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COMPETITION, TRADE AND WAGES*

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Abstract

I briefly review the empirical evidence in the trade and wages debate, which overwhelmingly rejects the Heckscher-Ohlin explanation for recent increases in OECD skill premia. I then argue that the same evidence is also difficult to reconcile in general equilibrium with the view that exogenous skill-biased technological progress is the sole culprit. Finally, I present a model of oligopolistic competition which is more consistent with the evidence. Removing quantitative import constraints (a metaphor for increased foreign competition) encourages both home and foreign firms to invest more aggressively, raising their demand for skilled labour even at unchanged relative wages.

JEL: F16, J31, F12.

Keywords: OECD wage inequality; oligopolistic competition; skill-biased technological progress; skill premia; trade and wages.

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1. Introduction: The Great Debate

Perhaps the single most striking feature of rich-country labour markets in recent decades is what Nickell and Bell (1995) call "the collapse in demand for the unskilled across the OECD". In "Anglo-Saxon" countries, this shows up as an increase in the premium paid to skilled relative to unskilled workers; in Continental Europe, it manifests itself as an increase in long-term unemployment among the unskilled. There seems to be fairly wide agreement that these differences reflect the response of different labour-market institutions to common shocks. But there is no consensus on the nature of those shocks. Much popular discussion and some academic observers (such as Wood (1994) and Leamer (1998)) have blamed "globalisation" in general, and increased imports from low-wage newly-industrialised countries ("NIC's") in particular. By contrast, a majority of academic commentators have pointed instead to skill-biased technological progress as the explanation.

This "trade versus technology" debate has prompted an extensive empirical literature.[1] As summarised and extended by Desjonqueres et al. (1999), three stylised facts in particular emerge from this literature. First, the rise in skill premia has been accompanied by increases in the ratio of skilled to unskilled employment in *all* sectors, not just those which use skilled labour intensively. Second, the skill premium has risen in less-developed and newly-industrialising countries as well as in OECD countries. Third (though the evidence here is less clear-cut, especially for the U.S.), there has been no significant decline in the relative price of less skill-intensive goods. All three of these stylised facts conflict with the view that the rise in skill premia is mainly due to cheaper unskilled-labour-intensive imports. Indeed Desjonqueres et al. entitle their paper "Another nail in the coffin" for the trade-based explanation.

My objective in this paper is not to try and revive the trade explanation, not at least

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[1] For representative overviews, see Francois and Nelson (1998), Haskel (1999), Johnson and Stafford (1999) and Slaughter (1998).

the standard version which emphasises the Stolper-Samuelson mechanism implied by the simple Heckscher-Ohlin-Samuelson ("HOS") model. There is no reason to dispute the message of the empirical evidence to date, as summarised by Robbins (1996), "HOS hits facts; facts win." Instead, I want to explore theoretically two other themes suggested by this literature.

First is the issue of how well the alternative explanation, which relies on exogenous skill-biased technological progress, deals with the stylised facts. While it is obvious that this perspective can explain the increases in skill premia, I want to suggest that in general equilibrium it does not provide a coherent account of other aspects of labour-market developments. This is despite the fact that the technology explanation is less specific, and hence has potentially greater explanatory power, than the trade one.

My second theme starts from the fact that, since Krugman (1995), almost all theoretical contributions to this debate have concentrated on competitive general equilibrium models. This constrains the discussion in significant ways. It means that "increased foreign competition" can only take the form of reductions in the prices or increases in the quantities of imports. It precludes any discussion of the impact of trade or technology shocks on mark-ups or profit rates. Finally, it is inconsistent with a small but suggestive number of empirical studies. Borjas and Ramey (1995) in a study using U.S. data, found that the impact of foreign competition on the skill premium depended on the market structure of the industry penetrated and, in particular, that employment changes in a small group of trade-impacted concentrated industries could explain part of the aggregate rise in wage inequality. Similarly, Oliveira-Martins (1994) in a study using OECD data, found a positive impact of import penetration on wages in industries with low product differentiation and market segmentation. Finally, Sachs and Shatz (1994) found that industries which have declined in the OECD in the face of competition from NIC's exhibited low skill intensities but paid higher wages, presumably reflecting the fact that they were also highly unionised. These empirical findings do not add up to a coherent picture of the interactions between imperfect competition, trade and wage inequality. But they suggest that it is worth trying to develop a framework which encompasses all these features.

This discussion sets the scene for the remainder of the paper. In the next section, I review the Heckscher-Ohlin approach. With two factors that can be thought of as skilled and unskilled labour, and two sectors, each intensive in one of the factors, the model lends itself immediately to addressing the central issues in the debate. But, as I hope to show, not all its implications have been explored. Section 3 introduces a simple but new model of two-stage oligopolistic competition in the presence of a quota constraint and Section 4 draws out its implications for the trade versus technology debate. Section 5 presents some conclusions and Appendices A and B give the detailed derivations underlying the results in Sections 2 and 3 respectively.

2. Trade versus Technology in the Heckscher-Ohlin-Samuelson Model

The basic outlines of the Heckscher-Ohlin story are well-known. Yet a compact restatement seems desirable, both to put recent theoretical debates in perspective and to allow us confront the trade and technology explanations with the stylised facts revealed by recent empirical work. This section draws on Jones (1965) to do just that.

2.1 Increased Import Competition

Begin then with the simplest setting of a competitive small open economy producing two goods, X_1 and X_2, using two factors, unskilled labour L and skilled labour S. Figure 1 illustrates the Stolper-Samuelson result. Each curve is a unit cost curve, showing the combinations of factor prices (*w* and *r* for unskilled and skilled labour respectively) which one sector can afford to pay and just break even. Given initial prices and technology, the locations of the curves are shown by the solid lines, so, if both goods are produced, equilibrium must be at point *A*. Finally, the slope of each sector's unit cost curve represents its employment ratio (skilled to unskilled), so sector 1 is relatively unskilled-labour intensive.

Now, assume an increase in import competition reflected in a fall in *p*, the relative price of the import-competing unskilled-labour-intensive good 1. That sector's unit cost curve shifts inwards as shown and, with the new equilibrium at *B*, the Stolper-Samuelson result follows immediately. The unskilled wage falls and the skilled wage rises. Algebraically, the result is given by a familiar equation (where a circumflex denotes a proportional change: $\hat{r} \equiv dr/r$):

$$\hat{r} - \hat{w} = -\frac{1}{\theta}\hat{p} \qquad \textbf{(1)}$$

The left-hand side is the change in the skill premium (the relative wage of skilled workers). The denominator θ on the right-hand side indicates the relative factor intensities of the two sectors: it is positive since sector 1 is relatively unskilled-labour-intensive.[2] Hence the standard result: a fall in the relative price of good 1 raises the skill premium. This might seem like a parsimonious explanation for the trends in relative wages in the OECD in recent decades. But note two corollaries. According to the model, the higher relative cost of skilled labour encourages a fall in the skilled-unskilled employment ratio in *both* sectors; and the fall

[2] θ equals the determinant of the matrix of sectoral factor shares $\theta_{L1}\theta_{S2}-\theta_{L2}\theta_{S1}$, which simplifies to $\theta_{L1}-\theta_{L2}$. θ is less than one, which gives what Jones (1965) calls the "magnification effect": the proportionate change in the skill premium exceeds the proportionate change in relative goods prices. So a modest change in goods prices could in principle explain a large change in the skill premium.

in price of the import good X_1 should correspond to a *rise* in its relative price in the exporting country, mandating a *fall* in the skill premium there. Both these implications of the simple trade explanation are clearly contradicted by two of the stylised facts quoted in the introduction.

Does it matter that I have assumed a small open economy so far? Krugman (1995) has criticised this framework because the phenomenon to be explained is a generalised shift in labour demand towards skilled labour throughout the OECD. He argues that analyzing this in a small open economy setting commits a fallacy of composition, and, as a first step towards a global analysis, he proposes examining both trade and technology shocks in a closed economy instead.[3] For a trade shock, the simplest way to do this is to assume a small relaxation in the tariff τ on imports from the rest of the world. Allowing for the endogenous adjustment of goods prices, the effect of such a relaxation on the skill premium is:

$$\hat{r} - \hat{w} \quad = \quad - \frac{\sigma_D}{\sigma_D + \sigma_S} \frac{1}{\theta} \hat{\tau} \qquad \textbf{(2)}$$

where σ_D and σ_S are the elasticities of substitution in demand and supply respectively. (See the Appendix for details.) Equation (2) shows that a fall in the tariff has the same qualitative effect as a fall in relative prices from (1), but reduced by a fraction $\sigma_D/(\sigma_D+\sigma_S)$. The form of this fraction, the ratio of a demand elasticity to an excess demand elasticity, is familiar from elementary tax incidence theory, and its interpretation is the same. The lower is the price responsiveness of aggregate demand relative to aggregate supply, the more the tariff

[3] Of course, there is a dangerous slippery slope here. Davis (1998a) criticises Krugman in turn for committing a different fallacy of composition, by allowing for endogenous price adjustment in a flex-wage "America" and a rigid-wage "Europe" without taking into account the constraints on mutual trade flows which are implied by these differences in labour-market institutions. Davis's point is well taken in general, though the particular rigid-wage model he uses imposes an implausible degree of structure on the world economy.

reduction is shifted forward onto goods prices, and the less it affects the skill premium. (The result for the small open economy in (1) is of course the limiting case as σ_D tends towards infinity.) So the Stolper-Samuelson effect is dampened but not reversed by price changes. This suggests that much of the debate between Krugman (2000) and Leamer (2000) is off the point. Irrespective of whether goods prices are exogenous or endogenous, any explanation which relies exclusively on trade effects yields the counter-factual prediction that all sectors should shift to more unskilled-labour-intensive techniques.

Of course, Krugman is right, at least in a competitive model, to stress that a shock which hits all OECD countries (and so affects goods prices) must be of a sufficiently large magnitude if it is to explain the relatively large changes in the skill premium. In (2) I use the device of an equivalent tariff to model a surge in imports, but there are other ways of doing this. A natural alternative approach is to ask what change in domestic factor endowments would have the same effect on the skill premium as the increased import competition. In principle, this can be calculated by using the fact that an actual change in factor endowments would affect the skill premium as follows:

$$\hat{r} - \hat{w} = \frac{1}{\sigma}(\hat{L} - \hat{S}) \qquad \text{where:} \qquad \sigma \equiv \lambda\,\theta(\sigma_D + \sigma_S) \qquad \textbf{(3)}$$

Here σ is Jones's "aggregate elasticity of substitution", which measures the effects on the skill premium of a change in factor endowments, taking into account the full adjustment of both supply and demand throughout the economy.[4] Combining (2) and (3) allows the "factor content equivalent" of the increased imports to be calculated, and empirical estimates have found relatively small values for it. Yet another nail in the coffin of the trade explanation,

[4] λ equals the determinant of the matrix of factor-to-sector allocations $\lambda_{L1}\lambda_{S2} - \lambda_{L2}\lambda_{S1}$, which simplifies to $\lambda_{L1} - \lambda_{S1}$. Like θ, λ is less than one and is positive since sector 1 is relatively unskilled-labour intensive.

apparently.

2.2 Technological Progress

The trade explanation is easy to reject, in part, because it makes such precise predictions. Skill-biased technological progress is not as specific: as we will see, how it is distributed across sectors matters greatly. The issues can be explored by considering the effects of technological progress in the same two-sector Heckscher-Ohlin framework I have just used to address the trade explanation.

First, we need a simple way to parameterise technological progress. Following Jones (1965), let $\hat{b}_{ji}$ denote its effect on the unit input requirement of factor *j* in sector *i* at given factor prices. There are four $\hat{b}_{ji}$ terms and they can be combined in insightful ways. First, within each sector we can define the *extent* and the *bias* of technological progress as follows:

$$\pi_i \equiv \theta_{Li}\hat{b}_{Li} + \theta_{Si}\hat{b}_{Si}, \qquad \beta_i \equiv \hat{b}_{Li} - \hat{b}_{Si}, \qquad i = 1,2 \tag{4}$$

Here π_i measures the reduction in unit cost in sector *i* at initial factor prices; while β_i measures the Hicksian bias of the technological progress: a positive value indicates that it is biased towards saving on unskilled labour, i.e., that it is *skill-biased*. Next, we can define two economy-wide indicators of the type of technological progress. Let π_j denote the sum of the $\hat{b}_{ji}$ terms for each factor *j*, weighted by their sectoral employment shares λ_{ji}:

$$\pi_j \equiv \lambda_{j1}\hat{b}_{j1} + \lambda_{j2}\hat{b}_{j2}, \qquad j = L,S \tag{5}$$

Just as each π_i term indicates the extent to which the technological progress acts in the same way as an increase in the price of good *i*, so each π_j term indicates the extent to which it acts in the same way as an increase in the endowment of factor *j*. Then $\pi_L - \pi_S$ measures the aggregate *factor bias* of the technological progress, while $\pi_1 - \pi_2$ measures its *sector bias*.[5]

Armed with these definitions, consider first the effect of technological progress on the skilled-unskilled employment ratio in each sector:

$$\hat{S}_i - \hat{L}_i = -\sigma_i(\hat{r} - \hat{w}) + \beta_i \quad \textbf{(6)}$$

Here σ_i is the elasticity of substitution between factors, and the bias term β_i indicates the effect of technological progress on the employment ratio at given factor prices. (Equation (6) applies whether goods prices are endogenous or not.) Now, recall two of the stylised facts already used to reject the simple trade explanation. The skill premium must rise throughout the economy: $\hat{r} > \hat{w}$; and the ratio of skilled to unskilled workers must rise in each sector: $\hat{S}_i > \hat{L}_i$. Equation (6) shows straight away that, if these stylised facts are to be explained by exogenous technological progress, then it must be skill-biased in *both* sectors. Moreover, the bias must be sufficiently great to offset the effect of the increased skill premium, which by itself tends to *lower* the skilled-unskilled ratio.

If technological progress cannot be Hicks-neutral and cannot be sector-specific, what is a natural way of specifying it? There seems no basis for assuming that substitution possibilities between skilled and unskilled workers are systematically lower in unskilled than in skilled-labour-intensive sectors. Nor is there evidence that skill premia have risen by more in skilled-labour-intensive sectors. Hence equation (6) suggests that a natural benchmark to use is the case where the bias of technological progress is *uniform* across sectors. This implies that $\hat{b}_{ji}$ is the same in both sectors and so the bias term β_i is independent of sectors, and can be written simply as β. This implies the following relationship between the two aggregate bias terms:

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[5] Jones (1965) calls these the "differential factor effect" and the "differential industry effect" respectively.

$$\pi_1 - \pi_2 \quad = \quad \theta(\pi_L - \pi_S) \quad = \quad \theta\beta \tag{7}$$

An immediate corollary is that uniform skill-biased technological progress benefits disproportionately the *unskilled*-labour-intensive sector. To see the implications of this, I turn at last to the general equilibrium effects of technological progress.

Consider first the case of a small open economy. The effect of technological progress on relative factor prices when goods prices are parametric is exactly the same as the effect of a goods price change itself (compare equation (1)):

$$\hat{r} - \hat{w} \quad = \quad -\frac{1}{\theta}(\pi_1 - \pi_2) \tag{8}$$

In particular, all that matters is the sector bias of the technological change; its factor bias is irrelevant. This has the bizarre implication that if technological progress is uniform skill-biased in the form specified in (7), then it should *reduce* the skill premium: skill-biased technological progress encourages substitution away from unskilled workers, but this is out-weighed by its favourable effect in disproportionately reducing costs in the unskilled-labour-intensive sector. Putting this differently, if skill-biased technological progress in a small open economy is to explain the rise in the skill premium, then it must be disproportionately concentrated in the skilled-labour-intensive sector, while at the same time sufficiently diffused throughout the economy to ensure from (6) that the skill ratio rises in both sectors.

These conclusions are modified when we switch to a large economy with goods prices determined endogenously. The effect of technological progress on the skill premium now has two components:[6]

$$\hat{r} - \hat{w} \quad = \quad - \frac{\sigma_D}{\sigma_D + \sigma_S} \frac{1}{\theta} (\pi_1 - \pi_2) + \frac{1}{\sigma} (\pi_L - \pi_S) \qquad \textbf{(9)}$$

The first term is identical to the effect of a change in an import tariff as in (2); the second to that of a change in relative factor endowments, as in (3). If demand is relatively inelastic, the second term dominates, giving the required rise in the skill premium. This is especially true with uniform skill-biased technological progress, when (9) simplifies to:

$$\hat{r} - \hat{w} \quad = \quad \frac{1 - \lambda\theta\sigma_D}{\sigma} \beta \qquad \textbf{(10)}$$

Recalling that both λ and θ are less than one, the numerator is likely to be positive.

However, there is a final implication of technological progress in a large economy which is less plausible. Consider its effects on relative goods prices:

$$\hat{p} \quad = \quad - \frac{\sigma_S}{\sigma_S + \sigma_D} (\pi_1 - \pi_2) - \frac{\theta}{\sigma} (\pi_L - \pi_S) \qquad \textbf{(11)}$$

As in the case of wages, technological progress has two effects, and the second one definitely tends to *lower* the relative price of the unskilled-labour-intensive good. This tendency is even more pronounced if technological progress is neutral skill-biased, when (11) becomes:

Crucially, *both* sector and factor bias effects tend to *lower* the relative price of the unskilled-

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[6] This equation contradicts Krugman's assertion (2000, p. 61) that "When technological change occurs in a large economy, ... [its] sectoral bias ... has an effect which is ambiguous if it is there at all." In Krugman's base-line case of fixed proportions technology, the weight $\sigma_D/(\sigma_D+\sigma_S)$ attached to the sectoral bias term reduces to unity (irrespective of whether preferences are Cobb-Douglas or not). However, Krugman is right to note that, with Hicks-neutral technological progress at a higher rate in sector 2, the skill premium does not rise if demands are inelastic. Hicks-neutral technological progress in both sectors implies: $\pi_L - \pi_S = \lambda(\pi_1 - \pi_2)$. Substituting into (9), $\hat{r} - \hat{w}$ reduces to $(\sigma_D - 1)\lambda(\pi_2 - \pi_1)/\sigma$. Hence the skill premium falls if σ_D is less than one. This result, which does *not* require fixed proportions in either sector, is stated explicitly in Jones (1965), page 570.

$$\hat{p} = -\frac{1+\lambda\theta\sigma_S}{\sigma}\theta\beta \qquad \textbf{(12)}$$

labour-intensive good. The same condition ($\lambda\theta\sigma_D<1$) which was necessary to guarantee an increase in the skill premium in (10) now ensures that the relative price falls by *more* than θ times the proportionate bias of technological progress. This seems clearly at odds with the empirical evidence quoted in the introduction.

3. Increases in Foreign Competition

The previous section showed that simple competitive general equilibrium models do not justify a trade-based explanation for observed changes in labour markets; but neither are they easy to reconcile with an explanation which emphasises exogenous skill-biased technological progress. Moreover, as noted earlier, there are other reasons why it seems worthwhile to explore these issues in an imperfectly competitive framework. In this section, therefore, I introduce a very different model which does just that.

Consider first an individual industry, in which two firms, one home and one foreign, compete on the home market (which I assume is segmented from the rest of the world). The firms compete in two stages, first choosing their levels of investment, k and k^*, and then choosing their levels of output, x and y.[7] To highlight the workings of the model I assume extremely simple functional forms. Investment incurs quadratic costs of $\gamma k^2/2$ ($\gamma^* k^{*2}/2$ for the foreign firm) in the first stage, and reduces marginal production costs linearly in the second stage:

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[7] Spencer and Brander (1983) is the classic presentation of this model in the trade literature. Neary and Leahy (2000) show how this approach can be extended to a wide range of intertemporal linkages. These papers, like most of the huge literature to which they contribute, concentrate on policy issues (in particular, the choice of optimal investment and export subsidies) and do not consider quotas.

$$c = c_0 - \theta k, \qquad c^* = c_0^* - \theta k^* \tag{13}$$

The home firm's profit function is therefore:

$$\pi(k,x,y) = -\gamma k^2/2 + (p-c)x, \tag{14}$$

where p, the price of the homogeneous good, is determined by a linear demand function:

$$p = a - b(x+y) \tag{15}$$

Begin with the case where competition from imports is unrestricted. The firms play a sub-game perfect Nash game in investment and outputs. In the second stage (with investment spending sunk) profit maximisation by each firm leads to first-order conditions for output (given by equation (29) in the Appendix) which define the output reaction functions. These in turn can be solved for the stage-2 output levels as functions of the investment levels: $x(k,k^*)$ and $y(k,k^*)$.

In the first stage, each firm chooses its investment anticipating the effect this will have on competition in stage 2. For the home firm, this leads to the first-order condition:

$$\frac{d\pi}{dk} = \pi_k + \pi_y \frac{dy}{dk} = 0 \tag{16}$$

The first term on the right-hand side, π_k, represents the "non-strategic" motive for investment: when this is zero, investment is at its socially efficient level. The second term represents the strategic motive. The home firm anticipates that a higher level of investment will lower its costs in the second stage, push the rival firm down its output reaction function, and so raise its profits. This gives it a strategic incentive to "over-invest" relative to the efficient level. Exactly the same arguments apply to the foreign firm of course. Solving explicitly, the first-order conditions for investment are:

$$\gamma k = \mu\theta x \qquad \text{and} \qquad \gamma^* k^* = \mu\theta y, \qquad \textbf{(17)}$$

where the parameter μ reflects the strategic effect. If firms did not behave strategically, μ would equal unity and investment would be at its efficient level. Strategic behaviour adds extra terms in dy/dk and dx/dk^* (both, from equation (30) in the Appendix, equal to $-\theta/3b$) to the first-order conditions, raising the value of μ to $4/3$. Other things equal, strategic behaviour leads firms to over-invest by 33% for a given level of output.

Figure 2, adapted from Neary and Leahy (2000), illustrates the special case where there is no foreign investment. The lower panel shows the home firm's first-order condition for investment from (17) with μ equal to either unity (along OK) or $4/3$ (along OK′). The upper panel shows the output reaction functions (given explicitly by equation (29) in Appendix B), with the appropriate values of k substituted to obtain the two home curves.[8] With unrestricted competition, equilibrium in the upper panel is at point *A*, where the foreign reaction function *FF′* intersects the strategic-investment home reaction function H_2H_2'; this corresponds to point *a* in the lower panel.

Now, assume that imports are restricted by a quota. To isolate its effects on the firms' strategic behaviour, assume initially that the quota is set at the free-trade level. Harris (1985) and Krishna (1989) considered the effects of a quota in a model with price (Bertrand) competition but no investment. They showed that, even when the quota is set at the free-trade level, it alters the equilibrium by changing the nature of strategic interaction between the firms. This effect has usually been assumed to apply only in Bertrand competition. However, it turns out that it also applies in Cournot competition, when firms first engage in

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[8] The explicit expressions are $(2-\mu\eta)bx=a-c_0-by$, where $\eta\equiv\theta^2/b\gamma$ measures the relative effectiveness of investment for the home firm, and where μ equals 1 for the curve H_1H_1' and $4/3$ for H_2H_2'.

investment.[9]

To show this, note that with foreign sales fixed by the quota, the strategic motive for investing (represented by the second term in the investment first-order condition (16)) disappears. Since the quota constraint prevents the foreign firm from responding to a cut in home sales by selling more, the home firm can reduce its investment from the free-trade level. Its only motive to invest is the non-strategic one, so the equilibrium is illustrated by point B in Figure 2. The foreign firm's quota-constrained reaction function is given by the kinked line $\bar{y}AF'$. Hence, with the foreign firm selling the free-trade level of imports, the home firm sells less. Since total sales are lower, the price must be higher and so the foreign firm earns higher profits. The home firm's investment locus shifts from OK′ to OK in the lower panel, so its investment-sales combination is denoted by point *b*. Its sales are lower, but price is higher and it has saved on some inefficient investment. Its profits are therefore also likely to be higher.

Relaxing the assumption that the quota is set at the free-trade level of imports has straightforward effects. As the quota is tightened, the home firm moves down its efficient-investment reaction function H_1H_1'. Its sales and profits increase at the expense of the foreign firm. Relaxing the assumption that the foreign firm does not invest has no effect on the conclusions reached so far, but adds the extra prediction that the foreign firm has no incentive to invest strategically.[10] In this case, both firms invest efficiently.

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[9] After this was written, I found that Reitzes (1991) also considers these issues, though with a very different substantive focus.

[10] Note that, unlike the one-stage game with Bertrand competition but no investment considered by Krishna (1989), assuming that the two firms continue to play simultaneously in the second stage need not pose problems for the existence of an equilibrium in pure strategies. Reitzes (1991) derives a necessary and sufficient condition for this, which I assume is satisfied.

So far, I have concentrated on the workings of the model. To show its relevance to the trade and wages debate, I need to reinterpret the policy change and to add a key assumption. The reinterpretation simply reverses the order in which the two equilibria are considered. Assume that imports are initially restricted by a quota and consider the effects of moving to free trade. The additional assumption concerns the factor intensities of the two components of costs. I assume that fixed costs (such as investments in marketing or R&D) require only skilled labour and that variable costs (i.e., production) require only unskilled labour.[11]

These two steps are simple in themselves, but their combined effect allows me to tell an interesting story about the effects of trade liberalisation. With the quota in place, both firms are in effect shielded from competition. In particular, their only concern in choosing their level of investment is to produce at minimum cost (trading off higher fixed costs of investment against lower production costs). Relaxing the quota changes the nature of the competition between the firms since the foreign firm can now potentially produce at a higher level (even if it does not choose to do so in equilibrium). To forestall this, the home firm now has an incentive to invest further, shifting its own reaction function outwards in order to force the foreign firm down its reaction function. The foreign firm faces a similar incentive and so it too invests beyond the cost-minimising level. Both firms behave more aggressively, which means that they increase their skill intensities. Hence, without any

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[11] Similar assumptions have been made in models of trade under monopolistic competition. Lawrence and Spiller (1983) distinguish between physical capital and labour (rather than skilled and unskilled labour) and assume that they are exclusively used in fixed and variable costs respectively. Flam and Helpman (1987) allow for differences in factor proportions between fixed costs (which they interpret as R&D costs incurred in product development) and variable costs. Many empirical studies of technology, trade and wages assume that the distinction between unskilled and skilled workers coincides with that between production and non-production workers.

change in factor prices, trade liberalisation induces a skill-biased change in techniques.

Of course, factor prices may be expected to change. To establish how much, the model needs to be imbedded in general equilibrium. This is no easy task in general, but it can be simplified by adopting a highly stylised approach which both reduces the relative scale of individual sectors and imposes an extreme symmetry across countries. Assume that the two countries are identical and that there is a continuum of industries, each identical to the one considered above. Each firm produces for the home or foreign market only, and takes factor prices as given in maximising its profits.[12] Aggregating across all domestic industrial sectors, equation (17) gives:

$$rS = \mu w L \tag{18}$$

where S and L represent aggregate demand for skilled and unskilled labour respectively, as in earlier sections, and the parameters γ and θ are replaced by factor prices r and w respectively.

Now, consider an across-the-board relaxation of import quotas. The strategic incentive to invest more aggressively raises μ; while the changes in factor demands depend on the output effects of the trade liberalisation. If quota levels are initially at the same levels as free-trade imports, then exporting firms raise their demand for skilled labour only, whereas

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[12] The latter assumption is controversial, but can be justified when there is a continuum of oligopolistic industries. Gabszewicz and Vial (1972) were the first to point out that the properties of general-equilibrium models with Cournot oligopolists are sensitive to the choice of numeraire. This has generated a large literature, which is generally pessimistic about the prospects of deriving a fully satisfactory model of oligopoly in general equilibrium. (See for example Dierker and Grodal (1999).) However, the approach I have adopted here seems intuitively plausible; assuming that firms take account of the effects of their actions on the full general equilibrium of the economy gives them an implausible degree of monopsony power. (See, for example, Melvin and Warne (1973).) Similar problems arise in models of monopolistic competition, and are routinely ignored in the many applications of the approach pioneered by Dixit and Stiglitz. See the discussion in d'Aspremont et al. (1996).

import-competing firms raise their demand for both types of labour. If, more realistically, quota levels are initially below the free-trade import levels, exporting firms expand but import-competing firms reduce their demands for both factors. Finally, the induced changes in factor prices in general equilibrium depend on how factor markets respond. The simplest assumption is that both factors are supplied at less than infinite elasticity to the production sector of each economy:

$$\hat{S} - \hat{L} \quad = \quad \epsilon(\hat{r} - \hat{w}) \tag{19}$$

where ε is the general-equilibrium elasticity of relative factor supply. Combining this with the total differential of (18) gives:

$$\hat{r} - \hat{w} \quad = \quad \frac{1}{1+\epsilon}\hat{\mu} \qquad \text{and} \qquad \hat{S} - \hat{L} \quad = \quad \frac{\epsilon}{1+\epsilon}\hat{\mu} \tag{20}$$

So, provided ε is positive, the relative return to skilled labour definitely rises, dampening but not reversing the initial rise in the ratio of skilled to unskilled employment demand in all sectors. Alternative assumptions about factor markets may modify these conclusions, but this remains the central case which may be expected to follow from relaxations of quotas in oligopolistic markets.

4. Extending and Interpreting the Model

The model presented in the last section provides a simple explanation of the effects of greater competition which is more consistent with the stylised facts than either of the competitive alternatives considered earlier. It would be going too far to suggest that the increase in OECD wage inequality can be attributed solely to relaxations of import quotas in oligopolistic markets. Nevertheless, in this section I want to argue that, despite many limitations, the model suggests a pattern of events, and a future research programme, which may illuminate a lot of what has happened in recent years.

The first point to emphasise is that the model's key result is robust to relaxing many of the assumptions made. For example, the assumption of homogeneous products is not restrictive. Suppose that, instead of (15), the demand function is $p=a-b(x+ey)$, where $e\leq 1$ is an inverse measure of product differentiation. It can then be checked that the strategic effect $(\mu-1)$, which equalled $1/3$ with homogeneous goods, becomes $e^2/(4-e^2)$, which is decreasing in e. So the qualitative prediction of strategic over-investment is robust to relaxing the assumption of homogeneous products, but the quantitative magnitude of 33% is an upper bound within the class of linear demand functions.

Similarly, the extreme assumption that investment requires only skilled labour and production only unskilled labour can easily be relaxed. The essential feature is that their factor intensities differ in such a way that investment is more skill-intensive. This innocuous assumption is all that is needed to give the prediction that an intensification of competition raises the relative demand for skilled labour even if factor prices and import volume remain unchanged.

Finally, do the model's conclusions hinge on the assumption of Cournot rather than Bertrand competition? The workings of the model are unchanged, with the home firm investing strategically in free trade but not in the presence of a quota.[13] The first-order condition for home investment, equation (16), now becomes:

where q is the foreign firm's price. Assuming goods are substitutes in demand, home profits

[13] As noted in an earlier footnote, an equilibrium in pure strategies does not exist if the firms set prices simultaneously in the presence of a quota. We must then assume that, in the second stage, either the home firm sets its prices as a Stackelberg leader (as in Harris (1985)), or that both firms continue to play simultaneously, in which case they adopt mixed strategies (as in Krishna (1989)). Provided goods are substitutes in demand, the qualitative outcome is the same.

$$\frac{d\pi}{dk} = \pi_k + \pi_q \frac{dq}{dk} = 0 \qquad \textbf{(21)}$$

are increasing in *q*: $\pi_q > 0$. The strategic effect therefore depends on how home investment affects the foreign firm's equilibrium price in the second stage game. With cost-reducing investment as in (13), the home price falls and, since prices are strategic complements, the foreign price too is pulled down. This gives the home firm a strategic *disincentive* to engage in investment, and so the effect highlighted in the last section is reversed. However, this is not the case if investment is *market-expanding*, tending to raise the price that consumers are willing to pay for home output. The foreign price then rises in unison, so a strategic incentive to over-invest relative to the efficient level is restored. This suggests that the effect of a quota relaxation in raising skill intensity is reasonably robust to alternative specifications of the nature of competition between firms and the technology of investment.[14]

Turning from robustness to interpretation, the effects highlighted by the model can be expected to follow any change which increases the degree of competition faced by home firms. In particular, there is nothing in the model which identifies foreign competition as coming from low-wage NIC's: increased competition from countries at similar levels of economic development is even more consistent with the model. In this context it is worth

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[14] With Cournot competition, market-expanding and cost-reducing investment generate the same strategic incentives. See Leahy and Neary (2000) for further details. All this can be expressed in terms of the taxonomy of business strategies of Fudenberg and Tirole (1985). (See also Neary and Leahy (2000).) In Cournot competition, investment of either kind makes firms "tough" (in the sense that it reduces the rival's output and profits) so they have an incentive to behave like a "top dog" and over-invest strategically. In Bertrand competition, cost-reducing investment lowers both firms' prices which reduces profits; each firm therefore has an incentive to behave like a "puppy dog" and under-invest strategically. By contrast, market-expanding investment in Bertrand competition raises the prices which consumers are willing to pay for the products of *both* firms. Hence each firm behaves like a "fat cat", over-investing relative to the non-strategic benchmark, thereby raising both its own and its rival's profits.

mentioning the finding of Hine and Wright (1998) that trade has a disciplinary effect on UK manufacturing labour demand: but trade with other OECD countries has a stronger impact than trade with NIC's.

A further consideration is that trade and technology are not necessarily competing explanations. Table 1 illustrates alternative channels whereby exogenous shocks can impinge on the wage structure. The diagonal cells, (1) and (4), indicate the direct channels, on which most commentators have focused: exogenous technology shocks in cell (1), exogenous trade shocks in cell (4). However, the off-diagonal cells are possibly more interesting. Cell (2) denotes trade-induced changes in techniques (observationally equivalent to changes in technology) such as those arising from quota relaxations as in Section 3 above.[15] Cell (3) denotes a different kind of change, whereby a change in technology can induce a change in trade patterns or in the extent of competition. For example, "just-in-time" production techniques, falls in the costs of transporting intermediate goods, or improvements in communications may allow foreign firms to respond more flexibly and thus compete more effectively. Their effects are thus very similar to policy-induced changes in the degree of competition as considered in Section 3. The model considered there seems more appropriate to all these shocks than the competitive models which dominate the literature to date.

5. Conclusion

Popular discussion and academic debate have focused on trade and technology as competing explanations for recent increases in the relative return to skills in OECD countries. In this paper I have tried to broaden the discussion of these issues in two directions. First,

[15] Trade-induced technological change has also been considered in models with out-sourcing, as in Feenstra and Hanson (1996) and Jones (1997); with defensive innovation as in Thoenig and Verdier (2000); and with entry of new firms as in Vandenbussche and Konings (1998).

I have suggested that the technology explanation should be subjected to the same scrutiny as the trade one. Second, I have argued that concentrating on models of perfect competition is inconsistent with some of the empirical evidence and misses some channels whereby increased import competition can impinge on factor markets.

I began by reviewing the stylised facts which emerge from a decade of empirical research on the fall in relative demand for unskilled labour in OECD countries. I noted that the Heckscher-Ohlin explanation, which blames increased competition from low-wage countries, is overwhelmingly rejected by the facts. I then turned to consider the technology explanation and, in particular, to question its consistency with the stylised facts in general equilibrium. The key difficulty with this explanation is that, though skill-biased technological progress is bad news for unskilled workers, it is good news for sectors which use them intensively. These sectors should have significantly lower costs, which, in an economy that is competitive but not small, should translate into significantly lower prices. These predictions seem inconsistent with the empirical evidence. And they cannot be rejected by asserting that skill-biased technological progress has only been important in skill-intensive sectors, since this conflicts with a different stylised fact: skilled to unskilled employment ratios have risen in *all* sectors despite economy-wide increases in skill premia.

I then introduced a model which highlights the effect of quantitative import restrictions on technology choice by oligopolistic firms. I showed that the model predicts that trade liberalisation encourages both exporting and import-competing firms to invest more aggressively, raising the investment-intensity of production in order to give themselves an advantage in competing against their rivals. Assuming plausibly that investment requires relatively more skilled labour, it follows that trade liberalisation raises the demand for skilled labour in both exporting and importing countries, even at initial factor prices and even if the initial import volume is unchanged. General-equilibrium responses of factor prices are likely to yield a rise in the skill premium which will dampen but not reverse the increase in demand for skilled labour. Since this mechanism operates in both countries, it is therefore consistent with all the stylised facts summarised in Section 1.

Finally, I have argued that relaxations of quantitative import controls are not the only type of shock to which the analysis is relevant. More generally, quota relaxations can be viewed as a metaphor for any change which intensifies the degree of competition in international markets. This includes changes which should properly be attributed to technological progress itself, even though they manifest themselves in more intense competition.

Fans of the *Hitchhiker's Guide to the Galaxy* may recall that the answer to the question "What is the secret of the universe?" was "42". Most answers to the question "What is the percentage contribution of trade to the rise in OECD wage inequality?" have been lower than that. But perhaps the second question is no better posed that the first. The analysis in this paper implies that empirically disentangling the effects of trade and technology is harder than existing studies suggest; but that an imperfectly competitive framework may be a more plausible one for understanding recent labour-market developments.

Appendix A: Solving the Heckscher-Ohlin Model

The change in the unit input coefficients in each sector may be written as:

$$\left.\begin{aligned} \hat{a}_{Li} &= -\theta_{Si}\sigma_i(\hat{w}-\hat{r}) - \hat{b}_{Li} \\ \hat{a}_{Si} &= \theta_{Li}\sigma_i(\hat{w}-\hat{r}) - \hat{b}_{Si} \end{aligned}\right\} \; i=1,2 \qquad \textbf{(22)}$$

Subtracting gives equation (6). Differentiating the price-equal-to-unit-cost equations in each sector gives:

$$\hat{p}_i + \hat{\tau}_i + \pi_i \quad = \quad \theta_{Li}\hat{w} + \theta_{Si}\hat{r} \qquad i = 1,2 \tag{23}$$

Subtracting (and setting $\hat{p}_1 - \hat{p}_2 = \hat{p}$ and $\hat{\tau}_1 - \hat{\tau}_2 = \hat{\tau}$) gives the Stolper-Samuelson relationship:

$$\hat{r} - \hat{w} \quad = \quad -\frac{1}{\theta}[\hat{p} + \hat{\tau} + (\pi_1 - \pi_2)] \tag{24}$$

When prices are endogenous, we must solve for them by equating aggregate supply and demand. In general this requires specifying the behaviour of the rest of the world (or, at least, its offer curve). Provided we assume that initial imports are zero, this can be avoided by simply positing a change in policy which imposes a wedge between home supply and demand (and hence home supply and demand prices). This is equivalent to modelling the change in trade policy as a reduction in the level of a *production subsidy* to the import-competing sector. (The income effects of this change will differ from a tariff, but this can be ignored since all income effects are zero in the neighbourhood of autarky.) Assuming homothetic tastes, the aggregate demand schedule may be written in differential form as:

$$\hat{X}_1 - \hat{X}_2 \quad = \quad -\sigma_D\hat{p} \tag{25}$$

To derive the aggregate supply schedule, consider first the total differentials of the two full employment conditions:

$$\begin{aligned} \lambda_{L1}\hat{X}_1 + \lambda_{L2}\hat{X}_2 \quad &= \quad \pi_L + \delta_L(\hat{w} - \hat{r}) \\ \lambda_{S1}\hat{X}_1 + \lambda_{L2}\hat{X}_2 \quad &= \quad \pi_S - \delta_S(\hat{w} - \hat{r}) \end{aligned} \tag{26}$$

The terms δ_L and δ_S isolate the substitution effects in aggregate factor demand: they give the effects of a change in the factor-price ratio on the demand for unskilled and skilled labour respectively, holding outputs fixed. Subtracting gives the aggregate supply schedule in differential form:

$$\hat{X}_1 - \hat{X}_2 \quad = \quad \sigma_S [\hat{p} + \hat{\tau} + (\pi_1 - \pi_2)] + \frac{1}{\lambda}(\pi_L - \pi_S) \qquad \textbf{(27)}$$

where $\sigma_S \equiv (\delta_L + \delta_S)\lambda\theta$. Equate this to the change in aggregate demand from (25) to obtain (11) in the text. Finally, substitute the solution for $\hat{p}$ into (24) to obtain (2) and (9) in the text.

Appendix B: Computing the Strategic Effects in Oligopoly

In free trade, the first-order conditions for output, which implicitly define the output reaction functions, are given by the following:

$$\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} bx \\ by \end{bmatrix} \quad = \quad \begin{bmatrix} a - c \\ a - c^* \end{bmatrix}. \qquad \textbf{(28)}$$

These can be solved for the functions $x(k,k^*)$ and $y(k,k^*)$, since outputs are functions of the cost parameters, c and c^*, and hence of the investment levels k and k^*:

$$3b \begin{bmatrix} x \\ y \end{bmatrix} \quad = \quad \begin{bmatrix} (a - 2c_0 + c_0^*) + 2\theta k - \theta k^* \\ (a - 2c_0^* + c_0) + 2\theta k^* - \theta k \end{bmatrix} \qquad \textbf{(29)}$$

The derivatives of these functions can now be used to calculate equation (17).

		Exogenous	
		Technology	Trade/Competition
Endogenous	Technology	(1)	(2)
	Trade/Competition	(3)	(4)

Table 1: Alternative Channels of Effects on Relative Wages

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