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Globalisation, co-operation costs, and wage inequalities

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1. Introduction[1]

The debate about the effects of globalisation on wage inequalities has focused on trade, and particularly on whether falling barriers to trade have increased inequality within developed countries and reduced inequality between developed and developing countries (e.g. Leamer, 1993; Wood, 1994; Lawrence, 1996; Cline, 1998). The possible effects on wage inequalities of other globalisation mechanisms, such as capital flows, migration and knowledge spillovers, have not been overlooked (e.g. Feenstra and Hanson, 1995; Sachs and Warner, 1995; Borjas, Freeman and Katz, 1997), but it is trade that has received most of the attention.

In this paper we examine a crucial but neglected non-trade globalisation mechanism, namely the dramatic decline in the cost of international business travel and communication, which has made it much easier for highly-skilled workers who live in developed countries to co-operate in production with less-skilled workers in developing countries, through a mixture of frequent short visits and telecommunication. Our summary label for this mechanism is reduction of 'co-operation costs', in contrast to the reduction of trade barriers or 'transport costs' on which most analyses of globalisation have focused. We suspect that the effects of falling co-operation costs on wage inequalities have been at least as large as those of falling transport costs. The rapid growth in the volume of travel and communications is common knowledge, as is the steep rise in the earnings of internationally mobile business people, but these features of reality have not been subjected to much economic analysis.[2]

We put forward a theoretical model, along the following lines. The concentration in developed countries (the North) of highly-skilled workers enables the North to produce better-quality goods than developing countries (the South), as a result of which less-skilled Northern workers earn more than less-skilled Southern workers. Falling co-operation costs make it economic to move part of the production of high-quality goods to the South: this raises the wages of highly-skilled Northern workers, by widening the market for their services, and of Southern workers, by widening the range of goods they produce, but it lowers the wages of less-skilled Northern workers, by eroding their

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[2] However, closely related ideas have been explored by Rosen (1981), Frank and Cook (1995) and much earlier, as Rosen points out, by Marshall, who wrote of the increase in income inequality caused by "the development of new facilities for communication, by which men ... are enabled to apply their constructive or speculative genius to undertakings ... extending over a wider area than ever before" (1920, book VI, ch. XII, § 11).

privileged access to production with highly-skilled workers. Inequality between Southern and Northern less-skilled workers thus declines, but inequality in the North between highly-skilled and less-skilled workers rises.

This mechanism is of course related in various ways to other aspects of globalisation, including trade. In particular, falling travel and communications costs have facilitated the growth of trade as well as of co-operative production, and the two activities can be combined, with the output of co-operative production in the South often being exported to the North. However, the two mechanisms are analytically distinct, and can operate separately in practice. Thus reduction of transport costs has increased exports from the South of goods which are not produced co-operatively, and there are goods and services which are produced co-operatively for consumption in the South and not exported to the North.

Our mechanism is also related to direct foreign investment, particularly insofar as this involves the provision not of finance but of expertise (or 'knowledge-intensive producer services' – Markusen, 1997). Transnational companies are channels through which highly-skilled Northern workers contribute their services to production activities in the South, and the spread and increasing sophistication of such companies is both a cause and a consequence of falling co-operation costs. But co-operation and direct foreign investment are far from fully overlapping. Much direct foreign investment in developing countries is aimed at natural resources, rather than at labour. More importantly, much co-operation of highly-skilled Northern workers in Southern production occurs through channels other than ownership: many Northern importers provide their Southern suppliers with assistance in production and packaging, as well as in design and marketing; while Southern firms, including those supplying Southern markets, can and do purchase the services of Northern experts.

Our 'highly-skilled' workers are a small group – managers, entrepreneurs, designers, engineers and other top business professionals – and their skills are not the usual sort of human capital, acquired by purposive investment in education and training. Most of them are well-educated, but the value of their services stems mainly from their creativity, experience and connections, acquired fortuitously from their genes, families and careers. Their skills are thus scarce, and the high wages they command are better thought of as a rent than as a return to investment. Nor do these skills contribute to production in the way that human capital is usually modelled as doing, which is just by adding to the quantity of output: highly-skilled workers do help to raise the volume (and lower the cost) of production, but their principal contribution is to improve the quality of output, by making it possible to produce new and better goods and services.

There is in principle a clear distinction between migration, which involves permanent or long-term relocation of residence, and the intermittent and usually brief visits which (with telecommunication) enable highly-skilled workers to co-operate in production in the South while continuing to reside in the North, although in practice the dividing line is somewhat arbitrary. Expatriate employment of Northern workers in Southern countries, which falls on the 'migration' side of the line, is a related phenomenon of long standing but generally small scale, because of the high cost to employers of compensating workers and their families for the loss of Northern amenities, which is avoided in the case of co-operation by maintenance of Northern residence. Co-operation also avoids another cost of long-term expatriate employment, which is that the skills and knowledge of the workers concerned tend to atrophy and become obsolete as a result of reduced contact with other skilled workers.

Co-operation has costs, however: it is not factor mobility as usually modelled, with the price of the factor equalised in all countries. Improvements in transport, communications, institutions and policies have much reduced the costs of co-operation, but they remain substantial, and have to be considered explicitly in analysing its economic effects. The direct costs of travel (air fares and hotel bills) are dwarfed by the opportunity costs of time wasted both while travelling and while working in the South (for example, waiting for appointments, and doing things which would be delegated to a secretary at home). Similarly, insofar as the co-operation is by telecommunication rather than by travel, the main cost is not the bills for phone calls, faxes and e-mail messages, but the additional time involved in distance-work, as compared with doing the same thing on the spot. For all these reasons, the services of highly-skilled workers cost much more in the South than in the North: what makes it worthwhile to employ them in the South is that the other sorts of labour with which these workers co-operate cost much less there.

Section 2 of this paper sets out our model of the determination of relative wages at a given level of co-operation costs. Section 3 analyses the effects of falling co-operation costs on wage inequalities. Section 4 compares the effects of falling transport costs with those of falling co-operation costs. Section 5 concludes.

2. Equilibrium with given co-operation costs

There are two countries, North (N) and South (S), and two skill categories of workers, both in fixed supply: highly-skilled workers, whose number is denoted by K (for know-how); and other workers, whose number is denoted by L (for labour). L-workers are divided in fixed proportions between the North and the South,

$$L = L_N + L_S \, , \tag{1}$$

and can work only in the countries where they live. All K-workers live (and consume) in the North, but can and do work both in the North and in the South, so that

$$K = K_N + K_S \, , \tag{2}$$

However, K-work in the South entails co-operation costs, consisting simply of wasted K-worker time, which is a fraction, t ($\geq$ 0), of effective working time (the 'iceberg' principle), so that the effective supply of K-work to the South is only $K_S/(1+t)$.In this section, we treat the value of t (which stands for travel and telecommunication) as a parameter.

There are two goods, a high-quality one (labelled A for advanced) and a low-quality one (labelled B for backward), where 'quality' may be a matter of the newness of the good, or of other attributes such as reliability, performance, appearance and after-sales service, or of the effects of advertising on consumers' perceptions of these attributes. Production of the B-good requires only L-workers, with a technology such that one unit of L-work produces one unit of B-output. Production of the A-good requires K-workers as well as L-workers, with a standard constant-returns-to-scale technology, which it will be convenient to express in the form $Q = Lf(k)$, where $f(k)$ is output per L-worker, k is the highly-skilled/other worker ratio, K/L, and $f' > 0, f'' < 0$. Transport costs are assumed for the time being to be zero, so that the prices of the two goods, p_A and p_B, are the same in both countries.

In the type of equilibrium on which we will focus, the North is completely specialised in production of the A-good, but the South produces both the A-good and the B-good. World output of the B-good, with its labour-only production technology, is thus simply

$$Q_B = L_S - L_{AS} \, , \tag{3}$$

where L_{AS} is the part of the Southern labour force that works in the A-sector. World output of the A-good is

$$Q_A = L_N f(k_N) + L_{AS} f(k_S) \tag{4}$$

where $k_N = K_N/L_N$ and $k_S = K_S/(1+t)L_{AS}$. (Co-operation costs may thus be regarded as a factor-specific inefficiency of Southern A-production.)

Product and labour markets are assumed to be perfectly competitive, so that the wages of all categories of workers are equal to their marginal value products. The wage of highly-skilled workers, w_N^K, relative to that of other Northern workers, w_N^L, is thus

$$\frac{w_N^K}{w_N^L} = \frac{f'(k_N)}{f(k_N) - f'(k_N)k_N} \tag{5}$$

where $f'(k_N)$ is the marginal physical product of K-workers, and $f(k_N) - f'(k_N)k_N$ that of Northern L-workers (output per L-worker minus skilled-wage payments per L-worker), with the p_A's cancelled out. This wage ratio, which we assume always to be greater than unity, is decreasing in k_N (because $f'' < 0$), and hence, since L_N is given, in K_N. Greater concentration of K-work in the North, in other words, reduces wage inequality within the North by making K-workers less scarce there, relative to L-workers.

The wage of Northern L-workers relative to that of Southern L-workers, w_S^L, is also equal to the ratio of the marginal contributions of these two groups to A-production

$$\frac{w_N^L}{w_S^L} = \frac{f(k_N) - f'(k_N)k_N}{f(k_S) - f'(k_S)k_S} \tag{6}$$

which depends on the sizes of k_N and of k_S. In particular, if $k_N > k_S$, this wage ratio will be greater than unity (that is, Northern L-workers will earn more than Southern L-workers). This is always the case in the type of equilibrium on which we focus, since what causes the North to specialise in A-production is the higher wage of Northern than of Southern L-workers, which makes it unprofitable to produce the B-good in the North (the unit cost of B-output being simply the L-wage).

These two wage ratios between them imply a third, namely the wage of K-workers relative to Southern L-workers $\left(w_N^K/w_S^L = \left(w_N^K/w_N^L\right)\left(w_N^L/w_S^L\right) \right)$. Our assumptions about the other two wage ratios guarantee that $w_N^K/w_S^L > 1$, and indeed that it is the largest of the three wage inequalities. The equations governing the other wage ratios also show that this third one is related to the values of k_N and k_S in a rather subtle way.

Relative wages in our model thus depend proximately on k_N and k_S, which in turn are determined, together with two other variables (Southern employment in the A-sector, L_{AS}, and the relative goods price, p_A/p_B), by a set of four equations. The first,

$$f'(k_N) = \frac{1}{1+t} f'(k_S) \tag{7}$$

is an arbitrage condition for K-workers, whose wage in the North must in equilibrium be equal to the wage they can earn in the South, net of wasted time. The left-hand side of the equation is thus their marginal product in Northern A-production, and the right-hand side is their marginal product in Southern A-production, multiplied by $1/(1 + t)$, the productive proportion of time spent away from the North. (For example, if $t = 2$, two-thirds of the time spent away is wasted, and so the wage in the North needs to be only one-third of that earned during effective working time in the South.) The higher marginal product of K-work in the South than in the North is possible because k_S is lower than k_N, which in turn is possible because Southern L-workers are paid less than Northern L-workers. In other words, Southern A-production is economically viable because the higher cost of K-workers is offset by the lower cost of L-workers. The second equation,

$$p_A\left[f(k_S) - f'(k_S)k_S\right] = p_B \ , \tag{8}$$

is an arbitrage condition for Southern L-workers, who are mobile across sectors and so in equilibrium must earn the same wage in A-production as in B-production. The left-hand side of the equation is their marginal value product in the A-sector, the right-hand side their marginal value product in the B-sector (which is simply p_B because each unit of labour produces one unit of output). This equation can be rearranged as

$$\frac{p_A}{p_B} = \frac{1}{f(k_S) - f'(k_S)k_S} \ , \tag{8a}$$

which shows that there is a fixed, inverse, relationship between the relative price of the two goods and the value of k_S. If p_A/p_B remains constant, so must k_S, and a fall (say) in p_A/p_B would require a rise in k_S, to increase the marginal physical productivity of A-work relative to B-work (otherwise, the A-sector wage would fall below the B-sector wage, causing an exodus of workers from the A-sector). The third equation is the full-employment condition for highly-skilled labour,

$$K = K_N + K_S = L_N k_N + L_{AS} k_S (1+t) \ , \tag{2a}$$

which can be rewritten as

$$L_{AS} = \frac{K - L_N k_N}{k_S (1+t)} \ , \tag{2b}$$

to show that the size of the Southern A-sector labour force, L_{AS}, is decreasing both in k_N (a rise in which, given L_N and t, reduces the supply of K-work to the South) and in k_S (a rise in which reduces the number of Southern L-workers employed per unit of effective K-supply).

The fourth equation is the demand function. For simplicity all workers are assumed to have identical homothetic preferences (so that their relative demand for the two goods is unrelated to their incomes). Given the world (North plus South) outputs of the two goods, Q_A and Q_B, the relative price is thus determined by a simple demand function

$$\frac{p_A}{p_B} = q \left[\frac{Q_A}{Q_B} \right]^{-\frac{1}{\varepsilon}} \tag{9}$$

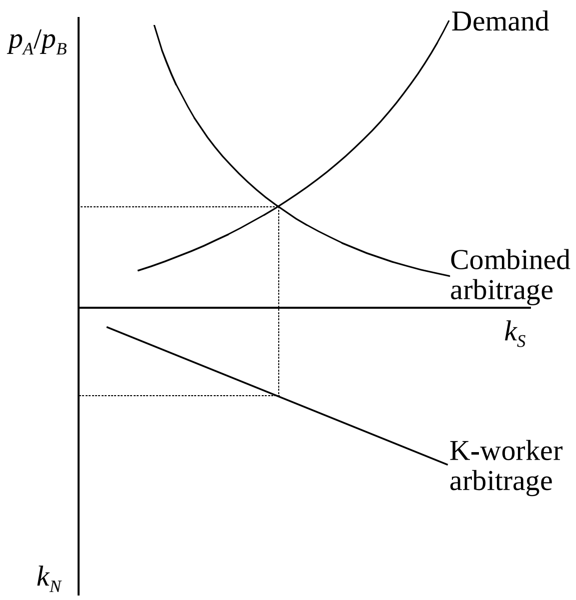
where the size of the parameter q reflects the degree of superiority of the A-good over the B-good in the eyes of consumers, and the parameter ε is a constant substitution elasticity. Replacing Q_A / Q_B with a fuller expression from equations (3) and (4), this equation becomes

$$\frac{p_A}{p_B} = q \left[\frac{L_N f(k_N) + L_{AS} f(k_S)}{L_S - L_{AS}} \right]^{-\frac{1}{\varepsilon}} \ , \tag{9a}$$

showing that the relative price depends on all three of the other variables (k_N, k_S and L_{AS}).

By substitution for k_S and L_{AS} from equations (7) and (2b), the demand function can be further transformed into a relationship between p_A / p_B and k_N alone, which is shown as an upward-sloping line in the top panel of figure 1. It has an upward slope (as is proved in the appendix) essentially because relocation of K-workers towards the North and a higher value of k_N leads to a relocation of Southern workers towards the B-sector, making the A-good scarcer and the B-good more abundant and increasing p_A/p_B.[3] The two arbitrage conditions (7) and (8) can also be combined into a relationship between p_A/p_B and k_N, which is the downward-sloping line in the top panel of the figure – its downward slope (also proved in the appendix) reflects the inverse relationship between p_A/p_B and k_S, coupled with the direct relationship between k_S and k_N. More K-workers, relative to L-workers, raises productivity of L-worker in the A-sector and requires a compensating change in the relative price since in equilibrium the marginal productivity of L-workers has to be same in the two sectors.

Figure 1 Equilibrium with given co-operation costs



[3] To explain more fully, a higher value of k_N means a higher value of K_N and hence (given K) a lower value of K_S and $K_S/(1 + t)$. The K-worker arbitrage condition shows that for a given t a higher value of k_N requires a higher value of k_S, and thus less employment of L-workers in Southern A-production. This reduces world A-output because the Northern input of L-work into A-production is fixed and because the reallocation of K-work between North and South does not affect A-output in the margin near the equilibrium (as a result of the K-worker arbitrage condition). It also increases world B-output, because employment of Southern L-workers in B-production rises as their employment in A-production falls.

The intersection of these two lines determines the equilibrium values of p_A/p_B and k_N. The bottom panel of the figure shows the K-worker arbitrage condition as a direct relationship (given t) between k_S and k_N, which, with k_N determined in the top panel, fixes k_S. The values of k_N and k_S then determine relative wages, as explained above.

This model applies only within certain limits. If t (the cost of co-operation) were at or above some prohibitively high level, there would be no A-production in the South (K_S and hence L_{AS} would be zero), and thus each country would be completely specialised in one of the two goods. The demand equation (9a) would become

$$\frac{p_A}{p_B} = q\left[\frac{L_N f(K/L_N)}{L_S}\right]^{-\frac{1}{\varepsilon}} ,$$

and the equation determining the relative wages of Northern and Southern L-workers would become

$$\frac{w_N^L}{w_S^L} = \frac{p_A\left[f(K/L_N) - f'(K/L_N)K/L_N\right]}{p_B}$$

This situation would be similar in some respects to that modelled by Krugman (1979), in which Northern workers earn more than Southern workers because new goods can be produced only in the North. A difference, though, is that in Krugman's model there is just one class of Northern workers, whereas in our model the North's monopoly of the ability to produce new goods is linked to its supply of highly-skilled workers.

At the other extreme, if t (the cost of co-operation) were zero, the basic nature of the model would change in a different way. K-work would no longer be more costly in the South than in the North, the wages of Northern and Southern L-workers would be equalised, and there would be no reason for the North to specialise in A-production. Indeed, given the other assumptions made in this section, there would be no economic reason to treat the North and the South as different countries.

Between these two limits, in the range on which we focus, suppression of the B-good would turn our model into the familiar sort of model with only one good, produced with K and L in both the North and the South, with barriers to the movement of K and L between the two countries, with all the K owned by Northern residents, and with a relatively larger stock of K in the North, so that the marginal product and earnings of L are higher in the North than in the South, and vice versa for K. This simplification of our model, however, would lose a feature which is of crucial importance in reality, namely the distinction between high-quality and low-quality goods – a distinction whose salience in the minds of businessmen (and in the business press and literature) is acknowledged in an increasing number of economic models – from Krugman (1979) to Murphy and Schleifer (1997).

3. Effects of falling co-operation costs

The previous section described an equilibrium at a given level of co-operation costs. However, co-operation costs have fallen sharply over the past few decades, largely as a result of improved transport and communications. In this section, we shall analyse how falling co-operation costs shift the equilibrium and hence affect wage inequalities.

Our conclusion will be that a fall in co-operation costs always narrows the wage gap between Northern and Southern L-workers, and in most cases widens the wage gap within the North between K-workers and L-workers. The latter outcome is less clear-cut because a fall in co-operation costs has two different and potentially offsetting effects. The more obvious, and usually the dominant one, is a 'substitution' effect, whereby K-workers are encouraged to do more work in the South and less in the North. The less obvious one is an 'efficiency' effect: lower co-operation costs tend to raise the effective world supply of K-workers, by reducing the amount of time they waste, so that more K-work in the South need not imply less K-work in the North.

The efficiency effect is relevant only if the initial equilibrium involved some Southern A-production, this being the case on which the model in the previous section focused. If the fall in co-operation costs were from a prohibitive level to a permissive level (causing Southern A-production to start up), only the substitution effect would matter, and wage inequality within the North would necessarily increase. And of course if co-operation costs remained prohibitive, even after the fall, neither effect would exist.

Wage inequality in the North

We consider first the impact of lower co-operation costs on wage inequality within the North between K-workers and L-workers. This depends simply on what happens to k_N (equation 5). If the substitution effect dominates and hence k_N falls, then w_N^K/w_N^L must rise (an increase in inequality), because the decreased ratio of K-workers to L-workers in the North raises the marginal productivity of Northern K-work relative to that of Northern L-work. But if the efficiency effect were to pull strongly in the opposite direction, k_N might rise and thus w_N^K/w_N^L would fall (a reduction in inequality).

The economic logic of the substitution effect emerges from the K-worker arbitrage condition (equation 7): given k_S, a fall in t makes working in the North less attractive than working in the South, which causes movement of K-work out of the North (a reduction in K_N), lowering k_N and hence raising the marginal productivity of Northern K-work until it is again just as attractive as Southern K-work. The economic logic of the efficiency effect also emerges from the K-worker arbitrage condition, because another result of the fall in t is a rise in k_S, which reduces the marginal productivity of Southern K-work, and thus diminishes the incentive to move K-work out of the North, tending to raise k_N. This rise in k_S occurs because lower co-operation costs increase the efficiency of Southern and hence global A-production, raising world output of the A-good, relative to the B-good, and hence driving down its relative price, which requires a rise in k_S to meet the arbitrage condition for Southern L-workers.

The conflict between these two pressures on k_N can be illustrated in the top panel of figure 1, in which the positions of both the lines relating p_A / p_B to k_N depend on t. As we show in the appendix, a fall in t is bound to lower the downward-sloping 'arbitrage' function, tending to reduce k_N, in accordance with the substitution effect. However, a fall in t might either raise or lower the upward-sloping 'demand' function: a rise in the function would reinforce the reduction in k_N, but a fall would offset it, and if large enough (because of a strong efficiency effect) could result in an increase in k_N.

To discover what the direction of the net outcome depends on, we need more explicit expressions for the two lines in this figure, which we derive in the appendix in terms of small proportional changes near the equilibrium (denoted by ˜), making use of

$$\tilde{w}_i^K = -\frac{1-s_i^K}{\sigma_i}\tilde{k}_i \quad \textbf{and} \quad \tilde{w}_i^L = \frac{s_i^K}{\sigma_i}\tilde{k}_i \ , \tag{10}$$

which relate proportional changes in wage rates (or more precisely in marginal products) to proportional changes in k_i $(i$ = N, S), the relationship depending on the share of K-worker wages in production cost, s_i^K, and on the (absolute value of the) elasticity of substitution in production between K-workers and L-workers, σ_i. We establish that the direction of the effect on k_N of a fall in t depends on two aspects of an expression

$$-\frac{1}{\varepsilon}\frac{Q_{AS}}{Q_A}\frac{1}{1-s^A}\left(\sigma_S + s^A s_S^K - 1\right) \tag{11}$$

in which Q_{AS}/Q_A is the South's share of global A-output and s^A is the share of A-goods in total world expenditure. One aspect of this expression is its sign, which depends on the sign of the ( ) term. If $\sigma_S > 1 - s^A s_S^K$, the sign of (11) is negative, a fall in t shifts the 'demand' function upward, and hence k_N is bound to fall. However, if the elasticity of substitution in production is low (as we shall suggest later is usually the case), and hence $\sigma_S < 1 - s^A s_S^K$, the sign of (11) is positive and the function shifts downward, tending to increase k_N.

In the latter case, whether the downward shift is large enough to yield an actual rise in k_N depends on another aspect of expression (11), namely its size, and in particular on whether it is bigger or smaller than $s_S^K / \left(1 - s_S^K\right)$. If it is smaller, then the net effect is still a fall in k_N, but if it is larger, the efficiency effect outweighs the substitution effect and the net result is a rise in k_N (and hence a reduction, rather than an increase, in wage inequality in the North). This result would require the elasticity of substitution in consumption, ε, to be low, so that the rise in world output of the A-good would greatly depress its price, and hence require a large increase in k_S to meet the southern L-worker arbitrage condition (the required increase in k_S being larger, the lower the value of s_S^K as can be seen from expressions 10). We will argue below that such a combination of parameter values is unlikely, and hence that the usual outcome is a fall in k_N and a rise in wage inequality in the North.

North-South inequality

Turning now to the impact of a fall in co-operation costs on wage inequality between Northern and Southern L-workers, it is clear from equation (6) that what happens to w_N^L/w_S^L depends proximately on what happens to k_N and k_S. Rewriting this equation in proportional changes (by making use again of expressions 10) as

$$\tilde{w}_S^N = \frac{s_N^K}{\sigma_N}\tilde{k}_N - \frac{s_S^K}{\sigma_S}\tilde{k}_S \ , \tag{12}$$

where $w_S^N = w_N^L/w_S^L$, shows that this wage ratio will usually move in the same direction as k_N/k_S. More specifically, in the usual case in which k_N falls and k_S rises as a result of a fall in co-operation costs, wage inequality between Northern and Southern L-workers will decrease. This is because, with $\tilde{k}_N$ negative and $\tilde{k}_S$ positive (and the s/σ's positive), the sign of the right-hand side of equation (12) is bound to be negative.

The outcome is less obvious in the unusual case in which k_N as well as k_S rises as a result of a fall in t (which makes the sign of the right-hand side of equation (12) ambiguous), but also turns out to be a reduction in North-South wage inequality. In other words, even though the marginal productivity of Northern L-workers rises in this case, it rises by less than the marginal productivity of Southern L-workers, because of the increase in the efficiency of Southern A-production. To establish this, we combine equation (12) with the K-worker arbitrage condition (equation (7), rewritten in proportional changes, as in the appendix), and rearrange as

$$\tilde{w}_S^N = \left(1 - \frac{s_S^K}{1-s_S^K}\frac{1-s_N^K}{s_N^K}\right)\frac{s_N^K}{\sigma_N}\tilde{k}_N + \frac{s_S^K}{1-s_S^K}\tilde{t} \ . \tag{13}$$

The final term shows that the direct effect of a fall in t is to reduce w_N^L/w_S^L. The effect of a rise in k_N (an indirect result of the fall in t) depends on the sign of $1-\left(s_S^K/1-s_S^K\right)\left(1-s_S^K/s_S^K\right)$, which must be negative, so that the result, with $\tilde{k}_N$ positive, is to reinforce the reduction in w_N^L/w_S^L. The sign must be negative because, as noted earlier, a necessary condition for k_N to rise is $\sigma_S<1-s^A s_S^K$, which implies, since $0<s^A, s_S^K<1$, that $\sigma_S<1$. Thus, with a substitution elasticity below unity, and k_N greater than k_S, s_N^K must be less than s_S^K and hence $\left(s_S^K/1-s_S^K\right)\left(1-s_S^K/s_S^K\right)$ is greater than unity.[4] So, whether k_N falls or rises, a decline in co-operation costs narrows the wage gap between Northern and Southern L-workers.

The effects of falling co-operation costs on wage inequalities are particularly clear-cut in the special case of Cobb-Douglas technology. For if σ were unity and hence $s_N^K=s_S^K$, the first term on the right-hand-side of equation (13) would vanish, and only the direct effect of the fall in t on w_N^L/w_S^L would remain. Moreover, with Cobb-Douglas technology it is certain that k_N will fall (because $\sigma_S=1>1-s^A s_S^K$) and hence that w_N^L/w_S^L will rise.

Other considerations

In the usual case, in which the wage of Northern L-workers falls relative to the wages of both K-workers and Southern L-workers, it is bound also to fall absolutely in real terms. This is because the decline in k_N reduces the marginal physical productivity of Northern L-workers and hence their wage in terms of their own product, with the decline in their consumption wage being reinforced by the fall in the price of their own product (the A-good) relative to the B-good. Even in the unusual case in which k_N rises, the real consumption wage of Northern L-workers is likely to decline as a result of the relative price change (which tends to be large in this case). By contrast, the real wage of Southern L-workers is bound to rise, because their wage in terms of the B-good does not alter, and the relative price of the B-good rises.

In the usual case, as we show in the appendix, a fall in co-operation costs raises GNP, measured in terms of the A-good, not only in the South but also in the North, because the worldwide income of K-workers (which is part of Northern GNP) increases by more than the income of Northern L-workers declines – so that in principle the K-workers could more than compensate the Northern L-workers for their loss. However, in the unusual case in which the efficiency effect of lower co-operation costs dominates, so

[4] Strictly speaking, there are two substitution elasticities, unless the technology is CES, but we neglect the complications which would arise if σ_N were above unity and σ_S below unity, or vice versa.

that wage inequality in the North is decreased rather than increased, the worldwide decline in the marginal productivity of K-workers (as a result of the rises in both k_S and k_N) causes the North's GNP to decline in terms of the A-good – and even more in terms of consumption, because of the fall in the relative price of the A-good.

Wages and incomes are not the only variables of practical interest to be affected by falling co-operation costs in the framework of our model. Another is the share of the South in world production of high-quality goods, which is relevant not only as a general indicator of development, but also as a point of contact with other models, particularly those of Feenstra and Hanson (1995) and Wood (1998). In the usual case, this share must rise as a result of a fall in co-operation costs, because world output of the A-good rises and Northern output falls, as a result of the reduction in k_N (given L_N). In the unusual case in which a fall in co-operation costs results in a rise in k_N, and hence in Northern output of the A-good, the South's share could either rise or fall.[5]

Our focus in this section has been on the effects of falling co-operation costs. It would of course be possible also to investigate the effects of changes in the other parameters and exogenous variables of the model in the previous section. In practice, moreover, it is certain that co-operation costs are not the only thing which has been changing, and thus that observed changes in wage inequalities reflect a mixture of effects. A full investigation lies outside the scope of this paper, but two variables whose movement is likely to have been important are the supplies of Northern and Southern L-workers, and in particular the size of L_S relative to L_N, which has been increasing over time, as a result of faster Southern population growth and rising literacy (making more people employable in non-traditional activities).

One unsurprising effect of a rise in L_S/L_N in our model is to widen the North-South gap in the wages of L-workers – that is, to raise w_N^L/w_S^L, thus pulling in the opposite direction to falling co-operation costs. The gap widens because the increased supply of Southern labour raises the output of the B-good, driving down its relative price and encouraging Southern L-workers to leave the B-sector for the A-sector, where their increased numbers, given the supply of K-work to the South, lower k_S and the marginal productivity of Southern L-work (relative to that of Northern L-work). The widening of the gap is damped, however, by an increase in the supply of K-work to the South, induced by the fall in k_S, which raises the marginal productivity of Southern K-work, relative to that of Northern K-work. The supply of K-work to the North is correspondingly reduced, and so k_N falls, increasing w_N^K/w_N^L. A more surprising effect of the rise in L_S/L_N in our model is thus to increase wage inequality in the North, reinforcing the (usual) effect of falling co-operation costs.

[5] Intuition suggests that the South's share must always rise (and our simulations reveal no case of a fall), but we have not been able to prove this – details are available on request.

Simulations

To assess the possible size of the effects of falling co-operation costs on wage inequalities, we use numerical simulations. We calibrate the model at the 'prohibitive' level of co-operation costs – at the point at which K-workers are still all employed in the North but are on the verge of supplying their services to the South – setting the value of t at 3, which implies that the marginal productivity of K-work in the South must be four ($1 + t$) times that in the North. We assume that K-workers are one-tenth of the Northern labour force (implying that $k_N = K/L_N = 1/9$) and at this point earn three times as much as Northern L-workers (making their share of production costs 0.25), and that the Southern labour force (L_S) is equal in size to the total Northern labour force ($K_N + L_N$). Given values for the σ's we derive the initial values of k_S, w_N^L/w_S^L and s_S^K, and complete the calibration by using derived values for Q_A and Q_B and given values for the demand parameters (ε and q) to derive the initial value of p_A/p_B.

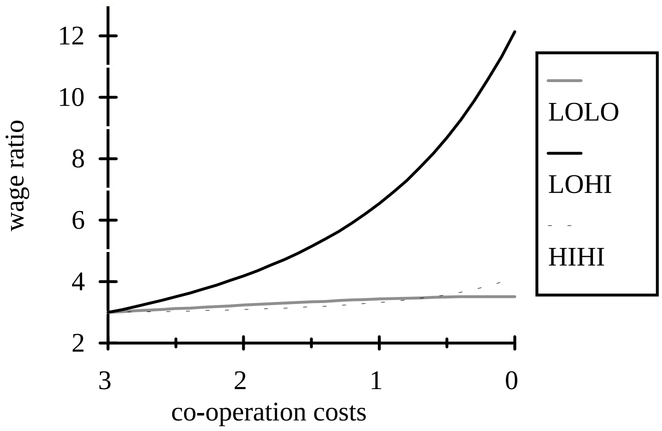
The simulations then consist of reducing the value of t from 3 to zero in small steps, with particular interest in what happens to relative wages. This depends on what values we assume for the substitution elasticities, both in production (σ, for simplicity setting $\sigma_N = \sigma_S$) and in consumption (ε). We believe that σ is likely to be low – that other workers are poor substitutes for K-workers in the production of A-goods, since they lack the knowledge needed to create, produce and market high-quality goods – and we set its value at 0.5 in our base case. By contrast, we believe that ε is likely to be fairly high – that low-quality goods are reasonable substitutes for high-quality goods – so we set its value at 3.0 in our base case (and label this case LOHI). However, we also try two alternative pairs of elasticities, in one of which we lower ε from 3.0 to 0.125, keeping σ at 0.5 (and labelling this the LOLO case), and in the other of which we raise σ from 0.5 to 1.5, keeping ε at 3.0 (and labelling this the HIHI case). The results of all three cases are summarised in figure 2, with more details in appendix table A1.

The top panel of the figure shows the effect of falling co-operation costs on wage inequality in the North, with each of the three lines referring to one of our pairs of elasticities. In the base (LOHI) case, there is a dramatic rise in inequality, with w_N^K/w_N^L quadrupling from 3 to 12 as t falls from its initially prohibitive level to zero. In both the other cases, the rise in inequality is much smaller. In the HIHI case, this is because the greater substitutability of L-workers for K-workers in production means that the decline in k_N due to more K-work being done in the South has far less effect on the relative marginal products of these two groups of workers. In the LOLO case, the rise in inequality is small because the low elasticity of substitution in consumption results in a steep fall in p_A/p_B as global A-production increases, raising k_S and thus discouraging movement of K-work to the South (so that the increase in Southern A-production is also small).[6] Indeed, as t approaches zero in this case, we observe the 'unusual' outcome – a (slight) rise in k_N and hence a fall in wage inequality in the North.

The middle panel of the figure shows how falling co-operation costs reduce wage inequality between Northern and Southern L-workers. In the base (LOHI) case, w_N^L/w_S^L falls from 2.3 at the prohibitive level of t to its expected value of 1 (no difference in wages) when t reaches zero. In the LOLO case, with a lower value of ε, the end-points are the same, but the decline in w_N^L/w_S^L is faster in the early stages of the decline in t and slower in the later stages. In the HIHI case, the degree of North-South inequality is less at all stages: easier substitution in production means that Northern L-workers gain less from the greater relative supply of K-work in the North than in the South.

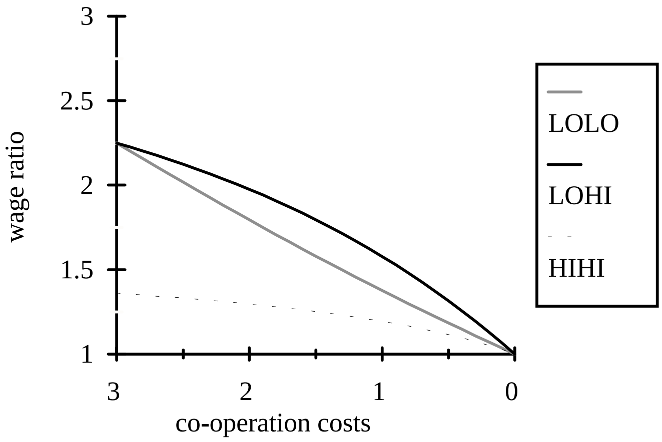
Figure 2 *Simulated effects of falling co-operation costs on wage inequalities*

Inequality between K-workers and Northern L-workers, w_N^K/w_N^L

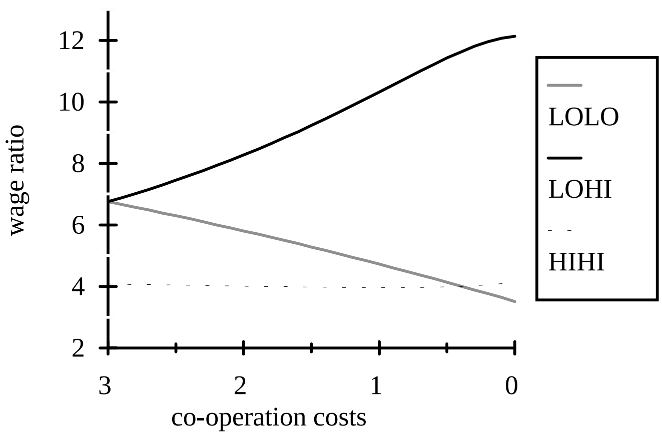


[6] As is shown in table A1, the South's share of world A-production in this case rises only to 8% (when t = 0), as compared to 50% in the LOHI case and 38% in the HIHI case. However, the South achieves a larger rise in real consumption in the LOLO case than in either of the other two cases, because of the steep rise in the relative price of the B-good (which prevents the North's real consumption from rising at all).

Inequality between Northern and Southern L-workers, w_N^L/w_S^L



Inequality between K-workers and Southern L-workers, w_N^K/w_S^L



The bottom panel of the figure shows the effects of falling co-operation costs on wage inequality between K-workers and Southern L-workers (the outcome being implied by the combination of the top and middle panels). In the base (LOHI) case, w_N^K/w_S^L almost doubles as t falls from 3 to zero: the decline in w_N^L/w_S^L is not nearly large enough to offset the steep rise in w_N^K/w_N^L. In the LOLO case, by contrast, w_N^K/w_S^L halves: the small rise in w_N^K/w_N^L is outweighed by the large fall in w_N^L/w_S^L, so that inequality between K-workers and Southern L-workers is reduced. In the HIHI case, the rise in w_N^K/w_N^L and the fall in w_N^L/w_S^L are both small, as a result of which there is little change in w_N^K/w_S^L.

4. Trade, payments and transport costs

In this section, we shall review the pattern of North-South trade and payments implied by our model, introduce transport costs, and compare the effects on wage inequalities of falling transport costs with those of falling co-operation costs.

In the model in section 2, which assumed zero transport costs, the South is bound to export the B-good to the North (which consumes it but does not produce it), and in most cases the North exports the A-good to the South. This pattern is in accordance with the principles of comparative advantage, because the A-good is more K-worker-intensive than the B-good, and because K-work is relatively (to L-work) cheaper in the North than in the South (because of co-operation costs). However, in our model we must consider not only the *composition* of trade, but also the *balance* of trade, since, when A-goods are produced in the South, the South must pay for the (factor) services rendered by K-workers, by running a trade surplus (in goods and non-factor services).[7] If this surplus were large, relative to the North's demand for the B-good, the South might need to export some of its production of the A-good as well as the B-good, with the North exporting only the services of K-workers (which would still accord with comparative advantage, since these services are more K-worker-intensive than the A-good).[8]

In statistical practice, payment of K-workers is not always recorded in the balance of payments as a flow of factor (or more precisely, labour) income. If the services of K-workers were supplied through a consultancy firm, they would probably be classified as non-factor services. If they were supplied through a multinational company with production facilities in the South, the payment might simply raise the profits of the Southern subsidiary and reduce those of the Northern parent, from whose bank account the K-workers are actually paid (with the profits of the Southern subsidiary not necessarily being repatriated). Or the payment might be concealed in the prices of

[7] Non-factor services are services involving an output (such as insurance or shipping) which is produced by a combination of factors, in contrast to factor services, which are rendered by a single factor. The South's trade surplus, measured in terms of the A good, is $w_N^K K_S$ or $w_N^K (K - K_N)$. Note that the South has to pay for the time that K-workers waste as well as for the time they are effectively working.

[8] Falling co-operation costs usually increase the trade imbalance, $w_N^K (K - K_N)$, since w_N^K rises and K_N falls, though the opposite is possible. Falling co-operation costs also usually reduce Northern imports of the B good, because of the rise in its relative price, although this may be offset by the rise in Northern incomes. The likelihood of the South exporting the A-good thus rises as co-operation costs fall. In our simulations, as shown in table A1, this happens in the LOHI case as t approaches zero.

transactions in goods between the Northern parent and its Southern subsidiary. Similarly, if the services were supplied through a Northern importer to an independent Southern producer, they would probably be paid for in the form of a lower price for the goods purchased. These considerations, all of which imply that the international flow of K-worker services tends to be underestimated, would need to be borne in mind in any attempt to apply our model.

An obvious extension of our model is to include transport costs (and other sorts of barriers to trade). A full analysis would be complicated, and lies beyond the scope of this paper, but useful insights can be obtained simply from the arbitrage conditions. Transport costs drive a wedge between prices in the North and in the South: of particular importance for the arbitrage conditions is their effect on the price of the A-good (which is produced in both countries, unlike the B-good). Denoting the transport cost wedge by τ, there are three possible cases: if the North exports the A-good, $p_A^S/p_A^N = 1+\tau$, so that the price is higher in the South; but if the South exports the A-good, $p_A^S/p_A^N = 1/1+\tau$, with the price lower in the South, and if neither country exports the A-good, $1/1+\tau < p_A^S/p_A^N < 1+\tau$. In the partial analysis which follows, we define p_A and p_B as the prices which prevail in the *exporting* country, excluding transport costs, and treat both these prices as parameters (a full analysis would take account of their movement to clear the goods markets).

Focusing initially on the case in which the North exports the A-good (so that $p_A = p_A^N$), the arbitrage condition for Southern L-workers and for K-workers become

$$(1+\tau)\frac{p_A}{p_B} = \frac{1}{f(k_S) - f^{/}(k_S)k_S} \tag{14}$$

and

$$f^{/}(k_N) = \frac{1+\tau}{1+t}f^{/}(k_s) \ . \tag{15}$$

Transport costs, by raising the price of the A-good in the South, increase the incentive to produce it there. Equation (14) shows how its higher price, relative to the B-good, attracts more Southern L-workers into the A-sector for any given supply of K-work (by permitting a lower value of k_S). Equation (15) shows how more K-work is attracted to the South by the higher price of the A-good there, relative to its price in the North, both directly (the 1 + τ term) and indirectly as a result of the lower value of k_S (which raises the marginal product of K-work in the South). Southern output of the A-good is thus increased (with more K-work and more L-workers per unit of K-work) and Northern output of the A-good reduced (because of the reduction in K_N, given L_N, and hence in k_N).

The consequences of a *fall* in transport costs – which is what is relevant in the context of globalisation – are evidently the opposite of those outlined in the previous paragraph, since a fall in τ, other things being equal, reduces the incentive to locate A-production in the South. The attractiveness of the A-sector to Southern L-workers is diminished, so k_S rises, and the attractiveness of the South to K-workers also diminishes, so that K_N and k_N rise. Thus with less of both K-work and L-work in Southern A-production, Q_{AS} falls, and Q_B (and Q_{AN}) rise. This makes sense in terms of standard trade theory: lower barriers to trade have caused the South to produce more of the good in which it has a comparative advantage, namely the B-good. The reduction in the supply of K-work to the South is like the experience of a country which had been receiving 'tariff-hopping' direct foreign investment in import-substituting industries, which then declines as a consequence of tariff cuts.

How does the fall in transport costs affect relative wages? Since k_N rises, w_N^K/w_N^L must fall – that is, there is a reduction in wage inequality within the North. The effect on the other two wage ratios is less straightforward, since both involve a North-South comparison in a context in which there has been a change in the North-South difference in product prices, so the result may depend on the choice of units in which wages are measured. For simplicity, we measure wages in each country relative to the price of the A-good in that country (that is, for K-workers and Northern L-workers in terms of p_A^N, and for Southern L-workers in terms of p_A^S). On this basis,

$$\frac{w_N^K}{w_N^L} = \frac{p_A^S f(k_S)/(1+t)p_A^N}{p_A^S\left[f(k_S)-f'(k_S)k_S\right]/p_A^S} = \frac{f'(k_S)(1+t)(1+\tau)}{f(k_S)-f'(k_S)k_S}$$

and wage inequality between K-workers and Southern L-workers is bound to diminish (since the rise in k_S reduces the marginal product of K-work in the South and raises that of L-work, and in addition the A-good becomes more expensive in the North relative to the South – that is, $1 + \tau$ falls). On the same basis,

$$\frac{w_N^L}{w_S^L} = \frac{p_A^N\left[f(k_N)-f'(k_N)k_N\right]/p_A^N}{p_A^S\left[f(k_S)-f'(k_S)k_S\right]/p_A^S} = \frac{f(k_N)-f'(k_N)k_N}{f(k_S)-f'(k_S)k_S}$$

showing that the direction of movement in wage inequality between Northern and Southern L-workers is ambiguous, because both k_N and k_S have risen, so that the outcome depends on the magnitudes of the changes in k_N and k_S and of the parameters of $f(k)$.

The process of globalisation involves reductions both in transport costs and in co-operation costs, which are to some extent driven by the same forces, such as improvements in transport and communications facilities. Falls in these two sorts of international transactions costs may, however, have different effects on wage inequalities. In particular, the analysis in the previous few paragraphs suggests that wage inequality in the North between K-workers and L-workers tends to be reduced by falls in transport costs but increased by falls in co-operation costs, and that falling transport costs may either reinforce or offset the tendency for wage inequality between Northern and Southern L-workers to be decreased by falling co-operation costs.

These conclusions about the effect of falling transport costs should be interpreted with caution. They are based on a partial analysis, which does not take account of the changes in p_A/p_B which would be needed to restore equilibrium in goods markets. They are also based on the assumption that only the North exports the A-good. If we were to consider instead the case in which the South exports the A-good (with the North exporting only K-worker services), the L-worker arbitrage condition would revert to equation (8) in section 2 (but with $p_A = p_A^S$), and the K-worker arbitrage condition would become

$$f'(k_N) = \frac{1}{(1+t)(1+\tau)} f'(k_S) \ .$$

In this case, a fall in τ would not alter k_S (because the relative price of the A-good and the B-good within the South would not alter), and it would make the South more (rather than less) attractive to K-workers, so that k_N would fall rather than rise. Wage inequality in the North would therefore increase, rather than decrease, and wage inequality between Northern and Southern L-workers would unambiguously decrease (since k_N falls and k_S is unchanged), these effects being the same as those of falling co-operation costs. This South-exporting case is unlikely in our model, but with more than one A-good (as in Wood, 1998), both the North and the South might export (different sorts of) high-quality goods, with the outcome being shaped by a mixture of the pressures identified in our North-exporting and South-exporting cases.

5. Conclusions and possible extensions

In this paper, we have explored, at a theoretical level, the effects on wage inequalities of an important but neglected aspect of globalisation: the increasing extent to which highly-skilled workers resident in the North have become involved in production in the South, as a result of improvements in travel and communications facilities, which have reduced the cost of co-operation with Southern workers. We analysed these effects in a model which distinguishes between high-quality and low-quality goods, and makes the services of highly-skilled workers essential for the production of high-quality goods. Our conclusion is that falling co-operation costs shrink the North-South gap in the wages of less-skilled workers, but in most cases widen the wage gap within the North between highly-skilled and less-skilled workers.

Our model could be extended in various directions. Wood (1998) divides the 'less-skilled' category between medium-skilled and unskilled workers, and divides the single A-good into many high-quality goods of varying medium/unskilled labour intensities, which integrates our approach with the usual Heckscher-Ohlin analysis of the effects of globalisation on wage inequalities. In this extended model, the combination of falling co-operation costs and falling transport costs can explain why the North has experienced not only falling relative wages of unskilled workers but also growing wage inequality among skilled workers, and why in the South increased openness has had mixed effects on wage inequality – facts which are hard to explain in a pure Heckscher-Ohlin framework.

Another possible extension would be to subdivide the South into a number of different countries, each with a different level of co-operation costs. Thus the costs to Northern highly-skilled workers of co-operating with Southern workers would be greater in some developing countries than in others, for example as a result of worse travel and communications facilities, less developed legal systems, or more hostile or unstable government policies. In such a model, the wages of Southern workers would vary among countries, being lower where co-operation costs are higher, as appears to be the case in reality.

Yet another subject for further investigation is the supply of highly-skilled workers, which we have taken as given. Our assumption that such workers are concentrated in the North is based on the seemingly realistic idea that frequent contact among them, face-to-face as well as by telecommunication, is essential for the acquisition, maintenance and use of their skills. However, what determines the supply of highly-skilled workers, and changes in it over time, is an important question, whose answer must in some way be related to the number of the high-quality goods for whose production the skills of these workers are essential, and thus to the balance between the rates of creation and of diffusion of new knowledge.

Like the South, the North can be thought of as a number of different countries, in each of which some part of the world's stock of highly-skilled workers resides (and within and among which the cost of co-operation between highly-skilled and other workers is negligible). The membership of this group is not fixed: if a Southern country acquired a sufficiently large number of highly-skilled residents, it would join the North. This could happen through migration, as in the case of the European colonisation of North America, or through learning by natives, as in the case of Japan. In particular, our model could be extended to include the possibility that Southern workers, in some circumstances, learn from the Northern highly-skilled workers with whom they co-operate in production.

Other possible extensions to the theoretical framework of the model can be imagined – for example, inclusion of nontraded goods and of natural resources – some of which might be necessary to put it into a testable form. However, the most important next step is surely to subject the model to some sort of empirical evaluation. That reduction of co-operation costs has shifted relative wages in the directions that our model suggests seems extremely plausible on the basis of casual observation. What needs to be more scientifically assessed is the likely size of these effects. If they turned out to be large, it would greatly strengthen the case for believing that globalisation has been a major cause of recent changes in wage inequalities, between and within countries.

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Appendix

To analyse the system of four equations in section 2 which determine k_N, k_S, L_{AS} and p_A/p_B (= p), we linearise them, expressing each variable as a relative deviation from its equilibrium value, $\tilde{x} = dx/x$ (except $\tilde{t} = dt/1+t$). The K-worker arbitrage condition becomes

$$\frac{1-s_N^K}{\sigma_N}\tilde{k}_N = \frac{1-s_S^K}{\sigma_S}\tilde{k}_S + \tilde{t} \ ,$$

$$\tilde{k}_S = \frac{\sigma_S}{1-s_S^K}\frac{1-s_N^K}{\sigma_N}\tilde{k}_N - \frac{\sigma_S}{1-s_S^K}\tilde{t} \ . \qquad \text{(A1)}$$

where $s_i^K = f^{/}(k_i)k_i/f(k_i)$ ($i = N,S$), and can be rearranged as
The arbitrage condition for Southern L-workers becomes

$$\tilde{p} = \frac{s_S^K}{\sigma_S}\tilde{k}_S \qquad \text{(A2)}$$

and the full-employment condition for K-workers becomes

$$\tilde{L}_{AS} = -\left(\tilde{k}_S + \tilde{t} + \frac{K_N}{K_S}\tilde{k}_S\right) \ . \qquad \text{(A3)}$$

To obtain a convenient linearised expression for the demand function, equation (9), we first rewrite it, using equations (2a), (3) and (4), as

$$p = q\left[\frac{L_N f(k_N) + L_{AS} f(k_S)}{L_S - L_{AS}}\right]^{-\frac{1}{\varepsilon}}$$

$$= q\left[\frac{L_N f\left(\frac{K - L_{AS} k_S(1+t)}{L_S - L_{AS}}\right) + L_{AS} f(k_S) + p^{-1}}{L_S - L_{AS}} + p^{-1}\right]^{-\frac{1}{\varepsilon}}$$

The marginal effect of a change in k_S and p on the right-hand side of the equation is nil. Also, a change in L_{AS} does not affect the numerator at the margin. Linearising then gives

$$\tilde{p} = \tilde{q} - \frac{1}{\varepsilon}\left[\frac{Q_A + p^{-1} Q_B}{Q_A} \frac{L_{AS}}{L_S - L_{AS}} \tilde{L}_{AS} - \frac{L_{AS}(1+t) f'(k_N) k_S}{Q_A} \tilde{t}\right]$$

$$= \tilde{q} - \frac{1}{\varepsilon}\left[\frac{L_{AS} f(k_S)}{Q_A}\left(\frac{1}{1 - s^A} \frac{p^{-1}}{f(k_S)} \tilde{L}_{AS} - \frac{f'(k_S) k_S}{f(k_S)} \tilde{t}\right)\right]$$

where $s^A = \dfrac{pQ_A}{pQ_A + Q_B}$, the share of the A-good in global expenditure, and hence

$$\tilde{p} = \tilde{q} - \frac{1}{\varepsilon} \frac{Q_{AS}}{Q_A}\left(\frac{1 - s_S^K}{1 - s^A} L_{AS} - s_S^K \tilde{t}\right) . \tag{A4}$$

Underpinnings of figure 1

To derive the two equations underlying the upper panel of figure 1, we substitute (A1) into (A2) to obtain the combined arbitrage function

$$\tilde{p} = -\frac{1 - s_N^K}{\sigma_N} \frac{s_S^K}{1 - s_S^K} \tilde{k}_N + \frac{s_S^K}{1 - s_S^K} \tilde{t} , \tag{A5}$$

in which p is clearly decreasing in k_N, justifying the downward slope in the figure. A fall in t will evidently shift this function downwards. We then substitute (A1) and (A3) into (A4), and set $\tilde{q} = 0$, to obtain the transformed demand function

$$\tilde{p} = -\frac{1}{\varepsilon}\frac{Q_{AS}}{Q_A}\left[\frac{1-s_S^K}{1-s^A}\left(\frac{\sigma_S}{1-s_S^K}\frac{1-s_N^K}{\sigma_N} + \frac{L_N k_N}{L_{AS} k_S}\right)\tilde{k}_N + \left(-\frac{1}{1-s^A}(\sigma_S - 1 + s_S^K) + s_S^K\right)\tilde{t}\right] \tag{A6}$$

in which p is clearly increasing in k_N, justifying the upward slope in the figure. A fall in t might shift this function either upwards or downwards.

Substitution effect versus efficiency effect

To determine whether and when the substitution effect is outweighed by the efficiency effect, we must establish the direction of the effect of a reduction in t on k_N. Both (A5) and (A6) are functions of both t and k_N, and can be rewritten as

$$\tilde{p} = \Omega_1 \tilde{k}_N + \Omega_2 \tilde{t} \tag{A5a}$$

$$\tilde{p} = \Omega_3 \tilde{k}_N + \Omega_4 \tilde{t} \tag{A6a}$$

where

$$\Omega_1 = \frac{1-s_N^K}{\sigma_N}\frac{s_S^K}{1-s_S^K}$$

$$\Omega_2 = \frac{s_S^K}{1-s_S^K}$$

$$\Omega_3 = \frac{1}{\varepsilon}\frac{Q_{AS}}{Q_A}\frac{1-s_S^{\,k}}{1-s^{\,A}}\left(\frac{1-s_N^{\,K}}{\sigma_N}\frac{\sigma_S}{1-s_S^{\,K}} + \frac{L_N k_N}{L_{AS} k_S}\right)$$

$$\Omega_4 = \frac{1}{\varepsilon}\frac{Q_{AS}}{Q_A}\frac{1}{1-s^{\,A}}\left(\sigma_S + s^{\,A} s_S^{\,K} - 1\right)$$

and combined to solve for $\tilde{k}_N$ as a function of $\tilde{t}$

$$\tilde{k}_N = \frac{\left(\Omega_4 - \Omega_2\right)}{\left(\Omega_1 - \Omega_3\right)}\,\tilde{t}$$

The sign of the denominator, (Ω_1-Ω_3),is negative (because $\Omega_1$is negative and all the terms in Ω_3 are positive. Ω_2 is also positive, so that the outcome depends on the sign and size of Ω_4. If $\sigma_s \geq 1 - s^{\,A} s_S^{\,K}$, Ω_4 is non-positive, (Ω_4-Ω_2), must be negative and hence a fall in *t* must reduce k_N. But if $\sigma_s < 1 - s^{\,A} s_S^{\,K}$, and hence Ω_4 is positive, the outcome depends on whether Ω_4 is larger or smaller than Ω_2.If smaller, then a fall in *t* still reduces k_N, but if larger, the efficiency effect dominates the substitution effect, and the net result is a rise in k_N.

Effect of lower co-operation cost on aggregate income

Expressing aggregate income as the sum of payments to factors, measured in terms of the A-good, the North's GNP is

$$\begin{aligned} Y_N &= f'(k_N)K_N + \frac{1}{1+t}f'(k_S)K_S + \left[f(k_N) - f'(k_N)k_N\right]L_N \\ &= f'(k_N)K + \left[f(k_N) - f'(k_N)k_N\right]L_N \end{aligned}$$

(because of the K-worker arbitrage condition), which increases in the usual case in which a fall in co-operation costs reduces k_N, since

$$\Delta Y_N = f^{//}(k_N)k_N(K - k_N L_N)\tilde{k}_N = f^{//}(k_N)k_N K_S \tilde{k}_N ,$$

where Δ indicates a marginal change, and $f^{//} < 0$. The South's GNP is

$$Y_S = \left[f(k_S) - f^{/}(k_S)k_S\right]L_{AS} + \frac{p_B}{p_A}\left(L_S - L_{AS}\right)$$

$$= \left[f(k_S) - f^{/}(k_S)k_S\right]L_S$$

(because of the L-worker arbitrage condition), which increases as a result of a fall in co-operation costs (which raises k_S). Total world GDP is thus

$$Y = Y_N + Y_S = L_N f(k_N) + L_{AS} f(k_S) + \left[f(k_S) - f^{/}(k_S)k_S\right]\left(L_S - L_{AS}\right)$$

and is increased by a fall in co-operation costs,

$$\Delta Y = -s_S^K Q_{AS}\tilde{t} - f^{//}(k_S)k_S\left(L_S - L_{AS}\right)\tilde{k}_S ,$$

both because the efficiency of K-work in the South improves and because this reduces the distortion caused by the inability of Southern L-workers to migrate to the North.

Table A1 Simulation results

LOHI case: σ=0.5, ε=3							
t	3.0	2.5	2.0	1.5	1.0	0.5	0.0
w_N^K/w_N^L	3.0	3.5	4.2	5.1	6.5	8.7	12.1
w_N^L/w_S^L	2.3	2.1	2.0	1.8	1.6	1.3	1.0
w_N^K/w_S^L	6.8	7.5	8.3	9.2	10.3	11.4	12.1
s_N^K	0.250	0.265	0.283	0.304	0.330	0.362	0.401
s_S^K	0.500	0.496	0.490	0.480	0.466	0.443	0.401
s^A	0.574	0.583	0.595	0.611	0.636	0.674	0.735
Q_{AS}/Q_A	0.000	0.042	0.095	0.164	0.252	0.365	0.503
Southern A-good-trade balance/GNP	-0.574	-0.526	-0.464	-0.384	-0.279	-0.143	0.025
Northern real GNP index[a]	100	100	101	103	106	111	121
Southern real GNP index[a]	100	102	105	109	116	129	155
LOLO case: σ=0.5, ε=0.125							
t	3.0	2.5	2.0	1.5	1.0	0.5	0.0
w_N^K/w_N^L	3.0	3.1	3.2	3.3	3.4	3.5	3.5
w_N^L/w_S^L	2.3	2.0	1.8	1.6	1.4	1.2	1.0
w_N^K/w_S^L	6.8	6.3	5.8	5.3	4.7	4.1	3.5
s_N^K	0.250	0.254	0.257	0.260	0.263	0.265	0.265
s_S^K	0.500	0.475	0.445	0.412	0.372	0.324	0.265
s^A	0.574	0.553	0.530	0.504	0.475	0.443	0.408
Q_{AS}/Q_A	0.000	0.010	0.022	0.034	0.047	0.061	0.076
Southern A-good-trade balance/GNP	-0.574	-0.540	-0.505	-0.470	-0.434	-0.396	-0.357
Northern real GNP index[a]	100	100	100	100	100	100	100
Southern real GNP index[a]	100	110	123	139	158	183	216

HIHI case: σ=1.5, ε=3							
t	3.0	2.5	2.0	1.5	1.0	0.5	0.0
w_N^K/w_N^L	3.0	3.0	3.1	3.2	3.3	3.6	4.1
w_N^L/w_S^L	1.4	1.3	1.3	1.3	1.2	1.1	1.0
w_N^K/w_S^L	4.1	4.0	4.0	4.0	4.0	4.0	4.1
s_N^K	0.250	0.249	0.247	0.245	0.241	0.234	0.221
s_S^K	0.125	0.133	0.143	0.155	0.170	0.191	0.221
s^A	0.450	0.459	0.470	0.484	0.502	0.528	0.565
Q_{AS}/Q_A	0.000	0.034	0.075	0.125	0.188	0.270	0.383
Southern A-good-trade balance/GNP	-0.450	-0.430	-0.407	-0.377	-0.338	-0.285	-0.206
Northern real GNP index[a]	100	100	101	101	102	103	106
Southern real GNP index[a]	100	102	105	108	113	120	131

[a] Deflated by the 'ideal' price index (the dual of the demand function): a CES function of p_A and p_B.

Abstract

The plummeting cost of international business travel and communication has enabled highly-skilled workers resident in developed countries to become increasingly involved in production in developing countries, where they can co-operate with less-skilled workers whose wages are lower than those of less-skilled workers in developed countries. Reduction of ‘co-operation costs’ thus has a double effect on wage inequalities. It narrows the gap between developed and developing countries in the wages of less-skilled workers, but in most cases widens the wage gap within developed countries between highly-skilled and less-skilled workers.