L_x^1. \tag{4.1}$$

The developing country can attain a higher rate of growth per unit of labour employed in R&D activities, because of technological spillover effects across countries as appears from (2.5):

$$\dot{h}^2/h^2 = \xi\beta L_x^2 d^{-\alpha}. \tag{4.2}$$

The relative change in the catch-up factor d can be written as $\dot{d}/d = \dot{h}^2/h^2 - \dot{h}^1/h^1$. Subtracting equation (4.1) from equation (4.2), and taking account of equations (2.3), (2.7) and (2.8), we arrive at:

$$\dot{d}/d = \xi\beta L_x^1 \left[\omega^{-\varepsilon} d^{\varepsilon-1-\alpha} - 1\right]. \tag{4.3}$$

The associated $\dot{d}=0$ locus is given by:

$$d = \omega^{\varepsilon/(\varepsilon-1-\alpha)}, \qquad (\dot{d}=0) \tag{4.4}$$

For $\alpha > \varepsilon$-1, the differential equation (4.3) is stable and the $\dot{d}=0$ locus (4.4) is downward sloping. This is illustrated in Figure 4a where the general equilibrium (GE) curve (3.7) is confronted to the $\dot{d}=0$ locus (4.4). The small arrows indicate the qualitative law of motion for the productivity gap variable *d*. Starting from an initial position d_0 and ω_0 the system moves along the general equilibrium locus towards the steady state where the GE locus and the $\dot{d}=0$ locus intersect, i.e. the point d = 1, ω = 1.

Figure 4a

Figure 4b

The country with lower productivity (the South) employes a smaller amount of labour in high-tech goods and performs less R&D activities than the high productivity country. However, it benefits from a higher productivity of R&D activities because of the technology spillover associated with the productivity gap. Under the condition ε-1<α, the latter effect of lagging behind in productivity outweighs the former effect so that productivity growth in the low productivity country is higher than in the high productivity country. Consequently, productivity and wage levels converge over time. In particular, the developing economy can assimilate easily advanced techniques from the developed country as indicated by a relative high value for α. Moreover, the product varieties supplied by the developing country differ substantially from that from the developed country, as indicated by a relatively low value for the substitution elasticity ε. Hence, despite the lower productivity and higher prices compared to the developed country, the developing country can compete relatively easily on the world market for high-tech goods. Products from the South have their own niche providing sufficient revenues to catch up. Productivity growth in the developed country (the North) is constant until the point d = d^* is attained[6]. Thereafter, growth in the North declines as an increasing amount of labour has to be used in the traditional sector.

The situation differs dramatically if ε-1>α. Under this condition the differential equation (4.3) is unstable and the economies may diverge completely as shown in Figure 5a. The $\dot{d}=0$ curve slopes positively and intersects the general equilibrium locus again at the points ω = 1, d = 1. The small arrows indicate the law of motion for *d*. Starting from an initial position d = d_0 the developing economy falls steadily behind the developed economy. There is divergence all the way to the bottom as *d* approaches zero. However with both curves sloping upward there is the possibility of multiple intersections as shown in Figure 5b. At point *S* there is a stable equilibrium. An initial situation in the region $\underline{d} < d_0 < 1$ leads to a long-run solution at point *S* in Figure 5b. For values of the catch-up variable which are not too low, partial convergence to the level $d=\bar{d}$ is possible. Which situation obtains depends upon the relative values of the elasticity of substitution ε

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[6] Growth in country 1 is a constant ($\xi\beta$) times L_x^1, see (4.1). Hence, the relation between L_x^1 and *d* presented in Figure 3b also indicates how $\dot{h}^1/h^1$ changes during the catch-up process.

and the catching-up elasticity α. Divergence (as illustrated in Figure 5a) is inevitable for $(\varepsilon - 1) >> \alpha$, but partial convergence (as in Figure 5b) may be the outcome for $(\varepsilon - 1) > \alpha$.

Figure 5a

Figure 5b

Under the condition ε-1$>\alpha$, competition on the world market for high-tech goods is relatively tough (i.e. ε large). As a consequence, a small productivity gap implies a large difference in market shares. The low productivity country has a relatively small fraction of its labour force employed in high-tech production and R&D. If the differences in R&D intensity are not offset by large differences in R&D productivity across countries due to low technology spillovers (i.e. α small), productivity growth in the North is higher than in the South, and world-wide productivity levels diverge.

However, Figure 5b shows that divergence may not be necessary if the initial productivity gap is not too large (i.e. if $d_0 > \underline{d}$) and if ε-1 exceeds α not too much. In that case, there is partial convergence towards the stable equilibrium *S*. In this long-run equilibrium, Southern firms allocate less labour in the R&D department than Northern firms, but the difference is exactly matched by the knowledge spill-over so that productivity growth in both regios is equal. In moving from d_0 to $\bar{d}$ in figure 5b, the rise in relative wages (ω) is moderate so that Southern firms can compete succesfully with Northern firms. Beyond $\bar{d}$ relative wages are high and Southern firms loose too much ground to maintain sufficiently large expenditures on R&D.

Profits and strategic considerations

It should be noted that profitability in the high-tech sector in the North may be relatively high initially. Production cost are lower than in the high-tech sector of the South and the number of firms (and traditional fixed costs) are assumed to be equal. This may give rise to some form of strategic behaviour on the part of Northern firms in case of convergence. Firms in the North could increase their R&D efforts relative to firms in the South to block full convergence. With $\beta^1 \neq \beta^2$ the $\dot{d}=0$ curve and the GE locus for the specialization regime read respectively (see appendix):

$$d = \left(\frac{\beta^1}{\beta^2}\right)^{1/(\varepsilon-1-\alpha)} \omega^{\varepsilon/(\varepsilon-1-\alpha)}, \qquad (\dot{d}=0) \qquad (4.5)$$

$$d = \omega \left(\frac{\left(\frac{1+\beta^1}{1+\beta^2}\right)\omega - \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1}{1+\beta^2}\right)}{1 + \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1}{1+\beta^2}\right)} \right)^{\frac{1}{\varepsilon-1}}. \qquad \text{(GE for } \omega<1) \qquad (4.6)$$

Assuming $\beta^1 > \beta^2$ and $\varepsilon\text{-}1 < \alpha$ leads to a downward shift of the $\dot{d}=0$ curve and GE locus compared with the situation presented in Figure 4a. For a sufficient high relative value of β^1 convergence may be attained in the specialization regime as shown in Figure 4b. Convergence comes to a halt before the developed economy is forced into the production of traditional goods. In the steady state equilibrium (point S in Figure 4b) the rate of productivity growth will be higher in both countries. More labour is allocated to R&D in the developed economy, whereas the developing economy keeps catching-up at a constant rate in the long-run equilibrium to compensate for a lower R&D effort.

It remains to be seen whether this strategy is profitable from the vantage point of Northern firms. Higher R&D efforts mean higher cost which have to be recouped by increased sales some time in the future. Whether this is possible depends on the parameters of the model. The numerical exercise[7] presented in Figure 6 sheds some light on this issue.

Figure 6

In figure 6 we show the time paths of real profits of high-tech firms in the developed economy for a situation with equal research efforts ($\beta^1 = \beta^2$), corresponding to the path of convergence in Figure 4a, and a situation with $\beta^1 > \beta^2$, corresponding to the path of convergence in Figure 4b.[8] In both cases profits rise over time due to the productivity growth. In case of equal research efforts ($\beta^1 = \beta^2$), the growth rate of real profits in the North slows down when a regime switch occurs at $t = t_1$ and the country starts production of traditional goods. For $t > t_1$, labour is gradually pulled out of the production of high-tech goods. The volume of production of x-goods declines and growth in real profits falls. In contrast, there is no regime switch in case $\beta^1 > \beta^2$. Therefore the high growth rate of profits can be maintained all the way in the latter case. However, profits start at a lower level since R&D expenditures are higher and it takes some time to overtake the other path. At the point $t = t_2$ profits on both paths are equal. Thereafter profits on the high R&D path exceed those on the equal R&D effort trajectory. The decision to raise R&D depends of course on the discount rate which is not specified in the model. For sufficient low values of the interest rate it may be worthwhile for high-tech firms in the developed economy to embark on an agressive R&D strategy.

[7] The exercise is based on the following values: $L^1 = L^2 = 5000$, $f^1 = f^2 = 20$, $n^1 = n^2 = 40$, $\xi^1 = \xi^2 = 0.0025$, $\sigma = 0.9$, $\varepsilon = 3$, $\alpha = 3$, $d(0) = 0.8$. In case of equal research efforts $\beta^1 = \beta^2 = 0.05$, in the asymmetric case, $\beta^1 = 0.06$ and $\beta^2 = 0.05$.

[8] Profits are deflated by the consumers price index.

5. Evaluation

As Romer (1993) argues, it can be stated that developing economies are poor because they suffer from an idea gap. Producers in these countries do not have access to the ideas that are applied in developed economies. Bridging the gap may be a matter of organizing the economy in a way that facilitates learning. Investment in physical infrastructure and education along with the maintaining of property rights may set the stage for catching-up. Foreign direct investment with important spillover effects on the domestic economy may accelerate the process. The factors are condensed in the catch-up parameter α.

However, as our analysis shows, toughness of competition is another important aspect of the convergence issue. If competition is mild, developing nations may easily find a niche for their products even if the quality leaves something to be desired. In a world with tough competition the engine of learning may be too weak to compensate for the lead in R&D performance in the industrialized world. Competition in our model is related to the elasticity of substitution between differentiated products ε. In reality there are other factors of importance like for instance entry or exit of firms and strategic behaviour of entrepreneurs. The latter issue was touched upon in considering the consequences of a higher R&D effort in developed countries to block a complete catching-up by developing nations.

The economic consequences of catching-up for the developed countries differ according to the specialization regime. As long as developing nations are partially specialized in the production of traditional goods, wages in the rich countries decline relative to wages in the poor countries. In the equal wage regime, labour has to be relocated in the developed economies from the high-tech sector towards the traditional sector. If labour markets are rigid, such structural changes may cause adjustment problems and unemployment.

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Appendix

This appendix solves the model allowing for differences in β, n, L, and f across countries.
Substitution of (2.3) and (2.8) into (2.7) yields:

$$L_x^2 = L_x^1\left[\omega^{-\varepsilon} d^{\varepsilon-1}\right] \tag{A.1}$$

Adding the labour market constraints (2.9) for both countries and substituting (2.4) we find the world labour market constraint [the counterpart of equation (3.2)]:

$$\left[L_y^1 + L_y^2\right] = \left[L^1 + L^2 - n^1 f^2 - n^2 f^2\right] - (1+\beta^1) n^1 L_x^1 - (1+\beta^2) n^2 L_x^2 \tag{A.2}$$

In the equal wage regime, $w^1 = w^2$ and $L_y^1 \geq 0$, $L_y^2 > 0$. Substitution of (2.1), (2.2), (2.3) and (2.8) into (2.6) yields the counterpart of (3.1):

$$\left[L_y^1 + L_y^2\right] = \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left[n^1 L_x^1 + n^2 L_x^2\right] \tag{A.3}$$

Equations (A.1), (A.2), (A.3), (2.9), and the condition $\omega \equiv w^2/w^1 = 1$ solve the allocation of labour (variables L_y^1, L_x^1, L_y^2, L_x^2) in the equal wage regime. Note that under asymmetry the worldwide intersectoral allocation of labour cannot be separated from the country-specific sectoral allocation as we did in Figure 1.
In the specialization regime, $L_y^1 = 0$ and $\omega \equiv w^2/w^1 < 1$. Substitution of (2.1), (2.2), (2.3) and (2.8) into (2.6) yields:

$$L_y^2 = \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left[n^1 L_x^1 \omega^{-1} + n^2 L_x^2\right] \tag{A.4}$$

High-tech employment in country 1 follows from (2.4) and (2.9) with $L_y^1 = 0$:

$$L_x^1 = \frac{L^1 - n^1 f^1}{n^1 (1+\beta^1)} \tag{A.5}$$

Substitution of (A.1) and (A.5) into (A.4) yields the counterpart of (3.5):

$$L_y^2 = \frac{1-\sigma}{\sigma}\,\frac{\varepsilon}{\varepsilon-1}\,\frac{L^1 - n^1 f^1}{1+\beta^1}\left[\omega^{-1} + \left(\frac{n^2}{n^1}\right)\omega^{-\varepsilon} d^{\varepsilon-1}\right] \tag{A.6}$$

Substitution of (A.1), (A.5) and (2.4) into (2.9) yields the counterpart of (3.6):

$$L_y^2 = (L^2 - n^2 f^2) - (L^1 - n^1 f^1)\,\frac{1+\beta^2}{1+\beta^1}\,\frac{n^2}{n^1}\,\omega^{-\varepsilon} d^{\varepsilon-1} \tag{A.7}$$

Equating (A.6) and (A.7), we find the GE locus for the specialization regime:

$$d = \omega\left(\frac{\left(\frac{L^2 - n^2 f^2}{L^1 - n^1 f^1}\right)\left(\frac{1+\beta^1}{1+\beta^2}\right)\omega - \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1}{1+\beta^2}\right)}{1 + \left(\frac{1-\sigma}{\sigma}\right)\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1}{1+\beta^2}\right)}\left(\frac{n^1}{n^2}\right)\right)^{\frac{1}{\varepsilon-1}} \quad \text{for } \omega < 1$$

We arrive at (4.6) by setting $n^1 = n^2$, $f^1 = f^2$, and $L^1 = L^2$.

Figures

Figure 1: equal wage regime

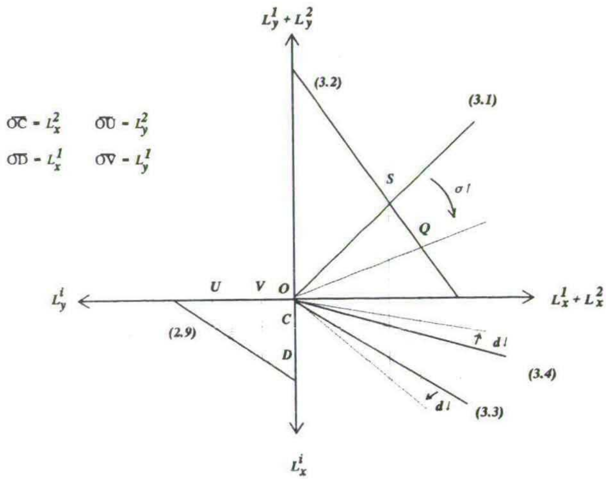


Figure 2: partial specialization regime

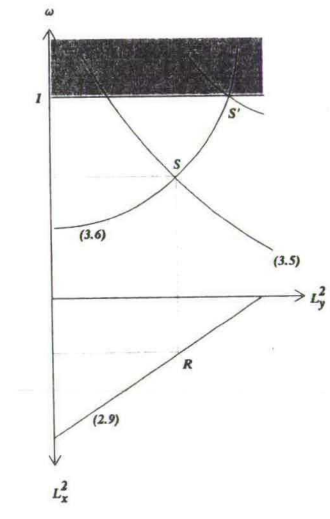


Figure 3: relative wages and labour allocation

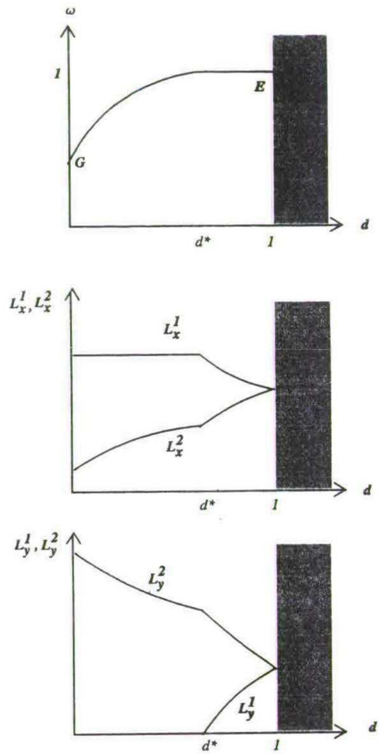


Figure 4: large international spillovers

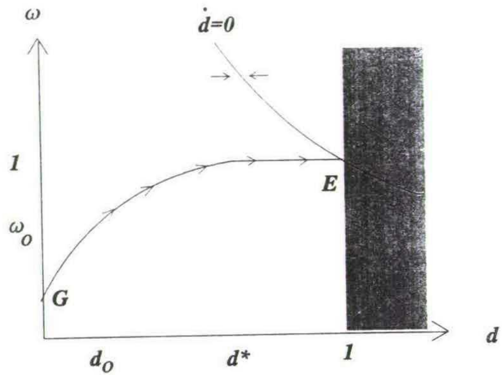


Fig. 4a: $\alpha > \varepsilon - 1$

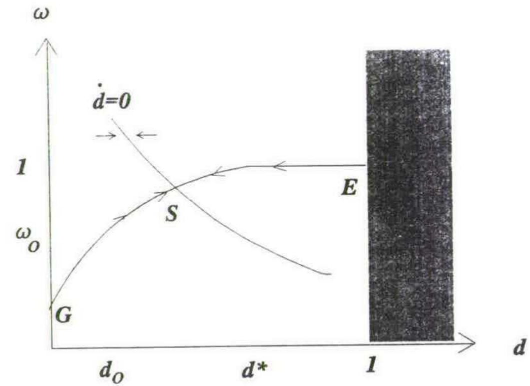


Fig. 4b: $\alpha > \varepsilon - 1$, $\beta^1 > \beta^2$

Figure 5: tough competition

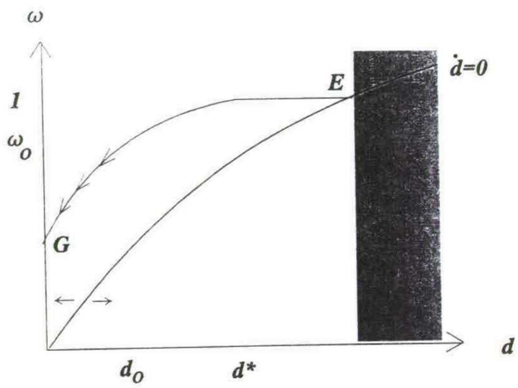


Fig. 5a: α<<ε−1

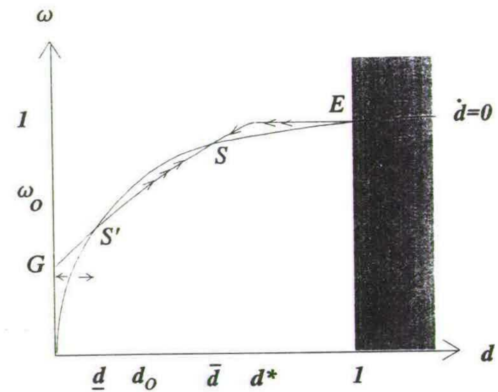
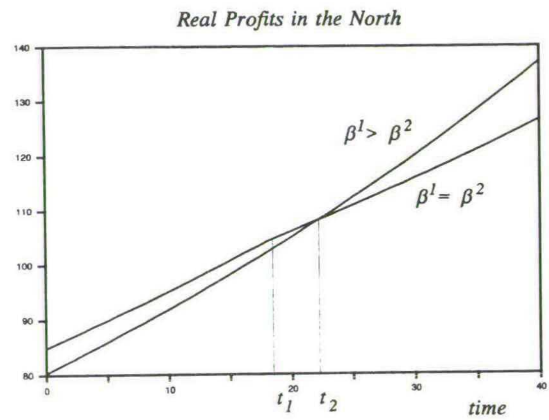


Fig. 5b: α<ε−1

Figure 6: blocking convergence



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