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ABSTRACT

Relative Wages and Trade-Induced Changes in Technology*

We develop a model where trade liberalization leads to skill-biased technological change, which in turn raises the relative return to skilled labour. As firms get access to a larger market, they have incentives to choose a more skill-intensive technology because a lowering of variable costs requires additional use of skilled labour. This way we establish a link between trade, technology and relative returns to skilled and unskilled labour. Moreover, we show that as market integration continues and trade costs fall below a certain threshold, the relative return to skilled labour may fall.

JEL Classification: F02, F12, J31
Keywords: imperfect competition, technology, trade, trade liberalization, wages

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NON-TECHNICAL SUMMARY

Although the debate about the causes of increased wage inequality in the industrialized countries has been going on for many years, no clear consensus has emerged. The empirical literature has established a number of empirical facts, but theorists have not agreed on which theory or theories are consistent with these facts. In particular, there is still no consensus about the extent to which increased foreign competition through trade has played a role in what seems to be a shift in labour demand towards highly skilled workers and away from low-skilled workers. A number of studies have concluded that skilled-biased technological change seems to be the main driving force behind this development, whereas increased import competition from low wage countries appears to have played only a minor role. It has also been pointed out, however, that technological change may be driven by factors related to the increased integration of product markets. Yet, the nature of a possible link between technological change and increased competition through trade remains largely unexplored.

In this Paper we explore such a link by developing a model of imperfect competition and intra-industry trade where firms have the choice between technologies that differ in their relative use of skilled and unskilled labor. The model links trade liberalization to changes in technology in a way that we think captures an important driving force behind the recent relative increase in the demand for skilled labor. We believe that our approach adds to the ongoing debate on the development of skill premiums and skill ratios in OECD countries. Most of the OECD countries' trade is trade with other industrialized countries with very similar relative factor endowments, and a major share of this trade is intra-industry in nature. Unlike explanations based on traditional trade theory, the model presented in this Paper allows us to address the link between trade, technology and wages within a framework that captures exactly these features of the real world.

In our model, market integration (i.e. reduced trade barriers) leads to an expansion of the market for the individual firm. With improved market access, the firm may have incentives to switch to a more skill-intensive technology. If there are technologies that differ in the relative size of fixed and variable costs, the firm's incentives to incur additional fixed costs in order to lower its variable costs will become stronger. On the assumption that fixed costs are more skill-intensive than variable costs, this leads to an increase in the relative demand for skilled labour. Such an assumption seems well motivated on the grounds that many activities that make up fixed costs, such as R&D, management, and marketing, typically require high-skilled labour.

The increase in the relative demand for skilled labour is reflected in an increase in the relative return to skilled labour. At the same time, the skill-intensity in the industry increases as a consequence of the shift to a more skill-intensive technology. This way, the model gives rise to a simultaneous increase in the skill-intensity and the skill-premium as trade becomes liberalized. Such a simultaneous increase in the skill-intensity and the skill-premium has been observed in the empirical literature but is difficult to reconcile with traditional trade theory.

We also show that when trade costs fall below a certain threshold, at which all firms have switched to a more skill-intensive technology, further trade liberalization may lead to a fall in the relative return to skilled labour. The reason for this is that as firms with a given technology expand their output, they increase their variable costs, which are relatively intensive in unskilled labour. Hence, the effect of trade liberalization on the relative wage between skilled and unskilled labour depends crucially on whether it leads mainly to changes in output in existing firms, which are producing with a given technology, or whether it leads mainly to changes in technology.

1 Introduction

Although the debate about the causes of increased wage inequality in the industrialized countries has been going on for many years, no clear consensus has emerged. The empirical literature has established a number of empirical facts, but theorists have not agreed on which theory or theories are consistent with these facts. In particular, there is still no consensus about the extent to which increased foreign competition through trade has played a role in what seems to be a shift in labor demand towards highly skilled workers and away from low-skilled workers. A number of studies have concluded that skilled-biased technological change seems to be the main driving force behind this development, whereas increased import competition from low-wage countries appears to have played only a minor role (e.g. Berman et al., 1994; Desjonqueres et al., 1999). However, it has also been pointed out that technological change may be driven by factors related to the increased integration of product markets (see e.g. Burda and Dluhosch, 1999; Haskel and Slaughter 1999, Falvey and Reed 2000, Neary 2000). Yet, the nature of a possible link between technological change and increased competition through trade remains largely unexplored.

In this paper, we explore such a link by developing a model of imperfect competition and intra-industry trade where firms have the choice between technologies that differ in their relative use of skilled and unskilled labor. The model links trade liberalization to changes in technology in a way that we think captures an important driving force behind the recent relative increase in the demand for skilled labor. In our model, market integration (i.e., reduced trade barriers) leads to an expansion of the market for the individual firm. The firm may then have incentives to incur additional fixed costs in order to lower its variable costs. On the assumption that fixed costs are more skill-intensive than variable costs, this leads to an increase in the relative demand for skilled labor. As a consequence, the relative return to skilled labor increases, at the same time as the skill-intensity in the industry increases; a phenomenon that has been observed in the empirical literature but that is hard to reconcile with traditional trade theory and the Heckscher-Ohlin-Samuelson model.

We show that trade liberalization may give rise to changes in technology that increase the relative demand for skilled labor. However, we also show that when trade costs fall below a certain threshold, at which all firms have switched to a more skill-intensive technology, further trade liberalization leads to a fall in the relative return to skilled labor. The reason is that as firms with a given technology expand their output, they increase their variable costs, which are relatively intensive in unskilled labor.

The rest of the paper is organized as follows: Section 2 gives a brief review of the related literature. Section 3 presents the basic features of the model, whereas section 4 analyzes the relationship between market integration and incentives for choosing different technologies in partial equilibrium. In section 5, we carry out the analysis in general equilibrium, and derive the impact on relative factor returns and factor intensities of decreased trade costs. Finally, in section 6 we offer some concluding remarks.

2 Related literature

The empirical literature on the sources of an increased skill-premium in the industrialized countries is vast. A number of studies have been carried out using data from different countries. This literature has produced a number of empirical facts on which most researchers in the area seem to agree. These facts include the following: (*i*) the wage premium to skilled workers has increased in several industrialized countries; and (*ii*) the skill-intensity has increased within most industries (see e.g. the survey by Wood, 1998).

Several trade theorists have pointed out that in a Heckscher-Ohlin framework, the simultaneous increase in the relative price of skilled workers and skill-intensity is difficult to explain. For a given technology, there should be a negative instead of a positive relation between relative factor price and factor intensity. This means that even if the relative wage to skilled labor increases as a consequence of an increased specialization in skill-intensive production, firms should substitute the relatively cheaper factor for the relatively dearer one, thus decreasing their skill-intensity. Technological change, on the other hand, needs to have a sectoral bias if it is going to affect relative factor prices in an *unambiguous* way: Technological progress in the skill-intensive sector leads to an increase in the relative return to skilled labor, whereas skilled-biased technological change in the whole economy does not necessarily affect relative factor prices. In order for the skill-intenisty to increase, the bias moreover needs to be of such a magnitude, that it offsets the effect of increased skill premium, which by itself tends to lower the skilled/unskilled ratio. Hence, as pointed out by Neary (2000), the only way skill-biased technological progress in a small open economy could explain the empirical facts is if it were disproportionately concentrated in the skill-intensive sector at the same time as it were sufficiently diffused throughout the economy to ensure that the skill-ratio would increase in all sectors.

There are a few theoretical papers that explore a possible link between trade, technological change and relative returns to skilled and unskilled labor. Dinopoulos and Segerstrom (1999) develop a dynamic general equilibrium model in which trade liberalization increases R&D investment. Assuming that R&D is skill-intensive relative to the production of final goods, trade liberalization also leads to an increase in the relative wage to skilled labor at the same time as there is skill upgrading within each industry. Markusen and Venables (1998) develop a model where firms may choose between being national exporting firms (with high variable costs and low fixed costs) and multinational firms (with low variable costs and high fixed costs). Their choice depends on a trade-off between the savings on trade costs that can be made by producing in proximity to consumers and the additional fixed costs that have to be incurred in order to set up an additional plant. They show that trade liberalization may create incentive for the firms to switch from a multinational strategy to a national exporting one.

Falvey and Reed (2000) investigate the link between the choice of technology in a non-liberalizing developed country when trade liberalization occurs elsewhere. In their model, the changes in relative factor prices that follow from changes in product prices as developing countries liberalize trade, induce firms in the developed country to switch to more unskilled labor intensive techniques. They make the point that if the cost savings associated with this switch are larger in the skill-intensive sector than in the unskilled labor intensive sector, this induced change in technology will tend to exacerbate the increase in the relative return to skilled labor. However, they acknowledge that the empirical literature does not seem to support a shift towards more unskilled labor intensive techniques in the developed countries.

Neary (2000) addresses the link between product market competition, trade and wages by developing an oligopoly model in which firms invest more aggressively in R&D (which are sunk costs) as a consequence of trade liberalization (in the form of removing import quotas). Assuming again that R&D is skill-intensive relative to production activities, this implies that the firms adopt more skill-intensive production techniques as a consequence of trade liberalization. The mechanism focused on in Neary's model is one where trade liberalization changes the nature of competition in the market, which causes firms to alter their strategic behaviour.

While our model shares some features with the model developed by Neary, e.g. the assumption of oligopolistic behavior, it is, from a methodological point of view, more similar to Markusen and Venables (1998). As in their model, firms are faced with a choice between two different technologies. Furthermore, in equilibrium, there will be no profitable opportunity for firms to enter with one or the other technology. Thus, we assume free entry and exit of firms and allow the simultaneous existence of firms producing with different technologies.

3 The model

We assume that there are two economies, Home (H) and Foreign (F), producing two homogenous goods, X and Y. There are two factors of production, skilled and unskilled labor. Labor is mobile between sectors, but internationally immobile. The good Y is produced with constant returns to scale, using unskilled labor only, and is sold under perfect competition. We choose this good as the numeraire. The good X is produced with increasing returns to scale, using both unskilled and skilled labor.

In the X-sector, a firm can choose between two technologies: a traditional one and a modern one. The traditional technology is characterized by relatively low fixed costs and relatively high variable costs, whereas the modern technology is characterized by relatively high fixed costs and relatively low variable costs. Fixed costs consist of costs of skilled labor (S) only, whereas variable costs consist of costs of unskilled labor (L) only. Firms compete as Cournot oligopolists and markets are assumed to be segmented. The number of firms is endogenously determined by free entry and exit.

The utility of a representative consumer is given by a Cobb-Douglas function, yielding the following demand functions:

$$D_{Yi} = (1-\beta)M_i, \qquad i = H, F \tag{1}$$

$$D_{Xi} = \beta M_i / p_i. \qquad i = H, F \tag{2}$$

where M_i is total income, p_i is the price of X in terms of Y and β is the budget share spent on good X. Total income is given by:

$$M_i = w_{Li}L_i + w_{Si}S_i, \qquad i = H, F \tag{3}$$

where L_i and S_i are country i's endowments of unskilled and skilled labor, respectively, while w_{Li} and w_{Si} are the returns to unskilled and skilled labor, respectively.

We choose units so that one unit of unskilled labor produces one unit of output of Y. Furthermore, we assume that Y is freely traded, which implies that the return to unskilled labor is equalized as long as both countries produce the good.

$$w_{Li} \geq 1, \qquad i = H, F \tag{4}$$

The different technologies available for firms in the X-sector are defined by the following cost function:

$$C_i^k = F^k w_{Si} + c^k w_{Li}(X_{ii}^k + X_{ij}^k) + t w_{Li} X_{ij}^k \tag{5}$$

$i = H, F,\ j = H, F,\ i \neq j,\ k \in T, M$. The superscript denotes type of technology so that T stands for the traditional technology and M stands for the modern technology. F^k is the fixed requirement of skilled labor, c^k the requirement of unskilled labor to produce one unit of output, t the amount of unskilled labor required in order to ship one unit of output across the border, X_{ii}^k the amount of output supplied to the domestic market and X_{ij}^k the amount of output exported to the foreign market. With respect to the two different technologies, we assume that

$$F^M > F^T \tag{6}$$

$$c^M < c^T \tag{7}$$

which implies that technology M requires higher fixed costs but lower marginal costs than technology T.

First-order conditions for profit maximization in each market imply that marginal revenue equals marginal cost. Written in complementary slackness form, we have that

$$p_i(1 - e_{ii}^k) \leq w_{Li} c^k, \qquad X_{ii}^k \geq 0, \qquad i = H, F,\ k = M, T \tag{8}$$

$$p_j(1 - e_{ij}^k) \leq w_{Li}(c^k + t), \qquad X_{ij}^k \geq 0, \qquad i, j = H, F,\ i \neq j,\ k = M, T \tag{9}$$

where e_{ij}, the optimal markup, is given by the firm's market share divided by the Marshallian price elasticity of demand in that market. As the price elasticity is one, given our assumption about demand, the firm's markup is simply its market share, i.e.:

$$e_{ij}^k = \frac{X_{ij}^k}{\sum_k \sum_i n_i^k X_{ij}^k}, \qquad i,j = H,F, \qquad k = M,T \tag{10}$$

where n_i^k is the number of firms in country i that produce with technology k.

Free entry and exit in the X-sector implies zero profits:

$$p_i X_{ii}^k + p_j X_{ij}^k \leq F^k w_{Si} + c^k w_{Li}(X_{ii}^k + X_{ij}^k) + t w_{Li} X_{ij}^k, \qquad n_i^k \geq 0 \tag{11}$$

$i,j = H,F$, $k = M,T$. The zero-profit condition in (11) is satisfied with equality if there are firms in country i producing with technology k; otherwise it is satisfied as an inequality (i.e. n_i^k is the associated complementary slackness variable).[1]

Goods-market clearing in the X-sector implies:

$$D_{Xj} = \sum_k \sum_i n_i^k X_{ij}^k \tag{12}$$

Finally, factor-market clearing gives us the following equilibrium conditions:

$$L_i = \sum_k n_i^k \left(c^k (X_{ii}^k + X_{ij}^k) + t X_{ij}^k \right) + Y_i, \qquad i,j = H,F \tag{13}$$

$$S_i = \sum_k n_i^k F^k, \qquad i = H,F \tag{14}$$

[1] Note that our specification of the model does not allow firms to choose technology strategically. The only strategic decision the firm faces is whether to enter or not. It is thus as if there were two populations of potential entrantants, where the firms in each population only have access to one of the technologies (cf. Markusen and Venables 1998).

4 Partial equilibrium analysis

Let us first consider a partial equilibrium variant of the model; taking factor prices as given, and focusing on the X-sector. Equilibrium in the X-sector is then determined by (2), (8), (9), (10), (11), and (12). Countries are assumed to be symmetric, in the sense that factor prices and incomes are equal across countries. This in turn means that prices, number of firms, domestic sales, as well as exports will be the same regardless of the consumers' or the firms' country of origin.

A firm will choose to adopt the modern technology if profits earned with the modern technology (π^M) are higher than profits earned with the traditional technology (π^T). In order to analyze what determines the choice of technology, we examine the conditions characterizing a mixed equilibrium, where modern and traditional firms co-exist. We focus on firms located in one of the countries, say H. This implies that (8), (9) and (11) hold with equality for both types of firms. From (8) and (9) follows that in a mixed equilibrium modern firms will produce larger quantities – have larger market shares – than traditional firms, i.e. $X^M \equiv X^M_{HH} + X^M_{HF} > X^T \equiv X^T_{HH} + X^T_{HF}$. The zero-profit condition (11) reveals that the higher the unskilled wages relative to the the skilled wages, the more profitable are modern firms relative to traditional firms.

By setting $w_L = w_S = 1$, we may rewrite the first order conditions (8) and (9), and the zero profit conditions in (11) as:

$$(p - c^k)X^k_{HH} + \Big(p - (c^k + t)\Big)\, X^k_{HF} - F^k = 0, \qquad k = M, T \tag{15}$$

$$p(1 - \frac{X^k_{HH}}{X}) = c^k, \qquad k = M, T \tag{16}$$

$$p(1 - \frac{X^k_{HF}}{X}) = c^k + t, \qquad k = M, T \tag{17}$$

where X is the total output sold in the market. By taking F^T, F^M, c^T, X, and t as given, we can solve for the four output levels, p and c^M.

In order to understand the basic properties of the model, and the range of possible equilibrium configurations we illustrate the partial equilibrium in Figure 1. The diagram shows the relationship between the ratio between marginal costs of modern and traditional firms and the ratio between fixed costs of modern and traditional firms for given levels of market size and trade costs.

{FIGURE 1: The ratio between fixed and marginal costs consistent with both firm types active}

The horizontal axis shows the ratio between the fixed costs of modern and traditional firms ($F^M/F^T > 1$ by assumption), while the vertical axis shows the ratio between the marginal cost of modern and traditional firms ($c^M/c^T < 1$ by assumption). The curves show combinations of the two ratios consistent with both modern and traditional firms making zero profits. Except in the borderline cases illustrated by the curves, only one technology will be used. To the left of a curve only modern firms will exist, while, to the right of the same curve, only traditional firms will exist.[2]

The location of a curve in the diagram is determined by the magnitude of trade costs and market size. Consider the role of trade costs. A reduction in trade costs impacts on profits through its effects on prices and quantities: Reduced trade costs have a pro-competitive effect and lead to lower prices in both countries. The reduction in trade costs moreover reduces home sales while raising exports. With symmetric countries, firms in both countries experience increased *total* production. However, the positive impact on profits stemming from increased production is relatively larger for modern firms than for traditional firms, as – due to lower marginal costs – the modern firms face larger variable profits (price - cost margins) per unit sales. Hence, a decrease in trade costs shifts the zero profits loci outward.

An increase in total demand in the market has the same impact as a reduction in trade costs. Initially, the increase in demand will lead to increased profits and expanded output. Because modern firms have larger per unit variable profits, their profits will increase more than profits of traditional firms.

The mixed-equilibria loci in Figure 1 are drawn for: (i) zero trade costs or a large market, (ii) intermediate trade costs or intermediate market size, and (iii) prohibitive trade costs or a small market. We see that as trade costs fall or the market size increases, the mixed-equilibria loci move outwards to the right. Such changes lead to a situation where the variable cost advantage necessary for modern firms to predominate over traditional ones declines.

[2] To the left of a curve, the lower variable costs of a firm using the modern technology outweigh the fixed-cost advantage of firms using the traditional technology. To the right of a curve, the opposite is true.

Thus, a lowering of trade costs or expansion of the market will increase the range of technology parameters leading to equilibria with modern firms only.

5 General equilibrium analysis

In this section we shall examine the relationship between trade costs, technology and relative wages in a general equilibrium setting.

Equilibrium is given by equations (1), (2), (3), (8), (9), (10), (11), (12), (13), and (14), which solve for unknown variables Y_{Ci}, w_{Li}, w_{Si}, p_i, e_{ii}^T, e_{ij}^T, e_{ii}^M, e_{ij}^M, X_{Ci}, n_i^T, n_i^M, X_{ii}^T, X_{ij}^T, X_{ii}^M, X_{ij}^M, M_i. This leaves us with a system of 32 equations and inequalities that solves simultaneously for 32 unknowns. In order to explore the more complicated general equilibrium effects, we shall mainly rely on simulations, although a number of analytical results are also derived in the appendix. Our focus is the impact of a process of trade liberalization on the choice of technology, relative wages and skill intensity.

When trade costs are high, there will be no trade between the two countries. Hence, the output of each firm is limited by the size of the domestic market. For a sufficiently small domestic market, no firm will find it profitable to produce with the modern technology. As trade costs fall, firms find it profitable to export part of their output abroad. Their incentives with respect to the choice of technology will then change. As shown in the previous section, the relative profitability of using modern technology increases. In general equilibrium, however, firms with traditional and modern technology may co-exist for a range of intermediate trade costs. As trade costs are lowered, firms with modern technology will become more and more predominant.

In order to analyze the effect of changes in technology on the relative wage between skilled and unskilled labor analytically, we carry out two different experiments. First, we compare the equilibria where all firms are using either traditional or modern technology – taking trade costs as given to be prohibitive, intermediate or zero. Second, we consider a mixed equilibrium, i.e. an equilibrium where firms using traditional and modern technology co-exist, and look at the three cases where trade costs are either prohibitive, intermediate or zero. We analyze the effect on the relative wage of increasing the number of firms using modern technology. Regardless of type of equilibrium and level of trade costs, in all cases, except one, the relative wage of skilled labor is always higher the more predominant are firms using modern technology (see section A.1.1 and A1.2 in the appendix). The exception is when we compare equilibria with only either traditional *or* modern firms under the assumption of intermediate trade costs. In this case, it is possible that the equibrium with firms using the traditional technology yields a higher relative return to skilled labor than the equilibrium with firms using the modern technology.

In order to understand why the relative return to skilled labor may be higher with traditional technology, it should first be noted that the return to skilled labor dependens crucially on the level of operating profits. For positive trade costs, firms have a lower per unit operating profits on exports than on domestic sales, and firms with a high export share then tend to have small operating profits. The share of output that is exported is in turn dependent on the relation between the per unit trade cost and the price. The higher the price relative to the trade cost, the higher the export share. The equilibrium price increases with both the level of fixed costs and the level of marginal costs. It increases with the former because a higher level of fixed costs leads to a smaller number of firms and hence less competition, while it increases with the latter because with constant markups on domestic sales any increase in marginal costs will be reflected in increases in the equilibrium price. This implies that firms with high fixed and marginal costs tend to have a high export share and low operating profits. Thus, in order for the relative return to skilled labor always to be higher in the equilibrium with modern technology we need to put restrictions on the relation between F^T, F^M, c^T, and c^M, ensuring that c^M is sufficiently low relative to c^T, and F^M not "too" high relative to F^T (see A.1.1 in the appendix). In the simulations illustrated below, parameters are set so as to rule out the case where the export share of modern firms becomes so large that their total operating profits are lower than that of traditional firms – thus, assuming these restrictions to hold.

As shown in Figure 2, a reduction in trade costs leads to a change in the composition of firms, from predominantly traditional ones to predominantly modern ones, which is associated with an increase in the relative return to skilled labor. Behind this rise in the relative return to skilled labor is an increase in the relative demand for skilled labor as firms using small amounts of skilled labor exit while firms using large amount of skilled labor enter.

{FIGURE 2: Relative returns to skilled labor}

The increase in the relative returns to skilled labor is thus associated with an increased proportion of skilled labor to unskilled labor in the X-sector. Hence, within a certain range of trade costs, declining trade costs produce an increased relative return to skilled labor as well as an increased skill-intensity in the industry (see Figure 3).

{FIGURE 3: Skill-intensity in X-sector}

However, at a certain level of trade costs, all firms in the X-sector will have chosen the modern technology. As trade costs fall below this threshold, the composition of firms using different technologies remains the same, and a further lowering of trade costs will induce the existing firms, which are all using the modern technology, to expand their output by drawing unskilled labor from the outside sector.[3] At this point, a reduction in trade costs will be associated with a decreased relative demand for skilled labor and a fall in the relative return to this factor.

With even further reductions in trade costs, there will be two counteracting forces affecting the relative demand for skilled labor. On the one hand, increased exports tend to increase the demand for unskilled labor, thereby decreasing the relative demand for skilled labor (see Figure 4). On the other hand, the reduction in trade costs, which are incurred in terms of unskilled labor, will in itself, below a certain threshold of trade costs, reduce the demand for unskilled labor. As the level of t decreases, the amount of unskilled labor needed to ship one unit of X across the border decreases, at the same time as the volume of X that is traded increases. Below some critical level of trade costs, the former effect will dominate the latter. This typically produces an inverse u-shaped relationship between the level of t and the amount of unskilled labor used in transportation as illustrated in Figure 4. When we are to the left of the peak of this curve, further reductions in trade costs will decrease the demand for unskilled labor in transportation. If this decrease outweighs the increased demand stemming from an expansion of output, the relative return to skilled labor may increase again as per Figure 2 (see section A.2 in the appendix for analytical proof) .

{FIGURE 4: Demand for unskilled labor in X-sector}

The main result of the analysis is the relationship between trade-induced changes in technology, on the one hand, and changes in skill-intensity and relative wages, on the other. This relationship, which exists for an interval of trade costs where a reduction in trade costs leads to a change in the compo-

[3] Note that in there will be no entry of new firms because skilled labor required for the fixed costs cannot be drawn from elsewhere in the economy. As discussed later, the main results are however not sensitive to this feature of the model.

sition of firms producing with different technologies, is robust to alterations in the assumptions about factor usage in the transport sector. The results pertaining to trade costs outside this interval, however, are sensitive to such alterations.

As seen in Figures 2 and 3, reduced trade costs entail a small decline in returns to skilled labor at the same time as the skill intensity in production actually rises when trade costs are relatively high and there are only traditional firms being active. This might seem as a puzzle, but is explained by the fact that the reduction in trade costs leads to increased exports and an expansion of the transport sector. As this sector – by assumption – only uses unskilled labor, its expansion increases the demand for unskilled labor, which is drawn out from production in the X and Y sectors. If the transport sector would have used skilled labor instead, there would have been an increase in the returns to skilled labor for this interval of trade costs. In such a case, the decline in the skill intensity of the production sector would have been outweighed by an increased use of skilled labor in the transport sector so that the relative demand of skilled labor increased.

Similarly, the tendency for the returns to skilled labour to exhibit a U-shaped relationship with trade costs in the interval where there are only modern firms is sensitive to the assumptions related to factor use in the transport sector. A skill-intensive transport sector would instead imply a monotonic decrease in returns to skilled labor as trade costs approach zero.

6 Concluding remarks

This paper has explored a possible link between increased competition through trade, technological change and the relative wage for skilled and unskilled labor. The link focused on is one where improved market access generates incentive to switch to a more skill-intensive technology. This way, we establish a link between trade, technology and relative returns to skilled and unskilled labor. Moreover, we show that as market integration continues and trade costs fall below a certain threshold, the effect on the relative return to skilled labor is reversed and further integration leads to a lower skill premium.

We believe that the present approach adds to the ongoing debate on the development of skill premia and skill ratios in OECD countries. Most of OECD countries' trade is trade with other industrialised countries with very similar relative factor endowments, and a major share of this trade is intra-industry in nature. Unlike the Heckscher-Ohlin-Samuelson model, the model presented here allows us to address the link between trade, technology and wages within a framework that captures exactly these features of the real world.

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A Appendix

A.1 Returns to skilled labour under different technology and trade regimes

A.1.1 Unmixed technology

Assume that there are only firms using technology k and that the two countries are completely identical. First-order conditions for profit maximization imply:

$$p\left(1-\frac{d^k}{n^k}\right)=c^k \tag{18}$$

$$p\left(1-\frac{(1-d^k)}{n^k}\right)=c^k+t \tag{19}$$

where d^k is the share of output sold in the domestic market (i.e., $d^k \equiv X_d^k/(X_d^k+X_e^k)$,where X_d^k is the amount of output sold in the domestic market and X_e^k is the amount of output exported to the foreign market). Dividing (18) by (19) and simplifying yield:

$$d^k=\frac{c^k+tn^k}{2c^k+t} \tag{20}$$

In order for the firm to sell in both markets, t has to be lower than per-unit operating profit in the domestic market, i.e. $t<p-c^k$. As t goes from zero to $p-c^k$, d^k goes from $\frac{1}{2}$ to 1.[4]

The zero profit condition implies:

$$(p-c^k-t(1-d^k))(X_d^k+X_e^k)=F^k w_S \tag{21}$$

Factor-market clearing implies:

$$n^k=\frac{S}{F^k} \tag{22}$$

[4] That d^k equals 1 for $t=p-c^k$ can be verified in the following way: Note that $(p-c^k)/p=d^k/n^k$. Substitute $d^k p/n^k$ for t in (20) and solve for d^k.

$$L = n^k(X_d^k + X_e^k)\left(c^k + t(1-d^k)\right) + Y \tag{23}$$

and clearing of the market for Y implies:

$$Y = (1-\beta)(L + w_S S) \tag{24}$$

Substituting (20) and (22) into (18) yields the equilibrium price:

$$p = \frac{S(2c^k + t)}{2S - F^k} \tag{25}$$

Solving for w_S for a given d^k yields:

$$w_S = \frac{\beta L\left[F^k\left(c^k + t(1-d^k)\right) + St(2d^k - 1)\right]}{S\left[(2S - \beta F^k)\left(c^k + t(1-d^k)\right) + (1-\beta)St(2d^k - 1)\right]} \tag{26}$$

Using (26) we find that the relative wage of skilled labor is higher in an equilibrium in which firms choose to produce with the modern technology compared to an equilibrium in which firms choose to produce with the traditional technology if the following condition holds:

$$\begin{aligned} & 2\left(c^M + t(1-d^M)\right)\left(c^T + t(1-d^T)\right)(F^M - F^T) \\ & +t\left(c^T + t(1-d^T)\right)(2d^M - 1)(2S - F^T) \\ > \; & t\left(c^M + t(1-d^M)\right)(2d^T - 1)(2S - F^M) \end{aligned} \tag{27}$$

Whether condition (27) is satisfied or not depends among other things on the relative size of d^M and d^T. Since the per unit operating profit is higher on domestic sales than on exports, a high share of domestic sales in total sales will tend to lead to a high level of operating profits. Therefore, all else equal, a higher d is associated with higher total operating profits and, thereby, a higher return to skilled labor.

Using (22) in (20) and taking partial derivatives of d^k with respect to c^k and F^k, respectively, we find that both derivatives are negative (i.e., $\frac{\partial d^k}{\partial c^k} < 0$ and $\frac{\partial d^k}{\partial F^k} < 0$). Thus, a higher fixed cost and a higher marginal cost both lead to a lower domestic share of total sales. The intuition for this is as follows: Both a higher fixed cost and a higher marginal cost lead to a higher price. Because a specific trade cost in percentage terms then will be lower in relation to the price (i.e., t/p decreases), the difference in the share of the price that constitutes operating profits in the domestic and foreign market will decrease. As a result, the firm will tend to export a larger share of its output. Comparing two technologies where one has high fixed costs while the other has high marginal costs, we cannot determine the sign of the difference in the share of domestic sales in total sales without knowledge of the exact levels of fixed and marginal costs. However, it can be shown that a sufficient condition for $d^M < d^T$ is that $F^M c^M \geq F^T c^T$, which means that modern firms will export a larger share of their output than traditional ones as long as the ratio between modern and traditional traditional fixed costs is at least as high as the ratio between traditional and modern marginal costs.[5]

a) Autarky

Using (25) we find that $p - c^k = \left(F^k c^k + St\right) / \left(2S - F^k\right)$ in equilibrium. This implies that the condition for prohibitive trade costs, $t \geq p - c^k$, in equilibrium becomes $t \geq F^k c^k / \left(S - F^k\right)$ (which implies $d^k = 1$). Using (21), (22), (23) and (25), we can derive equilibrium wages for skilled labour in autarky:

$$w_S = \frac{F^k \beta L}{S\left(S - F^k \beta\right)} \tag{28}$$

Using this expression, we find that the relative return to skilled labor is higher with modern firms if:

$$F^M > F^T,$$

which is true according to our assumptions.

b) Free trade

Assume that $t = 0$ (which implies that $d^k = \frac{1}{2}$). Using (21), (22), (23) and (25), setting $t = 0$, we can derive equilibrium wages for skilled labor with free trade:

[5] A necessary and sufficient condition for $d^M > d^T$ is:

$$\begin{aligned} 2S(F^T c^T - F^M c^M) \quad > \quad & F^M F^T (c^T - c^M) \\ & + St(F^M - F^T) \end{aligned}$$

$$w_S = \frac{F^k \beta L}{2S\left(S - F^k \beta\right)} \tag{29}$$

By using this expression, again we find that the relative return to skilled labor is higher with modern firms than with traditional firms if:

$$F^M > F^T,$$

which is true according to our assumptions..

Note that the return to skilled labor is independent of the level of marginal costs in the cases of autarky and free trade. The reason for this is that with the demand function assumed, operating profits will only depend on the the size of the fixed costs, and not on the marginal costs: Higher fixed costs lead to a smaller number of firms and higher total operating profits in the X-sector.[6]

c) Intermediate trade costs

According to (26), a sufficient condition for w_S to be higher in an equilibrium where firms produce with the modern technology is the following condition:

$$\begin{aligned} & \left(c^T + t(1-d^T)\right)(2d^M - 1)(2S - F^T) \\ \geq \; & \left(c^M + t(1-d^M)\right)(2d^T - 1)(2S - F^M) \end{aligned} \tag{30}$$

Whether (30) is satisfied or not depends crucially on the relation between d^T and d^M. A sufficient condition for (30) to be satisfied is that $d^T \leq d^M$, i.e., if firms producing with the traditional technology export at least as large a share of their output as firms producing with the modern technology, an equilibrium with the modern technology will be certain to exhibit a higher w^S than an equilibrium with the traditional technology. However, if $d^T > d^M$, so that firms using the modern technology are exporting a larger share of their output than firms using the traditional technology, it is possible that the negative effect of a high share of exports on total operating profits is so strong that w^S is lower in an equilibrium with the modern technology. Since $d^T > d^M$ for plausible parameter values, this case cannot be ruled out. Ultimately, the relation between d^T and d^M depends on the relation between

[6] As is well-known from industrial organization theory, total industry profit decreases with the number of firms (see e.g. Tirole, 1988, and Shy, 1995, pp. 103-104).

c^T, c^M, F^T, and F^M in a way such that the lower c^M in relation to c^T and F^M in relation to F^T, the higher d^M will be in relation to d^T. In other words, in order for modern firms to have a small exporting share relative to traditional firms, c^M should be low compared to c^T and F^M should be low compared to F^T. From this follows that in order for w^S to be higher in an equilibrium with modern technology in the case of intermediate trade costs, F^M may not be too high in relation to F^T.

A.1.2 Mixed technology

Assume now that there are firms using both traditional and modern technology. As both types of firms are active, zero profit conditions (11) must hold with equality, which implies:

$$\frac{\left(p-c^M\right)X_d^M+\left(p-c^M-t\right)X_e^M}{\left(p-c^T\right)X_d^T+\left(p-c^T-t\right)X_e^T}=\frac{F^M}{F^T} \tag{31}$$

Solving the first-order condition for profit maximization of traditional firms in the domestic market for the price and substituting into the same condition for modern firms yield:

$$c^T\left(X-X_d^M\right)=c^M\left(X-X_d^T\right) \tag{32}$$

where $X \equiv n^T(X_d^T+X_e^T)+n^M(X_d^M+X_e^M)$. From this expression follows that $X_d^M > X_d^T$ (since $c^T > c^M$).

Performing the same calculation with respect to the first-order conditions for profit maximization in the foreign market yields:

$$c^T\left(X-\left(\frac{c^T+t}{c^T}\right)X_e^M\right)=c^M\left(X-\left(\frac{c^M+t}{c^M}\right)X_e^T\right) \tag{33}$$

From this expression follows that $X_e^M > X_e^T$ and that the difference in output for the foreign market is larger than the difference in output for the domestic market (since $\frac{c^T+t}{c^T} < \frac{c^M+t}{c^M}$).

Factor-market clearing now implies:

$$S=n^TF^T+n^MF^M, \tag{34}$$

$$L = n^T c^T (X_d^T + X_e^T) + n^M c^M (X_d^M + X_e^M) + t(n^T X_e^T + n^M X_e^M) + Y, \tag{35}$$

while product-market clearing in the market for Y-goods is still given by expression (24).

a) Autarky

Assume that $t \geq p - c^M$ (which implies that $X_e^M = X_e^T = 0$). Using (24) and (34) in (35), we get the following expression for the return to skilled labor:

$$w_S = \frac{\beta}{1-\beta}\frac{L}{S} - \frac{c^T X_d^T}{F^T(1-\beta)} + \frac{n^M}{F^T(1-\beta)S}\left(F^M c^T X_d^T - F^T c^M X_d^M\right) \tag{36}$$

Differentiating this expression with respect to number of modern firms (n^M), we get

$$\frac{\partial w_S}{\partial n^M} = \frac{1}{(1-\beta)SF^T}\left(F^M c^T X_d^T - F^T c^M X_d^M\right). \tag{37}$$

From (31) follows that $F^M\left(p - c^T\right)X_d^T = F^T\left(p - c^M\right)X_d^M$, which implies that the term in brackets on the right hand side has a positive sign. Hence, $\frac{\partial w_S}{\partial n^M} > 0$: skilled labour's wage rises with the number of firms operating with modern technology.

b) Free Trade

Assume that $t = 0$, which implies that $X_e^M = X_d^M$ and $X_e^T = X_d^T$. Using (24) and (34) in (35) we get the following expression for the return to skilled labor:

$$w_S = \frac{\beta}{(1-\beta)}\frac{L}{S} - \frac{2c^T X_d^T}{F^T(1-\beta)} + \frac{2n^M}{F^T(1-\beta)S}\left(F^M c^T X_d^T - F^T c^M X_d^M\right) \tag{38}$$

Differentiating this expression with respect to n^M we get

$$\frac{\partial w_S}{\partial n^M} = \frac{2}{(1-\beta)SF^T}\left(F^M c^T X_d^T - F^T c^M X_d^M\right), \tag{39}$$

which again from (31) can be seen to be positive.

c) Intermediate Trade costs

Assume that $0 < t < p - c^M$, which implies that $X_e^M > 0$ and $X_e^T > 0$. Using (24) and (34) in (35) we get the following expression for the return to skilled labor:

$$\begin{aligned} w_S &= \frac{\beta}{1-\beta}\frac{L}{S} - \frac{\left(c^T X^T + tX_e^T\right)}{F^T(1-\beta)} \\ &+ \frac{n^M}{F^T(1-\beta)S}\left[F^M\left(c^T X^T + tX_e^T\right) - F^T\left(c^M X^M + tX_e^M\right)\right], \end{aligned} \tag{40}$$

where $X^T \equiv X_d^T + X_e^T$ and $X^M \equiv X_d^M + X_e^M$. By differentiating this expression with respect to n^M we get

$$\frac{\partial w_S}{\partial n^M} = \frac{1}{F^T(1-\beta)S}\left[F^M\left(c^T X^T + tX_e^T\right) - F^T\left(c^M X^M + tX_e^M\right)\right]. \tag{41}$$

From (31) follows that the term in brackets on the right hand side has a positive sign and, hence, that $\frac{\partial w_S}{\partial n^M} > 0$.

A.2 Economic integration and returns to skilled labour

Assume that trade costs are at a level where there are only modern firms operating. What is then the impact of reduced trade costs? Using (24) and (34) in (35) we get:

$$w_S = \frac{\beta}{1-\beta}\frac{L}{S} - \frac{\left(c^M X^M + tX_e^M\right)}{F^M(1-\beta)}. \tag{42}$$

Differentiation of this expression with respect to trade costs yields:

$$\frac{\partial w_S}{\partial t} = -\frac{1}{F^M(1-\beta)}\left[c^M\frac{\partial X^M}{\partial t} + X_e^M\left(\frac{\partial X_e^M}{\partial t}\frac{t}{X_e^M} + 1\right)\right] \tag{43}$$

This expression reveals that a change in trade costs has a twofold impact on skilled wages: First, as trade costs decrease, production will increase, drawing more unskilled labour into the X-sector and reducing the relative demand for skilled labor. This effect tends to decrease the return to skilled labor. Second, reduced trade costs lead to a reduced demand for unskilled labor per unit of output sold in the foreign market as the shipping of goods requires less labor. This effect tends to increase the return to skilled labor.

With symmetric countries, the effect on produced quantities from an increase in trade costs will be negative (i.e., $\frac{\partial\left(X_d^M+X_e^M\right)}{\partial t} < 0$ and $\frac{\partial X_e^M}{\partial t} < 0$). It then follows that if the elasticity of exports with respect to trade costs exceeds unity, $\frac{\partial w_S}{\partial t} > 0$ and reduced trade costs lead to a reduced return to skilled labor. However, if the elasticity of exports with respect to trade costs is less than unity, it may be the case that $\frac{\partial w_S}{\partial t} < 0$. From (43) it can be seen that this may occur when trade costs are low and exports large.

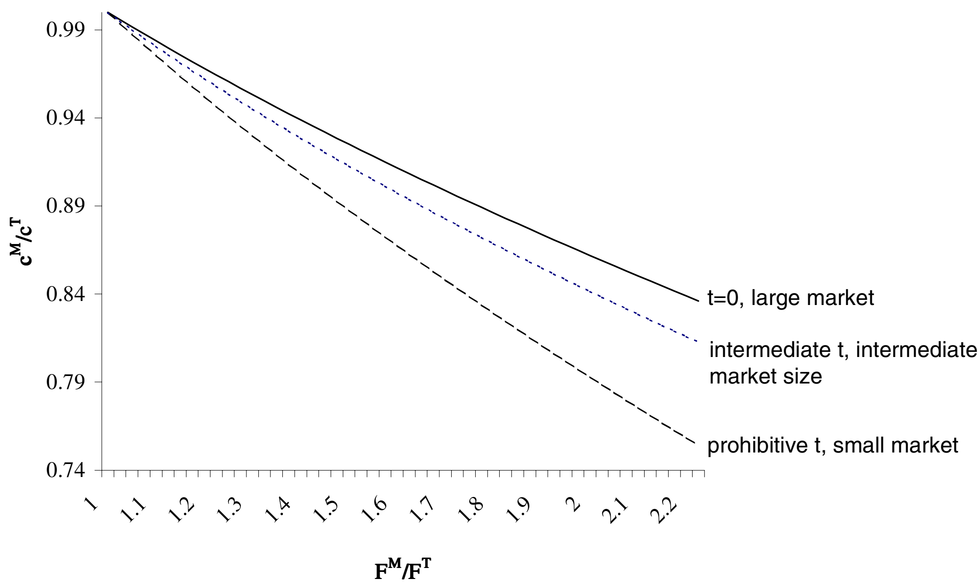

Figure 1: The ratio between fixed and marginal costs consistent with both firm types active

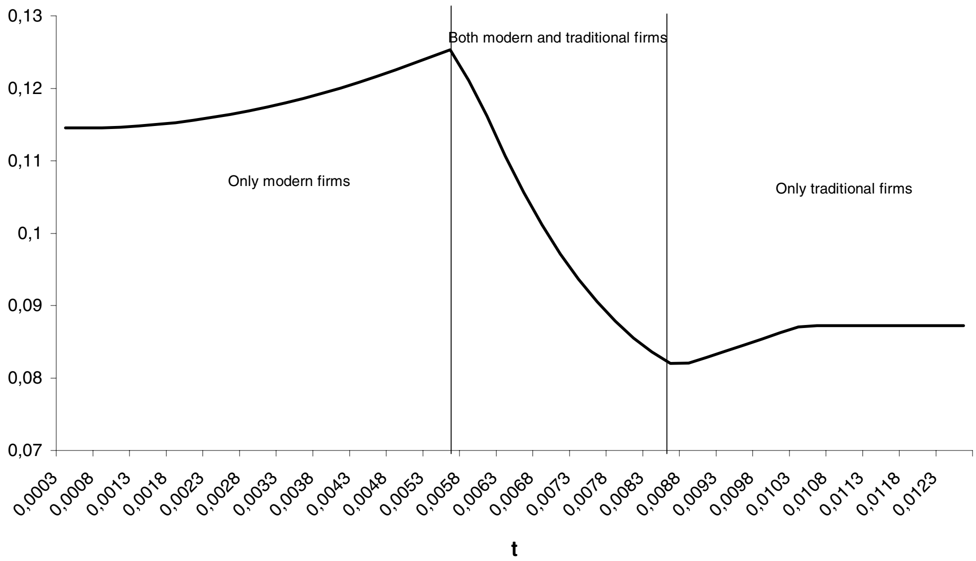

Figure 2: Relative return to skilled labor

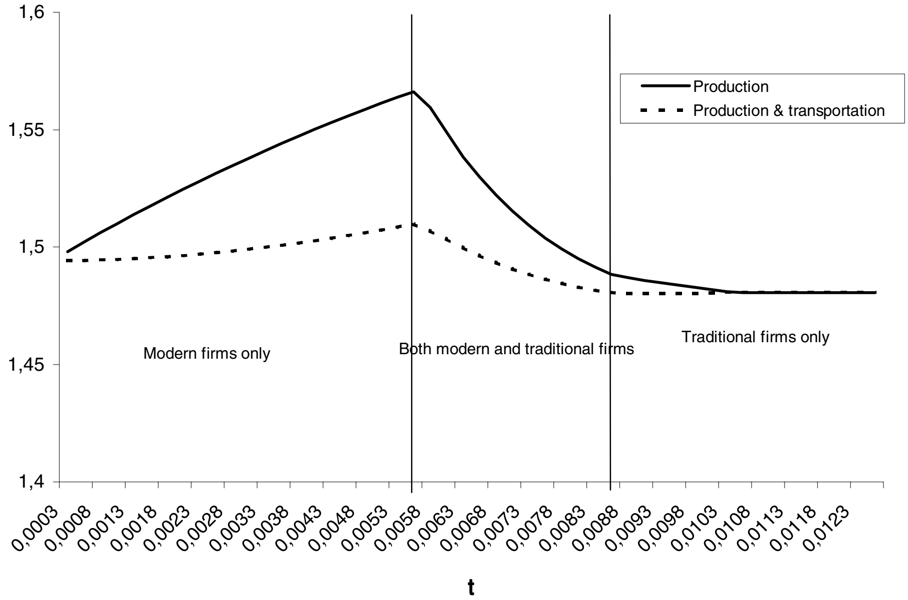

Figure 3: Skill-intensity in X-sector

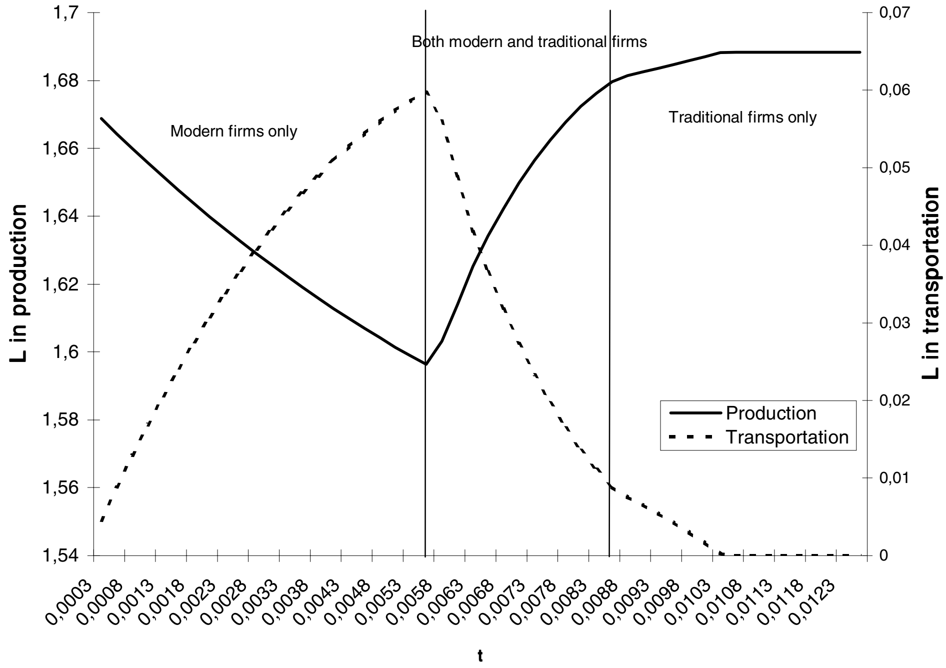

Figure 4: Demand for unskilled labor in X-sector