Institut für Weltwirtschaft
an der Universität Kiel
Düsternbrooker Weg 120
D-24105 Kiel

Kiel Working Paper No. 923

Sectoral Value Added Prices, TFP Growth, and the Low-skilled Wage in High-income Countries

by

Matthias Lücke

April 1999

Sectoral Value Added Prices, TFP Growth, and the Low-skilled Wage in High-income Countries

Abstract:

This econometric analysis investigates the impact of changes in sectoral value-added prices and total factor productivity (TFP) on the equilibrium relative wage of low-skilled workers in eleven high-income countries. The key finding is that TFP growth mandated an increase in the unskilled wage, relative to the remuneration of human capital, during the 1970s, but a decrease during the 1980s. This is consistent with the observation that, in most sample countries, the relative wage and employment opportunities of low-skilled workers tended to improve until about 1980, but have deteriorated since then. While the regression results suggest that technological change played a large role in shifting labour demand against low-skilled workers, this conclusion is qualified because the empirical evidence is also compatible with product upgrading and outsourcing of low-skill intensive production activities to low-income countries.

JEL Classification: F16; O33

Matthias Lücke
Kiel Institute of World Economics
P.O. Box 4309
D-24100 Kiel
Fax *49-431-85853
E-mail: Mluecke@ifw.uni-kiel.de

1 Introduction[*]

In most high-income OECD countries, the labour market position of low-skilled workers has deteriorated significantly since about 1980. This shows up in unemployment rates for low-skilled workers that are now substantially higher, and have been growing faster, than for high-skilled workers. Furthermore, in the United States and in the United Kingdom, the wage premium of high-skilled over low-skilled workers has increased considerably. The resulting increase in earnings inequality has contributed to increases in total income inequality in many countries.[1]

This shared experience of worsening labour market opportunities for low-skilled workers is remarkable because high-income countries differ considerably in terms of their industrial and technological specialisation, macroeconomic policies, labour market institutions, and even important labour market outcomes such as the aggregate unemployment rate. The fact that the position of low-skilled workers has deteriorated almost universally suggests common, rather than specific national causes. Furthermore, labour market opportunities for low-skilled workers deteriorated while their relative wages remained either stagnant or even declined and while the proportion of low-skilled workers in the labour force also declined. This observation suggests that demand for low-skilled labour has declined even more sharply than supply. Therefore, the debate on why labour market opportunities for low-skilled workers have deteriorated, has concentrated on possible causes of declining relative demand for low-skilled workers.

Much of this lively debate has dealt with the relative importance of labour-saving technological change vs. growing manufactured imports from low-income

---

* This paper is part of the research project "Globalisation and Social Exclusion", financed by the European Union under its Targeted Socio-Economic Research (TSER) programme and coordinated by Professor John Whalley at the Centre for the Study of Globalisation and Regionalisation at the University of Warwick. Earlier versions were presented at several seminars and conferences, including the 1998 annual meetings of the European Economic Association and the Verein für Socialpolitik (German Economic Association). I thank in particular, without implicating, Martin Falk, Rolf J. Langhammer, Karl-Heinz Paqué, Victor Steiner, and Thomas Ziesemer.

1 Since South Korea, Mexico, Poland, Hungary, and the Czech Republic are now OECD members, the sample countries are referred to as high-income countries. - The literature on the earnings and income distribution in the various high-income countries is extensive. A good overview is provided by Gottschalk (1997) and Gottschalk, Gustafsson and Palmer (1997). Relative earnings and unemployment rates for high-skilled and low-skilled workers are reviewed in OECD (1997 Employment Outlook). For a more detailed discussion, see Section 5.2 below.

countries.[2] This distinction matters particularly for the purpose of forecasting demand for low-skilled workers: If autonomous technological change dominates, then present trends can be expected to continue relatively smoothly. However, if manufactured imports dominate, then the labour market prospects for low-skilled workers may be affected strongly by trade policy shifts such as further trade liberalisation by large, labour-abundant developing countries like India or China. At the same time, the policy recommendations flowing from this debate are fairly independent of why labour market opportunities for low-skilled workers deteriorate. Here, the discussion revolves around the effectiveness (seldom the efficiency) of policies that either enhance demand for low-skilled labour, for example through lower payroll taxes or explicit subsidies, or reduce relative supply, particularly through improved schooling, continuing education, or vocational training.[3]

Empirical tests of the relative impact of technological change vs. manufactured imports on demand for low-skilled workers have used widely different approaches that are often related to Heckscher-Ohlin trade models. This paper contributes to the debate, first, by exploring carefully how technological change and shifts in global factor supply jointly impact upon relative factor prices in general equilibrium models in the Heckscher-Ohlin tradition. While the basic interaction can be clarified with the help of a small two-factor, two-sector model, the subsequent empirical analysis requires an extension to a three-factor, multi-sector framework (Section 2).

Second, an econometric analysis of changes in sectoral value added prices and total factor productivity (TFP) is undertaken for a sample of 13 manufacturing industries in each of 11 OECD countries. It is investigated what changes in the equilibrium unskilled wage relative to the remuneration of human capital were mandated by the changes in value added prices, TFP, and value added prices and TFP combined, during the 1970s and 1980s. These regression results provide insights into the impact of technological change and other factors, including trade, on the relative low-skilled wage. Section 3 describes the econometric model and discusses the specification of variables and data sources, while Section 4 presents the regression results. The main finding is that TFP growth worked in favour of

---

2 Helpful surveys of the debate at different stages include Burtless (1995), Slaughter and Swagel (1997), and Paqué (1998), as well as the symposia organised by the Journal of Economic Perspectives (Freeman 1995; Richardson 1995; Wood 1995; Rodrik 1998) and by the Economic Journal (Slaughter 1998; Francois and Nelson 1998; Hine and Wright 1998).

3 The discussion of policy implications by Wood (1994) is particularly lucid. Recent surveys of studies on the effectiveness of training programmes for the low-skilled include Friedlander and Greenberg (1997) for the US and Büttner and Prey (1998) for Germany.

unskilled labour during the 1970s, but benefited human capital disproportionately during the 1980s. Furthermore, during both the 1970s and the 1980s, the mandated user cost of physical capital declined relative to the unskilled wage. Section 5 discusses and interprets these findings in the light of the extensive existing literature on the labour market effects of technological change. Section 6 concludes on research strategies.

2 Trade, Technological Change, and Relative Factor Prices in a Heckscher-Ohlin Framework

This section starts by clarifying the links between trade, technological change, factor supplies, product and factor prices in a small, ‘two-by-two’ general equilibrium model in line with early work by Ronald Jones (1965; 1966; 1970). Subsequently, it is shown that the key features of this small model are maintained when it its extended to three factors of production and many goods and countries.

In the small general equilibrium model, the production side of the economy is described by assuming that both factors of production (which are henceforth referred to as labour and human capital for convenience) are fully employed. The production functions of both industries (to be called clothing and machinery) display constant returns to scale, and competition drives profits to zero in equilibrium. In a comparative-static interpretation, the model is written in relative rates of change. Exogenous technological change is introduced in the form of changes in factor input coefficients in each industry. The following two equations describe small differences in variables between two equilibria, assuming that both products are produced at both points in time (diversified production):

(1) $\lambda\left(\hat{Q}_C - \hat{Q}_M\right) = \left(\hat{L} - \hat{H}\right) + \left(\pi_L - \pi_H\right) + \delta\left(\hat{w}_L - \hat{w}_H\right)$

(2) $\theta\left(\hat{w}_L - \hat{w}_H\right) = \left(\hat{p}_C - \hat{p}_M\right) + \left(\pi_C - \pi_M\right)$

where

λ, δ, θ	positive constants (cf. Jones 1970 for details)
$\hat{x}$	percentage change in x
Q_C	clothing output
Q_M	machinery output
L	stock of labour

H	stock of human capital
w_L	wage
w_H	return to human capital
p_C, p_M	price of clothing/machinery

π_L and π_H are the rates of growth of productivity-adjusted factor stocks through technological change alone:

$$(3)\quad \pi_L = \lambda_{L,C} \cdot \hat{b}_{L,C} + \lambda_{L,M} \cdot \hat{b}_{L,M}$$

$$\pi_H = \lambda_{H,C} \cdot \hat{b}_{H,C} + \lambda_{H,M} \cdot \hat{b}_{H,M}$$

where

$\lambda_{L,C}$	share of economy-wide stock of labour employed in the clothing industry (etc.)
$\hat{b}_{L,C}$	relative change in labour input coefficient in the clothing industry due to technical progress at constant relative factor prices, multiplied by (-1)

π_C and π_M are the growth rates of total factor productivity (TFP) in the two sectors:

$$(4)\quad \pi_C = \theta_{L,C} \cdot \hat{b}_{L,C} + \theta_{H,C} \cdot \hat{b}_{H,C}$$

$$\pi_M = \theta_{L,M} \cdot \hat{b}_{L,M} + \theta_{H,M} \cdot \hat{b}_{H,M}$$

where

$\theta_{L,C}$	share of labour in production cost in clothing industry (etc.).

Leaving changes in factor input coefficients aside for the time being (i.e. setting $\pi_L = \pi_H = \pi_C = \pi_M = 0$), equation (2) reflects the Stolper-Samuelson theorem that the relative factor price $\left(\hat{w}_L - \hat{w}_H\right)$ changes if and only if the relative product price $\left(\hat{p}_C - \hat{p}_M\right)$ changes. Equation (1) reflects the Rybczinski theorem that, with a constant relative product price, a change in factor supplies $\left(\hat{L} - \hat{H}\right)$ affects the output mix $\left(\hat{Q}_C - \hat{Q}_M\right)$, but not the relative factor price ($\hat{w}_L - \hat{w}_H = 0$ because $\hat{p}_C - \hat{p}_M = 0$ from (2)). For example, immigration of predominantly low-skilled labour ($\hat{L} > \hat{H}$) leads to an increase in clothing production ($\hat{Q}_C > \hat{Q}_M$), but leaves the relative wage unaffected (equation (2)). This is a variant of the factor price equalisation theorem emphasised, inter alia, by Leamer (1995).

These relationships may be used to explore the impact of increasing trade with low-wage countries and technological change on the relative wage $\left(\hat{w}_L - \hat{w}_H\right)$. It is useful to assume initially that equations (1) and (2) describe a small open economy where product prices are determined solely by world demand and supply (i.e. demand for the home country's output is infinitely price-elastic). Turning first to the impact of trade, the integration of unskilled-labour-rich developing countries into the international division of labour may be thought of as shifting the world supply curve for clothing further outward than the supply curve for machinery. As a result, the relative price of clothing in the world market declines ($\hat{p}_C - \hat{p}_M < 0$).[4]

This shift in the relative product price leads to a new equilibrium that differs from the former in three important ways: First, according to equation (2), the relative wage declines: $\hat{w}_L - \hat{w}_H < 0$. Second, according to equation (1), clothing output decreases and machinery output increases. As domestic demand for clothing increases and demand for machinery decreases in response to the change in the relative product price, net imports of clothing and net exports of machinery both increase in such proportion as to balance trade. Third, because of the reduction of the relative wage, production in both sectors becomes more labour-intensive. This is achieved by transferring human capital and labour from clothing to machinery production in such proportion that the amount of human capital is reduced by a greater proportion than labour in clothing production; conversely, in machinery production, the amount of human capital is increased by a smaller proportion than labour.

Technological change, which is defined by some combination of exogenous (i.e. other than factor-price induced) changes in the factor input coefficients in the two industries, has two separate effects in this model. First, equation (2) includes changes in sectoral total factor productivities ($\mathrm{p}_C - \mathrm{p}_M$) whose impact on the relative wage $\left(\hat{w}_L - \hat{w}_H\right)$ is equivalent to a change in the relative product price ($\hat{p}_C - \hat{p}_M$). In the terminology of Jones (1965), this is the differential industry effect of technological change. Second, technological change involves a change in

---

4 This may also be seen by assuming that equations (1) and (2) describe not an individual economy but the integrated world equilibrium. In this case, the demand function links changes in output and product prices, and an increase in clothing output (from equation (1)) will only meet additional demand if the relative price of clothing declines.

productivity-adjusted factor supplies ($p_L - p_H$). As equation (1) shows, this is equivalent to a change in actual factor supplies, e.g. through migration ($\hat{L} - \hat{H}$). In the terminology of Jones (1965), this is the differential factor effect.

Under realistic conditions, the overall impact of technological change on labour demand depends crucially on whether it occurs only in the home country or world-wide. If it occurs only at home and thus leaves world market product prices unaffected, the differential industry effect (differences in sectoral TFP growth rates) represents the full impact of technological change on the relative wage. Any changes in product prices will only reflect changes in global supply and demand conditions, including export expansion by low-income countries. Thus there is a neat distinction between the labour market impact of technological change, on the one hand, and trade, on the other.

There is ample evidence, however, that international technology transfer is wide-spread and rapid (e.g. Helpman and Coe 1995; Lücke 1993, 1996). Hence it is necessary to explore the opposite assumption that technological change is similar world-wide. In this case, sectoral TFP growth shifts the global industry supply curve outward, leading to a lower world market price and increased output. Thus the impact of the differential industry effect on the relative wage depends crucially on the extent to which TFP growth it is passed through into lower product prices (see Section 3.1 for a more detailed discussion of how this issue is dealt with in the econometric analysis).

The role of the differential factor effect also changes when technological change occurs world-wide. Assume, for example, that 'labour-saving' innovations are introduced in many high-income countries so that the productivity-adjusted labour supply grows faster than the supply of human capital ($p_L - p_H > 0$). Because of this change in effective global factor supplies, the world supply curve of the labour-intensive product (clothing) will shift out farther than the global supply of machinery. As a result, the relative price of clothing and the relative wage will decline by more than mandated by the differential industry effect of the global technological change (equation (2)). Thus both, labour-intensive export expansion by developing countries and global, labour-saving technological change, lead to a decline in the relative price of clothing. In turn, the relative price shift, on its own, reveals nothing about the cause of the corresponding decline in the relative wage.[5]

---

5 Note, however, that the output effects of labour-saving technological change differ from those of labour-intensive export expansion by developing countries: The differential factor effect of technological change tends to shift factors of production towards the clothing industry, whereas any decline in the relative price of clothing (and in the relative wage) has the opposite effect

The preceding discussion assumes that both industries exist in the old as well as in the new equilibrium (diversified production). Therefore, if the domestic labour supply increases relative to human capital, clothing production can be expanded at the given world price to accommodate the extra labour. The relative wage changes only if the relative product price changes. However, when only one good is produced (complete specialisation), changes in effective factor supplies, either actual or through differential productivity growth, do affect factor prices. Imagine that the supply of human capital in the economy increases so much that all factors move into machinery production and clothing production ceases. With a further increase in human capital relative to labour, the full employment condition requires the relative return to human capital to fall so that all factors are employed in the machinery sector in the proportion in which they are nationally available. Thus, with complete specialisation, product prices no longer affect factor prices, but domestic factor endowments do.

The distinction between diversified production and complete specialisation remains important when the two-factor, two-industry model is extended to a three factor, multi-product framework.[6] Then each country produces a range of goods whose factor intensities are similar to the country's relative factor endowments (which may be represented graphically by a "Leamer triangle"). Like in the two-by-two model with diversified production, changes in factor endowments lead to shifts in the output mix, but do not affect factor prices as long as the country produces the same set of goods. This is true even if factors of production are not substitutable but are used in fixed proportions in each individual industry. In the absence of technological change, relative factor prices depend only on the relative prices of the goods that are actually produced. With technological change, the differential industry and factor affects impact upon factor prices and the output mix much as before.

(equation (1)). With technological change, it is therefore not clear *a priori* which of the two effects dominates. With export expansion by developing countries, there is only the price effect and the output mix shifts unambiguously towards machinery. Similarly, developing country export expansion results in production becoming more labour-intensive in both industries (see above), while technological change may lead to diverging changes in human capital intensity in the two sectors or higher human capital intensity across the board, depending on the technology-induced changes in factor input coefficients in each sectors.

6 This discussion closely follows Leamer (1987); for shorter summaries see Leamer (1995, 1996). - The econometric analysis in this paper is limited to the manufacturing sector so that unskilled labour, human and physical capital may be defined as the relevant factors of production and output may be measured by gross value added. See Section 3.2 for a more detailed description of the database.

Only if relative factor stocks change substantially, for example through sustained human or physical capital accumulation, then the set of goods that are produced may change. Production of the good that is least intensive in the rapidly growing factor ceases and products that use the growing factor intensively may enter the product mix. As a consequence, the relative price of the more widely available factor of production declines. This is similar to the case of complete specialisation in the two-by-two model.

The following empirical analysis is based on the assumption of diversified production. Thus the period of observation is assumed to be long enough for industries to contract and to expand, and for all three factors of production to move across sectors. From the point of view of data availability, the assumption of diversified production is also convenient because none of the industries in the sample ever disappears during the period of observation. All sample countries continue to produce manufactures with widely different factor intensities, including such relatively labour-intensive products as basic metalware and even footwear and clothing.[7]

3 Econometric Model, Data Sources, and Variable Specification

3.1 Regression Model

The econometric analysis is based on an extension of equation (2) to a three-factor, multi-product framework. It investigates what changes in the equilibrium unskilled wage relative to the remuneration of human capital were mandated by the changes in value added prices, TFP, and value added prices and TFP combined, during the 1970s and 1980s. The regression results are used to provide insights into the relative impact of technological change vs. other factors, including trade, on the relative low-skilled wage.

The zero-profit-condition, written in relative rates of change, indicates which (hypothetical) changes in factor prices would have been consistent with the observed changes in the value added price and total factor productivity of industry *i*:

7 It may be noted that this assumption, while appearing natural to trade economists, is not usually made by labour economists. They tend to assume that relative factor prices depend, *inter alia*, on effective factor supplies, which allows developments such as immigration to affect relative factor prices (e.g. Borjas, Freeman and Katz 1997).

(5) $p_i = a_{Li} w_L + a_{Hi} w_H + a_{Ki} w_K$

(zero-profit condition) where

a_{Li}, a_{Hi}, a_{Ki}	factor input coefficients
w_K	return to physical capital
i	industry index

Differentiating and dividing through by p_i we obtain

(6) $\hat{p}_i = \theta_{Li}\hat{w}_L + \theta_{Hi}\hat{w}_H + \theta_{Ki}\hat{w}_K$

$+\theta_{Li}\hat{a}_{Li} + \theta_{Hi}\hat{a}_{Hi} + \theta_{Ki}\hat{a}_{Ki}$

where

$\hat{x}$ relative change in variable x.

The weighted average of the relative changes in factor input coefficients is the growth rate of total factor productivity multiplied by (-1):

(7) $-\pi_i = \sum_j \theta_{ji}\hat{a}_{ji}$

Writing the growth rate of TFP (π_i) on the left hand side (LHS) and using $\theta_{Li} + \theta_{Hi} + \theta_{Ki} = 1$, we obtain:

(8) $\hat{p}_i + \pi_i = \hat{w}_L + \theta_{Hi}(\hat{w}_H - \hat{w}_L) + \theta_{Ki}(\hat{w}_K - \hat{w}_L)$

Equation (8) demonstrates how (small) changes in product prices and TFP are related to (small) changes in factor prices depending on each industry's human and physical capital intensity. This is already very close to the basic form of my regression model:

(9) $\hat{p}_i + \pi_i = \beta_1(\theta_{Li} + \theta_{Hi} + \theta_{Ki}) + \beta_2\theta_{Hi} + \beta_3\theta_{Ki} + u_i$

where

$\beta_1 = \hat{w}_L$

$\beta_2 = \hat{w}_H - \hat{w}_L$

$\beta_3 = \hat{w}_K - \hat{w}_L$

In its core form, this is a cross-section model estimated across sectors within each country, with the sum of price and TFP changes as the left hand side (LHS) variable, base-period factor income shares as the right hand side (RHS) variables, and individual manufacturing industries as the cross-section units.[8] If product prices and TFP growth are assumed to be exogenous (for example, determined by world supply and demand and by genuine technological innovations, respectively), the OLS regression yields coefficients that can be interpreted as the relative factor price changes mandated by the product price and TFP changes. The error term reflects the fact that, under realistic conditions, the zero-profit condition (5), on which equation (8) is based, does not hold exactly at every point in time because of measurement errors, limited factor mobility across sectors in the short run, etc.

This econometric model may appear counter-intuitive because the exogenous variables (world market prices and total factor productivity growth) are on the LHS of equation (9) whereas the "dependent" variables (mandated factor price changes) are on the RHS. Note, however, that this analysis seeks to find the combination of factor price changes that best reflects the underlying product price and TFP changes, given that there are more industries than factors of production. This means finding those values of b_1, b_2 and b_3 that "minimise the difference between" the sum of the products on the right-hand side of equation (4) and the sum of changes in product prices and total factor productivity on the left-hand side. This is exactly what the least-squares method does (cf. Leamer (1994), Krueger (1997), and Slaughter (1999).

This interpretation raises the question of how a regression based on (8) can do anything but reproduce the actual change in factor prices if the zero-profit condition in fact holds (Feenstra and Hanson 1997). This analysis is based on the assumption that the zero-profit condition does indeed hold in the long run. In the short to medium run, however, the factors of production, particularly physical capital, are probably less than perfectly mobile across sectors. Product price changes are therefore accommodated through cross-sectoral differences in the prices of temporarily sector-specific factors, particularly profit rates. In this case, a regression based on equation (8) reveals the long-term changes in factor prices that are mandated by the (exogenous) changes in product prices and TFP.

Furthermore, the implied factor price changes can be decomposed into those due to the differential industry effect of technological change (as long as TFP growth is not completely passed through into value added prices) vs. those due to other factors, including import competition. Three variants of the regression model (9)

---

8 I deliberately avoid the term 'dependent variable' because the direction of economic causality is assumed to be from the LHS variable to the estimated coefficients on the RHS, rather than from some 'independent' RHS to the 'dependent' LHS variable. Studies employing this approach include Baldwin and Cain (1997), Fitzenberger (1997), Haskel and Slaughter (1999), Krueger (1997), Leamer (1996), Lücke (1999), and Oscarsson (1997).

are estimated: First, the model is run with the product price change on the LHS but with TFP growth added to the right-hand-side (RHS) variables. In this regression, the coefficient of TFP growth gives a direct estimate of the pass-through rate. The implied relative factor price changes are those due to all factors other than the differential industry effect.

Second, with TFP growth as the LHS variable, the implied factor price changes are those due to the differential industry effect if the extreme assumption is made that TFP is not passed through into product prices. The actual effect is proportionately smaller depending on the pass-through rate (see Section 4 for an example).

Third, the basic form of the regression model as in (9) is interpreted as the total mandated change in relative factor prices. The factor price changes found by these regressions indicate to what extent the model accounts for the observed price changes.

When these three variants of the econometric model are estimated, the basic cross-section approach embodied in equation (9) is further modified in four significant respects: First, it turns out that the factor income shares change over time. If a regression based on (9) is run on rates of change over a long period, say, a decade, it is implicitly assumed that product price and TFP changes towards the end of the period affect the individual sectors in accordance with the factor income shares at the beginning of the period. As this is not plausible because of the change in factor income shares, I use annual rates of change for prices and TFP, pooled over the period of observation. A product price change from one year to the next affects factor prices in accordance with each industry's factor income shares in the first year, not several years ago. The mandated factor price changes may be viewed as averages for the relevant time period. Regressions are run over the full period for which data are available (for most countries, from 1970 to 1992) with dummy variables for sub-periods to capture possible shifts over time in the mandated factor price changes.

Second, with nominal product prices as in equation (9), the intercept term b_1 reflects mainly the underlying inflation rate which varies from year to year. Initially, this was accounted for by including an intercept dummy for each year in the pooled regression. It turned out, however, that very similar coefficient estimates were obtained for the implied relative factor price changes (b_2 and b_3) when changes in sectoral value added prices were calculated relative to total manufacturing (ISIC 3). As the number of intercept dummies would become very large when all sample countries are included in the regressions simultaneously (see the fourth point), relative price changes are used throughout the analysis.

Third, since the data include sectors of widely varying size, observations are weighted by each sector's share in manufacturing value added in each year, normalised by the average sector share (i.e. 1 divided by the number of sectors). Thus the average weight over all sectors is unity and the mean of the transformed LHS variable is a weighted average of the sectoral growth rates. This procedure accounts for the fact that output price and TFP changes in large sectors have a greater impact on economy-wide factor prices than similar changes in small sectors.

Fourth, when regressions were first run individually for each sample country, it turned out that the findings were broadly similar across countries. This is not unexpected because the low-skilled equilibrium wage has declined in nearly all high-income countries (cf. Section 1). Therefore, the data for all sample countries are pooled to test (through the inclusion of country-specific dummy variables) whether the changes in implied factor prices in the individual countries can be summarised by the same slope coefficients (b_2 and b_3). In these regressions, each observation (by sector and country) enters with a weight that depends only on the size of the sector within its own country, not on the size of the country relative to other countries. This weighting scheme is used because possible differences in coefficients across countries are already accounted for by the country-specific dummy variables.

3.2 Data Sources and Construction of Variables

The choice of data for this analysis is constrained by the need for international comparability in general and for capital stock data for individual industries in particular. Capital stock data are required to calculate the growth rates of total factor productivity. Hence I use data from the International Sectoral Database CD-ROM maintained by the OECD which, in turn, is based mainly on national accounts data. This database contains, *inter alia*, value added in current and constant prices, labour compensation, employment, and the capital stock for up to 13 manufacturing industries in each country. The sample includes all 12 countries for which value added in current and constant prices (required for calculating the value added price index) as well as capital stock data are available.[9]

Manufacturing industry is defined widely to include food processing and metallurgy and thus covers all ISIC 3 industries. These industries account for the lion's share of output and employment in the tradable goods sectors of most

---

9 Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, UK, US.

OECD economies.[10] By measuring output as gross valued added we assume that sectoral production functions are separable between primary inputs and purchased materials and services. This is a somewhat problematic assumption because, as reactions to the first oil price shock in 1973 show, physical capital in the form of more expensive, energy-conserving machinery may be substituted for energy inputs. However, limited data availability precludes the inclusion of materials as a separate input. The index of output prices is the implied value added price index obtained by dividing nominal by real value added. Thus the index relates to the goods that are actually produced in each country.

In order to measure the share of human capital in value added, it is assumed that the compensation received by each worker reflects remuneration both for (unskilled) labour services and for human capital services. This definition of human capital accounts for formal education as well as training on the job because both are reflected in wages (cf. Kruger 1997 and Harberger 1998). Therefore, the stock of (unskilled) labour is defined as the total number of persons engaged. The (unskilled) wage is proxied by one half the average compensation received by employees in retail trade. The total remuneration of human capital is defined as that part of employee compensation that exceeds the hypothetical compensation of labour. The remuneration of physical capital is the difference between gross value added and the remuneration of labour and human capital.

The use of average wages in retail trade as a proxy for the unskilled wage is necessitated by data availability. Ideally, one would aim for an occupational wage for an unskilled profession that is not affected by skill upgrading during the period of analysis. However, such occupational wages are not available in an internationally comparable format. Of the major sectors listed in the International Sectoral Database, the average per capita wage in retail trade can be calculated for all sample countries, and is nearly always the lowest average wage across sectors. Hence, at any point in time, it may be considered an adequate approximation of the unknown economy-wide unskilled wage.

Over time, however, there is some evidence that retail trade has been subject to substantial skill upgrading in many sample countries. In particular, the average wage has grown faster in retail trade than in other low-skill-intensive sectors such as transport and storage or construction. While average wage data for these two sectors are unavailable for many sample countries, the sensitivity of the

---

10 This restriction also avoids data problems related to the measurement of the stocks of natural resources and agricultural land. Lücke (1992) discusses the implications of this restriction in greater detail.

regression results to the implicit assumption of no skill upgrading in retail trade is tested through alternative estimates based on an adjusted unskilled wage in line with the slower growth of average wages in these two sectors.

The growth rate of total factor productivity is calculated with only physical capital and employment as factors of production. No time series for the price of human capital are available for the individual countries and hence no volume index can be calculated for human capital used in production. Sensitivity studies for Germany where a proxy for the price of human capital is available suggest that our measure of TFP does not differ much from sectoral growth rates of TFP that explicitly account for all three factors of production.

4 Regression Results

This paper analyses patterns of relative price and TFP changes that are believed to be common to the sample countries. Hence it is important to test whether the mandated relative factor price changes are indeed reasonably similar enough across countries. Table 1 reports regression results based on Equation (9) with a full set of country intercept and slope dummies so that all mandated relative factor price changes may differ across countries. As the mandated changes also differ between the 1970s and 1980s, results are reported separately for the two sub-periods. A stepwise regression procedure is employed to exclude dummy variables whose coefficients were close to zero: at each step, the dummy variable with the lowest t-value is excluded as long as a Wald test does not reject (at the 10 percent significance level or less) the hypothesis that the coefficients of all omitted slope dummies are jointly equal to 0. The remaining coefficients are reported in Table 1.[11]

Overall, the number of country slope dummies with significant coefficients is small. For the human capital share, no more than two countries show a distinctly different pattern from the rest in each regression. For the physical capital share, there are up to three significant coefficients for the 1970-80 period and up to five for the 1980-92 period (recall that there are 12 countries in the sample). However, many of these slope dummy coefficients are not very large; only Norway is clearly an outlier. The pass-through rate of sectoral TFP growth into relative prices (coefficient of TFP growth) appears to vary more widely across the sample countries, with up to six significant slope dummies.

---

11 The resulting subset of excluded slope dummies may of course not be the only subset whose coefficients are jointly not significantly different from zero. Hence, no particular interpretation is attached to the coefficients of the remaining dummy variables.

Because of its widely diverging coefficient estimates, Norway is excluded from the sample for the subsequent analysis. It is difficult to say whether there are substantial errors in the Norwegian data for the 1980s or whether the special position of the country as a small resource-rich oil-exporting economy causes price and TFP changes to differ so widely from the rest of the sample. All further regressions are estimated jointly for the remaining countries, with only the implied change in the real wage for low-skilled labour (the constant in Equation 9) differing across countries. It will be seen that this has no major impact on the coefficient estimates. However, joint estimation permits the testing of hypothesis about a possible change in coefficients between the 1970s and the 1980s which would be difficult in the presence of a large number of country and time period dummies.

Before proceeding to the joint estimates for all sample countries except Norway, I note five key findings from the regression results in Table 1 that will be confirmed by the subsequent analysis. The first relates to the changes in sectoral value added prices, allowing for the pass-through of technological change into value added prices through the inclusion of TFP growth among the RHS variables: Value added prices mandate a pronounced decline in the remuneration (i.e. user cost) of physical capital relative to unskilled labour particularly during the 1970s. In this particular regression, the rate of decline is estimated as 7.7 per cent annually.

Second, value added prices do not mandate a significant increase in the implied remuneration of human capital relative to unskilled labour (which one would expect if exports from low-income countries had indeed had a substantial impact on relative factor prices in high-income countries). On the contrary, the estimated coefficient mandates a decline at an annual rate of 1.4 per cent in both subperiods; however, it is not significantly different from zero so that no particular interpretation is attached to the negative sign.

Third, the pass-through rate of differential sectoral TFP growth into relative value added prices is significant at an estimated 19 per cent for both subperiods, but pass-through is far from complete (i.e. the rate is far below 100 per cent). Hence, the differential factor effect of technical progress may strongly affect relative factor prices.

Fourth, TFP growth is strongly biased against both human and physical capital intensive industries during the 1970s, with a mandated decline in the remuneration of human capital relative to unskilled labour of 11.7 per cent annually; the corresponding annual rate of decline for physical capital is 8.6 per cent. Put differently, for every 10-percentage-point increase in the human capital share across sectors, TFP growth is reduced by 1.17 percentage points. However, this pattern is reversed from 1980 to 1992: TFP growth mandates a 5.3 per cent annual increase in the relative remuneration of human capital, and only a small (and statistically insignificant) decline in the relative user cost of physical capital. The pass-through rate of TFP into product prices has been estimated at 19 per cent for the majority of countries, and somewhat higher for most of the rest. Therefore, although some of the potential effect of TFP growth on relative factor prices is cancelled out by compensating product price changes, the regression results suggest that up to 81 per cent of the potential change in relative factor prices due to TFP growth is actually realised.

Fifth, the relative factor price changes mandated by value added prices and TFP combined change markedly between the 1970s and 1980s. During the 1970s, the mandated relative remuneration of human capital and the mandated user cost of physical capital both decline sharply. From 1980 to 1992, the decline is far less pronounced for physical capital, and there is an increase (though not significantly different from zero) for human capital. This shift coincides with the shift, in many high-income countries, from decreasing to increasing inequality around 1980 and is clearly driven by the shift in the sectoral pattern of TFP growth from harming human capital during the 1970s to benefiting human capital in the 1980s.

Some implied changes in relative factor prices appear rather large. However, the value added share of unskilled labour is hypothetical so that all workers, even low-skilled ones, are assumed to be remunerated for some human capital services as well as for their unskilled labour services. A simple numerical example demonstrates the implications of a 10 per cent increase in the relative remuneration of human capital: Assume a low-skilled worker who initially earns the average retail wage (twice the hypothetical unskilled wage), and a high-skilled worker who initially earns twice the average retail wage. With an unchanged hypothetical unskilled wage, the low-skilled worker's income increases, say, from 100 to 105: unskilled wage of 50 plus remuneration of human capital growing by 10 per cent from 50 to 55. The high-skilled worker's income increases from 200 to 215: unskilled wage of 50 plus remuneration of human capital growing from 150 to 165. Thus, the ratio of the high-skilled to the low-skilled income grows from 2 to 2.048, or by 2.4 per cent. This figure is compatible with the order of magnitude of observed changes in inequality in the UK and the US.

All five findings are confirmed by the joint analysis for all sample countries (Table 2). Apart from separate regressions for the 1970s and 1980s as in Table 1, regressions are also reported for the whole period of observation with variable coefficients over time. In one set of regressions, slope dummies (1980sDUM: 1 for 1980 to 1992, 0 otherwise) allow coefficients to differ between the two periods. In another set of regressions, a time trend is used instead of the dummy variable so that coefficients shift continuously over time (rather than abruptly from the first subperiod to the second). In each case, the corresponding coefficients indicate whether a change from the first to the second subperiod, or an increase in a coefficient over time, is statistically significant.

As before, changes in value added prices mandate a decline in the relative user cost of physical capital by 10.5 per cent annually during the 1970s and, still significantly, by 4.4 per cent annually during the 1980s. The pass-through rate for TFP growth is 32 per cent during the 1970s and 18 per cent during the 1980s. The relative price changes adjusted for TFP pass-through mandate a (statistically not significant) decrease in the relative remuneration of human capital throughout the period of observation. Once again, this contrasts with the expectation of a significant increase if imports from low-income countries had had a major impact on the labour markets of high-income countries.

The change in the sectoral pattern of TFP growth now appears even more pronounced. TFP growth is biased against human and physical capital intensive sectors during the 1970s, with mandated declines of 9.5 per cent and 12.6 per cent annually for the relative remuneration of human and physical capital, respectively. By contrast, from 1980 to 1992, TFP growth mandates an increase in the relative remuneration of human capital of 10.2 per cent annually and only a statistically insignificant decrease in the relative user cost of physical capital. In the regressions for the full period of observation, the coefficients of the product variables (factor share*1980s dummy, factor share*time trend) indicate that this shift in the mandated relative factor price changes from the 1970s to the 1980s is statistically significant. Furthermore, it constitutes the driving force behind the shift in relative factor price changes mandated by value added price and TFP changes combined.

When only subsets of the RHS variables are included in the regression, some estimated coefficients diverge substantially from the full model (Table 3). In particular, for the 1970s, the simple correlations between the human capital share and the changes in value added prices and TFP are positive and significant, whereas the corresponding coefficients in the full regression model are negative. However, the discussion in Section 2 makes it clear that the full model where the change in value added prices and TFP is allocated to all three factors of production is the relevant one; therefore, no firm conclusions should be drawn from simple correlations.[12]

---

12 Without accounting for physical capital or TFP growth, Sachs and Shatz (1996) as well as Schmitt and Mishel (1996) find that US output prices shifted in favour of human-capital intensive sectors during the 1980s.

To examine the robustness of these findings further, a variety of specification tests have been undertaken. First, separate annual regressions were run to examine the cumulative annual changes in implied factor price changes separately for the 1970s and 1980s. It turns out that the cumulative factor price changes support the key conclusions drawn from the regression results in Tables 1 and 2.

Second, the physical capital share was instrumented with the capital stock in constant prices to eliminate the impact of short-term variations in profits (cf. Leamer 1996). Again, the resulting regression coefficients reproduced the key findings.

Third, the model was run in "long differences" instead of annual data, i.e. the LHS variables are in average annual rates of change over one or even two decades, and the RHS factor income shares are either average or first-year shares. In this setup, many mandated factor price changes are not statistically significant, and for several specifications, the F-statistics even indicate that the estimated coefficients are jointly not significantly different from 0. Two findings are nevertheless noteworthy as they partially support the conclusions drawn from the regressions based on annual data. First, TFP growth from 1970 through 1992 was biased in favour of both human and physical capital. There was no shift, however, in its sector bias. Second, value added prices corrected for TFP growth imply a significant decline in the relative remuneration of physical capital during the 1970s but not during the 1980s.

The inability of the model in long differences to reproduce the key findings calls for some comment because most similar studies use long differences rather than annual data. This regression analysis is based on annual data because these contain relevant information that is lost when the model is run in long differences. In particular, with factor income shares changing over time, regressions based on "long differences" that use first-year or average factor shares may not be appropriate. Therefore, the separate, year-on-year regressions used for specification tests may be viewed as the core version of the model. The subsequent pooling of year-on-year changes over time conveniently summarises the information contained in the annual data and to test for structural shifts in the estimated coefficients between different time periods.

5 Discussion

5.1 Related Econometric Studies

To put the key findings of this analysis into perspective, it is useful to compare them to the existing closely related studies (Baldwin and Cain 1997; Fitzenberger 1996, 1997; Haskel and Slaughter 1999; Kahn and Lim 1997; Krueger 1997; Leamer 1996; Oscarsson 1997). All these studies find it difficult to identify a shift in any of the determinants of relative factor prices that can explain the decrease in income inequality until about 1980 and the increase thereafter. Since they use different model specifications, countries, and time periods, their results are also difficult to compare. Nevertheless, two points are worth emphasising.

First, some support exists for the key finding of this paper that a shift in the sector bias of TFP - from working against human and physical capital during the 1970s to strongly benefiting human capital and being indifferent to physical capital during the 1980s - was the driving force behind changes in implied relative factor prices. Kahn and Lim (1997) analyse annual growth rates of TFP in several samples of US manufacturing industries and find a very similar shift in the sector bias of TFP around the mid-1970s. Fitzenberger (1996, 1997) finds that TFP growth in the German tradable goods sectors from 1975 through 1990 benefited college-educated labour far more than any other factor of production. However, the remaining studies find various other patterns of the sector bias of TFP growth over time.[13]

Second, according to the present regression results, value added price changes on their own as well as the sum of price and TFP changes implied a decline in the relative remuneration of physical capital, especially during the 1970s. Fitzenberger (1997) reports a similar finding. Leamer (1996) finds a decline in the implied remuneration of physical capital relative to production labour throughout the 1960s, 1970s, and 1980s. Again, the remaining studies find various other patterns of implied changes in the relative remuneration of physical capital.

Thus this paper adds to the somewhat diverse findings of similar existing studies. However, the present results are no outliers, which is noteworthy because this regression model differs from the others in its use of annual data and the human capital measure based on earnings. Furthermore, this analysis identifies a shift in

---

[13] Studying only skill-biased technological change in US and UK manufacturing, Haskel and Slaughter (1998) also find a shift in sector bias from low to high skill intensive industries around 1980.

the sector bias of technological change against low-skilled labour from 1980 onwards that constitutes a possible major cause of the trend reversal in income inequality. The mandated and observed decline in the relative remuneration of physical capital also suggests a closer examination of the role of physical capital, especially the implications for less-skilled workers of growing physical capital intensity. Both these working hypotheses are discussed further in Section 5.3 below against the background of the extensive literature on technological change. The following Section 5.2 returns to the question of why this paper as well as closely related studies fail to reproduce, in terms of mandated factor price changes, the observed decline in the relative low-skilled equilibrium wage from 1980.

5.2 Heterogeneous Products and the Nature of Growing Income Inequality

The wide-spread failure to reproduce more clearly the deteriorating position of low-skilled workers since 1980 in terms of mandated relative wage changes suggests at least four, complementary interpretations. First, it has so far been assumed that products within each industry are homogeneous and that changes in supply and demand conditions in the world market are therefore reflected in domestic value added prices. However, this assumption may be too strong. For example, most CGE models use the Armington assumption that imports and domestic output within each industry are close, but not perfect substitutes. Trefler (1995) finds evidence that a preference for national product varieties is a major influence on international trade patterns in the sense that trade flows are systematically smaller than predicted by national factor endowments relative to the rest of the world.

Hence, it is important to enquire how the price change regressions should be interpreted when products are heterogeneous and competition is monopolistic. Furthermore, in many high-income countries, the relative wage across education levels and occupations may be quite rigid. Under these circumstances, the zero-profit condition, on which the regression model is based, may still be assumed to hold with the usual caveats. However, output prices are no longer exogenous.[14] Consider, for example, how manufacturers of traditional low-skill intensive products may react to growing import competition from low-income countries. Initially, they may seek to use their monopoly power to maintain their output price level (as factor prices do not adjust) while import prices decline. However,

---

[14] Wood (1995) and Paqué (1997) discuss critically the role of relative output prices in transmitting the labour market effects of changes in the global labour supply.

with cheaper competing imports and relatively close substitutability between imported and domestic varieties, demand for domestic varieties ultimately declines and domestic output and employment (and the number of firms) are reduced. With a rigid relative wage, an overproportionate increase in low-skilled unemployment will ensue, although there may be little change in sectoral value added prices.[15] Furthermore, if relative factor prices are rigid, production need not become more low-skill intensive as it would under the original Heckscher-Ohlin model.

Second, the mandated relative remuneration of human capital may not increase because the observed wage premia and unemployment rates overstate the deterioration of the relative position of low-skilled workers. For example, education premia in individual earnings are typically measured with reference to the level of formal education.[16] In many high-income countries, average formal educational attainments have grown rather fast in recent decades so that the number of new entrants into the labour force without completed vocational training has decreased sharply. It is plausible that the average skill level and hence employability of this diminishing and increasingly marginal group has declined over time. Thus the observed growth in the education premium may partly reflect deteriorating skills in the low-skilled group.

Furthermore, a higher proportion of human capital may be unemployed than the unemployment rates of high-skilled workers suggest: High-skilled workers who fail to obtain employment that fully utilises their skills often accept jobs that leave some of their skills unused, or "unemployed" (Büchel and Weißhuhn 1997; Heise 1997). The reservation wage of both high-skilled and low-skilled workers is probably determined by social assistance which converges over time towards the social subsistence minimum in most high-income countries. Therefore, low-

---

15 Revenga (1992) finds a simultaneous relationship between industry employment and the price of the import substitute. Similar studies of the wage and employment effects of growing imports at the sectoral level include Grossman (1986, 1987), Konings and Vandenbussche (1995), Kletzer (1998), and Anderton and Brenton (1999). Borjas (1995) and Buckberg and Thomas (1995) study the impact of international competition on labour market institutions and outcomes, especially with regard to growing import competition in highly unionised durable goods industries.

16 Note that the frequently quoted OECD survey (1997 Employment Outlook) compares the earnings of highly educated workers (typically at the university or polytechnic level) to the earnings of workers without completed vocational training. Thus, these data do not account for changes in the earnings of workers with completed vocational training, who constitute the majority of the workforce. This raises the more general question - which cannot be answered satisfactorily within the confines of this study - whether human capital can be considered as homogeneous and thus as a single factor of production, or whether the results would be substantially affected by distinguishing between several levels (cf. Fitzenberger 1997) or different types of educational qualifications (technical, administrative, social, etc.).

skilled, low-income workers are more likely to remain unemployed if they lose their job (Dellas 1997). By contrast, high-skilled workers typically earn more than their reservation wage even if they accept a job that does not require or reward all their qualifications.

Third, increasing inequality in earnings, unemployment rates, and household incomes may be a more complex phenomenon that is not fully explained by structural shifts in labour demand. One important observation is that a large proportion of the increase in household income and earnings inequality (in those countries where it occurred) is linked to increasing inequality *within*, rather than between well-defined status, educational, or occupational groups (Gottschalk, Gustafsson and Palmer 1997). This phenomenon is difficult to explain by structural shifts in labour demand across broadly defined skill groups. Rather, it suggests an increasing role of unobservable characteristics or growing volatility of economic opportunities.[17]

Fourth, some recent studies emphasise that low-skilled unemployment rates may have grown overproportionately because aggregate labour demand has become more volatile. For example, low-skilled workers tend to be dismissed first in a business downturn, and to be hired last in an upturn (van Ours and Ridder 1995). If economic volatility increases because of globalisation, this may be sufficient to increase low-skilled unemployment. An increase in volatility might well be registered only at the level of individual firms rather than whole sectors or even whole national economies. Similarly, Baumol and Wolff (1998) demonstrate that, if technical progress is continuous, a speedup of change can increase the natural rate of unemployment and lengthen the average duration of unemployment, especially by cutting more severely the jobs of those who are relatively unprofitable to retrain (e.g. ill-educated and older workers).

In conclusion, this discussion suggests that growing inequality in earnings and unemployment rates between high-skilled and low-skilled workers may not be reflected well in sectoral value added prices because, under realistic assumptions, the latter are endogenous. Nevertheless, as long as TFP growth represents largely exogenous technological innovations, the shift in its sector bias remains a valid, though possibly partial explanation of growing inequality. At the same time, growing income inequality across skill categories is only one dimension, however important, of overall inequality. Any model that seeks to explain its evolution will

---

17 Recent studies that carefully analyse several dimensions of inequality include Wolfson and Murphy (1998) on Canada and the US; Picot (1998) on Canada; Hauser (1997) on Germany; Burkhauser and Poupore (1997) on the US and Germany.

therefore provide only a partial explanation of the growth in overall income inequality.

5.3 The Nature of Technological Change

The regression results suggest that technological change played an important role in the shift of labour demand against low-skilled workers. This section relates these findings to the growing literature on "skill-biased" technological change and on the impact of microelectronics-based innovations on labour demand. The aim is to find a set of stylised facts that are compatible both with the regression results and with this literature.

Many studies on skill-biased technological change (e.g. Berman, Bound and Griliches 1994; Berman, Bound and Machin 1997; Machin, Ryan and van Reenan 1996) conclude that human capital intensity, measured by the employment of high-skilled (or non-production) workers relative to low-skilled (or production) workers, has increased considerably during the 1970s and 1980s. This is true for a wide range of manufacturing industries not only in high-income countries, but also in those developing countries for which data are available. At the same time, the relative wage of high-skilled workers has either increased or has at least remained constant. Therefore, the continuing growth of human capital intensity is viewed as evidence of low-skilled labour saving technological change. By contrast, if import competition from low-wage countries had strongly affected relative labour demand, production throughout the manufacturing sector should have become less human-capital-intensive, not more so (cf. Section 2).

The continuous growth of human capital intensity throughout the 1970s and 1980s must be accounted for in any explanation of the growth of earnings inequality during the 1980s. However, it cannot explain, in and of itself, the shift from declining to increasing inequality around 1980. Furthermore, in the framework of the present multi-sector general equilibrium model with diversified production, world-wide technological change affects relative factor prices through two channels: first, through its sector bias in the absence of full pass-through into product prices (differential industry effect); and second, through its factor bias at the level of global, productivity-adjusted factor stocks via world market product prices (differential factor effect). The factor bias on its own determines relative factor prices only in a one-sector model because, here, changes in productivity-adjusted factor stocks cannot be accommodated through adjustments in the output mix (there being only one product, or - by extension - products of very similar capital intensity; cf. Gregg and Manning 1997).[18]

As the increase in human capital intensity is nevertheless an important stylised fact, it is reassuring that it is reflected in the dataset employed in this paper. Recall that this paper uses a measure of human capital based on income, rather than formal qualification, broad type of work (production vs. non-production), or years of experience. In this setup, the ratio of the value added share of human capital over the share of unskilled labour represents a plausible proxy for human capital intensity as long as the remuneration of human capital relative to unskilled labour remains constant. If the relative remuneration increases, then human capital intensity is overstated because part of any increase in the human capital share is caused by the increase in its relative price, not by an increase in its quantity.

A further complication arises if the underlying hypothetical unskilled wage incorrectly reflects some skill upgrading over time so that the growth in human capital intensity is understated. With the present dataset, this is conceivable because the hypothetical unskilled wage is based on the average wage in retail trade, not on some narrowly defined occupational wage. Therefore, the growth rate of human capital intensity is estimated using alternatively the hypothetical unskilled wage ("unadjusted") as in the regression analysis and a lower, "adjusted" growth rate of the unskilled wage. The adjusted rate is defined as the rate of growth of the average wage in other low-wage service sectors (transport and storage or construction), whenever these sectors experienced slower wage growth than retail trade (cf. Table 4).

Table 4 reports the annual growth rates of these alternative measures of human capital intensity for the 1970s and 1980s. While these data are for total manufacturing, similar calculations for individual sectors (not reported here) demonstrate that the growth rate of human capital intensity does not vary much across sectors within each country. No correction is made for the increase in the relative remuneration of human capital in the UK and the US because that increase cannot be estimated reliably in accordance with our definition of human capital. With the unadjusted growth rates for the unskilled wage, human capital intensity is found to have grown at an unweighted annual average rate across countries of only 0.4 per cent during the 1970s and 0.2 per cent during the 1980s. However, these low rates reflect in part a decline in measured human capital

---

18 Haskel and Slaughter (1998) discuss the choice of the relevant model in greater detail. Note that in a one-sector model (complete specialisation) any change in factor stocks, including immigration of low-skilled workers, directly affects relative factor prices.

intensity in Belgium, Denmark, Finland, France, and Sweden where retail wages probably incorporate some skill upgrading. With the adjusted rate, human capital intensity is estimated to have grown by approximately 2 per cent annually on average throughout the period of observation.

In sum, these estimates support the view that human capital intensity in manufacturing increased continuously during the 1970s and 1980s. At the same time, human capital intensity grew much more slowly than physical capital intensity (i.e. the capital stock in constant prices per person employed) which increased at an unweighted average rate across countries of about 4 per cent (cf. Table 4). This observation has far-reaching implications because there is substantial evidence that human and physical capital are complementary (Bergström and Pannas 1992; Fitzroy and Funke 1995; Fitzenberger and Franz 1998). Under the assumption of "capital skill complementarity", the regression results suggest that a decline in the relative remuneration of physical capital (which is mandated by the growth rates of value added prices and TFP) may have driven the increase in capital intensity which, in turn, may have led to the greater use of complementary human capital (cf. Krusell et al. 1997).

This raises the question of whether the decline in the *mandated* remuneration of physical capital was mirrored by a decline in the *observed* relative user cost of physical capital which determines investment decisions at the firm level. By definition, the user cost of physical capital, i.e. the cost of using buildings, machinery and equipment in the production process, has two components. The first is the purchase price of buildings and machinery that is reflected in annual depreciation. The true cost of buildings is difficult to gauge because in most OECD countries greenfield investment by manufacturing industries (where building costs matter most) has attracted substantial subsidies that would not normally be reflected in building price indices. A quick measure of the purchase prices of machinery and equipment is provided by the value added prices of the machinery sector (ISIC 382 minus data processing) in the present dataset (Table 4).[19]

The second component of the user cost of physical capital is the cost of financing. Plausible proxies include the interest rate on bank credit for buildings or machinery, or the interest rate of government bonds which may be viewed as representing the opportunity cost of investment in buildings or machinery. In the sample countries, real interest rates rose sharply, and subsequently returned more

19 The main problem with this measure is that the industrial machinery sectors of the sample countries are highly specialised so that their value added prices relate to a much more narrow range of machinery than is purchased by manufacturing firms in each country.

or less to their original levels, around 1973 and again around 1982 (IMF, International Financial Statistics CD-ROM). Beyond these rather violent swings, it is difficult to infer a pronounced trend in real or even in nominal interest rates during the 1970s and 1980s.

Therefore, with no clear long-term trend in interest rates or in the relative price of buildings, the change in the price of machinery relative to unskilled labour has probably driven long-term trends in the total user cost of capital. The last six columns of Table 4 list the annual average growth rates of the value added prices of non-electrical machinery and of the hypothetical unskilled wage in the sample countries. Taking a conservative approach and using the (lower) adjusted growth rate for the hypothetical wage as a point of reference, this rate was still at least 1 percentage point higher than the growth rate of machinery sector value added prices in 8 out of the 12 sample countries during both the 1970s and the 1980s. On average, the difference in growth rates was 3.3 percentage points during the 1970s and 1.9 percentage points during the 1980s. This decline in the relative price of machinery mirrors the decline in the *mandated* relative user cost of physical capital. Hence, it is a plausible proximate cause of the observed, rapid growth of physical capital intensity together with greater use of complementary human capital.

Since physical capital is a "produced means of production", it is further plausible that its relative price declined because of technological progress in the production of capital goods. Note that the reverse side of declining capital goods prices relative to the unskilled wage is the growth of real wages in terms of goods (including capital goods). However, the question remains why such technological change should have led to growing inequality during the 1980s although it went together with decreasing inequality during the preceding decades (Gundlach and Nunnenkamp 1997).

Our regression results suggest a crucial role for the shift in the sector bias of TFP growth towards human capital intensive industries around 1980, which coincided with the increasing use of microelectronics-based innovations in manufacturing.[20] Extensive firm-level evidence supports the view that microelectronics-based

---

[20] A closely related argument is made by Krusell et al. (1997) who simulate the wage premium of college-educated labour in the US on the basis of a macroeconomic production function with capital skill complementarity. They find that the increase in the premium since 1980 is ultimately driven by a more rapid decline of the relative price of equipment during the 1980s than during the 1970s and 1960s. Note that in the dataset used in this paper, the decline of the observed price of machinery relative to unskilled labour does accelerate in the US and Canada, but not in the remaining sample countries. Also, this paper finds no such acceleration in the *mandated* relative remuneration of physical capital.

innovations increase TFP predominantly in human capital intensive industries. Although the direction of causality is not clear, it is well established that firms with high effective wages and a more skilled workforce innovate more, *ceteris paribus*.[21] To the extent that the availability of high-skilled labour is a precondition for the effective use of microelectronics-based innovations, these innovations are bound to have their greatest impact in human capital intensive industries (Kahn and Lim 1997). Thus, the growing use of microelectronics-based innovations is consistent with the sector bias of TFP growth in favour of human capital intensive industries during the 1980s.

It is appropriate to note a qualification to this interpretation of the empirical evidence. While it is plausible to attribute sectoral TFP growth largely to technological innovations, economic restructuring within individual sectors may also increase measured TFP at the sector level. For example, with heterogeneous products, domestic firms that face growing import competition may specialise in high-quality, high-price product varieties. The shift from a broad product mix to a more narrow one is likely to be associated with an increase in conventionally measured TFP. A similar effect may arise from the outsourcing of low-skill intensive operations as improving communication technologies make it increasingly profitable to split up production chains according to the factor intensities of the individual activities, and to seek least-cost locations for each activity.[22]

Some studies also suggest that growing human capital intensity is linked to the increasing openness of many industries. In particular, Bernard and Jensen (1997) and Bertrand (1999) show that the growing skill intensity of US manufacturing was linked to a shift of industry employment towards exporting establishments which had disproportionately high skill requirements. Manasse and Turrini (1998) construct a model that rationalises this observation: Declining communication

---

21 See, for example, the Symposium on "Effects of Technology and Innovation on Firm Performance, Employment, and Wages" introduced by Hall and Kramarz (1998) as well as Bartel and Lichtenberg (1987), Bartel and Sichermann (1997), Doms et al. (1997), Haskel (1999), Haskel and Heden (1998).

22 Beginning with Feenstra and Hanson (1997), outsourcing has recently received a large amount of attention in the literature; see Burda and Dluhosch (1998), Campa and Goldberg (1997), Deardorff (1998), Hummels, Rapoport and Yi (1998), Lovely and Richardson (1998), Wood (1998). Schimmelpfennig (1998) argues on the basis of occupational data for Germany that the outsourcing of low-skill intensive activities may be viewed as part of a larger process of economic restructuring whereby manual production is automated or outsourced, while firms add more and more service activities that are either produced in-house or, once again, contracted out (e.g. R&D, marketing, customising of products, ultimately: selling 'solutions' instead of physical products).

costs and trade barriers redistribute income from a low-skill intensive nontradables sector to a high-skill intensive tradables sector, thus increasing wage inequality. At the same time, the incomes of the least-skilled decline if new technology and skills are complementary.

Notwithstanding this qualification, the following set of stylised facts emerges from this discussion. First, earnings inequality across skill groups is an important, though not the only dimension of overall income inequality. Therefore, it is important to explain why earnings inequality declined until about 1980 but has increased since then. Second, declining relative prices for capital goods go a long way towards explaining the growth of physical capital intensity in manufacturing which, in turn, has led to greater use of complementary human capital. Third, microelectronics-based innovations have their greatest impact on TFP in human capital intensive industries. As TFP growth is not fully passed through into product prices, microelectronics-based innovations benefit high-skilled workers disproportionately. Therefore, the wide-spread diffusion of microelectronics-based innovations since about 1980 has contributed considerably to the trend reversal in earnings inequality.

6 Conclusions

This paper seeks to explain why the relative earnings and employment opportunities of low-skilled workers have deteriorated in many high-income countries since about 1980, although previously their relative position had improved for several decades. In accordance with the Stolper-Samuelson theorem, the focus is on the impact of changes in sectoral value added prices and TFP on the remuneration of human and physical capital relative to unskilled labour. The paper finds that the sector bias of TFP growth shifted from benefiting unskilled-labour- intensive industries during the 1970s to benefiting human-capital-intensive industries during the 1980s. As TFP growth was only partly passed through into relative value added prices, its sector bias mandated a decrease in the remuneration of human capital relative to unskilled labour during the 1970s, and an increase during the 1980s. These implied relative factor price changes provide a partial explanation for the observed trend reversal in earnings inequality. Furthermore, the shift in the sector bias of TFP growth was probably related to the growing use of microelectronics-based innovations in manufacturing since the 1980s.

This paper also finds a decline in the mandated user cost of physical capital relative to unskilled labour throughout the 1970s and 1980s, which is mirrored by a decline in the observed value added prices of industrial machinery relative to the unskilled wage. This finding helps to explain why physical capital intensity has grown rapidly throughout the manufacturing sector in all sample countries. With physical and human capital as complementary factors in many production processes, this finding also helps to explain the more modest observed increase in human capital intensity. However, in the framework of the multi-sector model on which this paper is based, it is not technological change as such (which has occurred for many decades), but rather the shift in the sector bias of TFP growth, that has (partly) caused the trend reversal in earnings inequality around 1980.

While these findings point to an important role for technological change, this conclusion needs to be qualified. With heterogeneous products, monopolistic competition, and rigid relative wages between skill groups, changes in domestic value added prices are partly endogenous and do not exclusively reflect world market price changes. In this case, growing imports from low-income countries may affect labour demand through output rather than value added price effects. Furthermore, TFP growth may partly reflect economic restructuring in response to import competition rather than solely technological innovations.

Several promising avenues for future research emerge from this paper. Additional evidence would be desirable to confirm the important roles attributed to the shift in the sector bias of TFP growth and to technological progress as the driving force behind the declining relative user cost of physical capital. Product heterogeneity and monopolistic competition should be taken into account explicitly in studying the determinants of the skill structure of labour demand.[23] This is possible, in particular, in computable general equilibrium models (e.g. Cortes and Jean 1999; Nahuis 1999; Tyers and Yang 1997) where varying assumptions can be made about the price elasticities of demand for every domestic industry, and simulations can provide information about plausible orders of magnitude of trade and technology effects on relative wages.

---

23 Important information may be gained from earnings functions estimated on individual data where sectoral characteristics (such as import or export quotas) are allowed to influence individual earnings; cf. Aiginger, Winter-Ebmer and Zweimüller (1996) for Austria; Hanson and Harrison (1995) for Mexico; Robbins (1996) for several developing countries.

References

Aiginger, Karl, Rudolf Winter-Ebmer, Jürgen Zweimüller, "Eastern European Trade and the Austrian Labour Market". Weltwirtschaftliches Archiv, Vol. 123, 1996, No. 3, pp. 476-500.

Anderton, Bob, Paul Brenton, "Trade and Inequality in the UK: The Impact of Outsourcing". Bulletin of Economic Research, forthcoming 1999.

Baldwin, Robert E., Glen G. Cain, Trade and U.S. Relative Wages: Preliminary Results. NBER Working Paper 5934, 1997.

Bartel, Ann P., Frank R. Lichtenberg, "The Comparative Advantage of Educated Workers in Implementing New Technology". Review of Economics and Statistics, Vol. 69, No. 1, February 1987, pp. 1-11.

Bartel, Ann P., Nachum Sicherman, Technological Change and Wages: An Inter-industry Analysis. NBER Working Paper 5941, February 1997.

Baumol, William J., Edward N. Wolff, Speed of Technical Progress and Length of the Average Interjob Period. Working Paper No. 237, C.V. Starr Center for Applied Economics, New York University, May 1998.

Bergström, Villy, Epaminondas E. Panas, "How Robust is the Capital-skill Complementarity hypothesis?" Review of Economics and Statistics, Vol. 74, 1992, pp. 540-552.

Berman, Eli, John Bound, Zvi Griliches, "Changes in Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufactures". Quarterly Journal of Economics, Vol. 109, No. 2, 1994, pp. 367-397.

Berman, Eli, John Bound, Stephen Machin, Implications of Skill-biased Technological Change: International Evidence. NBER Working Paper 6166, January 1997.

Bernard, Andrew B., J. Bradford Jensen, "Exporters, Skill Upgrading, and the Wage Gap". Journal of International Economics, Vol. 42, 1997, pp. 3-31.

Bertrand, Marianne, From the Invisible Handshake to the Invisible Hand? How Import Competition Changes the Employment Relationship. NBER Working Paper 6900, January 1999.

Borjas, George J., "The Internationalization of the U.S. Labor Market and the Wage Structure". Economic Policy Review, Vol. 1, No. 1, January 1995, pp. 3-8.

Borjas, George J., Richard B. Freeman, Lawrence F. Katz, How Much Do Immigration and Trade Affect Labor Market Outcomes? Brookings Papers on Economic Activity, Vol. 1, 1997.

Buckberg, Elaine, Alun Thomas, Wage Dispersion in the 1980s: Resurrecting the Role of Trade Through the Effects of Durable Employment Changes. International Monetary Fund (IMF) Working Paper No. 88, August 1995.

Büchel, Felix, Gernot Weißhuhn, Ausbildungsinadäquate Beschäftigung in Deutschland und den USA. Bonn 1997 (Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie).

Burda, Michael C., Barbara Dluhosch, Globalization and European Labour Markets. CEPR Discussion Paper No. 1992, October 1998.

Burkhauser, Richard V., John G. Poupore, "A Cross-national Comparison of Permanent Inequality in the United States and Germany". Review of Economics and Statistics, Vol. 79, No. 1, February 1997, pp. 10-17.

Burtless, Gary, "International Trade and the Rise in Earnings Inequality". Journal of Economic Literature, Vol. 33, No. 2, June 1995, pp. 800-816.

Büttner, Thiess, Hedwig Prey, "Does Active Labor-Market Policy Affect Structural Unemployment? An Empirical Investigation for West German Regions, 1986 to 1993". Zeitschrift für Wirtschafts- und Sozialwissenschaften (ZWS), Vol. 118 No. 3, 1998, pp. 389-413.

Campa, José, Linda S. Goldberg, "The Evolving External Orientation of Manufacturing: A Profile of Four Countries". Economic Policy Review, Vol. 3, No. 2, July 1997, pp. 53-81.

Cortés, Olivier, Sébastian Jean, Does Competition from Emerging Countries Threaten Unskilled Labour in Europe? An Applied General Equilibrium Approach. In: Paul Brenton and Jaques Pelkmans (eds.), Global Trade and European Workers. Basingstoke and London 1999 (Macmillan), pp. 96-122.

Deardorff, Alan V., Fragmentation in Simple Trade Models. Research Seminar in International Economics (RSIE) Discussion Paper No. 422, January 1998.

Dellas, Harris, "Unemployment Insurance Benefits and Human Capital Accumulation". European Economic Review, Vol. 41, No. 3-5, April 1997, pp. 517-524.

Dolado, Juan J., Juan F. Jimeno, "The Causes of Spanish Unemployment: A Structural VAR Approach". European Economic Review, Vol. 41, No. 7, July 1997, pp. 1281-1307.

Doms, Mark, Timothy Dunne, Kenneth R. Troske, "Workers, Wages, and Technology". Quarterly Journal of Economics, February 1997, pp. 253-303.

Feenstra, Robert C., Gordon H. Hanson, The Exact Measurement of Productivity, Outsourcing and its Impact on Wages: Estimates for the U.S., 1972-1990. NBER Working Paper 1997.

Fitzenberger, Bernd, Wages Prices, and International Trade. Sonderforschungsbereich 178 "Internationalisierung der Wirtschaft", Diskussionsbeiträge, Series II - No. 323, University of Konstanz, October 1996.

Fitzenberger, Bernd, "Außenhandel, technischer Fortschritt und Arbeitsmarkt in Westdeutschland von 1975 bis 1990". Mitteilungen aus der Arbeitsmarkt- und Berufsforschung, Vol. 30, 1997, pp. 642-651.

Fitzenberger, Bernd, Wolfgang Franz, Flexibilität der qualifikatorischen Lohnstruktur und Lastverteilung der Arbeitslosigkeit: Eine ökonometrische Analyse für Westdeutschland. In: Gahlen, Bernhard, Helmut Hesse, Hans Jürgen Ramser (eds.), Verteilungsprobleme der Gegenwart. Tübingen (Mohr Siebeck) 1998, pp. 47-79.

Fitzroy, Felix, Michael Funke, Skills, Wages, and Employment in East and West Germany. International Monetary Fund (IMF) Working Paper No. 4, January 1995.

Francois, Joseph F., Doulas Nelson, "Trade, Technology, and Wages: General Equilibrium Mechanics". Economic Journal, No. 108, September 1998, pp. 1483-1499.

Freeman, Richard B., "Are Your Wages Set in Beijing?" Journal of Economic Perspectives, Vol. 9, No. 3, Summer 1995, pp. 15-23.

Friedlander, Daniel, David H. Greenberg, "Evaluating Government Training Programs for the Economically Disadvantaged". Journal of Economic Literature, Vol. 35, No. 4, December 1997 , pp. 1809-1855.

Gottschalk, Peter, "Inequality, Income Growth, and Mobility: The Basic Facts". Journal of Economic Perspectives, Vol. 11, No. 2, Spring 1997, pp. 21-40.

Gottschalk, Peter, Björn Gustafsson, Edward Palmer (eds.), Changing Patterns in the Distribution of Economic Welfare. Cambridge 1997 (CUP).

Gregg, Paul, Alan Manning, "Skill-biassed Change, Unemployment and Wage Inequality". European Economic Review, Vol. 41, No. 6, June 1997, pp. 1173-1200.

Grossman, Gene M., "Imports as a Cause of Injury: The Case of the U.S. Steel Industry". Journal of International Economics, Vol. 20, No. 3/4, 1986, pp. 201-223.

Grossman, Gene M., "The Employment and Wage Effects of Import Competition in the United States". Journal of International Economic Integration, Vol. 2, No. 1, Spring 1987, pp. 1-23.

Gundlach, Erich, Peter Nunnenkamp, Labor Markets in the Global Economy: How to Prevent Rising Wage Gaps and Unemployment. Kieler Diskussionsbeiträge No. 305, September 1997.

Hall, Bronwyn H., Francis Kramarz, "Effects of Technology and Innovation on Firm Performance, Employment, and Wages". Economics of Innovation and New Technology, Vol. 5, No. 2/4, 1998, pp. 99-107.

Hanson, Gordon H., Ann Harrison, Trade, Technology, and Wage Inequality. NBER Working Paper No. 5110, February 1994.

Harberger, Arnold, "A Vision of the Growth Process". American Economic Review, Vol. 88, No. 1, March 1998, pp. 1-32.

Haskel, Jonathan, "Small Firms, Contracting-out, Computers and Wage Inequality: Evidence from UK Manufacturing". Economica, Vol. 66, February 1999, pp. 1-21.

Haskel, Jonathan E., Matthew J. Slaughter, Does the Sector Bias of Skill-biased Technical Change Explain Changing Wage Inequality? NBER Working Paper No. 6565, May 1998.

Haskel, Jonathan, Ylva Heden, Computers and the Demand for Skilled Labour: Industry and Establishment-level Panel Evidence for the United Kingdom. CEPR Discussion Paper No. 1907, June 1998.

Haskel, Jonathan E,, Matthew J. Slaughter, Trade, Technology and U.K. Wage Inequality. Mimeo February 1999.

Hauser, Richard, "Armut, Armutsgefährdung und Armutsbekämpfung in der Bundesrepublik Deutschland". Jahrbücher für Nationalökonomie und Statistik, Vol. 216, No. 4+5, 1997, pp. 524-548.

Heise, Arne, "Wage Differentials between Skilled and Unskilled Workers". Jahrbücher für Nationalökonomie und Statistik, Vol. 216, No. 3, 1997, pp. 368-372.

Helpman, Elhanan, David T. Coe, "International R&D Spillovers". European Economic Review, Vol. 39, No. 5, 1995, pp. 859-887.

Hine, Robert C., Peter W. Wright, "Trade with Low Wage Economies, Employment and Productivity in UK Manufacturing". Economic Journal, Vol. 108, September 1998, pp. 1500-1510.

Hummels, David, Dana Rapoport, Kei-Mu Yi, "Vertical Specialization and the Changing Nature of World Trade". Economic Policy Review, Vol. 4, No. 2, June 1998, pp. 79-99.

International Monetary Fund (IMF), International Financial Statistics, Washington, D.C., April 1999, CD-ROM.

Jones, Ronald W., "The Structure of Simple General Equilibrium Models". Journal of Political Economy, Vol. 73, No. 6, December 1965, pp. 557-572.

Jones, Ronald W., "Comments on Technical Progress". Philippine Economic Journal, Vol. 5, No. 2, Second Semester 1966, pp. 313-332.

Jones, Ronald W., The Role of Technology in the Theory of International Trade. In: R. Vernon (ed.), The Technology Factor in International Trade. New York 1970, pp. 73-94.

Kahn, James A., Jong-Soo Lim, Skilled Labor-augmenting Technical Progress in U.S. Manufacturing. Rochester Center for Economic Research Working Paper No. 437, February 1997.

Kletzer, Lori G., Trade and Job Loss in U.S. Manufacturing, 1979-94. Department of Economics Paper prepared for the National Bureau of Economic Research Conference on "The Impact of International Trade on Wages, February 1998, Monterey, CA, mimeo May 6, 1998.

Konings, Jozef, Hylke Vandenbussche, "The Effect of Foreign Competition on UK Employment Wages: Evidence from Firm-level Panel Data". Weltwirtschaftliches Archiv, Vol. 131, No. 4, 1995, pp. 655-672.

Krueger, Alan B., Labor Market Shifts and the Price Puzzle Revisited. NBER Working Paper 5924, February 1997.

Krusell, Per, Capital-skill Complementarity and Inequality: A Macroeconomic Analysis. Federal Reserve Bank of Minneapolis Research Department Staff Report 239, September 1997.

Leamer, Edward E., "Paths of Development in the Three-factor, n-Good General Equilibrium Model". Journal of Political Economy, Vol. 95, No. 5, 1987, pp. 961-999.

Leamer, Edward E., Trade, Wages and Revolving Door Ideas. NBER Working Paper 4716, April 1994.

Leamer, Edward E., The Heckscher-Ohlin Model in Theory and Practice. Princeton Studies in International Finance, No. 77, February 1995.

Leamer, Edward E., In Search of Stolper-Samuelson Effects on U.S. Wages. NBER Working Paper 5427, January 1996.

Lovely, Mary E., J. David Richardson, Trade Flows and Wage Premiums: Does Who or What Matter? NBER Working Paper No. 6668, July 1998.

Lücke, Matthias, Technischer Fortschritt und die Arbeitsteilung zwischen Industrie- und Entwicklungsländern. Kieler Studien, 247, Tübingen 1992 (Mohr).

Lücke, Matthias, "The Diffusion of Process Innovations in Industrialized and Developing Countries: A Case Study of the World Textile and Steel Industries". World Development, Vol. 21, No. 7, July 1993, pp. 1225-1238.

Lücke, Matthias, "Diffusion of Innovations in the World Textile Industry". Journal of Economic Development, Vol. 21, No. 2, December 1996, pp. 121-143.

Lücke, Matthias, Trade with Low-Income Countries and the Relative Wages and Employment Opportunities of the Unskilled: An Exploratory Analysis for West Germany and the UK. In: Paul Brenton and Jaques Pelkmans (eds.), Global Trade and European Workers. Basingstoke and London 1999 (Macmillan), pp. 69-95.

Machin, S., A. Ryan, J. van Reenan, Technology and Changes in Skill Structure: Evidence from an International Panel of Industries. Centre for Economic Performance Discussion Paper No. 297, June 1996.

Manasse, Paolo, Alessandro Turrini, Trade, Wages and "Superstars". Innocenzo Gasparini Institute for Economic Research (IGIER) Working Paper No. 140, November 1998.

Nahuis, Richard, Global Integration and Wages in a general Equilibrium World Model: Contributions of WorldScan. In: Paul Brenton and Jaques Pelkmans (eds.), Global Trade and European Workers. Basingstoke and London 1999 (Macmillan), pp. 123-146.

Organisation for Economic Co-operation and Development (OECD), Employment Outlook. Vol. 15, OECD Publication No. 49351, Paris 1997.

Organisation for Economic Co-operation and Development (OECD), International Sectoral Database (ISDB), OECD Statistical Compendium No. 2, Rheinberg 1998, CD-ROM

Oscarsson, Eva, Trade and Relative Wages in Sweden 1968-91. Research Papers in Economics, 1997:6 WE, Department of Economics, Stockholm University, 1997.

van Ours, Jan C., G. Ridder, "Job Matching and Job Competition: Are Lower Educated Workers at the Back of Job Queues?" European Economic Review, Vol. 39, No. 9, December 1995, pp. 1717-1731.

Paqué, Karl-Heinz, Koreferat zu: Matthias Lücke, Auswirkungen des Außenhandels mit Niedriglohnländern auf den Arbeitsmarkt in Deutschland und Großbritannien. In: Rüdiger Pohl, Hilmar Schneider (eds.), Wandeln oder weichen: Herausforderungen der wirtschaftlichen Integration für Deutschland. Halle 1997 (Institut für Wirtschaftsforschung Halle), pp. 89-93.

Paqué, Karl-Heinz, Internationaler Handel, technischer Fortschritt und Lohndifferenzierung. Ein Blick in die empirische Literatur. In: Gahlen, Bernhard, Helmut Hesse, Hans Jürgen Ramser (eds.),Verteilungsprobleme der Gegenwart. Tübingen 1998 (Mohr Siebeck), pp. 359-379.

Picot, Garnett, What is Happening to Earnings Inequality and Youth Wages in the 1990s? Statistics Canada Research Paper No. 116, July 1998, available at http://www.statcan.ca.

Revenga, Ana L., "Exporting Jobs? The Impact of Import Competition on Employment and Wages in U.S. Manufacturing". Quarterly Journal of Economics, Vol. 107, No. 1, 1992, pp. 255-284.

Richardson, J. David, "Income Inequality and Trade: How To Think, What To Conclude". Journal of Economic Perspectives, Vol. 9, No. 3, Summer 1995, pp. 33-56.

Robbins, Donald J., HOS Hits Facts: Facts Win. Evidence on Trade and Wages in the Developing World. HIID Development Discussion Paper No. 557, October 1996.

Rodrik, Dani, "Symposium on Globalization in Perspective: An Introduction". Journal of Economic Perspectives, Vol. 12 (4), Fall 1998, pp. 3-8.

Sachs, Jeffrey D., Howard J. Shatz, "U.S. Trade with Developing Countries and Wage Inequality". American Economic Review, Vol. 86, No. 2, May 1996, pp. 234-239.

Schimmelpfennig, Axel, Skill-Biased Technical Change Vs. Structural Change. Kiel Working Paper No. 868, July 1998.

Schmitt, John, Lawrence Mishel, Did International Trade Lower Less-skilled Wages During the 1980s? Standard Trade Theory and Evidence. Economic Policy Institute Technical Paper, July 1996.

Slaughter, Matthew J., "International Trade and Labour-market Outcomes: Results, Questions, and Policy Options". Economic Journal, No. 108, September 1998, pp. 1452-1462.

Slaughter, Matthew J., What Are the Results of Product-price Studies and What Can We Learn From Their Differences? In: Feenstra, Robert C. (ed.), International Trade and Wages, NBER Conference Volume, forthcoming 1999.

Slaughter, Matthew J., Phillip Swagel, The Effect of Globalization on Wages in the Advanced Economies. International Monetary Fund (IMF) Working Paper No. 43, April 1997.

Trefler, Daniel, "The Case of the Missing Trade and Other Mysteries". American Economic Review, Vol. 85, No. 5, December 1995, pp. 1029-1046.

Tyers, Rod, Yongzheng Yang, "Trade with Asia and Skill Upgrading: Effects on Labor Markets in the Older Industrial Countries". Weltwirtschaftliches Archiv, Vol. 133, No. 3, 1997, pp. 383-418.

Wolfson, Michael C., Brian B. Murphy, New Views on Inequality Trends in Canada and the United States. Statistics Canada Research Paper No. 124, July 1998, available at http://www.statcan.ca.

Wood, Adrian, North-South Trade, Employment and Inequality. Oxford 1994 (Clarendon).

Wood, Adrian, "How Trade Hurt Unskilled Workers". Journal of Economic Perspectives, Vol. 9, No. 3, Summer 1995, pp. 57-80.

Wood, Adrian, A More General Theory of Globalisation and Wage Inequalities. Institute of Development Studies, University of Sussex, mimeo 19 March 1998.

Wood, Adrian, "Globalisation and the Rise in Labour Market Inequalities". Economic Journal, No. 108, September 1998, pp. 1463-1482.

Table 1 — Mandated Factor Price Changes, 1970-1992: Regression Results for Sub-periods with Slope Country Dummies

RHS variables	LHS variable					
	Relative price change		Relative TFP change		Relative price plus TFP change	
	1970-80	1980-92	1970-80	1980-92	1970-80	1980-92
Constant and intercept dummies	yes	yes	yes	yes	yes	yes
Human capital share	-1.4	-1.4	-11.7***	5.3*	-9.1**	1.5
*DUMBelgium			20.6***			
*DUMFinland				13.8*		
*DUMJapan			16.0**	15.2***	13.4*	
*DUMNorway		-103.8***				-97.8***
*DUMUK				9.7**		18.9**
Physical capital share	-7.7***	-1.5	-8.6***	-1.9	-13.3***	-5.8**
*DUMBelgium		-7.6**				
*DUMCanda			-27.8***	-15.1***	-22.4**	-10.2*
*DUMDenmark		-8.7**		10.7**		
*DUMFinland		-18.1***	-17.8		-24.7***	-26.5***
*DUMItaly	-14.9**		-11.3*		-17.0**	
*DUMNorway		-93.2***				-84.1***
*DUMUK		5.3*				15.8**
TFP growth	-.19***	-.19***				
*DUMBelgium	-.21**	-.25**				
*DUMCanada		.16**				
* DUMFinland	.37***	.25***				
*DUMItaly	-.50***	-.29**				
*DUMJapan	-.36***					
*DUMNorway	-.30*	-.28***				
*DUMUS		-.17**				
Number of obs.	1350	1560	1350	1560	1350	1560
Adjusted $\overline{R}^2$ (based on weighted data)	.165	.140	.055	.130	.079	.100

Note: Relative changes are annual log differences; a standard Wald test finds that all omitted slope dummies are jointly not significantly different from 0 at the 10 per cent significance level in a regression that includes all slope dummies.

Source: Data from OECD International Sectoral Database (ISDB) CD-ROM; definitions of variables see Section 3.2; own calculations.

Table 2 — Mandated Factor Price Changes, 1970-1992: Regression Results for Sub-periods

RHS variables	LHS variable											
	Relative price change				Relative TFP change				Relative price plus TFP change			
	1970-80	1980-92	1970-92		1970-80	1980-92	1970-92		1970-80	1980-92	1970-92	
Country intercept dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country intercept dummmies * 1980sDUM *(time trend)*	no	no	yes	*yes*	no	no	yes	*yes*	no	no	yes	*yes*
Human capital share	-4.8 (3.4)	-4.0 (2.4)	-4.8 (2.9)	-6.0 (4.1)	-9.5** (3.8)	10.2*** (2.8)	-9.5*** (3.3)	-9.5** (4.6)	-11.3*** (4.3)	4.4 (3.4)	-11.3*** (3.8)	-13.0** (5.3)
Human capital share * 1980sDUM *(time trend)*			0.8 (4.2)	*0.2* *(0.3)*			19.7*** (4.6)	*1.0**** *(0.4)*			15.7*** (5.4)	*1.0*** *(0.4)*
Physical capital share	-10.5*** (2.4)	-4.4** (1.7)	-10.5*** (2.0)	-14.6*** (2.9)	-12.6*** (2.6)	-1.6 (2.0)	-12.6*** (2.2)	-12.9*** (3.2)	-19.1*** (3.0)	-5.8** (2.4)	-19.1*** (2.6)	-23.5*** (3.7)
Physical capital share * 1980sDUM *(time trend)*			6.0** (2.9)	*0.7**** *(0.2)*			10.9*** (3.3)	*0.6*** *(0.3)*			13.3*** (3.8)	*1.1**** *(0.3)*
TFP growth	-.32*** (.03)	-.18*** (.02)	-.32*** (.02)	-.35*** (.03)								
TFP growth * 1980sDUM *(time trend)*			.14*** (.04)	*.01**** *(.00)*								
Number of observations	1260	1461	2721	2721	1260	1461	2721	2721	1260	1461	2721	2721
Adjusted $\overline{R}^2$ (based on weighted data)	.119	.044	.093	.093	.038	.120	.072	.061	.091	.065	.068	.065

Note: Relative changes are annual log differences.

Source: Data from OECD International Sectoral Database (ISDB) CD-ROM; definitions of variables see Section 3.2; own calculations.

Table 3 — Relative Price and TFP Changes: Regression Results with RHS Variables Included Individually

RHS variables(a)	LHS variable									
	Relative price change				TFP change			Relative price plus TFP change		
1970 - 1980										
Human capital share	5.9***		-1.8	-4.8	5.3***		-9.5**	11.2***		-11.3***
	(2.1)		(3.6)	(3.4)	(2.2)		(3.8)	(.5)		(4.3)
Physical capital share		-5.5***	-6.5***	-10.5***		-7.2***	-12.6***		-12.7***	-19.1***
		(1.4)	(2.5)	(2.4)		(1.5)	(2.6)		(1.7)	(3.0)
TFP growth				-.32***						
				(.03)						
Number of observations	1260	1260	1260	1260	1260	1260	1260	1260	1260	1260
Adjusted $\overline{R}^2$ (b)	.009	.014	.014	.119	.021	.033	.038	.040	.065	.091
1980 - 1992										
Human capital share	-1.0		-5.8**	-4.0	12.2***		10.2***	11.2***		4.4
	(1.4)		(2.5)	(2.4)	(1.5)		(2.8)	(1.8)		(3.4)
Physical capital share		-0.7	-4.2**	-4.4**		-7.7***	-1.6		-8.4***	-5.8**
		(1.0)	(1.8)	(1.7)		(1.1)	(2.0)		(1.3)	(2.4)
TFP growth				-.18***						
				(.02)						
Number of observations	1461	1461	1461	1461	1461	1461	1461	1461	1461	1461
Adjusted $\overline{R}^2$ (b)	.001	.001	.005	.044	.121	.113	.120	.061	.064	.065

Notes : Relative changes are annual log differences. - (a) All regressions include country intercept dummies on the RHS. - (b) Based on weighted data.

Source: Data from OECD International Sectoral Database (ISDB) CD-ROM; definitions of variables see Section 3.2; own calculations.

Table 4 — Annual Growth Rates of Human and Physical Capital Intensity in Total Manufacturing, 1970 - 1992

Countries	Human capital intensity				Physical capital intensity		Hypothetical unskilled wage				Value added price of industrial machinery sector	
	unadjusted		adjusted				unadjusted		adjusted			
	1970-80	1980-92	1970-80	1980-92	1970-80	1980-92	1970-80	1980-92	1970-80	1980-92	1970-80	1980-92
Belgium	-3.1	-1.4 (*)	1.3	2.8 (*)	4.6	4.5	14.1	6.0	11.5	3.5	-0.5	4.9
Canada	1.2	-0.2 (***)	1.2	-0.2 (***)	2.3	3.7 (**)	9.3	5.8	9.3	5.8	6.7	-0.2
Denmark	1.1	-2.2 (***)	3.2	0.1 (***)	4.9	1.5 (***)	12.0	6.2	11.0	5.2	9.1	6.2
Finland	-2.0	1.1 (***)	-0.2	2.6 (***)	3.6	5.1 (***)	15.6	7.8	14.6	6.8	9.1	5.7
France	1.6	-0.2 (***)	3.3	1.3 (***)	4.1	3.8	12.2	6.8	11.2	5.8	9.7	5.6
Germany	0.7	0.7	2.3	2.2	3.9	1.3 (***)	8.2	3.9	7.2	2.9	5.6	4.9
Italy	1.3	0.9	3.0	2.4	2.4	4.3 (**)	17.3	9.7	16.3	8.7	17.7	7.3
Japan	0.3	0.3	0.3	0.3	7.3	4.6 (***)	12.6	3.7	12.6	3.7	4.4	0.4
Norway	1.7	0.0 (***)	1.7	0.0 (***)	4.1	5.7 (***)	10.3	8.3	10.3	8.3	10.2	5.5
Sweden	-1.1	-0.9	1.6	1.7	3.3	2.7 (**)	12.0	9.1	10.5	7.6	9.1	6.0
UK	1.7	2.7	1.7	2.7	4.1	4.0	14.9	6.9	14.9	6.9	15.4	1.5
US	2.1	0.9 (***)	2.1	0.9 (***)	3.2	2.7	7.0	4.0	7.0	4.0	6.9	-0.6
Simple average (excl. Norway)	0.4	0.2	2.1	1.7	4.4	3.8	13.5	7.7	12.6	6.1	9.3	4.2

Note: Average growth rates are coefficients from a regression of the log dependent variable on a time trend. Asterisks indicate whether the growth rate for 1980-92 differs significantly from that for 1970-80 (2-tailed t test of the hypothesis that the slope dummy in a regression of the log dependent variable on a constant, a time trend (1970 ≙ 0) and the product of a 1980s dummy and a time trend (1980 ≙ 0) is significant).

Source: Data from OECD International Sectoral Database (ISDB) CD-ROM; definitions of variables see Section 3.2; own calculations.