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## **Globalization, Technology Transfer, and Skill Accumulation in Low-Income Countries**

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### **Abstract**

Globalization has drastically improved access of technological latecomers to advanced technologies and provides a unique opportunity for low-income countries to raise *per capita* income. This paper shows that low-income countries as a group have in fact substantially increased the GDP-ratio of technology imports over the past few years, but that there are large cross-country discrepancies in technology upgrading within this group. General-purpose technology continues to constitute the bulk of technology imports, while sector-specific technology used for labour-intensive activities has gained in importance. Improved access to technology imports appears not to have improved labour productivity and the demand for skilled labour in many low-income countries. To raise the benefits reaped from globalization, governments might need to make additional efforts towards a simultaneous increase in technology imports and the skill level of the domestic labour force.

Keywords: technology transfer, labour productivity, low-income countries.

JEL classification: O33, J24

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## Introduction

Both standard neoclassical growth theory and recent endogenous growth theory explain persistent poverty in developing countries as being partly due to differences in technology between rich and poor countries. Neoclassical theory considers technology as both universally available and applicable, and technological differences as gaps in the endowments of objects, such as factories or roads. By contrast, endogenous growth theory considers that gaps in the endowment of ideas and in the limited capability of developing countries to absorb new knowledge are the main reasons for poverty. The latter implies that development policy should concentrate on the interaction between technology and skills with a view to facilitating the reduction of the idea gap.

One of the main opportunities which globalization—the integration of national economies—is said to offer to developing countries is that they would have better access to the technical advances in developed countries. Integration would help to reduce the technology gap and to raise the level of total factor productivity and *per capita* income in developing countries. Coe and Helpman (1995), Keller (1998) and Coe, Helpman and Hoffmaister (1997)—henceforth CHH (1997)—have shown empirically that countries which have imported more from the world’s technology leaders have experienced faster growth in total factor productivity. This paper refines the measure which these authors used to proxy technology imports and assesses whether on this refined measure technology transfer to low-income countries has increased over the past few years.

The role of technology adoption in the process of economic development has been a recurrent theme in the economic literature. It highlights that the cross-country distribution of *per capita* income will move up over time with no change in its range if the distribution of technology adoption is constant over time, i.e. all countries adopt new technology equally. To reduce this range, backward countries will need to upgrade their level of technology faster than the advanced countries. The realization of technological improvements in backward countries is closely interrelated with their educational attainment: their skill supply influences the amount and degree of sophistication of technology which can be adopted and efficiently used, while in turn the amount and sophistication of newly introduced technology impacts on the demand for skills. This means that globalization can ignite a virtuous circle of technological upgrading and skill accumulation in technological latecomers.

It is clear that the interdependence between globalization, technology upgrading and skill accumulation is determined by many factors and a full specification of these mechanisms is beyond the scope of this paper. The more modest objective of the paper is to concentrate on trade flows as a vehicle for technology transfer to developing countries and to assess empirically two phenomena which reflect whether or not globalization has ignited a virtuous circle between technology upgrading and skill accumulation: (1) the evolution of machinery and equipment imports and their sectoral bias, and (2) the change in the demand for skilled labour.

Section 1 presents a simple framework regarding the interaction between technology upgrading and skill accumulation. Section 2 assesses technology imports by low-income countries from both developed countries and developing countries with significant

domestic research and development (R&D) spending, where the latter group will be called ‘technologically more advanced developing countries’. Section 3 discusses changes in labour productivity and the demand for skilled labour, and section 4 provides some concluding remarks. Throughout the paper, specific emphasis will be placed on low-income countries where—following UNCTAD (2000)—this group includes all developing countries with a *per capita* GDP of under US\$ 800 in 1995.

## 1 Technology and skill accumulation

The shortage of modern technology is widely assumed to hold down the level of *per capita* income in low-income countries. But there is little empirical evidence on whether the improved access to modern technology which has come about with globalization has helped alleviate this shortage. It is clear that their improved access to modern technology alone does not guarantee that low-income countries will realize productivity increases. They need the human capital required to absorb and efficiently use modern technology. Moreover, economic policies and institutional arrangements impact on the actual amount of modern technology which low-income countries can import.

The combined role of education and technology for output generation can be expressed in two alternative ways in the production function. First, they can be viewed as multiplicative inputs which implies that the ‘marginal productivity’ of education—determined by the number of inputs and the current technology—can remain positive even if the technology does not change. A second, and probably more useful, view (Nelson and Phelps, 1966; Lucas, 1993; Young, 1993) argues that education has a positive payoff only if the technology is always improving.

This second view can be formalized building on a model by Nelson and Phelps (1966). The model shows that the rate at which technological latecomers realize technology improvements made in technologically advanced countries is a positive function of their educational attainment (with  $\delta\alpha / \delta h > 0$ ) and proportional to the gap between the technology level in advanced countries ( $T(t)$ ) and their own ( $A(t)$ ):

$$\frac{\dot{A}(t)}{A(t)} = \alpha(h) \left[ \frac{T(t) - A(t)}{A(t)} \right]$$

Assuming that technology in advanced countries improves exogenously each year by \* percent, i.e.

$$T(t) = T_0 e^{\delta t}$$

implies that the equilibrium path of potential technological development of a technological latecomer is

$$A(t) = \left[ \frac{\alpha(h)}{(\alpha(h) + \delta)} \right] T_0 e^{\delta t}$$

Accordingly, the potential level of technology which is employed in a technologically backward country depends on its own educational attainment  $h$  and the rate of

technological progress in the advanced countries which becomes available to the backward countries. Assuming that production is characterised by a low elasticity of substitution between imported technology and domestic skilled labour, there are rapidly decreasing returns to the increase of either (imported technology or domestic skilled labour) in the absence of rising supply of the other.

The introduction of new technology can stimulate skill accumulation in two ways. First, the technology can be of a more recent vintage without affecting the sectoral composition of production (within-industry effects). Second, assuming the existence of a technology ladder in the production of goods ordered by increasing technical sophistication, the introduction of new technology can stimulate skill accumulation also—and perhaps most importantly—when it leads to a change in the sectoral composition of production by relating to activities which are one rung up on the technology ladder compared to those which already exist in an economy (between-industry effects). Hence, the full impact of technology adoption on skill accumulation depends on the amount of new technology that is introduced and on the degree of change in the structure of production up the technology ladder which the new technology entails.

The introduction of new technology is constrained by barriers to technology adoption. When such constraints are present, the technology inflows which can be realized ( $*_F$ ) will be lower than the potential inflows of modern technology (\*).

$$A(t) = \left[ \frac{\alpha(h)}{(\alpha(h) + \delta_F)} \right] T_0 e^{\delta_F t}$$

Several factors determine the difference between \* and  $*_F$ . Import rules and restrictions will limit technology imports—one effect of trade integration is the decline of such limits. Natural trade barriers such as geographical distance can reduce technology imports to the extent that geographical distance raises transportation costs of capital equipment which embodies technology to prohibitive levels. From a micro-economic perspective, high costs of firms to invest in new technology limit its adoption (see Parente and Prescott, 1994, for a detailed discussion) including a cumbersome legal and regulatory framework or high real interest rates and an unstable exchange rate which do not enable potential investors to make long-term plans.

From a macroeconomic perspective, a country's ability to import new technology will be seriously limited if it is subject to a balance-of-payments constraint because it cannot achieve export earnings that fetch the foreign exchange which is required to pay for such imports. The level of the export-earnings requirement is determined by the share of machinery investment which needs to be imported, as well as by the level of aggregate investment and the proportion of investment which is machinery (as distinguished from construction).

But increased trade integration also has a composition effect on the country's production structure. As argued above, this composition effect impacts on the direction of change up or down the technology ladder brought about by the sectoral bias of the new technology. On the import side, an inflow of new technology that raises productivity of all sectors equally will not alter comparative advantage in the framework

of standard trade theory. But the opposite will be the case if the inflow of technology is sectorally biased, since for Ricardian reasons this will alter comparative advantage.<sup>1</sup>

On the export side, the composition effect works through two channels that can pull in different directions. The first channel regards the terms of trade: to maximize its export earnings, the country should strive to export those products which are not subject to declining terms of trade. The second channel regards the country's comparative advantage: to maximize its export earnings, the country will need to change its production and export structure towards those sectors in which it has a competitive edge. Concern has often been expressed in this regard because to the extent that manufacturing is higher up on the technology ladder and provides a better growth potential than agriculture, developing countries might experience de-industrialization and lower growth because their comparative advantage is usually not in manufacturing.

Globalization further complicates the composition effect of trade integration. With an increasing number of countries integrating into the world economy, a specific country's comparative advantage changes over time depending on the evolution of effective global factor endowments in addition to changes in the country's own factor combination. The effective global factor endowment changes according to the additional factor supply from newly integrating countries. It has been argued by Wood (1997), for example, that China's increased trade integration in the early 1980s has significantly increased the effective world supply of labour with basic skills and that this has significantly lowered the comparative advantage which integrating Latin American countries would have had in low-skilled-labour-intensive activities in the absence of China's integration.

This suggests that the interrelationship between technology imports, the sectoral composition of production and skill accumulation depends on many factors, and a full specification of these mechanisms is beyond the scope of this paper. Nonetheless, the above implies that two measurable magnitudes play a role in whether or not globalization can ignite a virtuous circle of technology upgrading and skill accumulation in low income countries: (1) the inflow of modern technology, and (2) the sectoral bias of technology inflows. The following section focuses on an assessment of these magnitudes.

## **2 Trade integration and technology imports: some statistical evidence**

One measure of global integration is the extent to which a country has absorbed the global stock of technology and other knowledge. However, such a measure is difficult to calculate. This section examines indirect measures of (technological) integration by looking at the GDP-ratios of trade, total imports and, most importantly, machinery imports.<sup>2</sup> The group of 46 low-income countries analysed in this paper includes all

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<sup>1</sup> Comparative advantage will change also when technological progress has a factor bias.

<sup>2</sup> Data on international patenting has been suggested by, for example, Eaton and Kortum (1999) as an alternative road to identify international technology diffusion. However, given the lack of comprehensive data for developing countries in this regard, such studies have typically been confined to technology diffusion among the most developed countries.

developing countries with a *per capita* income of under US\$ 800 in 1995 for which data are available (see appendix for the list of countries).

The analysis of technology imports builds on CHH (1997) who provide evidence which suggests that there is significant technology transfer from the developed to developing countries. They measure the stock of foreign technology which a developing country can access as a weighted average of the domestic R&D capital stocks of its developed-country trading partners, with bilateral machinery and equipment import shares of each developing country with respect to the developed country serving as weights.

The statistical analysis<sup>3</sup> in this paper diverges from that in CHH (1997) in three main respects.<sup>4</sup> First, the technology imports of low-income countries are not weighted according to the domestic R&D capital stock of the country's trading partners. Coe and Hoffmaister (1999) in fact note that using simple import averages instead of bilateral import weights leads to essentially similar results. This suggests that whereas a country's level of total factor productivity is affected by its trading partners' level of technological development, the intensity of this relationship is not crucial because of the public good nature of knowledge. In other words, it matters for a developing country how much technology it imports from the developed countries, but it is unimportant whether it imports 50 per cent from the United States and 30 per cent from Japan or the other way round. Hence, this paper analyses imports from the technology leaders combined.

Second, due to data problems in the calculation of the foreign R&D capital stock, CHH (1997) do not take into account technology imports from other developing countries. However, such imports are likely to be important especially for the technologically least advanced economies because technology imports from technologically more advanced developing countries can be considered less sophisticated than those from developed countries as they are likely to be of an older vintage or a lower technological level. Accordingly, technologically least developed countries absorb technology imported from technologically more advanced developing countries more easily than technology imported from developed countries. Hence, technology imports from those developing countries with—according to CHH (1997)—significant domestic R&D expenditure (see Appendix), will be examined in addition to imports from developed countries.

Third, CHH (1997) follow conventional practice in the analysis of technology imports and limit their analysis to *aggregate* data on machinery and transport equipment (i.e., section 7 of SITC Rev.2). By contrast, a finer data breakdown appears to be suited better to the purposes of this paper for three reasons: first, parts of such imports – most importantly transport equipment, television sets etc, household-type equipment, and transistors and semi-conductor devices – are better classified as consumption or imports for re-export, rather than capital equipment. Second, specialized capital equipment will be singled out to see whether technology transfer has been of a general-purpose nature

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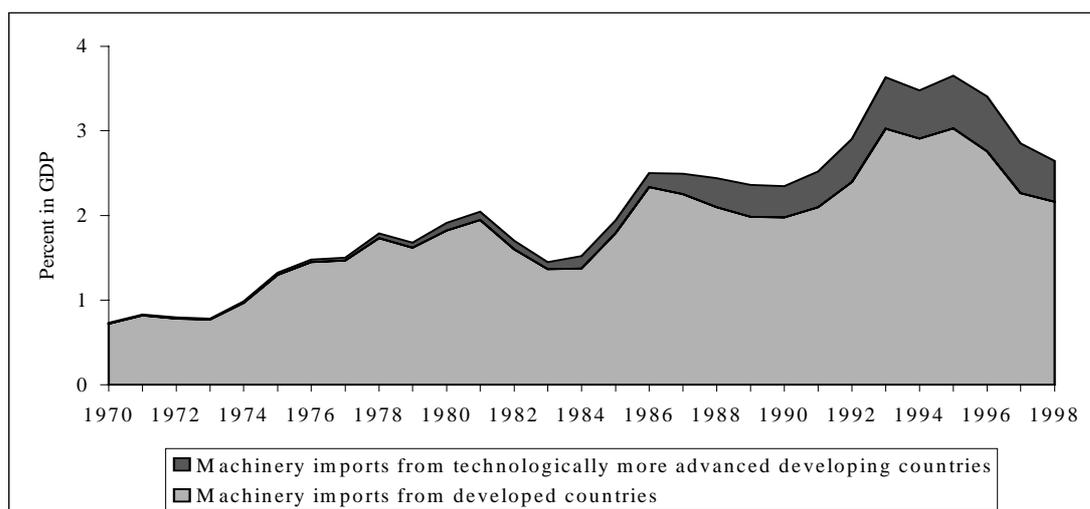
<sup>3</sup> The analysis is based on mirror trade data, i.e., exports from country A to country B are used to measure imports by country B from country A. The reason for this that the availability and reliability of import data of many low-income countries is very poor.

<sup>4</sup> The results reported by CHH (1997, pp. 138–9) were reproduced for consistency reasons. Only very small discrepancies were detected except for Zambia where the discrepancy is over three percentage points. These discrepancies are most likely due to the use of different sources for GDP-data.

or whether it has been sectorally biased.<sup>5</sup> Whereas general-purpose technology imports can be considered as raising productivity in all sectors equally, sectorally-biased technology imports affect the importing country's comparative advantage. As a result, a change in the structure of production (and exports) is likely to be associated with sectorally-biased technology imports. Third, a finer breakdown of technology imports allows to assess whether technology transfer in any given sector to low-income countries has been faster from the developed or from the technologically more advanced developing countries.

Figure 1 shows that the weighted GDP-ratio of machinery imports for the group of 46 low-income countries has been higher<sup>6</sup> over the last few years than during the 1970s and 1980s, despite the sharp drop after 1995 to its level during the second half of the 1980s.<sup>7</sup> The figure also shows that technology imports from technologically more advanced developing countries have considerably gained in importance and that they represent between one fifth and one fourth of all technology imports by low-income countries.

Figure 1  
GDP ratio of machinery imports by low-income countries 1970-98



Source: Trade data from COMTRADE, GDP-data from UNCTAD database.

Note: See appendix for the composition of country and product groups.

<sup>5</sup> In this paper, the term 'general-purpose technology' relates to technology which can be used in various industrial sectors. It therefore differs from the meaning in, for example, Bresnahan and Trajtenberg (1995) where general-purpose technologies are characterized by an inherent potential for technical improvements and innovative complementarities in addition to pervasiveness.

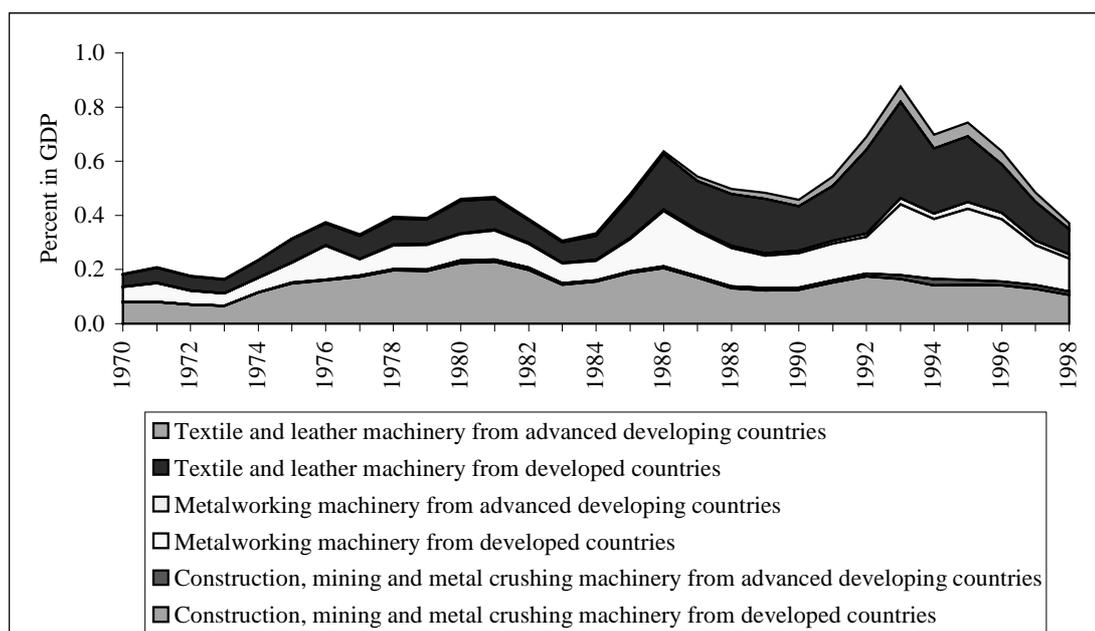
<sup>6</sup> A rise in the GDP-ratio of imports can be caused by purely accounting reasons because of real currency depreciation. However, table 1 below shows that machinery imports have grown faster than total imports so that the increase shown in figure 1 is not just a statistical artifact.

<sup>7</sup> This drop reflects a general slowdown of world trade caused initially by a sharp deceleration of import growth in developed economies and then by the turmoil following the outbreak of the East Asian crisis.

Figure 2 shows the weighted GDP-ratios of selected sectoral machinery imports.<sup>8</sup> Textile and leather machinery combined with metalworking machinery account for the bulk of specialized machinery imports and—with a very steep increase at the beginning of the 1990s and a sharp drop after 1995—both of these categories closely mirror the evolution of total machinery imports. Even though the absolute importance of these imports from technologically more advanced developing countries remains small, their proportional change during the first half of the 1990s is impressive: the GDP-ratio of metalworking machinery doubled and that of textile and leather machinery even rose fivefold between the mid-1980s and the mid-1990s.

Figure 2

GDP-ratio of selected specialized machinery imports by low-income countries, 1970–98



Source: Trade data from COMTRADE, GDP-data from UNCTAD database.

Note: See appendix for the composition of country and product groups.

Figure 3 assesses the sectoral bias of technology imports by plotting the ratio of sectorally-specific to general-purpose technology imports. The sectorally-specific technology imports have been classified according to the primary factors which are intensively employed in their use: agricultural land (agricultural machinery and tractors), mineral and fuel resources (metalworking machinery; and construction, mining and metal crushing machinery), low-skilled labour (textile and leather machinery), agricultural land and skilled labour (food-processing machinery and paper

<sup>8</sup> The ratios of agricultural machinery and tractors, paper and pulp mill machinery, printing and bookbinding machinery, and food-processing machinery imports are not shown because they are very small.

and pulp-mill machinery), and scale and skilled labour (printing and bookbinding machinery).<sup>9</sup>

Figure 3

Specialized and general-purpose machinery imports by low-income countries, 1970–98



Source: COMTRADE.

The figure shows that specialized-technology imports have always been small compared to imports of general-purpose technology, and that this fraction has become even smaller over the past few years: while the combined GDP-ratio of specialized-technology imports from both developed and technologically more advanced developing countries was about half that of general-purpose technology imports, it fell to about one third during the 1990s. This drop in the combined ratio is due to the drop in technology imports related to activities in the primary sector—both agricultural and, in particular, mineral and fuel-based. Even though the comparatively low ratio of agriculture-related technology is not surprising because of the well-known difficulties associated with the applicability of agricultural technology across different climatic and soil conditions, its substantial drop is noteworthy.

Whereas the ratio of skill-related technology imports has by and large remained constant, that of labour-related technology imports strongly increased during the second half of the 1980s and the early 1990s, reaching the same level as that of mineral-related technology, before falling in a similar way as technology imports related to the minerals sector. This means that, for the group of low-income countries as a whole, the sectoral

<sup>9</sup> The classification is partly based on OECD (1992, p. 152). As any such classification, it includes some arbitrariness.

bias of technology imports is small and that this bias has shifted from primary-sector-related to low-skilled-labour-intensive technology.

In addition to their GDP-ratios, the evolution of technology imports can also be assessed by their rate of growth compared to that of total imports. Table 1 shows that the average growth rate of the absolute value of machinery imports by low-income countries from both developed and technologically more advanced developing countries has exceeded that of total imports for all sub-periods since 1970. The growth rate of imports from both developed and advanced developing countries regarding textile and leather machinery, as well as regarding technology-including consumption goods, has dropped sharply during the 1990s, while the growth rate of transistor and semi-conductor imports has risen strongly. It is also noteworthy that all categories of technology imports from technologically more advanced developing countries have grown faster than total imports in all of the sub-periods, except the 1990s where the growth of several categories are lower than that of total imports.

Turning to country-specific evidence, Table 2 suggests that the GDP-ratio of machinery imports has increased in relatively few low-income countries between the 1970s and the 1990s. The unweighted cross-country median has risen only marginally, and the GDP-ratios of machinery imports from developed countries have increased by more than 1 percentage point in only 12 of the 46 countries, while they have fallen by more than half a percentage point in 8 countries. However, apart from a number of very small countries, large countries such as China, India and Nigeria are among those whose machinery-import ratios have risen most. This explains the more positive evidence discussed above on the basis of weighted averages (Figure 1). It is also noteworthy that there is no country for which the ratio between machinery imports from technologically more advanced developing countries and from developed countries has fallen; this confirms the evidence presented above regarding the increasingly important role of machinery imports from technologically more advanced developing countries.

To understand the reasons for the cross-country discrepancies in the ratio of machinery imports to GDP, it may be helpful to look for correlations across low-income countries between the change in the GDP-ratio of technology imports between the 1970s and the 1990s and variables which come readily to mind as influencing technology imports: low investment, factor combinations and geographical location which are not conducive to industrial development, high tariffs and other impediments to machinery and equipment imports, and a lack of foreign exchange to pay for such imports. From a methodological point of view, a pairwise correlation analysis is preferable to an analysis which combines the variables in multiple regressions because of the endogeneity between technology imports and, for example, educational attainment or investment.

For this purpose, the set of 46 countries was modified by omitting the two countries for which comprehensive data for the 1970s are not available (Angola and Mozambique), as well as the four countries with a population below one million inhabitants (Comoros, Equatorial Guinea, Guyana, and Sao Tome and Principe) whose very high technology imports ratios are statistical outliers. The first column of Table 3 reports the coefficients of correlation (R) across the 40 remaining countries between 14 variables and the absolute discrepancy between the GDP-ratio of machinery imports during 1990–1998 and that during 1970–1979 (or, as indicated for three variables, the absolute level of the GDP-ratio of machinery imports during 1990–1998). A glance down the column reveals that the sign of only one of the correlations (with external debt) is contrary to

expectations, indicated by square brackets around the number, and that the correlation with only two other variables (distance to the closest major port, and change in total import charges between the 1980s and 1990s) are weak.

Table 1  
Imports by low-income countries, selected categories  
1970–1998, average growth rates.  
(percentages)

	1970–79	1980–89	1990–98
<b>Total imports from world</b>	20.1	3.6	10.4
<b>Imports from developed countries, by category</b>			
Total	21.5	3.0	8.1
Machinery and transport equipment (SITC7)	11.1	1.2	9.5
<i>of which</i>			
Transport equipment	10.7	-3.6	4.6
Technology-including consumption goods	11.1	5.0	0.4
Transistors and semiconductor devices	11.9	28.0	27.2
Machinery	11.4	3.0	11.2
<i>of which :</i>			
Agricultural machinery	10.3	-6.9	0.1
Textile and leather machinery	8.8	10.0	1.2
Paper and pulp mill machinery	14.6	-1.9	22.1
Printing and bookbinding machinery	6.0	2.6	15.4
Food-processing machinery	16.8	1.1	9.0
Construction, mining and metal-crushing machinery	14.2	-5.3	6.5
Metalworking machinery	6.4	6.7	11.6
<b>Imports from technologically more advanced developing countries, by category</b>			
Total	30.3	11.1	13.6
Machinery and transport equipment (SITC7)	25.8	11.6	14.0
<i>of which</i>			
Transport equipment	25.9	-0.8	9.4
Technology-including consumption goods	37.9	5.3	9.1
Transistors and semiconductor devices	73.3	42.2	26.2
Machinery	23.1	18.5	14.4
<i>of which :</i>			
Agricultural machinery	24.9	3.0	15.0
Textile and leather machinery	18.9	17.5	9.0
Paper and pulp mill machinery	26.9	11.9	15.4
Printing and bookbinding machinery	15.3	22.3	9.9
Food-processing machinery	32.3	2.4	9.2
Construction, mining and metal-crushing machinery	55.3	-1.0	19.5
Metalworking machinery	24.2	12.8	20.4

Source: Total imports from world from UNCTAD database; all other data from COMTRADE.

Table 2:  
Share of machinery imports in GDP (percentages)

	Imports from			Imports from			Imports from		
	Developed countries	Advanced developing economies	ratio (2)/(1)	Developed countries	Advanced developing economies	ratio (4)/(3)	Developed countries	Advanced developing economies	ratio (6)/(5)
	(1)	(2)	(2)/(1)	(3)	(4)	(4)/(3)	(5)	(6)	(6)/(5)
	<b>1970-79</b>			<b>1980-89</b>			<b>1990-98</b>		
Afghanistan	0.9	0.1	0.1	1.1	0.1	0.1	0.7	0.4	0.6
Angola	n.a	n.a	n.a	3.6	0.3	0.1	5.3	0.5	0.1
Bangladesh	0.7	0.1	0.2	1.1	0.4	0.4	0.9	0.8	0.9
Benin	2.5	0.1	0.0	3.2	0.1	0.0	2.4	0.7	0.3
Burkina Faso	2.3	0.0	0.0	2.5	0.0	0.0	2.9	0.1	0.0
Burundi	1.3	0.0	0.0	2.3	0.0	0.0	2.2	0.1	0.1
Cameroon	3.2	0.0	0.0	2.9	0.0	0.0	2.0	0.1	0.0
CAR	2.3	0.0	0.0	1.9	0.1	0.0	1.8	0.1	0.0
Chad	1.5	0.0	0.0	1.3	0.0	0.0	1.7	0.0	0.0
China	0.4	0.0	0.0	1.7	0.2	0.1	2.8	0.7	0.2
Comoros	4.9	0.0	0.0	8.5	0.2	0.0	11.4	0.2	0.0
Congo (Dem. R)	2.3	0.0	0.0	2.4	0.1	0.0	1.5	0.1	0.0
Cote d'Ivoire	4.8	0.1	0.0	2.8	0.1	0.0	2.9	0.2	0.1
Eq. Guinea	3.9	0.0	0.0	9.1	0.2	0.0	9.7	0.3	0.0
Ethiopia	1.8	0.1	0.1	2.5	0.1	0.1	3.3	0.3	0.1
Gambia	4.4	0.1	0.0	5.6	0.5	0.1	4.8	0.7	0.1
Ghana	3.6	0.1	0.0	2.8	0.2	0.1	5.5	0.5	0.1
Guinea	1.9	0.0	0.0	3.4	0.1	0.0	2.8	0.2	0.1
Guinea-Bissau	4.5	0.0	0.0	8.7	0.3	0.0	5.0	0.3	0.1
Guyana	9.6	0.1	0.0	9.5	0.5	0.0	14.9	1.5	0.1
Haiti	4.3	0.0	0.0	4.8	0.1	0.0	1.7	0.1	0.1
Honduras	4.5	0.3	0.1	3.3	0.3	0.1	6.2	0.7	0.1
India	0.7	0.0	0.0	1.2	0.1	0.1	1.5	0.2	0.2
Kenya	4.5	0.2	0.0	4.0	0.3	0.1	4.5	0.6	0.1
Madagascar	2.2	0.0	0.0	2.5	0.0	0.0	2.7	0.2	0.1
Malawi	2.9	0.0	0.0	2.7	0.1	0.0	2.5	0.2	0.1
Mali	2.6	0.0	0.0	2.9	0.1	0.0	3.3	0.2	0.1
Mauritania	6.0	0.2	0.0	7.1	0.2	0.0	6.9	0.3	0.0
Mozambique	n.a	n.a	n.a	3.3	0.4	0.1	4.0	0.3	0.1
Nepal	0.5	0.3	0.6	1.3	0.5	0.4	1.3	1.2	0.9
Nicaragua	3.8	0.1	0.0	2.6	0.5	0.2	5.3	0.6	0.1
Niger	2.3	0.0	0.0	2.7	0.0	0.0	1.9	0.1	0.1
Nigeria	2.7	0.1	0.0	2.9	0.2	0.1	4.7	0.6	0.1
Pakistan	2.6	0.0	0.0	2.8	0.3	0.1	2.9	0.8	0.3
Rwanda	1.3	0.0	0.0	1.6	0.0	0.0	1.4	0.1	0.0
Sao Tome	3.0	0.0	0.0	7.0	0.1	0.0	16.2	0.6	0.0
Senegal	3.9	0.0	0.0	4.2	0.1	0.0	4.0	0.1	0.0
Sierra Leone	3.0	0.0	0.0	2.6	0.1	0.0	3.8	0.3	0.1
Somalia	4.7	0.0	0.0	6.4	0.1	0.0	1.7	0.2	0.1
Sri Lanka	1.8	0.3	0.2	3.6	0.9	0.2	3.0	1.5	0.5
Sudan	2.5	0.1	0.0	1.8	0.1	0.1	1.7	0.5	0.3
Tanzania	3.8	0.2	0.1	3.5	0.2	0.1	3.7	0.5	0.1
Togo	6.1	0.0	0.0	4.5	0.1	0.0	3.5	0.5	0.1
Uganda	0.8	0.0	0.1	0.9	0.1	0.1	1.8	0.2	0.1
Zambia	5.0	0.2	0.0	5.3	0.2	0.0	4.1	0.2	0.0
Zimbabwe	0.1	0.0	0.0	2.1	0.0	0.0	3.8	0.2	0.1
MEDIAN	2.7	0.0	0.0	2.9	0.1	0.0	3.0	0.3	0.1

Source: COMTRADE except for GDP data which are from UNCTAD database.

Notes: For the composition of the country groupings, see appendix.

Table 3:

## Factors associated with variation among low-income countries in technology imports

Explanatory (number of countries, if <	Means of explanatory variables for countries					
	Correlation (R) absolute between imports during 1990– and during 1970–	proportional difference about double or more (‘good performers’)	drop in absolute level by more than 2 percentage (‘poor performers’)	no significant change (‘average performers’)	P-value of t-test of difference of means (good vs poor performers)	P-value of t-test of difference of means (good vs performers)
	(1)	(2)	(3)	(4)	(5)	(6)
<b>A. Investment and</b>						
Gross domestic investment (% of GDP), 1990–97	0.58	23.2	11.8	15.9	0.15	0.01
Change in gross dom. investment, 1990s - 1970s	0.68	5.6	–9.8	–1.6	0.06	0.02
Risk index 1995 (ICRG): high = good	0.50	61.5	41.3	53.3	0.16	0.02
Inflows of FDI (% of GDP), 1990–	0.46 <sup>e</sup>	1.5	0.2	0.9	0.03	[0.31]
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<b>B. Factor endowment and</b>						
Square km of land per 100 workers, 1995	–0.25	2.0	1.6	9.1	[0.76]	0.00
Years of schooling, 1995	0.43	4.3	3.0	2.6	0.04	0.01
Population, 1995	0.29	244466	6900	18011	0.12	0.14
Mineral reserves, 1990: \$mn/100 sq	0.33	23.9	0.2	2.3	0.05	0.07
Distance to closest major port: km	–0.05	5246	4773	5625	[0.75]	[0.54]
---						
<b>C. Charges on imports of machinery and</b>						
Total import charges, most recent year	–0.44 <sup>d</sup>	18.1	n.a.	15.2	n.a.	[0.59]
Change in total import charges, 1990s - 1980s	–0.02	–35.7	n.a.	–12.0	n.a.	[0.29]
<b>D. Balance-of-payments</b>						
External debt, 1990–97: % of	[0.38] <sup>f</sup>	64.4	130.5	143	0.43	0.00
Change in capacity to import, 1990s - 1970s	0.36	3.7	1.3	1.4	0.08	0.09
Change in level of exports, 1990s -1970s,	0.36	3.8	1.5	1.7	0.07	0.09

Sources: see Mayer (2000)

Notes: Square brackets around an R-value or P-value indicate that the direction of relationship is contrary to expectations. 'Good performers' group contains 10 countries, 'poor performers' group contains 3 countries and 'average performers' group contains 27 countries. The superscript a indicates that the R-value refers to the relationship between the variable and the level of machinery imports during the 1990s.

The first four rows of the column (Panel A) shows positive relationships between the size of the change in GDP-ratios of machinery imports and measures of investment and investment climate: the average share of gross domestic investment in GDP in the 1990s, its absolute increase between the 1970s and the 1990s, the December-1995 value of the index of the international country risk guide (ICRG) which reflects the risk perception of international investors, and the average GDP-ratio of inflows of foreign direct investment in the 1990s. The link between domestic investment and the investment climate on the one side and machinery imports on the other is straightforward as imported capital equipment is put to productive use through investment. It is widely accepted that inward foreign direct investment should play a substantial role in the international diffusion of technology. However, the extent to which inward FDI is associated with technology diffusion in the form of machinery imports very much depends on the kind of FDI: it is likely to lead to machinery imports in the same year as the investment is undertaken in the case of greenfield investment, while anecdotal evidence suggests that FDI in the form of mergers and acquisitions is associated with machinery imports only after a lag of several years, or sometimes not at all. Unsurprisingly, the correlation coefficients in panel A are the highest of all, even

though the correlation between inward FDI and machinery imports is comparatively weak.

The selection of endowment-related and geographical variables in Panel B is based on the assumption that production activities in the manufacturing and minerals sectors require more machinery imports than agricultural production, and that transportation of machinery imports is more expensive for countries which are located further away from major ports. Following Wood and Mayer (forthcoming), we can expect that countries with a comparatively small natural-resource endowment (proxied by a country's total land area per worker) and a comparatively high educational attainment (proxied by the years of schooling per worker) have a comparative advantage in manufacturing (and hence require comparatively more machinery imports), and that a bigger size (proxied by total population) of countries is associated with more manufacturing activities because of economies of scale and external economies. A comparative advantage in the minerals sector is proxied by the value of known mineral reserves per land area, while the distance to the closest major port is used as a proxy for transportation costs associated with machinery imports. While all of the correlation coefficients for this group of variables have the expected sign, the correlation between the proxy for transportation costs and machinery imports is very low.

A low level of machinery imports can be caused by high tariff or non-tariff barriers to such imports (Panel C). A move towards greater trade openness is likely to be accompanied by tariff reform but this does not necessarily imply a decline in the tariffs on intermediate and capital goods because (i) budgetary revenues in developing countries often strongly depend on tariffs, and tariffs on machinery imports are pure revenue tariffs because these goods cannot be sourced domestically, and (ii) tariff reform has often aimed primarily at reducing tariff dispersion rather than the level of specifically targeted tariffs. This may explain the relatively low correlation coefficients in this panel.

The variables in panel D reflect the financing capacity of countries to pay for imports. The surprising result in this panel is the positive correlation between the ratio of external debt to GDP and the ratio of machinery imports to GDP. However, this may reflect the fact that a number of countries are unable to meet their external debt-servicing obligations and that they may prefer accumulating arrears which are unlikely ever to be paid, rather than foregoing the potential for future growth by renouncing machinery imports. Moreover, the analysis below suggests that this result which reflects the association within the entire sample is in fact driven by a few countries.

The correlation between some of the variables and machinery imports may be concealed by the inclusion of countries whose GDP-ratio of machinery imports during the 1990s was lower than during the 1970s. To investigate this possibility, the 40-country set was divided into three sub-groups: 'poor performers' (Haiti, Somalia and Togo) whose GDP-ratio of machinery imports strongly fell between the 1970s and the 1990s, 'good performers' (Bangladesh, China, Ghana, Honduras, India, Nepal, Nigeria, Sri Lanka, Uganda, and Zimbabwe) whose GDP-ratio of machinery imports more than doubled proportionally or strongly rose in absolute terms, and the group of 'average performers' which includes the remaining 26 countries. The comparison between 'good' performers on the one side and 'bad' or 'average' performers on the other show essentially the same results. But since it could be argued that civil unrest had a sizable impact on the results of the 'poor performers', it may be useful to focus on the comparison between

the ‘good’ and the ‘average performers’, reported in columns 3, 4 and 6 of Table 3. All of the associations are in the expected direction and significant, except for the geography variable, the charges on machinery and equipment imports, and inward FDI. Regarding the latter, the weak but still existing correlation is driven by the inclusion of China and Nigeria—whose GDP-ratios of inward FDI are by far the highest within the 40-country sample—in the group of good performers. When these countries are excluded, the P-value of the F-test reported in column 6 of Table 3 goes to 0.59, excluding only China, and 0.72, excluding also Nigeria.<sup>10</sup> This result is likely to be due to the fact that flows of FDI to developing countries have often been concentrated in a few middle-income countries plus China, so that the majority of low-income countries—especially those which do not have a large minerals sector—have to rely on other channels for technology transfer.

In summary, the statistical analysis of the causes of variation within the group of low-income countries with regard to the absolute change in the GDP-ratio of machinery imports between the 1970s and 1990s suggests positive and statistically significant associations with a high GDP-ratio of domestic investment and a good investment climate, a comparative advantage in manufacturing or in the minerals sector, and the availability of foreign exchange, while there is no statistically significant association with natural or policy-induced trade barriers and FDI-inflows.

In conclusion, the statistical analysis of the evolution of technology imports by low-income countries suggests that the technological integration of these countries as a group has increased, but that comparatively few individual countries account for this phenomenon. The heterogeneity of the countries included in the sample makes it difficult to find meaningful criteria which separate these countries from the others. There is some evidence suggesting that economies with either a very small or a very large size, and economies with a large minerals sector have made most advance in technological integration but it is clear that there are wide discrepancies even among these countries with regard to the barriers of technology adoption discussed in the previous section. The importance of technology imports from technologically more advanced developing countries remains small compared to such imports from developed countries, but has substantially risen over the past two decades. Whereas general-purpose technology has remained the most important part of technology imports from developed countries, specialized technology imports play a substantial role in technology imports from technologically more advanced developing countries. Whereas the sectoral bias of technology imports has remained small, it has been strongest for mineral-based activities; the importance of specialized technology imports related to agricultural activities has fallen, while that related to low-skilled-labour-intensive activities has substantially increased.

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<sup>10</sup> There is a statistically stronger correlation between the absolute change in FDI-inflows during the 1970s and the 1990s and the absolute change in machinery imports over this period but this evidence is difficult to interpret because of the small number of countries for which complete data are available.

### 3 Labour productivity and demand for skilled labour

The above has shown that the GDP-ratios of technology imports have risen in low-income countries as a group pointing to an increase in total factor productivity in these countries. But it is likely that developed countries have also introduced new technologies over the past few years so that the question arises as to whether the higher technology imports have actually reduced the productivity gap between developed and low-income countries.

It is clear that a country's productivity gap is influenced—in addition to technology imports—by a large number of domestic factors including structural characteristics, resource endowments and policies pursued. These factors vary from one country to another, and a full account of such influences requires detailed country analysis that goes beyond the scope of this paper. But as an approximation, it appears reasonable to assume that the introduction of new technology in low-income countries implies a reallocation of labour from low to high-productivity activities—both within and between industrial sectors—which in general are both more capital and skill-intensive. This means that increased technology imports are likely to be accompanied by an increase in labour productivity—in the growth-accounting framework, increases in labour productivity reflect a rising ratio of capital to labour and overall technical progress—and in the demand for skilled labour.<sup>11</sup>

#### 3.1 Labour productivity

Table 4 provides a simple assessment of the evolution of labour productivity in the United States—the world's technology leader—and various low-income countries for a number of low, medium and high-skill industries. Given the lack of data, the evidence needs to be interpreted cautiously. Nonetheless, the table suggests that only some of the 14 countries for which data are available have experienced rising labour productivity over the past few years. India appears to be the only one of the 14 countries which has succeeded in reducing the gap in labour productivity with respect to the United States across all industrial sectors. Pakistan, Sri Lanka and Zimbabwe have also been relatively successful in keeping up with productivity increases in the United States. It is also noteworthy that India achieved the highest increase in labour productivity in labour-intensive sectors (where India raised its specialized technology imports most) and minerals and metal-related sectors (where India's specialized technology imports have traditionally been highest, see Mayer (2000 table 5)). Whereas the evidence for the other countries is less uniform, the table (in conjunction with table 5 in Mayer (2000)) suggests that Sri Lanka also managed to raise labour productivity in those sectors where the country's specialized technology imports were highest. This means that there is some indication to suggest that those countries with high and/or rising specialized technology imports have indeed succeeded in raising sector-specific labour productivity faster than countries with low and/or falling specialized technology imports. But generally speaking, low-income countries have not been very successful in keeping up with productivity increases in the United States.

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<sup>11</sup> For a detailed discussion of technology-skill and capital-skill complementarities and their implications for labour productivity and skill demand, see O'Connor and Lunati (1999).

Table 4:

Labour productivity in selected low-income countries and industrial sectors, 1996 (index numbers 1980=1)

	Total Manufacturing (ISIC 300)	Food products (ISIC 311/12)	Textiles (ISIC 321)	Clothing (ISIC 322)	Footwear (ISIC 324)	Non-ferrous metals (ISIC 372)
Bangladesh	0.8	1.0	0.6	1.0	1.3	n.a.
Cameroon	0.7	0.6	1.2	1.7	n.a.	1.0
Central African Republic	0.7	n.a.	n.a.	n.a.	n.a.	n.a.
China	1.0	1.8	0.5	n.a.	n.a.	1.0
Gambia	1.2	n.a.	n.a.	n.a.	n.a.	n.a.
Ghana	0.8	1.2	0.7	n.a.	n.a.	0.5
India	2.6	5.1	1.9	3.1	1.7	3.2
Kenya	1.1	1.2	0.6	0.8	1.0	n.a.
Malawi	1.6	1.7	1.7	n.a.	n.a.	n.a.
Pakistan	1.5	1.0	2.5	1.3	1.6	0.8
Senegal	1.2	0.9	0.5	1.1	0.6	n.a.
Sri Lanka	1.4	2.6	2.3	1.7	1.8	2.5
Zambia	0.6	1.1	0.4	0.4	0.2	0.2
Zimbabwe	1.4	1.6	1.3	0.8	1.0	1.4
Memo item:						
United States	1.4	1.3	1.2	1.3	1.1	0.8

Source: UNIDO Industrial Statistics Database and UNCTAD database.

Notes: Labour productivity calculated as real value added (in US dollar) per worker. Nominal value added deflated by the GDP-deflator which was derived implicitly

by dividing the GDP series at current prices by constant price GDP series referenced to 1995.

All data for Ghana and Kenya for 1995, for Malawi and Zambia for 1994, for Central African Republic and Gambia for 1993, and for Bangladesh and Pakistan for 1992.

Data for Sri Lanka are for 1993 except for non-ferrous metals and metals products for 1992.

These results can be taken to suggest that even though low-income countries have increased their technology imports over the past few years, this increase has not been sufficiently high to match technological progress in developed countries. But the results can also be taken to support the hypothesis advanced by Acemoglu and Zilibotti (1999) that productivity differences between developed and developing countries continue to exist even with rapid diffusion of new technology. According to these authors, the reason for this are differences in skill scarcities, i.e. developed countries design new technologies for the factor combinations which prevail there so that developing countries, which import such technologies and whose relative supply of skilled workers is lower, must use unskilled workers in tasks performed by skilled workers in developed countries. This constraint may be particularly stringent for those countries whose absolute number of skilled workers falls short of some critical threshold. The two views combined underscore the importance of a simultaneous increase in technology imports and skill levels in low-income countries as emphasized in section 1.

### 3.2 Wage differentials and the demand for labour

In addition to affecting cross-country productivity convergence, changes in the GDP-ratio of technology imports are likely also to impact on the wage differential between skilled and unskilled workers.<sup>12</sup> This differential is likely to widen in the short run and to provide incentives to individuals to enhance their investment in education—Bartel and Lichtenberg (1987), for example, show that the process of adjustment to the implementation of new technology uses educated labour—so that over long periods skill supply and demand are likely to grow apace. To the extent that there is such a short-run impact, relative wages follow a path similar to technology imports, while in the long run this impact is conditioned by changes in the supply of skilled labour.<sup>13</sup> A rising wage differential provides greater incentives to individuals to afford the costs of investment in education and thus supports the virtuous circle of technology and skill upgrading from the supply side of skill accumulation. An individual's incentive to forego current income and invest in education depends on the wage differential between better and less educated labour, and on the probability of finding employment that adequately rewards the skills achieved.<sup>14</sup> There is evidence of such a differential in low-income countries and of its tendency to widen as education levels increase: the difference between the wages of workers with secondary and primary education tends to exceed that between workers with primary education and those with no schooling.<sup>15</sup>

The expectation of rising wage differentials is contrary to the view that globalization will promote greater income equality as it will benefit the poor, unskilled workers. This view relates to Heckscher-Ohlin trade theory according to which countries tend to produce and export goods which use their most abundant domestic resources intensively, and conversely import goods which require large inputs of resources that

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<sup>12</sup> Alternative understandings of the effects of factor-biased technical change in an open economy determine diverging expectations on the impact of such change on relative wages between skilled and unskilled labour. If technical change leads to an equal absolute change in the amount of labour used per unit of output, relative wages between skilled and unskilled workers will not change. However, this implies different relative changes in the amount of labour inputs across products. To the extent that this is true, only sector-biased technical change which limits technical progress to the production of a skill-intensive good changes the input of skilled labour and relative wages. Whether technical change leads to equal absolute or equal relative changes in skilled-labour inputs is largely an empirical question and depends on the degree of substitutability of factor inputs, while how enduring this effects is depends on the supply elasticity of skilled labour.

<sup>13</sup> It can also be argued that globalization raises capital flows from developed to developing countries. This means that – even without technology imports – capital-output ratios in developing countries would rise and given the complementarity between capital and skill, this would raise the relative demand for skilled labour.

<sup>14</sup> A vast empirical literature suggests that education is indeed a major determinant of an individual's earnings, that returns to education respond to this supply, and that educational choice is in large part an investment decision. But to the extent that parents finance their children's education, family income and wealth has an additional impact on the valuation of education, as well as on the interaction between demography and education.

<sup>15</sup> This evidence goes against the conventional wisdom that rates of return on education are highest for primary education, followed by secondary and tertiary education, as argued in many papers by Psacharopoulos (e.g. Psacharopoulos, 1994). But Bennell (1996, 1998) argues that this pattern does not prevail in sub-Saharan Africa and South Asia (i.e. the geographic location of most low-income countries) because of lacking wage employment opportunities (see also World Bank, 1995, p. 39).

are locally scarce. Recognizing the importance of relative endowments of skilled and unskilled labour, under free trade production in countries with abundant unskilled labour (such as the large low-income countries) should concentrate on agricultural and manufacturing goods that require unskilled labour. According to a simple variant of the theory, this is likely to lead to an increase in the demand for unskilled labour and hence a reduction in wage inequality.

However, even if trade integration causes resources to shift towards unskilled-labour-intensive sectors, the degree of skill intensity will tend to increase within each sector if integration is accompanied by increased (mainly general-purpose) technology imports. If these technology effects are sufficiently strong, the returns to skilled labour will rise not fall.

Unfortunately, available country-specific evidence on the evolution of wage differentials in developing countries is limited to high and middle-income countries. But it is noteworthy that this evidence points to a rapid improvement of the labour incomes of skilled manpower and the reduction or lack of growth in pay levels for workers not taking part in the modernization of production. Many Latin American countries share this experience as shown, for example, by Robbins and Gindling (1999) for Costa Rica. As an explanation, they point to the fact that trade integration was accompanied by an acceleration in the introduction of best-practice technology which requires skilled labour.<sup>16</sup> It can also be argued that in countries with surplus labour, employment of unskilled labour can increase without leading to rising real wages, and since unskilled-labour intensive activities also employ some skilled labour, this could lead to higher wages for skilled labour.

Tables 2 and 4 above suggest that not all low-income countries have achieved rising technology imports and that in some low-income countries there has been no increase in labour productivity. This is likely to imply that in many low-income countries globalization has not been associated with an increased demand for skills.<sup>17</sup> Rather, it appears to have been associated with a decline in an individual's returns to skill. Even though this could be welcomed in countries with high initial income inequality, it can also be interpreted as a reduction in the incentive to invest in education. To the extent that lower investment in education today implies reduced future *per capita* income levels and perhaps slower long-run growth, governments would need to make special efforts to raise technology imports and simultaneously bolster individual educational incentives.

#### **4 Concluding remarks**

An important determinant of the benefits which low-income countries can reap from globalization is whether they can ignite a simultaneous increase of technology imports and the skill level of the domestic labour force. This implies a need for government

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<sup>16</sup> But see Wood (1997) for a different explanation.

<sup>17</sup> Berman and Machin (2000) also find that there has been no increase in the demand for skilled labour in low-income countries (their group of low-income countries includes only seven countries in spite of a much broader definition of 'low income' than the one used in this paper).

policy to sustain incentives for human capital formation and for a reduction in the cost of technology adoption. The coordination of such efforts is crucial because investment in human capital alone will lead to diminishing returns of skill accumulation, while increased technology transfer alone is unlikely to be enduring and might have negative developmental effects from rising income inequality.

This is also one of the lessons from the East Asian development experience where rapid industrialization and skill accumulation were achieved by expansion of the education system in conjunction with a step-by-step upgrading of the skill intensity of economic activities. Doing so not only reduced the technology gap with advanced countries and raised the demand for educated labour, but also provided the training and experience needed to realize the economic potential of educated workers. The difference is that in low-income countries this upward spiral does not necessarily need to occur in skill-intensive manufacturing activities but—depending on the specific sectors in which a country has a competitive edge—might need to be based in primary sectors, unskilled-labour-intensive manufacturing, or services where this diversity reflects the heterogeneity within the group of low-income countries.

To the extent that these efforts imply increased budgetary spending, low-income countries are at a disadvantage because the problem of mobilizing additional government revenue is likely to be most acute in the poorest countries and especially difficult without external sources of finance.

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