Relative wages and trade-induced changes in technology*

Karolina Ekholm† and Karen Helene Midelfart Knarvik‡

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Abstract

We develop a model where trade liberalization leads to skill-biased technological change, which in turn raises the relative return to skilled labor. When firms get access to a larger market, the relative profitability of different technologies changes so that the relative profitability of the more skill-intensive technology increases. As the composition of firms changes to one with predominantely skill-intensive firms, the relative demand for skilled labor increases. This way, we establish a link between trade, technology and relative returns to skilled and unskilled labor.

Keywords: technology, trade, economic integration, relative wages
JEL: F12, F15, J31, O33

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†The Stockholm School of Economics and CEPR

‡The Norwegian School of Economics and Business Administration and CEPR

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 as yet emerged. The empirical literature has established a number of empirical facts, but theorists have not agreed on which theory or theories that 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, 2001a, 2001b). 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 with heterogenous firms utilizing technologies that differ in their relative use of skilled and unskilled labor. Two technologies are available: a "modern" one and a "traditional" one. The modern technology is associated with relatively high fixed costs and relatively low variable costs. Market integration (in the form of reduced trade costs) leads to an expansion of the market for the individual firm, and enhances the profitability of modern relative to traditional firms. 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.

In our analysis, the exogenous change that triggers an expansion of trade and a change in technology is product market integration between similiar economies. The resulting trade expansion is purely intra-industry in nature. Thus, unlike most of the literature on trade and income inequality, we focus on North-North trade rather than North-South trade. By focusing on market integration between industrialized countries, our model links trade liberalization to changes in technology in a way that we believe captures an important driving force behind the recent increase in the relative demand for skilled labor in these countries.

We show that product market integration may give rise to technological change – attained through a change in the composition of firms – which increases the relative demand for skilled labor. However, we also show that when trade costs fall below a certain threshold, at which all firms are using the more skill-intensive technology, and there can thus be no further change in the composition of firms, further trade liberalization leads to a fall in the relative return to skilled labor. The reason is that firms expand output by increasing 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. In section 4, we analyze the relationship between market integration and technological change, and derive the impact on relative factor returns and factor intensities of increased economic integration. Finally, in section 5 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 practically all industries (see e.g. the survey by Wood, 1998).

Several trade theorists have pointed out that within 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 sectorial bias 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-intensity to increase, the bias moreover needs to be of such a magnitude that it offsets the effect of an increased skill premium, which in itself tends to lower the ratio between skilled and unskilled labor. Hence, as pointed out by Neary (2001a), 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. Other models of endogenous innovation that generate a similar link between trade liberalization and skilled-biased technological change are Acemoglu (1999) and Thoenig and Verdier (2000).

Markusen and Venables (1997) focus on the role of foreign direct investment and multinational firms in explaining the increase in the skill premium. They develop a model with two types of firms; national exporting firms (with high variable costs and low fixed costs) and multinational firms (with low variable costs and high fixed costs); and identify the circumstances under which investment liberalization is likely to raise the skill premium in both the skilled-labor abundant and the unskilled-labor abundant country. Investment liberalization and convergence between countries tend to raise skill premia because the relative profitability of multinational versus national exporting firms is increased. Trade liberalization, however, tends to lower skill premia because it affects the relative profitability in the opposite direction.

Falvey and Reed (2000) investigate the link between the choice of production techniques and relative factor prices in a non-liberalizing developed country when trade liberalization occurs elsewhere. In their model, the increased skill premium that follows from an increased specialization in skill-intensive production induces firms 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 (2001a) addresses the link between product market competition, trade and relative 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. Neary (2001b) adopts a similar framework and shows how the threat of competition from foreign firms encourages domestic firms to increase investments, which in turn impacts on the skill intensity and skill premium. The mechanism focused on by Neary is one where trade liberalization changes the degree of competition in the market, which leads firms to alter their strategic behavior.

Our model shares some features with the model developed by Neary (2001b). As in Neary's analysis, we focus on market integration between developed countries and we assume that markets are characterized by Cournot competition. With respect to the former similarity, a crucial difference is that in Neary's analysis it is the *threat of import competition* that leads to technical change, while in ours it is the *rise in intra-industry trade* that causes such a change.[1] With respect to the latter similarity, a crucial difference is that we assume free entry and exit and a large number of firms, implying that we abstract from the strategic aspects of firm behavior, which is the main focus of Neary's analysis.

From a methodological point of view, our model is similar to Markusen and Venables (1997). As in their model, firms are heterogenous with respect to technology. Furthermore, we adopt a similar equilibrium concept where, in equilibrium, there are no profitable opportunities for firms to enter with either technology. Thus, as in Markusen and Venables (1997), we allow for the simultaneous existence of firms producing with different technologies. However, unlike in their analysis, here trade liberalization generates increased skill premia.

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 pro-

[1] Dinopoulos et al. (1999) also develop a model where a rise in intra-industry generates an increased skill premium. They assume non-homotheticity in consumption as well as production, the latter taking the form of skill-biased output expansion. Because trade liberalization leads to an output expansion at the level of the firm, it tends to increase the relative demand for skilled labor.

duction, 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, there are two types of potential entrants: firms producing with traditional technology and firms producing with modern technology. 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. There is free exit and entry.[2] As firms enter, they compete as Cournot oligopolists in nationally segmented markets. The number of firms in each market, which is endogenously determined by free entry and exit, is treated as a continuous variable

We assume that countries are completely symmetric, and shall therefore only present the equations defining Home's tastes and technology, simply noting that the same equations apply to Foreign. The utility of a representative consumer is given by a Cobb-Douglas function, yielding the following demand functions:

$$D_Y = (1 - \beta)E, \tag{1}$$

$$D_X = \beta E/p. \tag{2}$$

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

$$E = w_L L + w_S S, \tag{3}$$

where L and S are Home's endowments of unskilled and skilled labor, respectively, while w_L and w_S 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 the numeraire good Y is freely

[2] Note that our specification of the model does not allow firms to choose technology strategically. The only strategic decision the firm faces is whether or not to enter the market (cf. Markusen and Venables, 1997).

traded, which implies that the return to unskilled labor is equal to one in both countries (since they are symmetric, they will always produce both goods):

$$w_L = 1. \tag{4}$$

This means that the relative return to skilled labor is captured by w_S.

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

$$C^k = F^k w_S + c^k w_L (X_d^k + X_e^k) + t w_L X_e^k, \qquad k = M, T. \tag{5}$$

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_d^k the amount of output supplied to the domestic market, and X_e^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.

Note that, according to (5), trade costs are incurred in unskilled labor only. This is a simplifying assumption that does not affect the main results of the analysis. However, some of the results discussed in subsequent sections are sensitive to the assumption about factor intensity of trade costs. Therefore, before concluding, we shall discuss how alternative assumptions would affect the analysis.

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

$$p(1-\theta_d^k) \le w_L c^k, \qquad X_d^k \ge 0, \qquad k = M, T \tag{8}$$

$$p(1-\theta_e^k) \le w_L(c^k + t), \qquad X_e^k \ge 0, \qquad k = M, T \tag{9}$$

where θ, 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. Using that countries are symmetric, this may be written as:

$$\theta_d^k = \frac{X_d^k}{\sum_k n^k(X_d^k + X_e^k)}, \qquad k = M, T \tag{10}$$

$$\theta_e^k = \frac{X_e^k}{\sum_k n^k(X_d^k + X_e^k)}, \qquad k = M, T \tag{11}$$

where n^k is the number of firms in Home that produce with technology k.

Free entry and exit in the X-sector implies that profits are either zero (for firms that operate in the market), or negative (for potential entrants that do not operate in the market):

$$p(X_d^k + X_e^k) \le F^k w_S + c^k w_L(X_d^k + X_e^k) + t w_L X_e^k, \qquad n^k \ge 0, \quad k = M, T \tag{12}$$

The zero-profit condition in (12) is satisfied with equality if there are firms in Home producing with technology k; otherwise it is satisfied as an inequality (i.e., n^k is the associated complementary slackness variable).

Goods-market clearing in the Y-sector is given by:

$$D_Y = Y, \tag{13}$$

while factor-market clearing is given by the following conditions:

$$L = \sum_k n^k \left(c^k(X_d^k + X_e^k) + t X_e^k \right) + Y \tag{14}$$

$$S = \sum_k n^k F^k \tag{15}$$

4 Market integration and relative wages

We now turn to the impact of market integration on technical change, skill intensity and relative wages. The equilibrium is given by equations (2), (3), (4), (8), (9), (10), (11), (12), (13), (14) and (15) and the unknown variables Y, w_L, w_S, p, θ_d^T, θ_e^T, θ_d^M, θ_e^M, D_Y, n^T, n^M, X_d^T, X_e^T, X_d^M, X_e^M, and E. This leaves us with a system of 16 equations and inequalities that solves simultaneously for 16 unknowns.

We shall first explore the effect of market integration on the relative return to skilled labor when there is no technical change. We show that, in this case, there will be a negative effect on the relative return to skilled labor from reductions in trade costs. Then, we investigate how the possibility of technical change affects the relationship between trade costs and relative wages. In order to explore the more complicated general equilibrium effects, we have to rely on numerical simulations.

4.1 Market integration without technical change

We start by analyzing the relationship between w_S and t in a situation where there is only one type of firm, say, traditional type.[3] Using (13) and (15) in (14) we get:

$$w_S = \frac{\beta}{1-\beta}\frac{L}{S} - \frac{\left(c^T X^T + t X_e^T\right)}{F^T(1-\beta)}. \tag{16}$$

where $X^T \equiv X_d^T + X_e^T$. Differentiation of this expression with respect to trade costs yields:

$$\frac{\partial w_S}{\partial t} = -\frac{1}{F^T\left(1-\beta\right)}\left[c^T\frac{\partial X^T}{\partial t} + t\frac{\partial X_e^T}{\partial t} + X_e^T\right] \tag{17}$$

The derivative $\frac{\partial X_e^T}{\partial t}$ is negative since an increase in trade costs will lead to decreased trade volumes. The deriviate $\frac{\partial X^T}{\partial t}$ is also negative because the increase in domestic sales will be less than the decrease in exports. The two first terms in (17) are thus positive (taking the minus sign outside the brackets into account) while the last term is negative. Thus, expression (17) reveals that a change in trade costs has two counteracting effects on the

[3] The model then becomes similar to a reciprocal dumping model with free entry and exit (cf. Brander and Krugman, 1983).

return to skilled labor: On the one hand, the tendency of firms to produce smaller quantities when home markets become more protected will have a positive impact on the relative return to skilled labor.[4] On the other hand, increased costs in terms of unskilled labor for exporting a given quantity will have a negative impact on the relative return to skilled labor. The first term in (17) shows the effect of changes in the demand for unskilled labor as firms' variable costs are altered in response to output changes. The second term shows the effect of changes in the demand for unskilled labor used in exporting the good as firms respond to changes in trade costs by reducing exports. Both these effects will contribute to increasing w_S as trade costs increase. The last term shows the effect of changes in the demand for unskilled labor as the amount of labor required to export a given quantity changes. This effect pulls in the other direction and contributes to a decrease in w_S as trade costs increase.

Figure 1 shows the relationship between w_S and t when we use the equilibrium conditions of the model [5] We see that w_S is increasing in trade costs, implying that the two first terms in (17) dominate over the last term. We also see that this increase is larger for high levels of t than for low levels of t. The reason for this is that there is a non-monotonic relationship between t and the total amount of unskilled labor used to trade goods. While an increase in trade costs from a low level tends to increase the demand for unskilled labor stemming from trade costs, an increase from a high level tends to decrease this demand.[6]

{FIGURE 1: The return to skilled labor with one type of firm only}

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[4] Note that here the number of firms is fixed. Entry of new firms is not possible because skilled labor required to cover the fixed costs cannot be drawn from elsewhere in the economy. The return to skilled labor is determined by the ratio between total operating profits and the number of skilled workers.

[5] The equations that are used to find the relationship between w_S and t are given in appendix. The graph in Figure 1 is based on the following parametrization: $S = L = 10$, $F = 1$, $c = 0.1$ and $\beta = 0.5$.

[6] Total trade costs exhibit an inverted u-shaped relationship with trade costs so that the demand for unskilled labor stemming from trade costs is the highest for intermediate levels. This implies that for a high level of t, further increases in t will unambiguously lead to increases in w_S. For low levels of t, however, we cannot *a priori* exclude the possibility that the increased demand for unskilled labor used to export the good dominates so that w_S decreases with increases in t. Of course, were trade costs to be intensive in skilled labor instead, the effects would go in the exact opposite directions.

4.2 Market integration with technical change

The main point made in this paper is that when we allow for entry of firms producing with another technology, this positive relationship between w_S and t may turn negative. In other words, with the possibility of entry of firms with another technology, reduced trade costs may lead to increased relative returns to skilled labor. In this section, we shall first show that market integration will make it more attractive for firms producing with the modern technology to enter (for a certain range of parameter values). Then, we shall analyze the effect of an increased share of modern firms on the relative demand for skilled and unskilled labor. Finally, we shall explore the effect on the relative demand for skilled and unskilled labor of a change in trade costs, taking into account that this change will both affect the relative profitability of modern and traditional firms and lead to changed trade and output levels of firms.

Suppose that we are in an equilibrium where only traditional firms are operating. Whether this equilibrium is stable or not depends on whether a firm producing with the modern technology finds it profitable to enter. As will be shown in this section, for a certain range of paramenter values, an equilibrium with only traditional firms is stable under autarky, but not under free trade. In such a case, market integration creates incentive for firms producing with the modern technology to enter. Their entry will then trigger technical change and affect relative wages.

In order for a an equilibrium with only traditional firms to be stable, a modern firm that would potentially enter the market has to make negative profits. This will be the case in autarky if the following condition holds (the proof is given in appendix):

$$\left(c^M F^T + (c^T - c^M)S\right)^2 < \frac{SF^T F^M (c^T)^2}{(S - F^M)} \tag{18}$$

This condition will hold for a sufficiently large F^M. However, if F^M is not too large, it may still be the case that a modern firm will find it profitable to enter an equilibrium with only traditional firms when goods are traded freely. In order for a modern firm to make non-negative profits under free trade, the following condition has to hold (see appendix):

$$(c^M F^T + (c^T - c^M)2S)^2 \geq \frac{2SF^T F^M (c^T)^2}{(S - F^M)}, \tag{19}$$

which will hold for a sufficiently low F^M. If both (18) and (19) hold, an equilibrium with only traditional firms is stable under autarky, but not under free trade. A necessary condition for both conditions to hold simultanously is that $(c^M F^T + (c^T - c^M)2S)^2 > 2\left(c^M F^T + (c^T - c^M)S\right)^2$. This implies that

$$2(c^T - c^M)^2 S^2 > (F^T c^M)^2,$$

which will be true if S is sufficiently large (again, proof can be found in appendix).

Choosing parameter values so that these conditions are satisfied, we get a situation where, in autarky, an equilibrium with only traditional firms is stable, while, in free trade, a stable equilibrium has to include modern firms.[7] When we move from autarky to complete market integration, the number of modern firms will then increase while the number of traditional firms will decrease. Because of the non-linearities that the inclusion of trade costs gives rise to, we cannot rule out the possibility that the composition of firms will change in the other direction within certain intervals of trade costs, but we can be sure that as we move from a trade-prohibitively high level of trade costs all the way to zero trade costs, the composition of firms must change in favor of modern firms.

The change in the composition of firms in turn impacts on the relative demand for skilled and unskilled labor. Since unskilled labor is also used in the numeraire sector, the relative demand for skilled labor will increase if the change in the composition of firms leading to a decrease in the total demand for unskilled labor from the X-sector. Total demand for unskilled labor in the X-sector is given by:

$$L_X = n^M(c^M X^M + tX_e^M) + n^T(c^T X^T + tX_e^T) \tag{20}$$

where $X^T \equiv X_d^T + X_e^T$ and $X^M \equiv X_d^M + X_e^M$. Differentiating (20) with respect to n^M, using $dn^T = -\left(F^M/F^T\right) dn^M$, yields:

$$\frac{\partial L_X}{\partial n^M} = \frac{1}{F^T}\left[F^T(c^M X^M + tX_e^M) - F^M(c^T X^T + tX_e^T)\right]$$

[7] Either modern firms will be the only firm type active or there will be a mixed equilibrium where both types of firms co-exist.

It can be shown (see appendix) that the term in brackets is negative and $\frac{\partial L_X}{\partial n^M} < 0$ if the following condition holds:

$$c^T - c^M > t\left[\frac{X_e^M}{X^M} - \frac{X_e^T}{X^T}\right] \tag{21}$$

The left hand side (21) is positive by assumption. The right hand side is non-negative (see proof in appendix). Thus, in order for condition (21) to be satisfied, the product between trade costs and the difference in export shares between modern and traditional firms has to be sufficiently small. It is evident that the condition will hold as t approaches zero and as it approaches the trade-prohibitive level of t (since $X_e^M = X_e^T = 0$ at that level). It is thus only for intermediate levels of t that condition (21) may not hold. The reason for this is that the higher export propensity of modern firms may entail a larger total demand for unskilled labor as unskilled labor is used to export goods.

If a change in the composition of firms leads to a decrease in the X-sector's demand for unskilled labor (and thereby to an increase in the X-sector's skill-intensity), the relative return to skilled labor will increase. This can be shown by using (1), (4), (14), and (15) to derive the relative return to skilled labor as a function of the exogenous variables and n^M:[8]

$$\begin{aligned} w_S = {} & \frac{\beta}{1-\beta}\frac{L}{S} - \frac{\left(c^T X^T + tX_e^T\right)}{F^T(1-\beta)} \\ & + \frac{n^M}{F^T(1-\beta)S}\left[F^M\left(c^T X^T + tX_e^T\right) - F^T\left(c^M X^M + tX_e^M\right)\right], \end{aligned} \tag{22}$$

By differentiating w_S with respect to n^M we get

$$\frac{\partial w_S}{\partial n^M} = \frac{1}{F^T(1-\beta)S}\left[F^M\left(c^T X^T + tX_e^T\right) - F^T\left(c^M X^M + tX_e^M\right)\right]. \tag{23}$$

We see that the condition for this expression to be positive is the same as the condition for total demand for unskilled labor to decrease with the number of modern firms (i.e. condition (21)).

Our primary interest, however, is in the effect of a reduction in trade costs, with its subsequent technological change through a change in the

[8] Note that this expression is derived assuming an equilibrium where both modern and traditional firms are operating.

composition of firms, on the relative return to skilled labor. In analyzing this effect, we also have to take into account the fact that a reduction in trade costs tends to increase produced quantity per firm and the volume of trade, leading to increased demand for unskilled labor in production and trade (as implied by Figure 1). Because of the complexity of the analysis, we here use numerical simulations. The simulations are carried out using a solver supplied in the GAMS package which is able to handle complementary slackness problems directly (see Rutherford, 1995).[9]

Our model experiment consists of a successive lowering of trade costs, starting from a trade-prohibiting level. When trade costs are at the trade-prohibiting level or higher, the output of each firm is limited by the size of the domestic market. For a sufficiently small domestic market, producing with the modern technology will not be profitable, and only firms with the traditional technology will be active. As trade costs fall, exports eventually become profitable, and the firms' market expands. As a consequence, the profitability of modern relative to traditional firms increases, and eventually this will trigger entry of modern firms (and simultanous exit of traditional ones). As the composition of active firms changes, the economy experiences technological change in the sense that traditional firms become more and more predominant. Firms with traditional and modern technology may co-exist for a range of trade costs. However, below some threshold level of trade costs, all traditional firms will have exited the market and only modern firms will be active.

Figure 2 illustrates the impact of lowering trade costs on the relative return to skilled labor.[10] As can be seen from the figure, in the interval of trade costs where there is coexistence of traditional and modern firms, a successive lowering of trade costs leads to an increase in the relative return to skilled labor. Behind this is an increase in the relative demand for skilled labor as firms using small amounts of skilled labor exit while firms using larger amounts of skilled labor enter.[11]

{FIGURE 2: The return to skilled labor with the possibility of entry by two types of firms}

[9] The programme performs the necessary checks whether an equilibrium is consistent with the zero profit conditions.

[10] In the simulation shown, the following parametrization has been used: $S = L = 5.0$, $\beta = 0.7$, $F^T = 0.1$, $F^M = 1.0$, $c^T = 0.05$, $c^M = 0.045$.

[11] In order to address the issue of possible multiplicity of equilibria, we have performed the simulations changing trade costs in both directions; that is, decreasing as well as increasing trade costs.

The increase in the relative return to skilled labor is thus associated with an increased proportion of skilled labor to unskilled labor in the X-sector. This is shown in Figure 3, where the effect of changes in t on the skill-intensity in the X sector is simulated. From this figure it is clear that the skill-intensity increases with reduced trade costs in the interval where there is coexistence of modern and traditional firms.

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

As trade costs fall below the threshold at which there are only modern firms operating, a further lowering of trade costs will induce the existing firms to expand their output by drawing unskilled labor from the outside sector. This increase in the demand for unskilled labor can be seen from Figure 4. Its negative impact on the relative demand for and relative return to skilled labor is apparent in Figures 3 and 2, respectively. Figure 4 also shows the inverted u-shaped relationship between total trade costs and t referred to above.

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

The main result of our analysis; the relationship between trade-induced changes in technology on the one hand, and changes in skill-intensity and relative wages on the other; is robust to alterations in the assumptions about the factor intensity of trade costs. This relationship exists for the interval of trade costs in which a reduction in trade costs leads to a change in the composition of firms producing with different technologies. The results pertaining to trade costs outside this interval, however, are sensitive to such alterations.

As seen in Figure 3, reduced trade costs entail a decline in the return to skilled labor whenever there is only one type of firm active and trade costs are sufficently low to induce trade. This is what we would expect given the relationship between w_S and t shown in Figure 1. However, were trade costs to be incurred in skilled labor only, the relationship between w_S and t in these intervals is less clear-cut. As skilled labor is used to trade goods, any reduction in t that leads to increased *total* trade costs will in itself put upward pressure on w_S. Because of the non-monotonic relationship between t and total trade costs, this may happen for high levels of t. Thus, a reduction in trade costs may lead to increases in w_S in the interval where there are only traditional firms exporting goods.[12]

A plausible alternative assumption about the factor intensity of trade costs is that both skilled and unskilled labor are used to trade goods. We have simulated reductions in trade costs assuming that t is incurred in both skilled and unskilled labor, using fixed coefficients. The results are similar to the ones shown in Figures 2-4.

4.3 Discussion of the results

We have shown that when we have firms producing with technologies that differ in their relation between fixed and variable costs, market integration between identical countries may lead to entry of firms with relatively large fixed costs and exit of firms with relatively large variable costs. On the assumption that fixed costs are more skill-intensive than variable costs, this will increase the relative demand for skilled labor and put upward pressure of the relative return to skilled labor.

There are a number of empirical results that fit in well with such a story. For instance, Greenaway *et al.* (1999) examine the effect of both exports and imports on employment in a large number of manufacturing industries in the UK. They find that increases in both export and import volumes lead to reductions in derived labor demand, indicating that the effect may not primarily work through an increased substitution of foreign for domestic workers in import competing industries. Instead, it appears as if openness to trade in itself affects the production techniques chosen by firms, an interpretation that is consistent with the analysis in this paper. Moreover, Greenaway *et al.* (1999) find that the employment effects are larger for trade with other EU countries than for trade with low-wage countries in Asia. This suggests that the labor market effects of North-North trade may be more important than the effects of North-South trade. They note that the stronger impact of EU trade may well reflect the fact that most trade between the UK and other EU countries is intra-industry in nature.

Another empirical study that reports results consistent with our analysis is Morrison and Siegel (2000), who examine the relationship between trade, technology, and labor demand using industry-distributed data for the US.

[12] Counteracting this effect is the increased demand for unskilled labor induced by increased output levels by firms. However, when the total amount of skilled labor used to trade goods increases, the number of firms will decrease since there is less skilled labor to cover fixed costs. This will dampen the output expansion, not only because there are fewer firms producing the same level of output, but also because a market with fewer firms will let firms hold back output levels more.

They report that technological change has had a greater effect on labor demand than trade, but emphasize that there is a significant *indirect* impact from trade. According to their result, trade stimulates computerization, which in turn enhances the relative demand for skilled labor. They stress that trade-induced changes in technology are crucial to the full understanding of the impact of trade on the labor market.

5 Concluding remarks

This paper has explored a possible link between increased international competition through trade, technological change and the relative wage of skilled and unskilled labor. The link focused on is one where improved market access provides 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 the OECD countries. Most OECD trade is made up by trade between industrialized 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 Market integration without technical change

The relationship between w_S and t for situations where there are only firms using technology k is found in the following way: The first-order conditions for profit maximization imply:

$$p\left(1-\frac{d^k}{n^k}\right)=c^k \tag{24}$$

$$p\left(1-\frac{(1-d^k)}{n^k}\right)=c^k+t \tag{25}$$

where $d^k \equiv X_d^k/(X_d^k+X_e^k)$. Dividing (24) by (25) and simplifying yield:

$$d^k=\frac{c^k+tn^k}{2c^k+t} \tag{26}$$

The zero profit condition implies:

$$(p-c^k-t(1-d^k))(X_d^k+X_e^k)=F^k w_S, \tag{27}$$

factor-market clearing implies:

$$n^k=\frac{S}{F^k}, \tag{28}$$

$$L=n^k(X_d^k+X_e^k)\left(c^k+t(1-d^k)\right)+Y, \tag{29}$$

and clearing of the market for Y implies:

$$(1-\beta)(L+w_S S)=Y \tag{30}$$

Using (28) in (26) gives:

$$d^k = \frac{St + F^k c^k}{F^k(2c^k + t)} \tag{31}$$

Substitution of (30), (28), and (31) into (29) and solving for w_S give:

$$w_S = \frac{\beta L}{(1-\beta)S} - \frac{\left(2F^k c^k(c^k + t) + t^2(F^k - S)\right)}{(1-\beta)(F^k)^2(2c^k + t)}(X_d^k + X_e^k) \tag{32}$$

Substituting (26) and (28) into (24) yields the equilibrium price:

$$p = \frac{S(2c^k + t)}{2S - F^k} \tag{33}$$

Using (33) we find that per unit operating profits are:

$$p - c^k = \frac{St + F^k c^k}{2S - F^k}$$

Using this in (27), substituting for d^k and solving for w_S, give:

$$w_S = \frac{1}{F^k}\left[\frac{St + F^k}{(2S - F^k)} + \frac{(t^2(S - F^k) - F^k c^k t)}{F^k(2c^k + t)}\right](X_d^k + X_e^k) \tag{34}$$

By solving (32) for $(X_d^k + X_e^k)$ and substituting into (34) we get an expression that implicitly defines the relationship between w_S and t.

A.2 Market integration with technical change

We use the following definitions: A variable with superscript $f(T)$ denotes the value of the variable in a free trade equilibrium in which there are only traditional firms. A variable with superscript $a(T)$ denotes the value of the variable in an autarky equilibrium in which there are only traditional firms. The profit of a modern firm that enters the market when there are only traditional firms operating and free trade prevails is given by:

$$\pi^{Mf(T)} = (p^{f(T)} - c^M)X^{Mf(T)} - w_S^{f(T)}F^M$$

The profit of a modern firm that enters the market when there are only traditional firms operating and trade costs are trade-prohibitively high is given by:

$$\pi^{Ma(T)} = (p^{a(T)} - c^M)X^{Ma(T)} - w_S^{a(T)}F^M$$

Proposition 1 $\pi^{Ma(T)} < 0$ *if the following condition holds:*

$$\left(c^M F^T + (c^T - c^M)S\right)^2 < \frac{SF^T F^M (c^T)^2}{(S - F^M)}.$$

Proof. $\pi^{Ma(T)} < 0$ if $(p^{a(T)} - c^M)X^{Ma(T)} < w_S^{a(T)} F^M$. By solving the model on the assumption that there is no trade we find the following expressions for the endogenous variables in autarky:

$$w_S^{a(T)} = \frac{\beta L F^T}{S(S - \beta F^T)},$$

$$p^{a(T)} = \frac{c^T S}{S - F^T},$$

$$X^{Ma(T)} = \frac{(p^{a(T)} - c^M)}{p^{a(T)}} n^{Ta(T)} X^{Ta(T)},$$

$$n^{Ta(T)} = \frac{S - F^M}{F^T},$$

$$X^{Ta(T)} = \frac{\beta L F^T (S - F^T)}{c^T S (S - \beta F^T)}.$$

By substituting for $w_S^{a(T)}$ and $X^{Ma(T)}$ in the inequality we find that it can be expressed as:

$$\frac{(p^{a(T)} - c^M)^2}{p^{a(T)}} n^{Ta(T)} X^{Ta(T)} < \frac{\beta L F^T F^M}{S(S - \beta F^T)}$$

By substituting for $n^{Ta(T)}$ and $X^{Ta(T)}$ and simplifying this can be expressed as:

$$(S - F^T)\frac{(p^{a(T)} - c^M)^2}{p^{a(T)}} < \frac{F^M c^T F^T}{(S - F^M)}$$

Finally, substituting for $p^{a(T)}$ and simplifying we get:

$$(c^M F^T + (c^T - c^M)S)^2 < \frac{SF^M F^T (c^T)^2}{(S - F^M)}.$$

■

Proposition 2 *$\pi^{Mf(T)} \geq 0$ if the following condition holds:*

$$(c^M F^T + (c^T - c^M)2S)^2 \geq \frac{2SF^T F^M (c^T)^2}{(S - F^M)}$$

Proof. $\pi^{Mf(T)} \geq 0$ if $(p^{f(T)} - c^M)X^{Mf(T)} \geq w_S^{f(T)} F^M$. By solving the model on the assumption that $t = 0$ we find the following expressions for the endogenous variables in free trade:

$$w_S^{f(T)} = \frac{\beta L F^T}{2S(S - \beta F^T)},$$

$$p^{f(T)} = \frac{2c^T S}{2S - F^T},$$

$$X^{Mf(T)} = \frac{(p^{f(T)} - c^M)}{p^{f(T)}} n^{Tf(T)} X^{Tf(T)},$$

$$n^{Tf(T)} = \frac{S - F^M}{F^T},$$

$$X^{Tf(T)} = \frac{\beta L F^T (2S - F^T)}{2c^T S(S - \beta F^T)}.$$

By substituting for $w_S^{f(T)}$ and $X^{Mf(T)}$ into the inequality we find that it can be expressed as:

$$\frac{(p^{f(T)} - c^M)^2}{p^{f(T)}} n^{Tf(T)} X^{Tf(T)} \geq \frac{\beta L F^T F^M}{2S(S - \beta F^T)}$$

By substituting for $n^{Tf(T)}$ and $X^{Tf(T)}$ we get:

$$\frac{(p^{f(T)} - c^M)^2}{p^{f(T)}}(2S - F^T) \geq \frac{F^T F^M c^T}{(S - F^M)},$$

which, by substituing for $p^{f(T)}$ can be expressed as:

$$(c^M F^T + (c^T - c^M)2S)^2 \geq \frac{2SF^T F^M (c^T)^2}{(S - F^M)}.$$

■

Proposition 3 *A necessary condition for* $\pi^{Ma(T)} < 0$ *and* $\pi^{Mf(T)} \geq 0$ *to hold is* $2(c^T - c^M)^2 S^2 > (F^T c^T)^2$.

Proof. According to proposition 1 and 2, in order for $\pi^{Ma(T)} < 0$ and $\pi^{Mf(T)} \geq 0$ to hold the following inequality has to be satisfied:

$$\begin{aligned}(c^M F^T + (c^T - c^M)2S)^2 &\geq \frac{2SF^T F^M (c^T)^2}{(S - F^M)} \\ &> 2\left(c^M F^T + (c^T - c^M)S\right)^2\end{aligned}$$

This requires that

$$(c^M F^T + (c^T - c^M)2S)^2 > 2\left(c^M F^T + (c^T - c^M)S\right)^2$$

This expression can also be written as :

$$\begin{aligned}& (c^M F^T)^2 + 4(c^T - c^M)^2 S^2 + 4c^M F^T (c^T - c^M)S \\ > \quad & 2(c^M F^T)^2 + 2(c^T - c^M)^2 S^2 + 4c^M F^T (c^T - c^M)S\end{aligned}$$

By simplifying this expression we get:

$$2(c^T - c^M)^2 S^2 > (c^M F^T)^2.$$

■

Proposition 4 $F^T\left(c^M X^M + tX_e^M\right) < F^M\left(c^T X^T + tX_e^T\right)$ *if* $c^T - c^M > t\left(\frac{X_e^M}{X^M} - \frac{X_e^T}{X^T}\right) > 0$.

Proof. By rearranging $F^T\left(c^M X^M + tX_e^M\right) < F^M\left(c^T X^T + tX_e^T\right)$ we can express this condition in the following way:

$$\frac{F^M}{F^T} > \frac{\left(c^M X^M + tX_e^M\right)}{(c^T X^T + tX_e^T)} \tag{35}$$

From (37) follows that

$$\frac{F^M}{F^T} = \frac{(p - c^M)X^M - tX_e^M}{(p - c^T)X^T - tX_e^T}$$

Substituting for $\frac{F^M}{F^T}$ in (35) and rearranging yields:

$$\left((p-c^M)X^M - tX_e^M\right)\left(c^T X^T + tX_e^T\right) > \left(c^M X^M + tX_e^M\right)\left((p-c^T)X^T - tX_e^T\right),$$

which can be simplified to

$$X^M\left(c^T X^T + tX_e^T\right) > X^T\left(c^M X^M + tX_e^M\right) \tag{36}$$

Dividing both sides of (36) by $X^M X^T$ and rearringing yield:

$$\left(c^T - c^M\right) > t\left[\frac{X_e^M}{X^M} - \frac{X_e^T}{X^T}\right].$$

■

Proposition 5 *When both modern and traditional firms co-exist in equilibrium, the export share of a firm producing with the modern technology is at least as large as the export share of a firm producing with the traditional technology, i.e.,* $X_e^M/X^M \geq X_e^T/X^T$.

Proof. In an equilibrium where both modern and traditional firms co-exist, profits for both types of firms are zero. Using the zero-profit conditions for both types of firms, we get:

$$\frac{\left(p-c^M\right)X_d^M + \left(p-c^M-t\right)X_e^M}{\left(p-c^T\right)X_d^T + \left(p-c^T-t\right)X_e^T} = \frac{F^M}{F^T} \tag{37}$$

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

$$c^T\left(X - X_d^M\right) = c^M\left(X - X_d^T\right) \tag{38}$$

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:

$$c^T\left(X - \left(\frac{c^T+t}{c^T}\right)X_e^M\right) = c^M\left(X - \left(\frac{c^M+t}{c^M}\right)X_e^T\right) \tag{39}$$

From this expression follows that $X_e^M > X_e^T$. It also follows that $X_e^M - X_e^T \geq X_d^M - X_d^T$ since $\frac{c^T+t}{c^T} \leq \frac{c^M+t}{c^M}$. This implies that $X_e^M/X^M \geq X_e^T/X^T$. ■

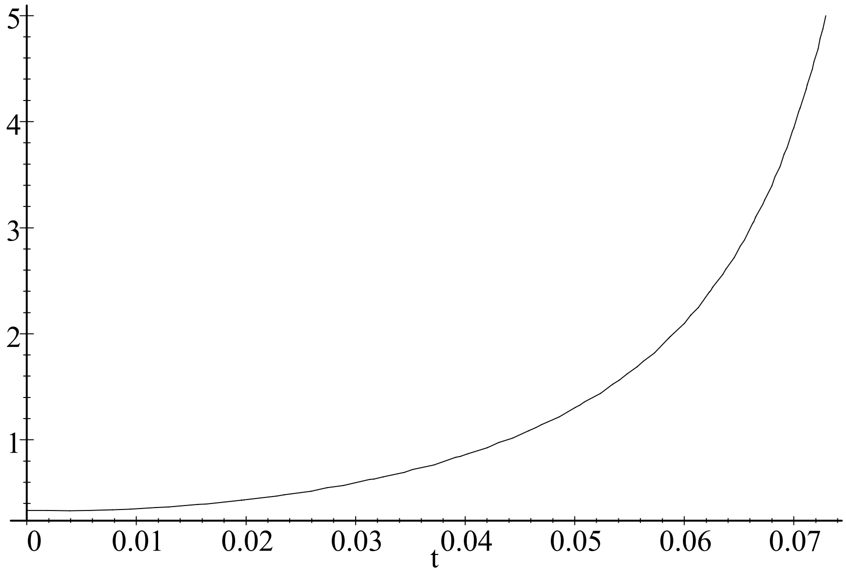

Figure 1: The return to skilled labor with one type of firm only

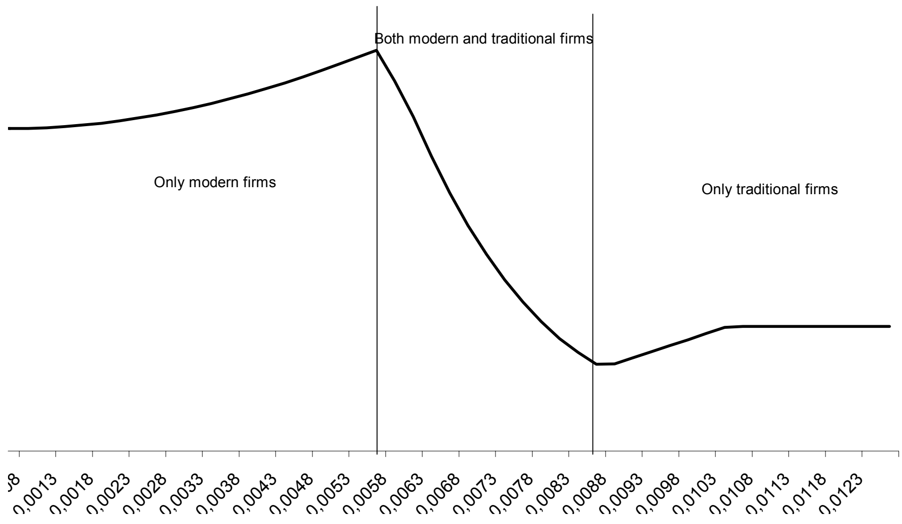

Figure 2: The return to skilled labor with the possibility of entry by two types of firms

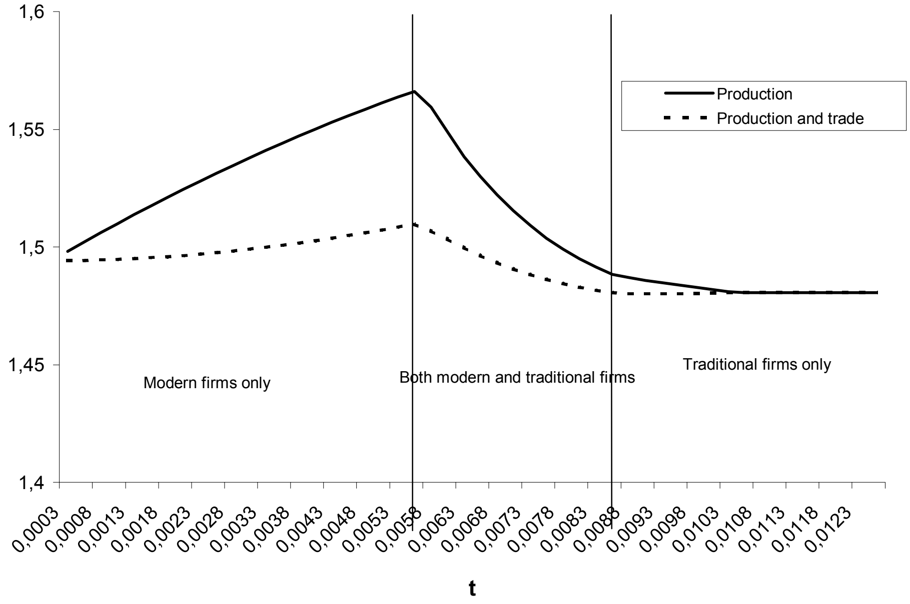

Figure 3: Skill-intensity in X-sector

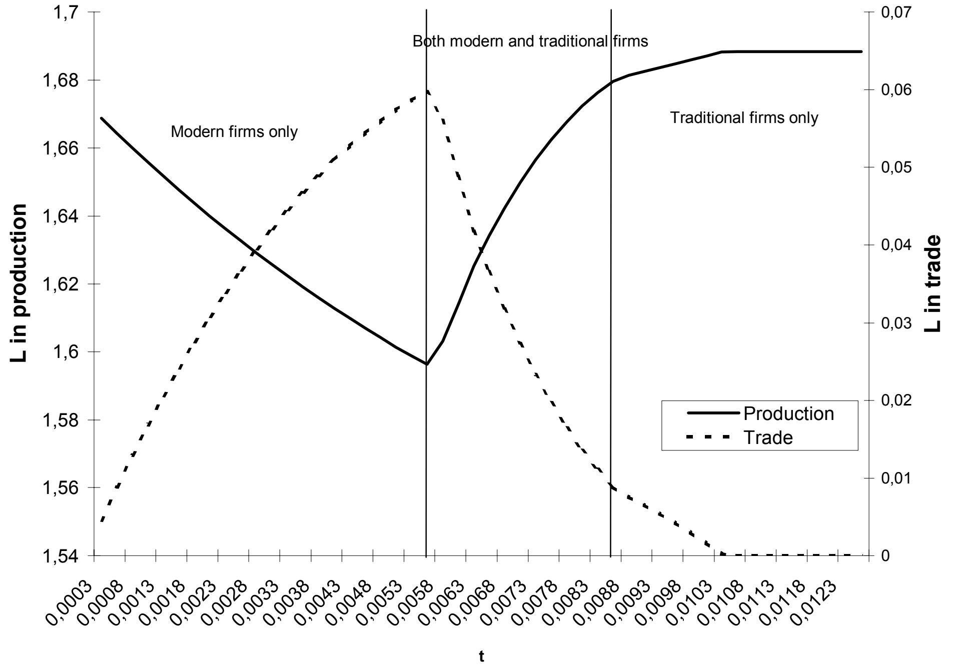

Figure 4: Demand for unskilled labor in X-sector