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3

Globalization, Skill-Biased Technological Change and Labour Demand

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3.1 Introduction

Globalization is commonly regarded as having two economic aspects: the integration of national markets is one and the diminished economic importance of distance due to technological changes in communication and transportation is the second. Both these aspects contribute to the likelihood that changes in production technology in developed countries may migrate increasingly quickly to less developed countries. Accelerated transfer of production technologies would be important to global labour because technological change in developed countries in recent decades has been biased towards skilled workers. Indeed there is by now a large body of evidence showing that employers' demand for skilled workers in OECD economies has been rising over time and that this increased demand is closely linked to technology (Katz and Autor, 1999). Employers increasingly want, and are increasingly prepared to pay higher wages to workers with the aptitude and knowledge to utilize the new forms of technologies that are permeating into workplaces throughout the world.

This has had clear and marked ramifications for gaps between the richest and poorest workers in many countries, which have widened. Shifts in skill demand have contributed to this rising labour market inequality, with the principal driver appearing to be skill-biased technological change (SBTC), namely technologies that benefit the relative labour market position of workers with higher skill levels.

Our purpose in this chapter is to outline a model of how biased technological change could increase inequality within developing countries (DCs). The model has three elements: a production technology with biased technological change, a Ramsey–Solow growth model and technology transfer from OECD to lower income countries. That discussion is interspersed with

a review of the evidence supporting each element and with some new evidence for the early 1990s.

This chapter should be seen as a complement to other theories of increasing wage inequality within countries. The literature in labour economics and international trade has reached a near consensus on the relative importance of biased technological change and Stolper–Samuelson effects in explaining rising wage inequality in OECD countries (see Wood, 1998; Katz and Autor, 1999). Yet the literature has only just begun investigating increasing wage inequality within countries outside the OECD. The possibility that opening up to trade has increased inequality in these countries, despite the predictions of the Stolper–Samuelson theorem is a very recent theme in the empirical literature (Feliciano, 1995; Hanson and Harrison, 1995; Robbins, 1995; Berman *et al.*, 1998). Several of the chapters in this volume provide original contributions to this question and review the relevant literature (see section 2.5, section 7.2.2, sections 8.2 and 8.5, sections 9.3 and 9.5 in this book).¹

The structure of the chapter is as follows. Section 3.2 describes the skill-biased technological change hypothesis and discusses what evidence exists in its favour. We know quite a lot about this process in some advanced countries where data sources contain rich information on the skill structure of the workforce over time and on observable measures of technological change (like the UK and US). Descriptive statistics about within-sector shifts in the composition of employment outside the OECD are provided and we also discuss evidence of correlations between these shifts and technology transfer. We also present some new evidence from the period after 1990 which, like some of our earlier work, uncovers important commonalities in cross-country patterns of shifts in skill demand. However, much less is known in a wider international context in the period after 1990, at least partly due to data deficiencies we discuss below.

Section 3.3 outlines a growth model with factor-biased technological change, allowing a context within which to interpret evidence of skill upgrading over time. We then introduce technology transfer within that framework, providing evidence of the transfer of skill-biased and capital-biased technologies from OECD economies to middle-income economies in the 1980s and early 1990s. Section 3.4 concludes by briefly discussing some of the policy implications of the key findings of the research.

3.2 Factor-biased technological change and labour markets

3.2.1 Factor-bias

The first aspect of our framework is a definition of factor-biased technological change.² Consider a production technology

$$Y = (K, S, L, t) \quad (3.1)$$

where K is capital, S is skilled labour, L is unskilled labour and t is time. To be concrete, consider the Cobb–Douglas technology, for example:

$$Y = e^{\alpha t} K^{\beta} S^{\gamma_S} L^{\gamma_L} t^{\beta_S + \gamma_L} \quad (3.2)$$

Now define the bias of technological change as the rate at which the elasticity of output with respect to any factor $f \in (K, S, L)$ $\frac{\partial \ln Y}{\partial \ln f}$, changes with time:

$$\frac{\partial^2 \ln Y}{\partial \ln f \partial \ln t} \equiv \gamma_f \quad (3.3)$$

In the Cobb–Douglas case, the elasticity of output with respect to an input is just the exponent, so that the factor-bias term is the constant γ_f multiplying the trend.

In this context, technological change is absolutely skill-biased if $\gamma_S > 0$. Absolute skill-bias implies increased demand for skills because their marginal product is increasing. Conversely, technological change is absolutely labour-saving if $\gamma_L < 0$, which implies decreased demand for unskilled labour.

The literature has defined skill-bias as a *relative* shift in demand from unskilled to skilled workers, a definition which does not require an absolute decline in demand for unskilled workers. (Technically, it is equivalent to $\frac{\partial \ln Y}{\partial \ln S}$ growing at a faster rate than $\frac{\partial \ln Y}{\partial \ln L}$ or in the Cobb–Douglas case to the exponent of S growing at a faster rate than the exponent of L .)

We will see some evidence below that in global manufacturing, technological change is both absolutely skill-biased and absolutely labour-saving (i.e. $\gamma_S > 0$ and $\gamma_L < 0$), which is sufficient but not necessary for relative skill-bias.³ We begin with evidence on *relative* skill-bias, henceforth referred to simply as *skill-bias*.

3.2.2 Evidence on skill-biased technological change from demand shifts

The skill-biased technological change (SBTC) hypothesis argues that employers' increased demand for skilled workers has been largely driven by the kinds of new technologies that are permeating into modern workplaces. The critical idea is that these new technologies lead to higher productivity, but favour more educated workers. As such, employers increasingly demand more skilled (i.e. more educated⁴) workers who complement the new technology. At the same time workers who do not possess the appropriate skills to operate the new technologies face decreased demand. As such, the wages and employment of the more skilled rise relative to their less skilled counterparts. So SBTC acts as a driver of increased labour market inequality.

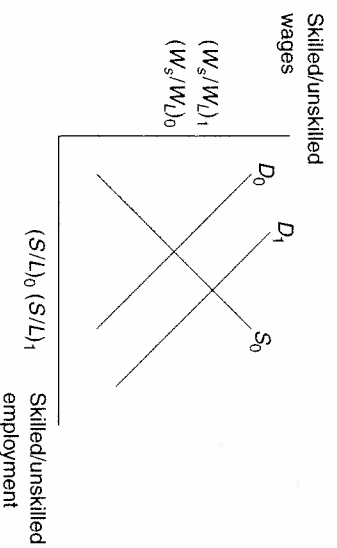


Figure 3.1 Demand and supply curves for two skill types

One can rationalize simultaneously rising relative wages and employment for the skilled in terms of a simple relative demand and supply framework, making the standard assumption that factors are paid their marginal products. Consider Figure 3.1.

The figure shows a labour market with two skill types, skilled and unskilled (namely, high and low educational qualifications), where employers demand a certain number of each. Equilibrium in the model is given by the intersection of the relative demand and supply curves given by D_0 and S_0 in the figure, with a relative wage of $(W_s/W)_0$ and relative employment of $(S/L)_0$. The experience of many countries in recent years is that the ratio of skilled to unskilled wages has increased or remained steady while the ratio of skilled to unskilled employment has risen (Berman *et al.*, 1998). To get such an outcome, there has to have been an outward shift in the relative demand curve. Suppose the demand curve shifts out to D_1 , one then ends up with simultaneously higher relative wages and employment for the skilled at $(W_s/W)_1$ and $(S/L)_1$. Much of the literature has argued that the key driver of the observed relative demand shifts has been skill-biased technological change. A range of evidence has been brought to bear on this question. Some is rather indirect, and some relates the observed changes to direct measures of technology.

3.2.3 'Within-between' decompositions

The SBTC hypothesis requires that technology drives shifts in skill demand. Because of this, one should see skill use shifts occurring where employers have more to gain from the introduction of new technology. Consequently there should be systematic differences in the extent of relative demand shifts within particular workplaces, firms and industries, each of whom is likely to differ in their demand for and the extent of their use of new technologies. A first indirect test of relevance to the SBTC argument therefore comes from a decomposition of aggregate changes in skill demand (usually measured by

wage bill or employment shares of skilled workers), say $\Delta\psi_j$, for j ($= 1, \dots, N$) industries as follows:

$$\Delta\psi = \sum_{j=1}^N \Delta\psi_j \bar{P}_j + \sum_{j=1}^N \Delta P_j \bar{\psi}_j \quad (3.4)$$

The decomposition breaks the overall shift in skill demand into two components. The first is the within-industry component of skill upgrading (weighted by P , the relative size of industry j , and where a bar is a time mean). The second measures between industry shifts, namely how much bigger or smaller an industry is becoming over time (weighted by the time averaged skill demand).

A number of studies using this kind of decomposition have systematically found that the bulk of the aggregate changes have occurred within, rather than between-industries or workplaces. These studies cover different countries, levels of aggregation, time period and skill measures. Table 3.1 shows a summary of the studies from the US and UK. It is clear that the bulk of the skill upgrading that has occurred since the start of the 1970s has been within, rather than between, industries.

The same appears to be the case if one considers a broader range of countries. Berman *et al.* (1998) looked at this for 28 manufacturing industries in 12 countries in the 1970s and 1980s, decomposing changes in the non-production⁵ share of employment into within and between industry components. Table 3.2 reproduces their table on this. The table clearly shows the bulk of industry shifts in non-production employment shares occurring within, rather than between, industries.

Moreover, the same is true in the developing world. Berman and Machin (2000) extended their earlier sample to consider middle and low-income countries, again for the 1970s and 1980s. Table 3.3 reports within-between decompositions for high, middle and low-income countries, and again the within-industry component is seen to be more important almost everywhere.⁶

It therefore seems that across the world the within-industry aspect of skill demand is what matters most. Of course it could be consistent with other possible explanations, but the fact that the bulk of the shifts are seen within industries, when increased relative wages of skilled workers predict within-industry skill-downgrading (i.e. substitution away from the input with the rising relative wage) provides one form of evidence. This is entirely consistent with SBTC altering relative wage and employment outcomes globally.

3.2.4 Evidence from technology indicators

The evidence of the previous sub-section is consistent with SBTC being important, but does not relate shifts in skill demand to observable technological

Table 3.1 Within/between decompositions of skill demand changes in the US and UK

<i>Study</i>	<i>Unit of analysis</i>	<i>Time period</i>	<i>Skill demand measure</i>	<i>Annualized change (percentage points)</i>	<i>% within</i>
Autor, Katz and Krueger (1998)	140 US industries	1990-6	College employment share	.300	87
			College wage bill share	.587	82
		1980-90	College employment share	.469	79
			College wage bill share	.878	70
		1970-80	College employment share	.586	79
			College wage bill share	.662	84
		1960-70	College employment share	.324	27
			College wage bill share	.511	45
Berman, Bound and Machin (1998)	450 US manufacturing industries	1979-87	Non-production employment share	.552	70
			Non-production wage bill share	.774	60
(1998)	360,000 US manufacturing plants	1977-87	Non-production employment share	.367	82
		1979-90	Non-production employment share	.387	82
	100 UK manufacturing industries	1979-90	Non-production wage bill share	.669	83
			Non-production employment share	.41	83
Machin (1996)	402 British workplaces	1984-90	Non-production employment share	.41	83
	402 British workplaces	1984-90	Managers' employment share	.14	86
			Senior technical and professionals employment share	.19	95

Table 3.4 Regression correlations of skill demand changes and technology measures

<i>Study</i>	<i>Unit of analysis</i>	<i>Time period</i>	<i>Skill demand measure</i>	<i>Technology measure</i>	<i>Coefficient (Standard Error)</i>	<i>Controls</i>	
Autor, Katz and Krueger (1998)	140 US industries	1990–96	College wage bill share	Industry computer use (1984–93)	.289 (.081)	None	
		1980–90		.147 (.046)			
	123 US industries	1970–80	Non-production wage bill share	Computer investment per FTE	.127 (.031)		Change in log(capital/labour), decade dummies
		1960–70		.071 (.025)			
Berman, Bound and Griliches (1994)	450 US manufacturing industries	1960–90	Non-production wage bill share	Computer investment/investment	.130 (.027)	Change in log(capital/output), Change in log(output)	
				1959–89	Computer investment/investment		.027 (.007)
	143 US manufacturing industries	1979–87	Non-production wage bill share	Computer investment/investment	.028 (.006)	Change in log(plant/output), Change in log(equipment/output), Change in log(output)	
			R&D/sales	.097 (.021)			
Machin (1996)	16 UK manufacturing industries	1982–89	Non-production wage bill share	R&D/sales	.065 (.026)	Change in (log)capital, Change in log(real sales), 1 digit industry dummies	
	16 UK manufacturing industries	1980–85		Innovation count from 1970s	.092 (.053)		
	398 British workplaces	1984–90	Managers, senior technical and professional employment share	Micro computers introduced	.044 (.022)	Dummy for employment decline, 1 digit industry dummies	
Machin and Van Reenen (1998)	15 UK manufacturing industries	1973–89	Non-production wage bill share	R&D/value added	.026 (.009)	Change in log(capital), Change in log(output), year dummies	

Table 3.3 Continued

	1970-80		1980-90		Notes
	Change in % non-production wage bill (annual)	% within	Change in % non-production wage bill (annual)	% within	
Malta	-0.26	43	0.72	76	1970,80,88
Poland			0.06	80	1970,80,89
Chile	1.12	92	0.05	153	
Czechoslovakia	0.06	61	0.22	92	1970,80,89
Malaysia			-0.35	86	n/a,83,90
Korea			0.08	36	1973,80,90
Colombia	-0.13	145	0.66	84	1972,80,90
Peru	0.13	-247	1.38	103	1972,80,88
Turkey			0.60	79	n/a,83,90
Guatemala	0.36	50	0.96	69	1973,80,87
<i>Low-income group</i>					
Philippines	0.68	46			1970,77,n/a
Egypt	0.23	49	0.44	83	1971,80,88
Pakistan			0.50	72	n/a,80,88
Bangladesh	0.21	152	0.32	20	1970,80,88
India	0.19	-11	-0.08	303	1970,80,88
Tanzania	-0.43	93	0.65	84	1970,80,85
Ethiopia			0.58	91	n/a,80,88

Source: Berman, E. and Machin, S. (2000) 'Skill-Biased Technology Transfer Around the World', *Oxford Review of Economic Policy*, vol.16, pp.12-22 (table 3, p.17), reproduced with the permission of Oxford University Press.

change. Indicators of technological change are available which can be correlated with skill-upgrading as a further test of the SBTC hypothesis. One (frequently used) formal test is to estimate cost share equations relating changes in the skilled wage bill/employment share in a given industry to observable measures of technology (Berman *et al.*, 1994; Machin and Van Reenen, 1998). For industry j in year t , the share equation

$$\Delta(\text{Skilled wage bill share})_j = \eta + \lambda \Delta \log(\text{Capital})_j + \mu \Delta \log(\text{Output})_j + \phi \text{TECH}_j + \varepsilon_j \quad (3.5)$$

can be derived from a translog cost function with two labour inputs (skilled and unskilled), assuming capital to be a quasi-fixed factor. The equation makes clear that one possible explanation for increased demand for skill is capital-skill complementarity (Griliches, 1969), which would be reflected here as $\lambda > 0$. While capital-skill complementarity is important in explaining the cross-sectional pattern of skill use in US manufacturing, it turns out to be a relatively minor source of skill upgrading in the past few decades (Berman *et al.*, 1994).

The focus in these equations is whether the coefficient ϕ on the technology indicator *TECH* is estimated to be positive. Table 3.4 summarizes the US and UK estimates of ϕ .

Clearly, for a range of time periods, different levels of aggregation and different technology measures there is a positive association between industry shifts in skilled wage bill or employment shares and observable technology measures. Put differently, 'technologically' more advanced industries show faster increases in the relative demand for skilled workers. We interpret this as further evidence that skill-biased technology changes have contributed to demand shifts favouring relatively skilled workers.

Another possible explanation for increased demand for skills, even at the plant level, despite their rising relative wages, is 'foreign outsourcing' of low-skill intermediate-good production to imports while concentrating on high-skill parts of the production process. Previous work on US manufacturing finds this to be a relatively minor source of decreased demand for unskilled labour in US manufacturing in the 1970s and 1980s (Berman *et al.*, 1993 and 1994).

3.2.5 Evidence of factor-bias from the 1990s

The evidence considered thus far mainly terminates at the start of the 1990s. This may be of particular relevance for the developing world countries if one believes that the rate of technology transfer lags behind the developed world. In this section we therefore present some new evidence that goes into the 1990s.

Data constraints prevent the same kind of analysis as described in section 3.2 being extended to the 1990s for DCs. Unfortunately, the main data

Table 3.2 Patterns of international skill upgrading

Country	1970-80			1980-90			Note
	Change in % non- production (annualized)	% within	Change in wage ratio (%)	Change in % non- production (annualized)	% within	Change in wage ratio (%)	
US	0.20	81	-2	0.30	73	7	
Norway	0.34	81	-3	-	-	-	1970,80,n/a
Luxembourg	0.57	90	6	0.30	144	12	
Sweden	0.26	70	3	0.12	60	-3	
Australia	0.40	89	-17	0.36	92	2	1970,80,87
Japan	-	-	-	0.06	123	3	n/a,81,90
Denmark	0.44	86	-11	0.41	87	7	1973,80,89
Finland	0.42	83	-11	0.64	79	-2	
West Germany	0.48	93	5	-	-	-	1970,79,n/a
Austria	0.46	89	7	0.16	68	7	1970,81,90
UK	0.41	91	-3	0.29	93	14	
Belgium	0.45	74	6	0.16	96	-5	1973,80,85
Average	0.40	84.3	-1.8	0.28	91.5	4.2	

Note: The percent within column is based on comparing changes over time in the same 28 industries in each country (except for Belgium [24], West Germany [22], Japan [27], Luxembourg [9 in 1970-80, 6 in 1980-90] and Norway [26]).

Source: Berman, E., Bound, J. and Machin, S. (1998) 'Implications of Skill-Biased Technological Change: International Evidence', *Quarterly Journal of Economics*, vol.113, pp.1245-80 (table II, p. 1257), reproduced with the permission of the President and Fellows of Harvard College and the Massachusetts Institute of Technology.

Table 3.3 Within/between decompositions in high, middle and low-income countries

	1970-80		1980-90		Notes
	Change in % non-production wage bill (annual)	% within	Change in % non-production wage bill (annual)	% within	
<i>High-income group</i>					
US	0.19	86	0.51	76	
Australia	0.06	52	0.42	92	1970,80,87
Sweden	0.38	81	0.07	25	
Norway	0.33	76			1970,80,n/a
West Germany	0.67	95	0.42	83	1970,79,90
Luxembourg	0.90	95	0.73	123	
Denmark	0.12	42	0.64	89	1973,80,89
Belgium	0.77	86	-0.06	92	1973,80,85
Finland	0.27	82	0.70	83	
Austria	0.69	93	0.36	76	1970,81,90
UK	0.39	91	0.62	92	
Japan	0.37	98	0.14	98	1969-75,78-90
<i>Middle-income group</i>					
Venezuela	0.78	141	0.56	62	1970,81,91
Spain			0.70	92	n/a,80,90
Ireland	0.02	25	0.58	75	1970,80,89
Greece	0.38	104	0.93	90	
Cyprus			-0.07	108	n/a,81,91
Uruguay			0.17	51	n/a,80,88
Hungary			0.93	96	n/a,80,90
Portugal	-0.97	96	0.48	90	1972,80,87

source used above, the United Nations Industrial Statistics Database, stopped disaggregating industrial wages and employment by non-production/production worker status around 1990. However, the same data source continued in a limited fashion, allowing exploration of changing labour demand using a different approach.

Using an updated version of the UN data (now named UNIDO manufacturing data) and a capital-prediction method as in Berman (2000) we can construct capital-labour ratios (K/E), where $E = S + L$, and examine how changes in industry (K/E) are correlated across countries in the 1990s. Since most manufacturing workers are production workers, increased K/E ratios are a crude indicator of demand shifts away from less skilled labour.

To see how those demand shifts are related to the bias of technological change, consider technological change in the Cobb-Douglas production function above. Technological change cannot favour all three factors without returns to scale increasing over time. Unchanging returns require that $\gamma_K + \gamma_S + \gamma_L = 0$. Thus, for K/L to increase (at the plant level) at constant factor prices requires that technological change be relatively biased towards capital, in the sense that the exponent of capital is growing faster than that of unskilled labour. In a two-factor model (without skilled labour), assuming unchanging returns, relative capital bias and absolute capital bias are the same, since $\gamma_K > 0$ implies that $\gamma_L < 0$. In other words, in a two-factor model with unchanging returns, capital-bias and labour-saving technological change are the same. That insight allows us to learn about labour-saving technological change by studying changes in capital-labour ratios.

We continue in the vein of Berman and Machin (2000) who split countries that report suitable industry data over time into high, middle and low-income countries. Table 3.A1 in the Appendix reports some descriptive statistics on changes in (K/E) for middle and high-income countries and we focus upon these for our analysis of the 1990s. The most important fact to start with is that capital-labour ratios in manufacturing increased quickly in both high and middle-income countries during the 1980s and through the mid-1990s. In the high-income sample capital-labour ratios increased by an average of 2.9 per cent per annum in the 1980s and 2.8 per cent per annum in the early 1990s, with employment shrinking at the same time. Less well known is that capital-labour ratios increased even more quickly in the middle-income countries, by 3.4 per cent annually in the 1980s and 8.9 per cent in the early 1990s, as employment grew slowly while investment accelerated.

3.2.6 Evidence on capital-biased technological change

Was that increase in capital intensity in middle-income countries a technology transfer phenomenon? Table 3.5 reports within-between industry decompositions of changes in industry capital-labour ratios for the middle

Table 3.5 Within/between decompositions of changes in K/E in the 1980s and 1990s

	1980s		Early 1990s		Notes
	% Change in K/E (annualized)	% within	% change in K/E (annualized)	% within	
<i>Middle-income countries</i>					
Barbados	6.71	-72	-4.34	93	1980,90,95
Colombia	3.57	104	0.53	244	1980,90,97
Hong Kong	5.56	59	15.38	150	1982,90,98
Hungary	1.28	87	-	-	1980,90
Ireland	4.74	69	-	-	1980,89
S. Korea	5.86	108	21.26	93	1980,90,98
Poland	-0.76	106	-	-	1980,90
Portugal	1.62	114	-1.69	-134	1980,89,95
Spain	8.96	13	1.81	88	1980,87,95
Turkey	0.15	323	1.06	273	1983,90,97
Venezuela	-1.30	116	2.95	89	1982,91,95
<i>High-income countries</i>					
Austria	2.78	95	-	-	1981,90
Belgium	4.95	-123	-	-	1980,90
Denmark	0.95	119	-	-	1980,85
Finland	4.52	87	3.77	89	1980,90,98
Japan	0.86	229	4.43	103	1979,90,95
Luxembourg	1.07	20	-	-	1980,90
Norway	3.30	95	-1.13	-17	1980,90,98
UK	4.03	114	4.02	114	1980,90,98
US	3.03	115	1.72	107	1980,90,95
<i>Means (simple)</i>					
Middle-income	3.31	93	4.62	112	
High-income	2.83	83	2.56	79	
<i>Means (weighted)¹</i>					
Middle-income	2.89	111	7.03	91	
High-income	2.52	144	2.76	181	

¹ Weights are the employment levels in ending years.

and high-income countries on which we were able to assemble consistent data in the 1980s and 1990s.

A clear pattern emerges for both samples of countries and for both time periods. Almost everywhere one sees rises in the change in K/E , and the bulk of the shifts have occurred within, rather than between, industries. This new finding is consistent with a change in factor demand driven by technological change, though we certainly cannot rule out the possibility of factor