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TECHNOLOGY DIFFUSION, HUMAN CAPITAL AND ECONOMIC GROWTH IN DEVELOPING COUNTRIES

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DISCUSSION PAPERS

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* Tel. 022-907.5733; Fax 907.0274; E.mail: nicole.winch@unctad.org

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CONTENTS

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Jörg Mayer

United Nations Conference on Trade and Development (UNCTAD)

Abstract

This paper (i) uses a newly constructed dataset on machinery imports from both developed and developing countries with significant domestic R&D expenditure to assess technology transfer to developing countries, and (ii) employs a cross-country, growth-accounting framework to analyse the impact of machinery imports, in association with human capital stocks, on economic growth. The findings suggest that machinery imports by developing countries have been higher over the past few years than during the 1970s and 1980s, and that such imports from technologically more advanced developing countries have gained considerably in importance. The growth-accounting results suggest that machinery imports combined with human capital stocks have a positive and statistically strongly significant impact on cross-country growth differences in the transition to the steady state. This gives support to earlier findings in the literature which suggest that the main role of human capital in economic growth is to facilitate the adoption of technology from abroad, rather than to act as an independent factor of production.

I. INTRODUCTION

Recent advances in the theory of endogenous technological progress have led to renewed interest in the relation between trade, technological change, human capital and economic growth. A number of studies have identified channels through which productivity levels of countries are interrelated, emphasizing the role of international trade. Coe and Helpman (1995), Coe et al. (1997) and Keller (1998), for example, consider foreign trade as a carrier of knowledge and assess the importance of imports in introducing foreign technology into domestic production and spurring total factor productivity. They conjecture that a country that is more open to machinery and equipment imports derives a larger benefit from foreign research and development (R&D), and show empirically that countries that have experienced faster growth in total factor productivity have imported more from the world's technology leaders.

A similar reasoning underlies Benhabib and Spiegel (1994), who focus on the role of human capital in economic development and interpret cross-country differences in the level of human capital as differences in technology. The results of their cross-country, growth-accounting exercise suggest that the role of human capital in economic growth is one of facilitating the adoption of technology from abroad and the creation of appropriate domestic technology. This contrasts with studies based on the human-capital-augmented Solow model (such as in Mankiw et al., 1992), which treat human capital as a separate factor of production.

The main purpose of this paper is to combine these two strands of the literature by refining the indicator which Coe et al. (1997) use to measure technology transfer, and using the refined indicator in combination with human capital stocks as a measure for changes in total factor productivity in a cross-country growth regression, following Benhabib and Spiegel (1994). In addition, the paper assesses whether, on such a refined measure, technology transfer to developing countries has increased over the past few years, as might be expected given the rising integration of national economies.

The structure of the paper is as follows. Section II presents the theoretical framework regarding the impact of technology imports and skill accumulation on economic growth, where the combination of technology imports and level of human capital is modelled as determining total factor productivity. Rivera-Batiz and Romer (1991) outline two channels for the transfer of technological knowledge: (i) the transmission of ideas which can be traded independently from goods, and (ii) the trade of capital goods that embody new knowledge. International knowledge flows raise growth in both models, but this paper will emphasize the second channel, i.e. knowledge transfer which is embodied in machinery and equipment imports. Section III analyses the development during 1970–1998 of machinery and equipment imports by developing countries from both developed and developing countries with significant domestic R&D spending, where the latter group will be called "technologically more advanced developing countries". Section IV employs the model in section II in a cross-country growth-regression framework for the 1970–1990 period, and section V provides some concluding remarks. The Appendix to this paper discusses data sources and coverage, and the Annex reports the results of the main regressions for the period up to 1997.

II. HUMAN CAPITAL, TECHNOLOGY IMPORTS AND ECONOMIC GROWTH

A number of recent studies on the determinants of economic growth highlight the importance of total factor productivity, such as Easterly and Levine (2000), who explain that the salient features of countries' growth experience cannot be explained by factor accumulation alone. Several factors impact on changes in total factor productivity, including changes in technology and externalities, changes in the sectoral composition of production, and organizational changes such as the adoption of lower cost production methods. It is likely that among these factors the improved access to knowledge capital, that has come about with globalization, has had the most important influence over the past few years.

An important characteristic of the role of foreign trade in the technological catch-up of developing countries is the complementary nature of technological change and human capital formation. Acemoglu (2000) finds, for example, that technical change has been skill-biased over the past 60 years. The level of education has a crucial impact on the growth of total factor productivity because it determines the capacity of an economy to (i) carry out technological innovation (Romer, 1990a), and (ii) most importantly for developing countries, adopt and efficiently implement technology from abroad. Economic historians also discuss global growth in terms of the gradual diffusion of technological innovations from a small set of innovators to the much larger group of imitators (Rosenberg, 1980). They thereby oppose the polar positions of standard neoclassical growth theory, that considers technology as both universally available and applicable, and early models of endogenous growth theory, that attributes a country's technological progress only to its own innovations.

The combined role of human capital and technology upgrading for output generation can be formalized by building on a model from 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 (*H*) and proportional to the gap between the technology level in advanced countries (*T(t)*) and their own (*A(t)*):

$$\frac{\dot{A}(t)}{A(t)} = \varphi(H)\left[\frac{T(t) - A(t)}{A(t)}\right] \qquad \varphi^{/}(H)>0 \qquad (1)$$

Assuming that technology in advanced countries improves exogenously by ϕ per cent each year, i.e.:

$$T(t) = T_0 e^{\phi t} \qquad (2)$$

and that A_0=0, the implied equilibrium path of potential technological development of a technological latecomer is given by:

$$A(t) = \left[\frac{\varphi(H)}{(\varphi(H)+\phi)}\right] T_0 e^{\phi t} \qquad (3)$$

Accordingly, whereas in the long run the growth of technology settles down to a rate of n, in the transition to the steady state it is influenced by the level of human capital: 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.[1] This means that a greater supply of human capital will have no effect on the level of output generated with conventional inputs unless new technology is introduced, and skill accumulation will continue only when technical progress is sustained.

In the spirit of Romer (1990b), Benhabib and Spiegel (1994) extend the Nelson and Phelps (1966) model by adding an endogenous growth component $g(H)$ – the level of human capital enhances the ability of a country to develop its own technological innovations – as a determinant of the growth of total factor productivity:

$$\frac{\dot{A}(t)}{A(t)} = g(H) + f(H)\left[\frac{T(t) - A(t)}{A(t)}\right] \qquad g^{/}(H)>0 \text{ , } \varphi^{/}(H)>0 \qquad (4)$$

They then employ this specification of growth in total factor productivity in a novel way in a cross-country growth-accounting framework. Standard cross-country growth regressions augmented by human capital – such as those in Mankiw et al. (1992) – specify an aggregate production function in which per capita income in a given period t (Y_t) is dependent on three input factors – labour (L_t), physical capital (K_t) and human capital (H_t). Using a Cobb-Douglas production function, $Y_t=A_t K_t^{\alpha} L_t^{\beta} H_t^{\gamma}$, and taking differences in the log of per capita income levels, the relationship for long-term growth from time 0 to time T can be expressed as:

$$(\log Y_T - \log Y_0) = (\log A_T - \log A_0) + \alpha (\log K_T - \log K_0)$$
$$+ \beta (\log L_T - \log L_0) + \gamma (\log H_T - \log H_0) + \varepsilon$$

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1 In addition to low levels of education, the adoption of technology from abroad can be constrained by several factors, including import regulations and restrictions; natural trade barriers, such as geographical distance; high costs of firms to invest in new technology, such as a cumbersome legal and regulatory framework; high real interest rates and an unstable exchange rate, which do not enable potential investors to make long-term plans; and the presence of a balance-of-payments constraint, i.e. a country cannot achieve export earnings that fetch the foreign exchange which is required to pay for such imports. See Mayer (2000) for a discussion of these issues as well as of the impact of trade integration associated with the balance-of-payments constraint on the composition of a country's production structure. The latter mechanism, as well as externalities and cost-saving organizational changes, can also have an impact on changes in total factor productivity, but these effects will be assumed to be negligible in what follows.

By contrast, Benhabib and Spiegel (1994) treat human capital as affecting productivity rather than entering as an input factor, so that the Cobb-Douglas production function can be expressed as $Y_t=A_t(H_t)\ K_t^{\alpha}\ L_t^{\beta}$. Taking log differences, the relationship for long-term growth becomes:

$$(\log Y_T - \log Y_0) = [\log A_T(H_t) - \log A_0(H_t)] + \alpha\ (\log K_T - \log K_0) + \beta\ (\log L_T - \log L_0) + \varepsilon \qquad (5)$$

The novelty of this model is that part of it is specifically designed to capture the cross-country variation in the growth of total factor productivity. Benhabib and Spiegel (1994) express the growth rate of total factor productivity through their extension of the Nelson and Phelps model given in equation (4). But diverging from Nelson and Phelps, who express T_t as the exogenously growing technology of advanced countries, Benhabib and Spiegel express T_t as the technology level of the world's leading country and measure the technology gap of country *i* with respect to the technology leader as the ratio between the two countries' per capita income multiplied by the lagging country's level of human capital averaged over the period *0* to *T*, i.e.:

$$(\log A_T(H_t) - \log A_0(H_t))_i = c + gH_i + mH_i\ ((Y_{max} - Y_i) / Y_i))$$

where *c* stands for exogenous technological progress, gH_i for endogenous technological progress associated with the ability to innovate domestically, and $mH_i\ ((Y_{max} - Y_i)\ /\ Y_i)$ for the diffusion of technology from abroad.

However, the term specifying the diffusion of technology from abroad can be expressed such that it is directly related to technology transfer. Coe et al. (1977) and Bayoumi et al. (1999) use the following equation to express a developing country's level of total factor productivity:

$$\log A_{it} = \alpha_i^0 + \alpha_i^S \log S_{it} + \alpha_i^M M_{it} + \alpha_i^H H_{it} + \mu_{it} \qquad (6)$$

where *i* and *t* index countries and time periods, *A* is total factor productivity, α is a country-specific parameter, *S* is the R&D capital stock in the importing country's trade partner, *M* is the GDP ratio of machinery and equipment imports from countries with substantial domestic R&D expenditure in GDP, *H* is educational attainment, the superscripts ^{S}, ^{M} and ^{H} are the marginal factor products, and μ is an error term.[2]

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[2] Coe et al. (1997) also include country-specific time trends and fixed effects because they conduct a pooled data estimation.

There has been some controversy on whether or not it is necessary to use bilateral import weights for the measure of the foreign capital stock *S* (Keller 1998). Following a detailed analysis, Coe and Hoffmaister (1999: 13) conclude that “regressions using a measure of foreign R&D capital based on bilateral import weights or on a simple average ... tend to be quite similar”. They also point out that a “foreign R&D capital stock computed as the sum or average of other countries’ domestic R&D capital can be thought of as a measure of the world R&D capital stock”. In other words, it matters for a developing country how much technology it imports from the technologically more advanced 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. Following this reasoning, *S* will be interpreted here as the world technology stock, which is equal for all developing countries and can thus be eliminated from the equation.

It has been stressed above that there might be important interactions between technology imports and educational attainment, because imports of machinery and equipment boost productivity only when the economy has an educational attainment that is high enough to allow for an efficient use of the imported technology. This means that as an alternative to equation (6), a developing country’s level of total factor productivity can be expressed as:

$$\log A_{it} = \alpha_i^0 + \alpha_i^M M_{it} + \alpha_i^H H_{it} + \alpha_i^{HM} HM_{it} + \mu_{it} \qquad (7)$$

If the estimated coefficient on the interaction of trade with educational attainment is positive ($\alpha_i^{HM} > 0$), then the higher is the country’s educational attainment, the larger is the effect of a given GDP ratio of imports of machinery and equipment on domestic productivity.

Following the reasoning of Benhabib and Spiegel (1994) as expressed in equation (4) – but (i) measuring the technology-transfer term on the basis of the interaction between human capital and the GDP ratio of machinery and equipment imports, such as in Coe et al. (1997) and Bayoumi et al. (1999), and (ii) assuming that the impact of domestic R&D on total factor productivity is negligible in developing countries – a developing country uses its human capital exclusively to implement imported technology. As a result, the level of total factor productivity is determined solely by the interaction between the country’s human capital and its GDP ratio of machinery and equipment imports, i.e.:

$$\log A_{it} = \alpha_i^0 + \alpha_i^{HM} HM_{it} + \mu_{it} \qquad (8)$$

Expressing the adjusted equation (6) and equations (7) and (8) in terms of changes between time *0* and time *T* and inserting them into equation (5) gives the following testable equations:

Model 1:

$$(\log Y_T - \log Y_0)_i = \alpha_0 + \alpha_1(H_T - H_0)_i + \alpha_2(M_T - M_0)_i + \alpha_3(\log K_T - \log K_0)_i + \alpha_4(\log L_T - \log L_0)_i + \varepsilon \quad (9)$$

Model 2:

$$(\log Y_T - \log Y_0)_i = \alpha_0 + \alpha_1(H_T - H_0)_i + \alpha_2(M_T - M_0)_i + \alpha_3((HM)_T - (HM)_0)_i + \alpha_4(\log K_T - \log K_0)_i + \alpha_5(\log L_T - \log L_0)_i + \varepsilon \quad (10)$$

Model 3:

$$(\log Y_T - \log Y_0)_i = \alpha_0 + \alpha_1((HM)_T - (HM)_0)_i + \alpha_2(\log K_T - \log K_0)_i + \alpha_3(\log L_T - \log L_0)_i + \varepsilon \quad (11)$$

Considering imported capital equipment as part of total factor productivity in growth accounting is related to the issue of what technological change in capital goods means for productivity. In studying growth in the United States, Greenwood et al. (1997) attribute as much as 60 per cent of total factor productivity growth to new technology embodied in capital equipment, while Hulton (1992) estimates this contribution to be a more modest 20 per cent. In any case, these studies indicate that a substantial part of productivity gains are related directly to new technology embodied in capital equipment. Focusing on developing countries, De Long and Summers (1993) use the share of equipment imports in GDP to predict equipment investment and show that there is a strong correlation between equipment investment and growth in total factor productivity. An important consequence for growth-accounting in developing countries is that imported capital equipment can be considered as more productive than existing domestic capital stocks. This means that imported capital equipment can be used as an indirect measure of changes in total factor productivity, while investment goods of different generations in the existing domestic capital stock may be considered as differing only by some fixed factor of depreciation associated with wear, tear and retirement. Productivity increases due to imported capital equipment may encourage domestic capital accumulation, but this effect is assumed to be negligible in this paper. To the extent that this spillover effect is of significant importance, it will cause the growth effect of machinery imports to be underestimated in the empirical analysis of the following section.

It could be argued that the above relationships are subject to the problem of reverse causality. For example, developing countries are generally assumed to be finance constrained, so that low growth could lead to low levels of domestic savings and thereby to constraints on the countries' capacity to import capital equipment. But even if domestic savings are sufficient to finance all the needed imports of capital equipment, a developing country will still be unable to undertake these imports if it does not earn the foreign exchange to pay for the imports required. Given that foreign exchange earnings depend on export performance rather than economic growth, this potential channel of reverse causality is likely to be of little importance for developing countries. Reverse causality could arise also from the fact that poor countries tend to resort to tariffs to raise revenue more frequently than rich countries because their tax systems are not well developed. Such tariffs often focus on machinery imports because they are pure revenue taxes. However, over the past few years there has been a general tendency in developing countries towards greater trade openness, accompanied by tariff reform whereby the level of tariffs on machinery imports has generally declined. This implies that this potential channel of reverse causality has increasingly lost in importance.[3]

III. MACHINERY AND EQUIPMENT IMPORTS: SOME STATISTICAL EVIDENCE

The extent to which a country has accessed the world stock of technology is difficult to measure. This section examines an indirect measure of technological integration by looking at the evolution of the GDP ratio of machinery imports during the period 1970–1998.[4] The group of 89 developing countries analysed in this section includes all developing countries for which meaningful data are available (see Appendix for the list of countries).

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

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3 It should be noted that the problem of reverse causality in growth regressions most often regards the relationship between growth and investment. Given that this paper applies capital stock data rather than investment data, this potential channel of reverse causality does not apply.

4 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.

The statistical analysis[5] in this paper differs from that in Coe et al. (1997) in three main respects. First, the technology imports of developing countries are not weighted according to the domestic R&D capital stock of the country's trading partners, as discussed in section II.

Second, due to data problems in the calculation of the foreign R&D capital stock, Coe et al. (1997) do not take into account technology imports from other developing countries. However, such imports are likely to be important for the technologically less 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 a lower technological level. Accordingly, developing countries absorb technology imported from technologically advanced developing countries more easily than technology imported from developed countries. Hence, technology imports from those developing countries with – according to Coe et al. (1997) – significant domestic R&D expenditure (see Appendix for the list of countries) will be examined in addition to imports from developed countries.

Third, Coe et al. (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 better suited to the purposes of this paper for four reasons:

(i) Parts of such imports – most importantly, transport equipment, television sets, etc., and household-type equipment – are better classified as infrastructure capital or consumption, rather than as capital equipment that embodies new technology.

(ii) Aggregate data on machinery and transport equipment includes several items which are classified as "parts and components", and which developing countries import in order to re-export them after adding comparatively little extra value. Regarding machinery, the vast majority of such trade concerns four items, namely parts of office machines, telecommunications equipment, switch gear, and (of particular importance for the rapidly growing developing countries in East Asia) transistors and semi-conductor devices, as discussed by Yeats (1998) and Ng and Yeats (1999). These four items have also been excluded from the category "machinery" used in this paper (see Appendix for details).

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5 The analysis is based on mirror trade data, i.e. exports from country A to country B are considered as imports of country B from country A. The reason for this that the availability and reliability of import data of many developing countries is very poor.

(iii) Specialized capital equipment will be singled out to see whether technology transfer has been of a general-purpose nature or whether it has been sectorally biased (see Appendix for the division between general-purpose and specialized technology).[6]

(iv) A finer breakdown of technology imports allows to assess whether technology transfer in any given sector to developing countries has been faster from the developed countries or from the technologically more advanced developing economies.

Figure 1 shows that the weighted GDP ratio of machinery imports for the group of 89 developing countries has been higher 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.[7] The figure also shows that technology imports from technologically more advanced developing countries have gained considerably in importance, and that they now represent between one fifth and one fourth of all technology imports by developing countries.

Figure 2 shows the weighted GDP ratios of selected sectoral machinery imports. Textile and leather machinery combined with metalworking machinery account for the bulk of specialized machinery imports and – with a steep increase between the mid-1980s and the mid-1990s and a drop after 1995 – both of these categories 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 noteworthy: the GDP ratio of both metalworking machinery and textile and leather machinery rose about fourfold between the mid-1980s and the mid-1990s.

Figure 3 assesses the sectoral bias of technology imports by plotting the ratio of sector-specific to general-purpose technology imports. The sector-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 and pulp-mill machinery), and scale and skilled labour (printing and bookbinding machinery). The classification is partly based on OECD (1992: 152). Like any such classification, it includes some arbitrariness.

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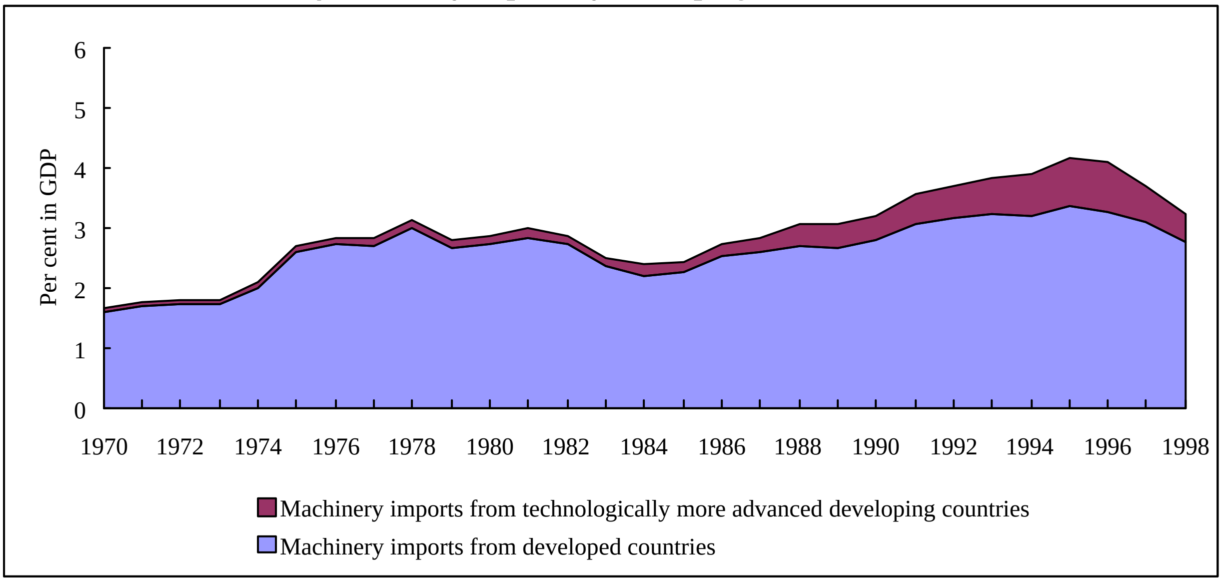
6 In this paper, the term "general-purpose technology" relates to technology which can be used in various industrial sectors. It therefore differs from the meaning in, for example, Bresnahan and Trajtenberg (1995), where general-purpose technologies are characterized by an inherent potential for technical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

7 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 1

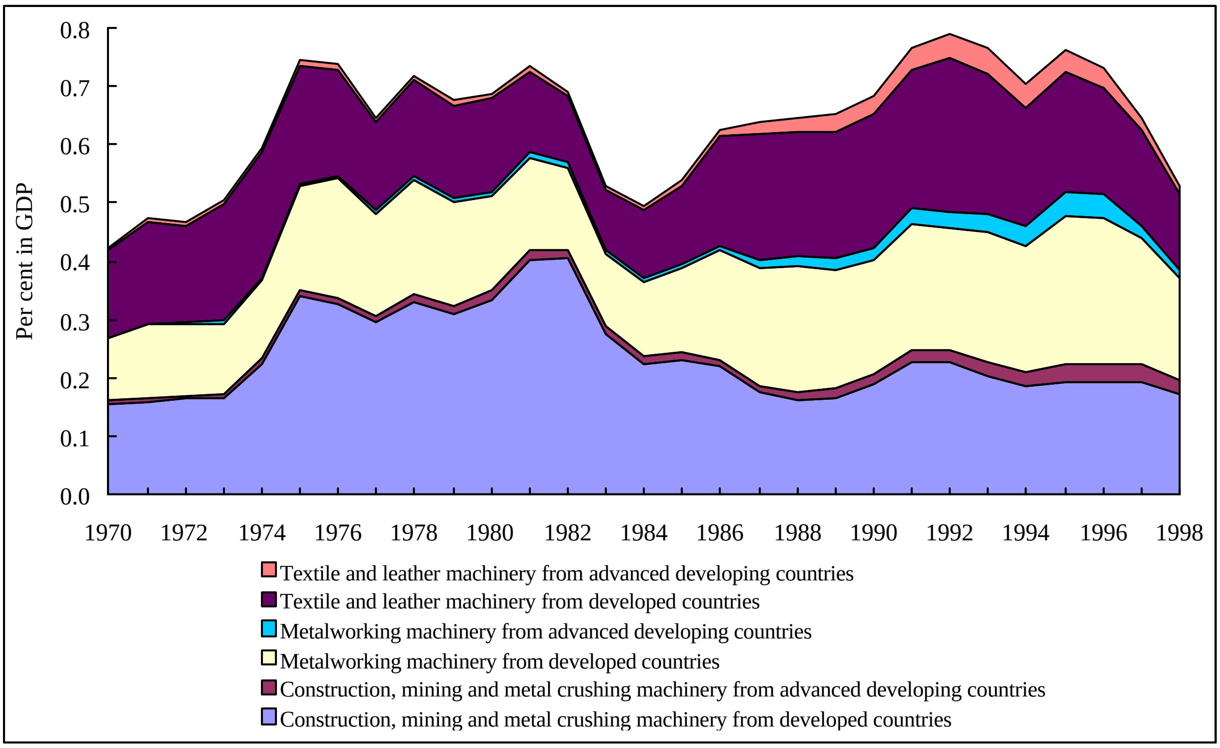
GDP-ratio of machinery imports by developing countries, 1970–1998



Source: Trade data from COMTRADE, GDP-data from UNCTAD database.
Note: See appendix for the composition of country and product groups.

Figure 2

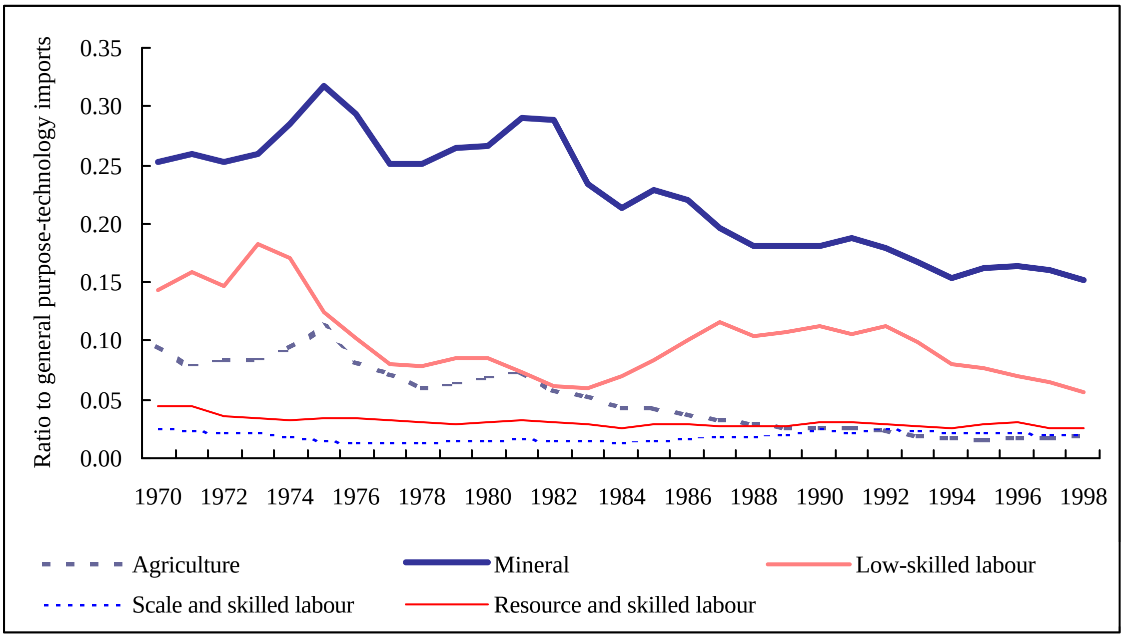
GDP-ratio of selected specialized machinery imports by developing countries, 1970–1998



Source: COMTRADE.
Note: The ratios of agricultural machinery and tractors, paper and pulp machinery, printing and bookbinding machinery, and food-processing machinery imports are not shown because they are very small.

Figure 3

Specialized and general-purpose machinery imports by developing countries, 1970–1998



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 slightly more than half that of general-purpose technology imports, it fell to about one fourth during the 1990s. This drop in the combined ratio was due to the drop in technology imports related to activities in the primary sector – both agricultural and, in particular, mineral and fuel-based activities. 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.

The ratio of skill-related technology imports has by and large remained constant, while that of low-skilled labour-intensive technology imports strongly increased during the second half of the 1980s, before falling during most of the 1990s, as did technology imports related to the mineral and fuels sector. This means that, for the group of developing countries as a whole, the sectoral bias of technology imports was small and that it 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 presents data on total imports, as well as on imports with respect to the entire category “machinery and transport equipment” (rows 3, 16 and 29) – the category analysed by Coe et al. (1997) – and several subsections thereof, including the category “machinery” (rows 7, 20 and 33) used in this paper. The table shows that during the 1990s the average growth rate of the absolute value of machinery imports by developing countries from developed countries fell slightly short of that of total imports from the latter country group (panel I), while for imports from technologically more advanced developing countries the former imports exceeded the latter (panel II). Considering imports from the two country groups combined (panel III), imports of machinery and total imports by developing countries grew at the same rate. This contrasts with (i) the 1980s, when machinery imports from technologically more advanced developing countries also grew faster than total imports – but such imports from both the group of developed countries alone and the group of developed and technologically more advanced developing countries combined grew less than total imports – and, in particular, with (ii) the 1970s, when the growth rate of machinery imports was above that of total imports from both country groups alone, as well as from the two groups combined. By contrast, the growth rate of imports in the category “machinery and transport equipment” exceeded that of total imports for all the periods and country groups. This rapid growth was driven by the category “parts and components for electrical and electronic goods” (rows 6, 19 and 32).

These results suggest that the measure used by Coe et al. (1997) both overestimates technology transfer to developing countries because their measure includes categories which have no direct impact on the level of technology of capital equipment in developing countries, and underestimates such transfers because their measure excludes machinery imports from technologically more advanced developing countries which, over the past few years, have grown significantly faster than machinery imports from developed countries. To the extent that the consideration that in developing countries imports of parts and components for electrical and electronic goods serve as production inputs for re-exports rather than as capital equipment is justified, using the measure proposed by Coe et al. (1997) in the present paper will lead to an underestimation of the impact of technology transfer on growth in developing countries.

Regarding specialized technology imports (rows 8–14, 21–27 and 34–40), the results show that the growth rates of most of these categories were substantially below that of the category “machinery” (rows 7, 20 and 33), which supports the finding of figure 1 that general-purpose technology constituted the bulk of machinery imports by developing countries. Comparing the growth rates reported in rows 8–14 with those in rows 21–27 reveals that technology imports related to activities in the primary sector (i.e. agricultural machinery, food-processing machinery, and construction, mining and metal-crushing machinery) in all the subperiods grew faster from technologically more advanced developing countries than from developed countries. This was also

Table 1

Imports by developing countries, selected categories 1970–1998, average growth rates

(Percentages)

		1970–1979	*1980–1989*	*1990–1998*
1.	Total imports from world	11.1	3.4	7.7
I.	**Imports from developed countries, by category**			
2.	Total	10.4	3.3	6.1
3.	Machinery and transport equipment (section 7 of SITC Rev. 2)	12.3	3.4	7.1
	of which:			
4.	Transport equipment	13.3	-0.1	4.5
5.	Technology-including consumption goods	11.3	1.9	-0.7
6.	Parts and components for electrical and electronic goods	14.1	10.5	12.9
7.	Machinery	11.5	2.9	5.9
	of which:			
8.	Agricultural machinery	8.3	-8.3	1.0
9.	Textile and leather machinery	3.7	9.3	-1.9
10.	Paper and pulp mill machinery	8.9	4.7	7.6
11.	Printing and bookbinding machinery	6.6	6.4	4.2
12.	Food-processing machinery	9.3	0.1	3.7
13.	Construction, mining and metal-crushing machinery	14.4	-7.4	3.2
14.	Metalworking machinery	13.4	6.9	5.9
II.	**Imports from technologically advanced developing countries, by category**			
15.	Total	15.7	10.1	6.7
16.	Machinery and transport equipment (section 7 of SITC Rev. 2)	21.7	16.1	10.6
	of which:			
17.	Transport equipment	25.7	11.3	9.0
18.	Technology-including consumption goods	23.2	19.6	-1.3
19.	Parts and components for electrical and electronic goods	30.3	20.2	16.2
20.	Machinery	16.4	15.2	8.3
	of which:			
21.	Agricultural machinery	30.3	3.8	10.4
22.	Textile and leather machinery	10.7	20.8	-5.0
23.	Paper and pulp mill machinery	14.4	7.4	-5.5
24.	Printing and bookbinding machinery	11.0	15.5	0.5
25.	Food-processing machinery	23.0	3.8	3.7
26.	Construction, mining and metal-crushing machinery	17.3	-0.8	11.9
27.	Metalworking machinery	17.1	15.1	2.3
III.	**Imports from both developed and technologically advanced developing countries, by category**			
28.	Total	11.1	4.7	6.3
29.	Machinery and transport equipment (section 7 of SITC Rev. 2)	12.8	4.8	7.8
	of which:			
30.	Transport equipment	13.7	0.9	5.1
31.	Technology-including consumption goods	12.4	6.4	-0.9
32.	Parts and components for electrical and electronic goods	15.1	12.0	13.8
33.	Machinery	11.7	4.0	6.3
	of which:			
34.	Agricultural machinery	9.1	-7.1	2.2
35.	Textile and leather machinery	3.9	10.2	-2.2
36.	Paper and pulp mill machinery	9.1	4.9	6.3
37.	Printing and bookbinding machinery	6.7	6.8	4.0
38.	Food-processing machinery	9.9	0.4	3.7
39.	Construction, mining and metal-crushing machinery	14.5	-7.0	4.1
40.	Metalworking machinery	13.5	7.4	5.6

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

Note: Growth rates based on imports expressed in constant 1995 US dollars. The implicit GDP deflator between GDP expressed in current US dollars and that expressed in constant 1995 US dollars was used as deflator. See Appendix for the composition of country and product groups.

true for the other categories regarding the periods 1970–1979 and 1980–1989, while the opposite holds for the 1990s.

Turning to country-specific evidence, table 2 suggests that the GDP ratio of machinery imports increased in relatively few developing countries between the 1970s and the 1990s. The GDP ratios of machinery imports from developed countries increased by more than 1 percentage point in only 16 of the 89 countries (and by more than 2 percentage points in nine of these 16 countries), while they fell by 1 percentage point or more in 14 countries (and by 2 percentage points or more in six of these 14 countries). However, apart from a number of very small countries (Comoros, Equatorial Guinea, Guyana, and Sao Tome and Principe), countries with a large GDP (such as China, India, Indonesia, Mexico, Thailand and Turkey) are among those whose GDP ratio of machinery imports rose 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 fell; 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 GDP ratio of machinery imports, it may be helpful to look for correlations across developing countries between the change in the GDP ratio of machinery imports between the 1970s and the 1990s and variables which come readily to mind as influencing such imports: investment, factor combinations and geographical location which are conducive to industrial development, and the availability 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 endogeneity problems.

For this purpose, the set of 89 countries was modified by omitting the two countries for which comprehensive data for the 1970s were not available (Angola and Mozambique) as well as the seven countries (Comoros, Equatorial Guinea, Guyana, Hong Kong (China), Malaysia, Sao Tome and Principe, and Singapore), for which the absolute difference in machinery imports between the 1970s and 1990s was significantly above that of the other countries, and which may therefore be considered statistical outliers. The first column of table 3 reports the coefficients of correlation (R) across the 80 remaining countries between 13 variables and the absolute discrepancy in the GDP ratio of machinery imports between the two periods 1990–1998 and 1970–1979 (or, as indicated for seven 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.

Table 2

Share of machinery imports in GDP, individual developing countries, 1970–1998

(Percentages)

	Imports from								
	Developed countries	*Advanced developing economies*	*Ratio*	*Developed countries*	*Advanced developing economies*	*Ratio*	*Developed countries*	*Advanced developing economies*	*Ratio*
	(1)	*(2)*	*(2)/(1)*	*(3)*	*(4)*	*(4)/(3)*	*(5)*	*(6)*	*(6)/(5)*
	1970–1979			*1980–1989*			*1990–1998*		
Afghanistan	0.8	0.1	0.1	1.0	0.1	0.1	0.5	0.4	0.8
Algeria	6.9	0.0	0.0	3.3	0.0	0.0	3.3	0.1	0.0
Angola	NA	NA	NA	3.1	0.2	0.1	4.5	0.5	0.1
Argentina	1.2	0.1	0.1	1.2	0.1	0.1	1.0	0.3	0.3
Bangladesh	0.6	0.1	0.2	0.9	0.3	0.4	0.7	0.7	1.0
Benin	2.3	0.1	0.0	2.7	0.1	0.0	1.8	0.7	0.4
Bolivia	3.2	0.9	0.3	1.6	1.1	0.7	2.1	1.6	0.8
Brazil	1.6	0.0	0.0	0.8	0.0	0.0	1.0	0.1	0.1
Burkina Faso	2.0	0.0	0.0	2.1	0.0	0.0	2.1	0.0	0.0
Burundi	1.1	0.0	0.0	1.8	0.0	0.0	1.7	0.1	0.1
Cameroon	2.8	0.0	0.0	2.5	0.0	0.0	1.6	0.1	0.0
Central African Rep.	1.9	0.0	0.0	1.6	0.1	0.0	1.4	0.1	0.0
Chad	1.2	0.0	0.0	1.0	0.0	0.0	1.3	0.0	0.0
Chile	2.2	0.3	0.1	2.8	0.4	0.1	3.7	0.7	0.2
China	0.4	0.0	0.0	1.5	0.1	0.1	2.2	0.3	0.2
Colombia	2.4	0.1	0.1	2.3	0.2	0.1	2.4	0.3	0.1
Comoros	4.0	0.0	0.0	6.6	0.1	0.0	8.0	0.2	0.0
Congo	4.8	0.0	0.0	5.2	0.2	0.0	5.6	0.1	0.0
Congo (Dem. Rep. of)	1.9	0.0	0.0	2.1	0.1	0.0	1.3	0.1	0.1
Costa Rica	4.2	0.2	0.1	2.9	0.4	0.1	3.7	0.6	0.2
Côte d'Ivoire	4.3	0.1	0.0	2.4	0.1	0.0	2.3	0.2	0.1
Dominican Republic	3.2	0.1	0.0	3.4	0.3	0.1	3.7	0.3	0.1
Ecuador	4.3	0.3	0.1	3.2	0.3	0.1	3.6	0.5	0.1
Egypt	3.8	0.1	0.0	6.3	0.2	0.0	4.4	0.3	0.1
El Salvador	3.2	0.1	0.0	2.5	0.2	0.1	2.6	0.3	0.1
Equatorial Guinea	3.5	0.0	0.0	7.9	0.2	0.0	8.1	0.3	0.0
Ethiopia	1.5	0.1	0.1	2.2	0.1	0.1	2.9	0.3	0.1
Gabon	5.0	0.0	0.0	3.7	0.0	0.0	3.4	0.1	0.0
Gambia	3.9	0.1	0.0	4.8	0.5	0.1	3.5	0.6	0.2
Ghana	3.4	0.1	0.0	2.5	0.2	0.1	4.6	0.5	0.1
Guatemala	2.4	0.1	0.0	1.6	0.2	0.1	2.4	0.4	0.2
Guinea	1.7	0.0	0.0	3.0	0.1	0.0	2.2	0.2	0.1
Guinea-Bissau	3.5	0.0	0.0	7.4	0.3	0.0	4.0	0.2	0.1
Guyana	8.7	0.1	0.0	9.1	0.5	0.1	13.2	1.5	0.1
Haiti	3.1	0.0	0.0	3.4	0.1	0.0	1.3	0.1	0.1
Honduras	4.1	0.2	0.1	2.8	0.2	0.1	4.9	0.7	0.1
Hong Kong (China)	4.7	0.6	0.1	6.0	2.0	0.3	7.2	5.6	0.8
India	0.6	0.0	0.0	1.0	0.0	0.0	1.3	0.2	0.1
Indonesia	2.8	0.1	0.0	2.3	0.3	0.1	3.7	0.6	0.2
Iran (Islamic Rep. of)	3.9	0.0	0.0	1.6	0.1	0.0	2.9	0.2	0.1
Iraq	3.9	0.1	0.0	4.9	0.2	0.0	0.7	0.1	0.1
Jamaica	3.6	0.0	0.0	4.0	0.2	0.1	4.2	0.3	0.1
Jordan	6.0	0.1	0.0	6.6	0.4	0.1	5.7	0.8	0.1
Kenya	3.9	0.2	0.0	3.2	0.3	0.1	3.5	0.5	0.1
Korea (Rep. of)	4.4	0.0	0.0	4.0	0.1	0.0	4.2	0.3	0.1
Kuwait	2.8	0.1	0.0	4.0	0.2	0.0	3.3	0.2	0.1

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Table 2 (concluded)

Share of machinery imports in GDP, individual developing countries, 1970–1998

(Percentages)

	Imports from								
	Developed countries	*Advanced developing economies*	*Ratio*	*Developed countries*	*Advanced developing economies*	*Ratio*	*Developed countries*	*Advanced developing economies*	*Ratio*
	(1)	*(2)*	*(2)/(1)*	*(3)*	*(4)*	*(4)/(3)*	*(5)*	*(6)*	*(6)/(5)*
	1970–1979			*1980–1989*			*1990–1998*		
Libya	4.5	0.0	0.0	4.0	0.1	0.0	3.1	0.2	0.1
Madagascar	1.9	0.0	0.0	2.2	0.0	0.0	2.2	0.2	0.1
Malawi	2.4	0.0	0.0	1.9	0.1	0.0	1.9	0.2	0.1
Malaysia	3.8	1.6	0.4	4.3	2.5	0.6	8.0	5.8	0.7
Mali	2.3	0.0	0.0	2.6	0.1	0.0	2.7	0.2	0.1
Mauritania	5.3	0.2	0.0	6.4	0.2	0.0	6.1	0.3	0.0
Mauritius	3.8	0.3	0.1	3.1	0.6	0.2	3.6	0.8	0.2
Mexico	1.7	0.1	0.0	2.6	0.1	0.0	3.7	0.2	0.0
Morocco	3.3	0.0	0.0	3.2	0.0	0.0	3.5	0.1	0.0
Mozambique	NA	NA	NA	2.7	0.4	0.1	3.0	0.2	0.1
Myanmar	1.9	0.1	0.1	1.9	0.2	0.1	0.2	0.2	1.4
Nepal	0.4	0.3	0.6	0.9	0.5	0.5	1.0	1.0	1.0
Nicaragua	3.3	0.1	0.0	2.3	0.4	0.2	4.2	0.5	0.1
Niger	2.0	0.0	0.0	2.3	0.0	0.0	1.5	0.1	0.1
Nigeria	2.3	0.1	0.0	2.6	0.2	0.1	4.0	0.5	0.1
Pakistan	2.2	0.0	0.0	2.4	0.3	0.1	2.5	0.7	0.3
Papua New Guinea	4.2	0.1	0.0	4.7	0.7	0.1	4.0	1.0	0.3
Paraguay	1.5	1.8	1.2	1.2	1.4	1.2	2.6	2.3	0.9
Peru	2.4	0.1	0.1	2.3	0.3	0.1	1.4	0.3	0.2
Philippines	3.6	0.2	0.1	2.5	0.4	0.1	4.4	1.1	0.3
Rwanda	1.0	0.0	0.0	1.3	0.0	0.0	0.9	0.1	0.1
Sao Tome	2.3	0.0	0.0	5.5	0.1	0.0	11.4	0.5	0.0
Saudi Arabia	3.2	0.1	0.0	4.6	0.2	0.0	3.5	0.3	0.1
Senegal	3.4	0.0	0.0	3.5	0.1	0.0	3.2	0.1	0.0
Sierra Leone	2.7	0.0	0.0	2.2	0.1	0.0	3.0	0.3	0.1
Singapore	15.3	0.8	0.1	16.9	1.9	0.1	15.8	3.9	0.2
Somalia	4.1	0.0	0.0	5.2	0.1	0.0	1.3	0.2	0.1
Sri Lanka	1.6	0.3	0.2	2.9	0.8	0.3	2.2	1.2	0.5
Sudan	2.3	0.1	0.0	1.7	0.1	0.1	1.5	0.5	0.3
Syria	4.0	0.1	0.0	2.0	0.1	0.0	1.5	0.2	0.1
Taiwan Prov. of China	5.7	0.1	0.0	4.9	0.2	0.0	4.8	0.6	0.1
Tanzania (United Rep. of)	3.4	0.2	0.1	3.1	0.2	0.1	3.0	0.4	0.1
Thailand	3.2	0.3	0.1	3.0	0.6	0.2	5.6	1.4	0.3
Togo	5.2	0.0	0.0	3.7	0.1	0.0	2.7	0.5	0.2
Trinidad and Tobago	4.9	0.1	0.0	3.8	0.1	0.0	5.5	0.2	0.0
Tunisia	5.1	0.0	0.0	5.5	0.0	0.0	5.9	0.2	0.0
Turkey	1.8	0.0	0.0	2.2	0.0	0.0	3.1	0.1	0.0
Uganda	0.6	0.0	0.1	0.8	0.1	0.1	1.4	0.2	0.1
United Arab Emirates	5.4	0.1	0.0	4.3	0.3	0.1	6.4	1.0	0.2
Uruguay	1.2	0.6	0.5	1.2	0.8	0.7	1.6	1.1	0.7
Venezuela	4.5	0.2	0.0	3.4	0.1	0.0	3.8	0.3	0.1
Zambia	4.4	0.2	0.0	4.4	0.2	0.0	3.6	0.2	0.0
Zimbabwe	0.0	0.0	0.0	1.6	0.0	0.0	3.1	0.2	0.1
MEDIAN	3.2	0.1		2.8	0.2		2.9	0.3	

Source: COMTRADE except for total imports which are from UNCTAD database.

Table 3
Factors associated with variation among developing countries in technology imports

Explanatory variable (number of countries, if < 80)	*Correlation (R) with absolute discrepancy between machinery imports during 1990–98 and during 1970–79* (1)	*Means of explanatory variables for countries with:* Prop. difference more than double and/or abs. diff. over 2 percentage points ("good performers") (2)	*Proportional decline by more than 25 per cent ("poor performers")* (3)	*No significant change ("average performers")* (4)	*P-value of t-test of difference of means (good vs. poor performers)* (5)	*P-value of t-test of difference of means (good vs. average performers)* (6)
A. Investment and risk						
Gross domestic investment (% of GDP), 1990–1998 (75)	0.56[a]	24.1	16.9	20.2	0.01	0.04
Change in gross dom. investment, 1990s - 1970s (69)	0.53	4.0	–7.9	–0.4	0.00	0.02
Risk index 1995 (ICRG): high = good (68)	0.52[a]	66.1	51.9	63.2	0.00	0.28
Inflows of FDI (% of GDP), 1990–1998 (78)	0.37[a]	1.7	0.5	1.5	0.00	[0.55]
Change in inflows of FDI (% of GDP), 1990s - 1970s (51)	0.41	1.7	–0.3	0.7	0.00	0.06
B. Factor endowment and geography						
Square km of land per 100 workers, 1995 (74)	–0.16	3.2	5.6	6.9	0.20	0.03
Years of schooling, 1995 (74)	0.44[a]	5.2	3.7	4.5	0.02	0.25
Population ('000), 1995	0.19	167696	28158	21706	0.14	0.12
Mineral reserves ($mn/100 sq km), 1990 (74)	0.31	21.8	1.9	4.3	0.03	0.06
Distance to closest major port (km) (75)	–0.25[a]	5285	4667	4884	[0.38]	[0.46]
C. Balance-of-payments constraint						
External debt (% of GDP), 1990–1997 (78)	[0.10][a]	57.5	112.3	102.4	0.04	0.01
Prop. change in capacity to import, 1990s / 1970s (68)	0.43	4.9	1.7	2.1	0.02	0.03
Abs. change in level of exports (mn 1995-US$), 1990s - 1970s (68)	0.30	22600	5900	5150	0.13	0.11

Source: See Appendix.
Note: Square brackets around an R-value or P-value indicate that the direction of relationship is contrary to expectations. The "good performers" group includes 16 countries, the "poor performers" group includes 13 countries, and the "average performers" group includes 51 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 five rows of the column (panel A) show 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; the average GDP ratio of inflows of foreign direct investment (FDI) in the 1990s; and the change of this ratio between the 1970s and 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. Regarding FDI, such inflows are widely expected to 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 depends very much on the kind of FDI: in the case of greenfield investment it is likely to lead to machinery imports in the same year the investment is undertaken, 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 (2001), we can expect 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) to have a comparative advantage in manufacturing (and hence require comparatively more machinery imports), and for a bigger size (proxied by total population) of countries to be associated with more manufacturing activities because of external economies. A comparative advantage in the minerals sector is proxied by the value of known mineral reserves per land area,[8] while the distance to the closest major port is used as a proxy for transportation costs associated with machinery imports. All of the correlation coefficients for this group of variables have the expected sign, but the correlation coefficients of the proxies for transportation costs and for natural-resource endowments are low.

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[8] The results of the table associated with this variable are based on a reduced sample, which excludes the major petroleum exporters as defined in UNCTAD (2000a): Algeria, Congo, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, Syria, Trinidad and Tobago, United Arab Emirates, and Venezuela – as well as Jamaica, whose very high value of known reserves is a statistical outlier in this reduced sample. The correlation coefficient drops to 0.03 when all these countries are included.

The variables in panel C reflect the capacity of countries to finance imports. The surprising result in this panel is the positive correlation between the GDP ratios of external debt and machinery imports. However, this may reflect the fact that many countries are unable to meet their external debt-servicing obligations and that they may prefer to accumulate arrears which are unlikely ever to be paid, rather than to forego the potential for future growth by renouncing machinery imports. Moreover, the analysis below suggests that this result based on the entire sample is 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 substantially lower than during the 1970s. To investigate this possibility, the 80-country set was divided into three subgroups: "poor performers" (Algeria, Brazil, Cameroon, Democratic Republic of Congo, Côte d'Ivoire, Gabon, Haiti, Iraq, Libya, Myanmar, Peru, Somalia, Syria, and Togo), whose GDP ratio of machinery imports fell by over 25 per cent between the 1970s and the 1990s, "good performers" (Bangladesh, Chile, China, Ethiopia, Ghana, India, Mexico, Nepal, Nigeria, Paraguay, Philippines, Sri Lanka, Thailand, Uganda, United Arab Emirates, and Zimbabwe), whose GDP ratio of machinery imports more than doubled proportionally and/or rose in absolute terms by more than 1.5 percentage points during this period, and the group of "average performers", which includes the remaining 50 countries. In addition to the variables analysed in table 3, the fact that three out of the seven countries which were identified as statistical outliers and two of the countries which were classified as "good performers" are from South-East or East Asia suggests that being located in these geographical regions has been associated with substantial machinery imports.

The comparison between good performers on the one side and poor or average performers on the other shows essentially the same results.[9] But since it could be argued that civil unrest had a sizeable impact on the results of some 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 imports, and inward FDI. Regarding the latter, the fact that the correlation is statistically insignificant is largely due to the inclusion of Trinidad and Tobago (whose GDP ratio of inward FDI is by far the highest within the 80-country sample) in the group of average performers. When it is excluded, the P-value of the F-test reported in column 6 of table 3 becomes 0.43 which, however, still is a substantially lower level of significance than might be expected. By contrast, the

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[9] The main exception regards FDI inflows during the 1990s (row 4 of panel A): while the difference of means is statistically strongly significant for the comparison between good and poor performers, this is not the case when good and average performers are compared.

hypothesis that inward FDI is associated with technology transfer is supported by the comparison between the good and poor performers, as well as by the results regarding the absolute change in FDI inflows during the 1970s and the 1990s (row 5 of table 3). But evidence regarding the latter variable needs to be interpreted cautiously because of (i) the substantially smaller number of countries for which complete data are available, and (ii) the fact that flows of FDI to developing countries have often been concentrated in a few middle-income countries, as well as China, i.e. those countries for which complete data are available.

Tables 4 and 5 give country-specific evidence on the sectoral bias of machinery imports. Columns 4, 8 and 12 of table 4 show that specialized machinery imports from developed countries have in general been substantially lower than imports of general-purpose machinery. The countries which import a comparatively high share of specialized machinery include those with important minerals or fuels sectors – e.g. Angola, Bolivia, Congo, Democratic Republic of Congo, Papua New Guinea, Peru, Trinidad and Tobago, Zambia, and Venezuela – and, to a lesser extent, those where labour-intensive activities constitute an important part of domestic economic activity – e.g. Bangladesh, Mauritius, Pakistan, and Turkey. It is also interesting to note that among the countries with a small share of specialized machinery imports are many of those whose overall machinery imports were substantially higher during the 1970s and 1980s than during the 1990s – e.g. Hong Kong (China), Malaysia, Mexico, Philippines, and Singapore. This suggests that the countries which substantially increased their machinery imports over the past three decades tended to do so with respect to general-purpose rather than specialized machinery.

The other columns in the table show that the importance of agricultural machinery has continuously fallen over the past three decades, while mineral-related machinery has been the most important sector of specialized machinery imports, even though its importance fell between the 1980s and 1990s. The countries whose ratios of machinery imports for low-skilled labour-intensive activities are highest unsurprisingly include the large economies of Bangladesh, Mauritius, Pakistan and Turkey.

Table 5 which refers to imports from technologically more advanced developing countries shows a different picture. There is a, albeit declining, number of countries whose specialized machinery imports has exceeded imports of general-purpose machinery. But similar to imports from developed countries, these specialized machinery imports are also concentrated in the mineral and labour-intensive sectors.

To summarize, the statistical analysis of the evolution of machinery imports by developing countries shows that the technological integration of these countries as a group has increased, but that comparatively few individual countries account for this phenomenon. The evidence suggests that economies (i) located in South-East or East Asia, (ii) with a high GDP ratio of domestic investment

Table 4

Ratio between specialized and general-purpose technology imports from developed countries, 1970–1998

	1970–1979				*1980–1989*				*1990–1998*			
	Agri-culture	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Afghanistan	0.06	0.16	0.12	0.38	0.00	0.05	0.06	0.23	0.00	0.03	0.01	0.06
Algeria	0.09	0.29	0.06	0.49	0.06	0.28	0.06	0.44	0.03	0.22	0.03	0.33
Angola	0.14	0.29	0.09	0.58	0.06	0.74	0.05	0.89	0.03	0.49	0.01	0.56
Argentina	0.05	0.31	0.16	0.59	0.03	0.21	0.11	0.42	0.05	0.16	0.09	0.40
Bangladesh	0.03	0.11	0.22	0.44	0.02	0.12	0.15	0.35	0.02	0.08	0.35	0.51
Benin	0.05	0.17	0.10	0.38	0.05	0.24	0.04	0.41	0.03	0.15	0.15	0.36
Bolivia	0.18	0.41	0.14	0.81	0.11	0.37	0.07	0.62	0.08	0.40	0.10	0.66
Brazil	0.09	0.40	0.15	0.72	0.01	0.26	0.10	0.41	0.02	0.19	0.12	0.44
Burkina Faso	0.10	0.15	0.07	0.46	0.09	0.20	0.05	0.39	0.04	0.10	0.04	0.23
Burundi	0.09	0.19	0.03	0.38	0.10	0.24	0.03	0.45	0.04	0.13	0.03	0.29
Cameroon	0.11	0.26	0.10	0.60	0.06	0.34	0.04	0.50	0.07	0.25	0.04	0.43
Central African Rep.	0.07	0.16	0.07	0.32	0.05	0.21	0.06	0.34	0.05	0.33	0.03	0.44
Chad	0.12	0.19	0.15	0.60	0.05	0.21	0.15	0.47	0.04	0.18	0.06	0.34
Chile	0.07	0.33	0.10	0.59	0.05	0.39	0.06	0.60	0.06	0.27	0.05	0.49
China	0.03	0.56	0.04	0.65	0.01	0.30	0.19	0.56	0.01	0.25	0.17	0.50
Colombia	0.12	0.21	0.21	0.62	0.06	0.35	0.13	0.62	0.03	0.26	0.10	0.49
Comoros	0.16	0.31	0.01	0.50	0.05	0.33	0.02	0.42	0.05	0.20	0.01	0.31
Congo	0.06	0.33	0.02	0.43	0.06	0.39	0.01	0.50	0.02	0.44	0.00	0.48
Congo (Dem. Rep. of)	0.04	0.27	0.06	0.39	0.07	0.40	0.05	0.58	0.03	0.34	0.04	0.50
Costa Rica	0.23	0.21	0.15	0.69	0.09	0.14	0.12	0.46	0.08	0.17	0.09	0.43
Côte d'Ivoire	0.16	0.21	0.09	0.53	0.08	0.18	0.10	0.43	0.06	0.15	0.05	0.35
Dominican Republic	0.14	0.21	0.08	0.54	0.09	0.16	0.07	0.39	0.05	0.10	0.11	0.33
Ecuador	0.20	0.24	0.15	0.68	0.11	0.25	0.09	0.52	0.05	0.30	0.08	0.52
Egypt	0.04	0.23	0.20	0.52	0.04	0.24	0.11	0.46	0.02	0.22	0.10	0.41
El Salvador	0.12	0.16	0.27	0.67	0.03	0.08	0.09	0.27	0.03	0.12	0.15	0.42
Equatorial Guinea	0.08	0.42	0.04	0.55	0.14	0.24	0.04	0.45	0.02	1.63	0.01	1.69
Ethiopia	0.19	0.31	0.25	0.82	0.19	0.40	0.18	0.86	0.13	0.32	0.10	0.67
Gabon	0.12	0.35	0.01	0.50	0.06	0.44	0.01	0.53	0.05	0.40	0.00	0.48
Gambia	0.11	0.14	0.03	0.34	0.07	0.14	0.02	0.25	0.04	0.07	0.02	0.19
Ghana	0.12	0.32	0.11	0.63	0.08	0.37	0.03	0.53	0.04	0.34	0.02	0.45
Guatemala	0.21	0.24	0.22	0.77	0.08	0.25	0.15	0.64	0.08	0.16	0.14	0.52
Guinea	0.11	0.25	0.01	0.39	0.04	0.32	0.03	0.43	0.03	0.26	0.00	0.33
Guinea-Bissau	0.07	0.12	0.03	0.26	0.14	0.46	0.01	0.65	0.09	0.14	0.01	0.28
Guyana	0.24	0.49	0.02	0.85	0.21	0.55	0.01	0.89	0.18	0.46	0.01	0.78
Haiti	0.07	0.14	0.13	0.41	0.04	0.07	0.08	0.29	0.03	0.21	0.06	0.38
Honduras	0.23	0.25	0.11	0.72	0.09	0.20	0.05	0.44	0.09	0.17	0.19	0.53
Hong Kong (China)	0.01	0.09	0.22	0.35	0.00	0.08	0.12	0.24	0.00	0.08	0.09	0.22
India	0.04	0.32	0.10	0.52	0.02	0.30	0.10	0.47	0.01	0.23	0.16	0.45
Indonesia	0.06	0.22	0.16	0.50	0.02	0.22	0.11	0.41	0.01	0.20	0.18	0.51
Iran (Islamic Rep. of)	0.06	0.23	0.10	0.43	0.09	0.27	0.06	0.44	0.03	0.25	0.09	0.42
Iraq	0.08	0.31	0.08	0.52	0.07	0.30	0.02	0.41	0.09	0.08	0.00	0.21
Jamaica	0.08	0.17	0.04	0.37	0.09	0.24	0.05	0.49	0.04	0.15	0.03	0.30
Jordan	0.08	0.22	0.04	0.38	0.04	0.20	0.02	0.30	0.03	0.14	0.05	0.30
Kenya	0.20	0.25	0.16	0.78	0.15	0.23	0.10	0.61	0.10	0.17	0.05	0.47
Korea (Rep. of)	0.01	0.27	0.28	0.59	0.01	0.20	0.10	0.36	0.02	0.18	0.08	0.34
Kuwait	0.01	0.16	0.01	0.19	0.01	0.09	0.01	0.14	0.01	0.11	0.01	0.16

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Table 4 (concluded)

Ratio between specialized and general-purpose technology imports from developed countries, 1970–1998

	1970–1979				1980–1989				1990–1998			
	Agri-culture	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Libya	0.10	0.21	0.02	0.34	0.10	0.24	0.03	0.40	0.06	0.17	0.02	0.28
Madagascar	0.12	0.19	0.19	0.58	0.15	0.35	0.18	0.77	0.07	0.15	0.10	0.39
Malawi	0.19	0.27	0.15	0.67	0.10	0.25	0.20	0.59	0.08	0.13	0.10	0.38
Malaysia	0.12	0.27	0.07	0.51	0.05	0.25	0.03	0.38	0.02	0.18	0.04	0.28
Mali	0.16	0.16	0.14	0.50	0.11	0.22	0.04	0.42	0.04	0.19	0.08	0.35
Mauritania	0.04	0.43	0.01	0.50	0.04	0.37	0.01	0.45	0.05	0.20	0.01	0.29
Mauritius	0.08	0.14	0.13	0.41	0.05	0.14	0.34	0.60	0.05	0.14	0.30	0.57
Mexico	0.11	0.26	0.15	0.59	0.05	0.24	0.07	0.41	0.02	0.11	0.04	0.21
Morocco	0.11	0.21	0.16	0.55	0.11	0.21	0.17	0.57	0.08	0.15	0.16	0.47
Mozambique	0.18	0.20	0.16	0.60	0.13	0.26	0.07	0.53	0.10	0.20	0.03	0.41
Myanmar	0.05	0.41	0.08	0.58	0.05	0.26	0.06	0.44	0.06	0.36	0.03	0.51
Nepal	0.16	0.35	0.16	0.84	0.10	0.35	0.07	0.57	0.02	0.18	0.07	0.37
Nicaragua	0.20	0.22	0.10	0.63	0.26	0.15	0.08	0.56	0.15	0.12	0.02	0.38
Niger	0.09	0.27	0.03	0.41	0.06	0.27	0.03	0.38	0.03	0.18	0.01	0.24
Nigeria	0.09	0.33	0.15	0.65	0.07	0.24	0.07	0.47	0.02	0.36	0.06	0.50
Pakistan	0.22	0.17	0.23	0.68	0.18	0.21	0.29	0.74	0.05	0.14	0.39	0.62
Papua New Guinea	0.17	0.54	0.01	0.75	0.16	0.55	0.01	0.76	0.07	0.48	0.00	0.59
Paraguay	0.33	0.15	0.14	0.69	0.06	0.11	0.08	0.31	0.02	0.06	0.04	0.16
Peru	0.06	0.38	0.17	0.68	0.08	0.46	0.15	0.77	0.03	0.26	0.12	0.49
Philippines	0.08	0.24	0.13	0.54	0.02	0.18	0.06	0.30	0.01	0.14	0.04	0.23
Rwanda	0.03	0.16	0.02	0.25	0.07	0.19	0.08	0.41	0.07	0.13	0.06	0.30
Sao Tome	0.08	0.06	0.15	0.33	0.11	0.16	0.03	0.31	0.03	0.04	0.00	0.13
Saudi Arabia	0.05	0.22	0.01	0.28	0.05	0.11	0.01	0.18	0.03	0.12	0.02	0.20
Senegal	0.10	0.22	0.07	0.44	0.05	0.15	0.07	0.33	0.04	0.13	0.02	0.25
Sierra Leone	0.09	0.34	0.01	0.50	0.08	0.40	0.01	0.53	0.06	0.22	0.01	0.34
Singapore	0.07	0.30	0.03	0.42	0.01	0.25	0.02	0.30	0.01	0.12	0.02	0.17
Somalia	0.16	0.28	0.16	0.70	0.21	0.39	0.03	0.69	0.06	0.27	0.00	0.37
Sri Lanka	0.17	0.16	0.13	0.57	0.10	0.22	0.06	0.44	0.07	0.11	0.12	0.39
Sudan	0.23	0.20	0.27	0.85	0.26	0.22	0.06	0.63	0.21	0.19	0.04	0.52
Syria	0.12	0.22	0.17	0.58	0.13	0.32	0.09	0.57	0.05	0.23	0.24	0.57
Taiwan Prov. of China	0.02	0.17	0.27	0.49	0.02	0.17	0.17	0.40	0.01	0.17	0.09	0.31
Tanzania (United Rep. of)	0.17	0.29	0.23	0.84	0.20	0.33	0.20	0.82	0.07	0.16	0.04	0.35
Thailand	0.11	0.20	0.22	0.57	0.05	0.24	0.11	0.45	0.02	0.24	0.08	0.40
Togo	0.08	0.36	0.06	0.55	0.05	0.16	0.03	0.28	0.03	0.11	0.04	0.25
Trinidad and Tobago	0.06	0.41	0.02	0.56	0.04	0.43	0.02	0.56	0.02	0.47	0.01	0.54
Tunisia	0.15	0.25	0.11	0.56	0.11	0.27	0.13	0.58	0.08	0.18	0.16	0.49
Turkey	0.20	0.34	0.27	0.87	0.06	0.33	0.23	0.66	0.03	0.19	0.34	0.64
Uganda	0.23	0.36	0.23	0.94	0.25	0.27	0.18	0.86	0.10	0.16	0.07	0.47
United Arab Emirates	0.02	0.29	0.00	0.32	0.02	0.25	0.01	0.29	0.02	0.15	0.02	0.21
Uruguay	0.21	0.11	0.20	0.59	0.11	0.09	0.23	0.54	0.12	0.09	0.14	0.44
Venezuela	0.11	0.32	0.08	0.58	0.08	0.34	0.07	0.57	0.03	0.48	0.03	0.60
Zambia	0.09	0.37	0.03	0.54	0.10	0.52	0.10	0.78	0.09	0.48	0.11	0.75
Zimbabwe	0.01	0.16	0.31	0.56	0.17	0.20	0.22	0.67	0.25	0.26	0.18	0.82
MEDIAN	0.09	0.24	0.10	0.52	0.06	0.24	0.06	0.45	0.04	0.19	0.05	0.42

Source: COMTRADE.

Table 5

Ratio between specialized and general-purpose technology imports from advanced developing countries, 1970–1998

	1970–1979				*1980–1989*				*1990–1998*			
	Agri-culture	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Afghanistan	0.05	0.05	0.38	0.55	0.02	0.02	0.15	0.21	0.01	0.00	0.06	0.08
Algeria	0.78	4.70	0.12	5.60	0.19	0.37	0.04	0.61	0.01	0.13	0.05	0.29
Angola	0.69	0.10	0.13	1.02	0.30	0.64	0.02	0.98	0.06	6.63	0.02	6.73
Argentina	0.07	0.21	0.03	0.36	0.06	0.15	0.05	0.30	0.10	0.12	0.04	0.28
Bangladesh	0.01	0.10	0.35	0.51	0.02	0.20	0.32	0.63	0.10	0.13	0.43	0.71
Benin	0.32	0.11	0.67	1.17	0.06	0.09	0.15	0.37	0.01	0.02	0.16	0.19
Bolivia	0.50	0.34	0.11	1.09	0.74	0.25	0.04	1.13	0.32	0.24	0.03	0.66
Brazil	0.09	0.06	0.02	0.19	0.01	0.15	0.04	0.21	0.01	0.07	0.08	0.18
Burkina Faso	0.00	3.42	0.03	3.45	0.18	0.30	0.02	0.52	0.14	0.52	0.00	0.72
Burundi	0.00	0.05	0.03	0.09	0.11	0.14	0.39	0.67	0.07	0.15	1.49	1.83
Cameroon	0.56	0.61	3.84	5.01	0.18	0.58	0.62	1.39	0.08	0.51	0.12	0.74
Central African Rep.	0.00	0.51	0.18	0.76	2.72	1.44	0.28	4.52	0.26	0.18	0.03	0.56
Chad	0.00	0.13	0.00	0.13	0.00	1.46	0.00	1.50	0.08	1.54	0.11	2.30
Chile	0.29	0.26	0.14	0.77	0.13	0.16	0.05	0.41	0.06	0.20	0.05	0.38
China	0.01	0.56	0.32	1.06	0.01	0.27	0.17	0.47	0.00	0.11	0.13	0.28
Colombia	0.14	0.18	0.20	0.57	0.22	0.21	0.09	0.56	0.03	0.13	0.07	0.28
Comoros	0.00	0.00	0.00	0.50	2.52	0.94	1.00	4.48	0.01	0.01	0.06	0.11
Congo	0.04	0.00	1.75	1.81	0.74	1.12	0.19	2.06	0.02	0.15	0.03	0.21
Congo (Dem. Rep. of)	0.05	1.33	0.93	2.37	0.53	0.16	0.80	1.54	0.14	0.15	0.09	0.42
Costa Rica	0.09	0.06	0.15	0.36	0.14	0.11	0.11	0.44	0.04	0.09	0.08	0.26
Côte d'Ivoire	0.28	0.68	0.69	1.71	0.50	0.23	0.21	0.98	0.09	0.12	0.13	0.38
Dominican Republic	0.24	0.10	0.15	0.82	0.26	0.12	0.11	0.54	0.18	0.07	0.19	0.49
Ecuador	0.25	0.52	0.21	1.04	0.12	0.14	0.10	0.41	0.08	0.14	0.06	0.31
Egypt	0.01	0.22	0.59	0.84	0.06	0.11	0.13	0.31	0.02	0.12	0.11	0.29
El Salvador	0.13	0.07	0.19	0.68	0.07	0.08	0.17	0.34	0.03	0.10	0.18	0.38
Equatorial Guinea	0.00	0.28	0.05	0.33	0.20	0.17	0.06	0.42	0.00	0.83	0.02	0.86
Ethiopia	0.02	0.03	0.03	0.09	0.19	0.17	0.13	0.63	0.06	0.21	0.11	0.50
Gabon	3.94	0.31	0.65	4.89	1.30	1.26	0.44	3.00	0.02	1.19	0.04	1.27
Gambia	2.96	0.72	0.82	4.69	0.16	0.03	0.06	0.26	0.02	0.05	0.05	0.13
Ghana	0.36	0.16	1.08	1.76	0.45	0.28	0.21	1.34	0.04	0.16	0.16	0.40
Guatemala	0.21	0.14	0.08	0.48	0.09	0.10	0.13	0.37	0.06	0.25	0.21	0.61
Guinea	1.35	4.07	0.10	5.53	0.91	1.34	0.06	2.32	0.02	0.15	0.04	0.22
Guinea-Bissau	0.12	0.09	0.15	0.45	0.08	0.48	0.02	0.63	0.07	0.02	0.05	0.49
Guyana	0.11	0.08	0.40	0.79	0.64	0.66	0.03	1.36	0.40	0.42	0.16	1.09
Haiti	0.04	0.08	0.40	0.55	0.20	0.09	0.20	0.59	0.01	0.12	0.05	0.19
Honduras	0.26	0.09	0.13	0.63	0.16	0.10	0.09	0.41	0.13	0.27	0.33	0.80
Hong Kong	0.00	0.04	0.06	0.11	0.00	0.06	0.08	0.16	0.00	0.06	0.07	0.14
India	0.01	0.58	0.04	0.66	0.01	0.29	0.06	0.38	0.00	0.13	0.13	0.28
Indonesia	0.01	0.30	0.57	1.07	0.01	0.23	0.28	0.70	0.01	0.19	0.30	0.59
Iran (Islamic Rep. of)	0.01	0.07	0.38	0.47	0.36	0.22	0.08	0.66	0.01	0.17	0.05	0.24
Iraq	0.12	0.19	0.05	0.37	0.09	0.14	0.01	0.25	0.11	0.04	0.01	0.17
Jamaica	0.07	0.06	0.27	0.43	0.55	0.12	0.16	0.88	0.06	0.05	0.14	0.26
Jordan	0.00	0.07	0.20	0.28	0.01	0.08	0.19	0.30	0.05	0.12	0.11	0.30
Kenya	0.05	0.12	0.17	0.48	0.11	0.30	0.29	0.77	0.06	0.15	0.13	0.39
Korea	0.00	0.19	0.53	0.75	0.00	0.07	0.03	0.11	0.00	0.07	0.02	0.11
Kuwait	0.00	0.06	0.03	0.09	0.03	0.13	0.07	0.23	0.00	0.08	0.02	0.11

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Table 5 (concluded)

Ratio between specialized and general-purpose technology imports from advanced developing countries, 1970–1998

	1970–1979				1980–1989				1990–1998			
	Agri-culture	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*	*Agri-culture*	*Mineral*	*Low-skilled labour*	*All specialized technology*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Libya	0.00	0.05	0.27	0.32	0.05	0.23	0.05	0.34	0.01	0.16	0.04	0.22
Madagascar	0.07	0.34	3.27	3.79	0.10	0.67	0.34	1.27	0.06	0.13	0.33	0.65
Malawi	0.01	0.20	0.04	0.28	0.37	0.23	0.04	0.69	0.03	0.20	0.10	0.46
Malaysia	0.01	0.45	0.08	0.60	0.01	0.27	0.04	0.36	0.00	0.16	0.03	0.22
Mali	0.00	2.68	0.00	2.68	0.17	0.12	0.06	0.71	0.05	0.28	0.17	1.22
Mauritania	0.40	0.46	0.04	0.89	0.87	0.25	0.34	1.46	0.05	0.14	0.12	0.32
Mauritius	0.01	0.11	0.38	0.54	0.05	0.19	1.34	1.71	0.01	0.09	0.52	0.69
Mexico	0.05	0.39	0.02	0.50	0.02	0.20	0.04	0.38	0.02	0.10	0.06	0.19
Morocco	0.01	0.02	1.41	1.45	1.44	0.12	0.44	2.02	0.06	0.09	0.26	0.45
Mozambique	1.33	0.24	0.17	1.77	1.86	0.20	0.06	2.13	0.11	0.12	0.17	0.42
Myanmar	0.03	0.52	0.03	0.59	0.02	0.14	0.06	0.23	0.06	0.32	0.04	0.48
Nepal	0.13	0.06	0.03	0.28	0.02	0.20	0.07	0.37	0.06	0.06	0.04	0.19
Nicaragua	0.22	0.13	0.16	0.74	0.64	0.40	0.03	1.10	0.13	0.22	0.19	0.61
Niger	0.00	0.78	3.06	3.88	0.01	1.39	0.16	1.57	0.05	0.24	0.24	0.58
Nigeria	0.07	0.26	0.35	0.74	0.06	0.15	0.09	0.38	0.03	0.09	0.13	0.30
Pakistan	0.03	0.11	0.14	0.29	0.05	0.15	0.11	0.35	0.01	0.11	0.25	0.39
Papua NG	0.02	0.51	0.03	0.56	0.02	0.79	0.03	0.87	0.03	0.50	0.01	0.54
Paraguay	0.43	0.20	0.04	0.74	0.30	0.25	0.04	0.64	0.21	0.11	0.02	0.39
Peru	0.17	0.20	0.17	0.58	0.25	0.19	0.09	0.58	0.09	0.37	0.07	0.59
Philippines	0.02	0.30	0.17	0.53	0.01	0.17	0.08	0.31	0.01	0.11	0.06	0.21
Rwanda	0.00	0.10	0.84	0.94	0.00	0.05	1.18	1.28	0.08	0.50	0.12	1.06
Sao Tome	NA	NA	NA	NA	0.00	0.00	0.00	0.05	0.01	0.08	0.38	0.48
Saudi Arabia	0.01	0.11	0.07	0.19	0.02	0.06	0.05	0.13	0.01	0.15	0.03	0.20
Senegal	0.49	0.19	0.60	1.39	0.15	0.23	0.39	0.79	0.10	0.16	0.10	0.39
Sierra Leone	0.04	0.04	0.12	0.26	0.13	0.10	0.06	0.38	0.02	0.01	0.03	0.13
Singapore	0.01	0.13	0.11	0.28	0.01	0.08	0.03	0.13	0.00	0.07	0.02	0.09
Somalia	0.07	0.07	0.12	0.27	0.29	0.32	0.08	0.72	0.02	0.07	0.75	0.83
Sri Lanka	0.05	0.17	0.22	0.48	0.02	0.18	0.25	0.55	0.06	0.11	0.35	0.57
Sudan	0.03	0.07	0.15	0.29	0.11	0.06	0.07	0.30	0.09	0.22	0.17	0.53
Syria	0.09	0.05	0.45	0.60	0.14	0.38	0.19	0.72	0.06	0.11	0.24	0.43
Taiwan Prov. of China	0.01	0.12	0.09	0.23	0.01	0.07	0.04	0.13	0.00	0.04	0.02	0.06
Tanzania (United Rep. of)	0.21	0.16	0.26	0.87	0.60	0.42	0.21	1.49	0.11	0.13	0.18	0.52
Thailand	0.01	0.27	0.24	0.61	0.04	0.35	0.15	0.61	0.01	0.16	0.07	0.27
Togo	0.32	0.02	1.55	1.89	0.07	0.24	0.49	0.85	0.02	0.03	0.35	0.42
Trinidad and Tobago	0.30	0.06	0.36	0.76	0.24	0.06	0.16	0.50	0.05	0.09	0.05	0.21
Tunisia	0.00	0.14	1.96	2.15	0.03	0.15	0.19	0.37	0.03	0.29	0.15	0.49
Turkey	1.64	0.39	0.39	2.43	0.01	0.16	0.18	0.35	0.00	0.26	0.22	0.50
Uganda	0.34	0.04	0.40	2.52	0.41	0.59	0.31	1.98	0.08	0.16	0.03	0.41
United Arab Emirates	0.00	0.27	0.01	0.29	0.04	0.20	0.13	0.37	0.00	0.16	0.07	0.25
Uruguay	0.53	0.21	0.09	0.93	0.29	0.19	0.05	0.58	0.23	0.09	0.03	0.40
Venezuela	0.10	0.11	0.06	0.31	0.15	0.15	0.09	0.45	0.04	0.12	0.05	0.26
Zambia	0.13	0.05	0.04	0.24	0.57	0.25	0.18	1.05	0.07	0.11	0.11	0.32
Zimbabwe	0.00	0.00	0.00	0.00	0.61	0.40	0.11	1.18	0.18	0.35	0.14	0.74
MEDIAN	0.07	0.13	0.17	0.67	0.15	0.17	0.11	0.58	0.05	0.13	0.08	0.34

Source: COMTRADE.

and a good investment climate, as well as a comparative advantage in manufacturing or in the minerals sector, and (iii) which are not subject to balance-of-payments constraints have made the most advance in technological integration. But it is clear that there are wide discrepancies even among these countries. Statistically, there is no significant association between cross-country variation in the GDP ratio of machinery imports and natural trade barriers, and the evidence regarding FDI inflows is mixed. The importance of machinery imports from technologically more advanced developing countries remains small compared to such imports from developed economies, but has risen substantially over the past two decades. Whereas general-purpose technology has remained the most important part of machinery imports from developed countries, specialized machinery imports play a substantial role in machinery imports from technologically more advanced developing countries. Although the sectoral bias of machinery imports has remained small, it has been strongest for mineral-based activities; the importance of specialized machinery imports related to agricultural activities has fallen, while that related to labour-intensive activities has increased.

IV. ESTIMATION RESULTS

The empirical results are based on a sample of 53 developing countries for which comprehensive data over the 1970–1990 period are available (see Appendix for the composition of the sample). Data on per capita income, capital (capital stock per worker based on aggregate investment) and labour are from Easterly and Yu (2000), education data (number of school years of the population aged 15 or above) from Barro and Lee (2000), and data on machinery imports from the United Nations COMTRADE database. Given that Easterly and Yu (2000) have capital stock data only through 1990, the time period analysed in this section ends in 1990. Income, capital stocks and the labour force are measured as the differences in log values between 1970 and 1990, while, following Benhabib and Spiegel (1994), human capital is measured as the average of log values of mean years of schooling in 1970 and 1990.[10] Technology diffusion is measured as the average of the GDP ratios of machinery imports over the sample period 1970–1990. This measure reflects the hypothesis that a persistent increase in the stock of ideas requires a continuous stream of technology inflows. The measure used by Coe et al. (1997), namely the difference between the GDP ratios of machinery imports at time *0* and time *T* reflects differences in investment rates, and thus accords well with their measuring human

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[10] The regressions were also run on the average levels of human capital and the log of the average levels during the 1970–1990 period. These yielded similar results to those reported below.

capital as school enrolment rates. However, taking such differences is a less appropriate measure of how the stock of ideas develops over a period of time, because such a measure would overestimate the relative amount of new technology used in production over the period for a country whose stock of ideas grew rapidly over the estimation period from a low basis.[11]

The model is specified in levels rather than growth rates, following Benhabib and Spiegel (1994) and, more recently, Hall and Jones (1999). This is an alternative to the basic cross-country growth specification derived from a neoclassical growth model, as provided, for example, by Mankiw et al. (1992), which operates with investment data. Studies based on that specification generally use initial income as a proxy for initial efficiency because when investment data are used to proxy for changes in the input of capital, the transitional dynamics induced by factor accumulation need to be controlled for. Such transitional dynamics occur because the relatively poorer economies have a lower stock of capital, so that the marginal product of an additional unit of capital is higher in these countries, and their rate of growth will be higher for any given rate of investment. By contrast, estimations based on stock data directly regress the change of output on changes in inputs. The advantage of using capital stock data is that it allows for the omission of a term in initial efficiency and, as a result, more precise estimates are obtained (Jones 2000; Temple 1999a: 121–125). However, Temple (1999b) points out that estimations based on the method used in this paper may be biased by influential outliers. He suggests testing to see whether the residuals are normally distributed; if they are not, the regression should not be applied to the entire sample.

Caution is required in assuming that the variable representing total factor productivity growth actually measures the contribution of technological change to economic growth. The measurement bias can go in either direction. The contribution of technological change will be overestimated to the extent that the increased integration of developing countries into the world economy (as reflected here by increased machinery imports) has improved the efficiency with which capital and labour are used. The bias will be the reverse to the extent that the elasticity of substitution between production factors is less than unity and technological change has a Hicks-labour saving bias (see O'Connor and Lunati, 1999, for discussion of this issue). The underestimation of the contribution of technological change to economic growth will increase with the growth in the capital/labour ratio, the degree of labour-saving bias and the inelasticity of substitution. In addition, to the extent that endogenous innovation drives growth, part of the contribution to growth of an increase in the varieties of capital goods facilitated by R&D will be attributed to capital rather than to total factor productivity. However, this endogenous

[11] Running the regressions on this measure yields similar results to those reported in table 6, with the difference that in most cases the point estimates on machinery imports increase.

growth component in technological progress is largest in developed countries and is considered to be negligible in this paper because only developing countries are considered.

All the growth regressions in this paper were based on ordinary least squares and run with White's heteroscedasticity-consistent covariance estimation method. The results of the basic estimations which use total machinery imports as the measure for technology transfer and overall educational attainment as the measure for human capital are shown in table 6.[12] In all the regressions, changes in the stock of physical capital (dK) and of the labour force (dL) enter with their expected signs. Human capital (H) enters with a positive sign at a high level of significance in model 1, and the coefficients on machinery imports from both developed and technologically more advanced developing countries ($Mach_{imp}$) and from developed countries alone ($MachInd_{imp}$) have the expected positive sign and are statistically strongly significant. However, once an interaction term is introduced (model 2), human capital takes a negative sign and becomes statistically insignificant, thus mirroring the result obtained by Benhabib and Spiegel (1994). The coefficients on the interaction terms are positive and statistically highly significant. The results of model 3 show that the coefficient on the interaction terms remains significant with a positive sign, even when the other two variables (human capital and machinery imports) are dropped from the equation. This suggests that human capital is really used for the adoption of imported machinery.

Machinery imports from technologically more advanced developing countries appear to have an insignificant impact on economic growth, given that the results change little when only machinery imports from developed countries ($MachInd_{imp}$) are included, as can be seen by comparing columns 2, 4 and 6 with columns 1, 3 and 5 of table 6. This could be due to the fact that the GDP ratio of machinery imports from technologically more advanced developing countries strongly rose only over the last ten years or so (figure 1), and that this feature is not taken into account in the regressions because the sample period ends in 1990. However, this hypothesis is not corroborated by the regressions on the extended period 1970–1997, which also give similar results for the two measures of machinery imports (see Annex table).[13] This might indicate that in spite of its strong relative increase over the past few years, the level of machinery imports from technologically more advanced developing countries is still too low, compared to that from developed countries, to have a significant measurable impact on productivity in developing countries.

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[12] The P-value of the normality test on the residuals reported in the last row of the table suggests that the regression results are not biased by influential outliers. Excluding Iran and Tunisia from the regressions on model 3 raises the P-value of the normality test above 0.90. Doing so affects the results reported in the table only with regard to dL for which both the point estimates and the t-values (becoming significant at the 10 per cent level) rise.

[13] However, these results are only approximative, given that comprehensive data on physical capital stocks for the period after 1990 are not available, so that the time series on the stock of physical capital was extended using the rate of gross domestic investment and the same fixed annual depreciation rate for all the countries.

Table 6

Cross-country growth regressions with overall educational attainment and machinery imports, 1970–1990

Dependent variable – differences in log levels of per capita income

	Model 1		*Model 2*		*Model 3*	
Constant	–0.55 (–3.27)[a]	–0.55 (–3.30)[a]	–0.11 (–0.39)	–0.14 (–0.51)	–0.33 (–2.37)[b]	–0.33 (–2.32)[b]
H	0.18 (2.07)[b]	0.19 (2.16)[b]	–0.10 (–0.62)	–0.08 (–0.49)		
$Mach_{imp}$	0.03 (2.97)[a]		–0.12 (–1.58)			
$H * Mach_{imp}$			0.10 (2.15)[b]		0.03 (3.36)[a]	
$MachInd_{imp}$		0.03 (2.97)[a]		–0.12 (–1.45)		
$H * MachInd_{imp}$				0.10 (2.00)[b]		0.04 (3.27)[a]
dK	0.47 (7.44)[a]	0.48 (7.60)[a]	0.46 (7.21)[a]	0.46 (7.45)[a]	0.47 (7.26)[a]	0.48 (7.58)[a]
dL	0.49 (1.73)[c]	0.49 (1.75)[c]	0.49 (1.86)[c]	0.51 (1.90)[c]	0.41 (1.55)	0.41 (1.56)
R^2	0.65	0.69	0.68	0.68	0.65	0.65
F-stat.	22.0	25.5	20.0	19.6	35.5	29.9
N	53	53	53	53	53	53
Normality P-value	0.95	0.96	0.85	0.85	0.86	0.85

Note: White's heteroskedasticity correction used; t-statistics in parentheses; the superscript ***a*** denotes significance at the 1 per cent, ***b*** at the 5 per cent and ***c*** at 10 per cent confidence level.

When the models are estimated with technology imports measured as imports of general-purpose machinery ($GMach_{imp}$) rather than total machinery, both the point estimates and the t-values of the variables measuring human capital and technology imports rise, as shown in table 7. This suggests that within the category "machinery", imports of general-purpose machinery have a significantly stronger positive impact on economic growth than specialized machinery. A possible explanation of this result is that developed countries design 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

Table 7

Cross-country growth regressions with overall educational attainment and general-purpose machinery imports, 1970–1990

Dependent variable – differences in log levels of per capita income

	Model 1		*Model 2*		*Model 3*	
Constant	–0.54 (–3.28)[a]	–0.55 (–3.33)[a]	–0.11 (–0.38)	–0.13 (–0.46)	–0.32 (–2.28)[b]	–0.32 (–2.27)[b]
H	0.18 (2.11)[b]	0.19 (2.20)[b]	–0.10 (–0.59)	–0.08 (–0.50)		
$GMach_{imp}$	0.05 (3.38)[a]		–0.19 (–1.65)			
$H * GMach_{imp}$			0.15 (2.18)[b]		0.04 (3.32)[a]	
$GMachInd_{imp}$		0.05 (3.45)[a]		–0.19 (–1.54)		
$H * GMachInd_{imp}$				0.15 (2.04)[b]		0.05 (3.20)[a]
dK	0.47 (7.33)[a]	0.47 (7.50)[a]	0.46 (7.13)[a]	0.46 (7.34)[a]	0.47 (7.18)[a]	0.47 (7.49)[a]
dL	0.49 (1.76)[c]	0.50 (1.79)[c]	0.50 (1.91)[c]	0.51 (1.94)[c]	0.42 (1.60)	0.43 (1.62)
R^2	0.65	0.65	0.68	0.68	0.65	0.65
F-stat.	22.3	22.2	20.1	19.8	30.3	29.8
N	53	53	53	53	53	53
Normality P-value	0.97	0.97	0.82	0.84	0.89	0.86

Note: White's heteroskedasticity correction used; t-statistics in parentheses; the superscript ***a*** denotes significance at the 1 per cent, ***b*** at the 5 per cent and ***c*** at 10 per cent confidence level.

in developed countries. Even though this constraint applies to all imported technology, it may be more binding for specialized machinery whose productive use tends to require specialized knowledge which may be particularly scarce in developing countries.

The results of the regressions run using the entire category “machinery and transport equipment” to measure technology imports, such as in Coe et al. (1997), are shown in table 8. As expected, the point estimates of this measure of technology imports are substantially lower than those

Table 8

Cross-country growth regressions with overall educational attainment and imports of machinery and transport equipment, 1970–1990

Dependent variable – differences in log levels of per capita income

	Model 1		*Model 2*		*Model 3*	
Constant	–0.54	–0.55	–0.06	–0.09	–0.31	–0.32
	(–3.31)[a]	(–3.36)[a]	(–0.23)	(–0.31)	(–2.27)[b]	(–2.25)[b]
H	0.18	0.19	–0.11	–0.10		
	(2.13)[b]	(2.22)[b]	(–0.67)	(–0.59)		
$SITC7_{imp}$	0.01		–0.06			
	(3.31)[a]		(–1.84)[c]			
$H * SITC7_{imp}$			0.05		0.01	
			(2.38)[b]		(3.32)[a]	
$SITC7Ind_{imp}$		0.02		–0.07		
		(3.38)[a]		(–1.68)[c]		
$H * SITC7Ind_{imp}$				0.05		0.02
				(2.19)[b]		(3.12)[a]
dK	0.47	0.47	0.46	0.46	0.47	0.48
	(7.23)[a]	(7.36)[a]	(7.11)[a]	(7.29)[a]	(7.06)[a]	(7.29)[a]
dL	0.50	0.50	0.47	0.48	0.42	0.42
	(1.79)[c]	(1.80)[c]	(1.77)[c]	(1.80)[c]	(1.61)	(1.60)
R^2	0.65	0.65	0.68	0.68	0.65	0.65
F-stat.	22.5	22.4	20.4	20.0	30.4	29.9
N	53	53	53	53	53	53
Normality P-value	0.96	0.97	0.73	0.77	0.89	0.85

Note: White's heteroskedasticity correction used; t-statistics in parentheses; the superscript ***a*** denotes significance at the 1 per cent, ***b*** at the 5 per cent and ***c*** at 10 per cent confidence level.

based on either total machinery imports (table 6) or general-purpose machinery imports (table 7), while the level of significance remains by and large unchanged. A comparison of these results shows a remarkable hierarchy in the impact of the different measures of technology imports on growth, with that of general-purpose machinery being highest, followed by total machinery, and with the measure used by Coe et al. (1997) having the lowest impact.

Table 9

Cross-country growth regressions with specific educational attainment and general-purpose machinery imports, 1970–1990

Dependent variable – differences in log levels of per capita income

	Model 1		*Model 2*		*Model 3*	
Constant	–0.54 (–3.30)[a]	–0.55 (–3.34)[a]	–0.35 (–1.85)[c]	–0.37 (–1.92)[c]	–0.37 (–2.51)[b]	–0.37 (–2.52)[b]
H_{high}	0.09 (2.29)[b]	0.10 (2.39)[b]	0.02 (0.36)	0.02 (0.43)		
$GMach_{imp}$	0.04 (1.74)[c]		–0.20 (–1.74)[c]			
$H_{medium} * GMach_{imp}$			0.07 (2.17)[b]			
$GMachInd_{imp}$		0.04 (1.70)[c]		–0.19 (–1.65)		
$H_{medium} * GMachInd_{imp}$				0.07 (2.09)[b]		
$H_{high} * GMach_{imp}$					0.03 (3.43)[a]	
$H_{high} * GMachInd_{imp}$						0.03 (3.36)[a]
dK	0.48 (6.66)[a]	0.48 (6.71)[a]	0.48 (6.87)[a]	0.47 (6.86)[a]	0.47 (6.70)[a]	0.47 (6.74)[a]
dL	0.64 (2.38)[b]	0.65 (2.41)[b]	0.73 (2.78)[a]	0.73 (2.77)[a]	0.56 (2.17)[b]	0.57 (2.20)[b]
R^2	0.68	0.68	0.71	0.71	0.69	0.68
F-stat.	24.8	24.7	22.6	22.3	35.0	34.7
N	52	52	52	52	52	52
Normality P-value	0.92	0.91	0.97	0.98	0.96	0.93

Note: White's heteroskedasticity correction used; t-statistics in parentheses; the superscript ***a*** denotes significance at the 1 per cent, ***b*** at the 5 per cent and ***c*** at 10 per cent confidence level.

It may be argued that including primary, secondary and tertiary schooling in the measure of human capital results in too broad a category to be used in association with technology. This is because only that part of the labour force with advanced education will be able to conduct domestic R&D

activities. Moreover, Bartel and Lichtenberg (1987) have shown that more educated workers have an advantage in implementing imported technology. Therefore, the regressions were run with two modifications: first, the human-capital variable measuring domestic R&D activities was defined as the share of the adult population with some tertiary and completed secondary education (H_{high}) and, second, the human-capital part of the interaction term between human capital and imported machinery in model 2 was defined as the share of the adult population with some secondary education (H_{medium}). The interaction term in model 3 uses H_{high}. The results of this exercise are shown in table 9 for imports of general-purpose machinery (the results for total machinery imports are not materially different, and are thus not shown). With this specification, all the variables regarding human capital have the expected sign, while the interaction terms remain statistically highly significant in both models 2 and 3.

V. CONCLUDING REMARKS

This paper has explored technology transfer to developing countries and its contribution to economic growth. The paper highlights the importance of trade as a vehicle for technological spillovers and attempts to trace the combined role of human capital and technology diffusion in economic growth during the transition to the steady state.

The statistical analysis of the evolution of machinery imports by developing countries shows that the technological integration of these countries as a group has increased, but that comparatively few individual countries account for this phenomenon. There is some evidence suggesting that economies either (i) located in South-East or East Asia, or (ii) very small or large sized, or (iii) with a good investment climate, or (iv) with a large minerals sector, have made the most advance in technological integration; but it is clear that there are wide discrepancies even among these countries. In spite of a substantial increase over the past two decades, the importance of machinery imports from technologically more advanced developing countries remains small compared to such imports from developed countries.

The results of the growth-accounting exercise for a sample of 53 developing countries that relates productivity differences to differences in the stock of human capital and machinery imports suggest a positive and statistically strongly significant impact of the combination of machinery imports and the stock of human capital on economic growth during the transition to the steady state. This impact is most significant when general-purpose machinery imports are combined with that part of the labour force which has a high level of education. An important implication of this finding is that the role of human capital in economic development is described best as affecting the speed of adoption of technology from abroad and hence productivity, rather than as being an independent factor of production.

These results suggest that an important determinant of the benefits which developing countries can reap from globalization is whether they can ignite a simultaneous increase of technology diffusion and the skill level of the domestic labour force. This implies a need for government policy to sustain incentives for both human capital formation and a reduction in the cost of technology adoption. The coordination of such efforts is crucial because investment in human capital alone would 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.

To the extent that disparities in productivity reflect differences in the technology that countries use, it will be important to improve policies and institutions that permit developing countries to benefit from advanced technologies. It appears that unilateral trade liberalization in developing countries has not had the expected positive effect on technology imports and growth. This is due, at least to some extent, to the insufficiency of export revenues which has tightened the balance-of-payments constraint and reduced the beneficial effects of improved access to foreign technology. While constraints on the earning capacity of developing countries are partly of domestic origin (for example, impediments to productive investment and an insufficient level of human capital), the continued existence in developed countries of trade barriers in areas of export interest to developing countries is likely to have also played a role. Action on this front taken by developed countries would be an important step towards increasing the growth prospects of developing countries.

APPENDIX

Coverage and sources of data

The sample of 89 developing countries used in the statistical analysis of section III includes the following countries: Afghanistan, Algeria, Angola, Argentina, Bangladesh, Benin, Bolivia, Brazil, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Costa Rica, Côte d'Ivoire, Democratic Republic of Congo, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong (China), India, Indonesia, Iran, Iraq, Jamaica, Jordan, Kenya, Kuwait, Libya, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mauritius, Mexico, Morocco, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Papua New Guinea, Pakistan, Paraguay, Peru, Philippines, Republic of Korea, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, Sao Tome and Principe, Somalia, Sri Lanka, Sudan, Syria, Taiwan Province of China, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, United Arab Emirates, United Republic of Tanzania, Uruguay, Venezuela, Zambia, Zimbabwe.

Developing countries with significant domestic R&D expenditures (15 countries): Argentina, Brazil, Chile, China, Hong Kong (China), India, Indonesia, Mexico, Pakistan, Republic of Korea, Singapore, Taiwan Province of China, Thailand, Turkey, Venezuela.

The sample of 53 developing countries used in the regression analysis of section IV includes the following countries: Algeria, Argentina, Bangladesh, Benin, Bolivia, Brazil, Cameroon, Central African Republic, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Ghana, Guatemala, Honduras, Hong Kong (China), India, Indonesia, Iran, Jamaica, Jordan, Kenya, Malawi, Malaysia, Mali, Mauritius, Mozambique, Nicaragua, Pakistan, Papua New Guinea, Paraguay, Peru, Philippines, Republic of Korea, Rwanda, Senegal, Sierra Leone, Singapore, Sri Lanka, Syria, Taiwan Province of China, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela, Zambia, Zimbabwe.

Breakdown of "machinery and transport equipment" imports (SITC Revision 1 codes):

- Machinery: 71 + 72 + 86169 + 89112, less 71941, less 7295, less 71966, less 7241, less 7242, less 725, less 71962, less 7293 (corresponds to SITC Rev. 2: 71–77, less 761–3, less 775–776)
- Transport equipment: 73 + 8941 + 71966 + 89999 (corresponds to SITC Rev. 2: 78–79)
- Television and radio-broadcast receivers, gramophones, and household equipment: 7241 + 7242 + 89111 + 725 + 71962 + 6566 (corresponds to SITC Rev. 2: 761–3 plus 775)
- Parts and components for electrical and electronic goods: 71492 + 86169 + 7249 + 89112 + 7222 + 7293 (corresponds to SITC Rev. 2: 759, 764, 772, 776)

The sum of the above corresponds to SITC Revision 2, section 7.

The following sub-categories of "machinery" have been made:

- Agricultural machinery and tractors: 712 (corresponds to SITC Rev. 2: 721 + 722)
- Textile and leather machinery: 717 (corresponds to SITC Rev. 2: 724)
- Paper and pulp mill machinery: 7181 (corresponds to SITC Rev. 2: 725)
- Food-processing machinery: 7183 (corresponds to SITC Rev. 2: 727)
- Construction, mining, metal crushing: 7184 + 7185
- Metalworking machinery: 715 + 71954 + 72992 (corresponds to SITC Rev. 2: 736 + 737)

Data sources for table 3

Panel A:

- Investment data from World Bank, World Development Indicators CD-ROM 1999.
- Risk data from Political Risk Services, 1996, International Country Risk Guide. Syracuse, New York.
- Data on FDI from UNCTAD (2000b).

Panel B:

- Education data from Barro and Lee (2000).
- Land and population data from World Bank, World Development Indicators CD-ROM 1999.
- Distance to closest major port: Gallup et al. (1999).
- Mineral reserves: value of known metal, gas, coal and oil reserves in 1990 per unit of land area (US$ million per square kilometre). For the data sources, see Wood and Mayer (1998).

Panel C:

- External debt: Easterly and Yu (2000).
- Exports as a capacity to import reflects the current price value of exports of goods and services deflated by the import price index (in local currency): World Bank, World Development Indicators CD-ROM 1999.
- Export data from World Bank, World Development Indicators CD-ROM 1999.

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ANNEX

Results of the extension of the regression analysis to the period 1970–1997

Given that a deflator for investment goods is not available, the time series on the stock of physical capital was extended, using the rate of gross domestic investment; an annual depreciation rate of 0.07 was assumed, as suggested by King and Levine (1994). The 1997 values of the education variable were calculated as arithmetic averages between the 1995 values and the estimates for 2000 in Barro and Lee (2000). The regressions on the extended period include a smaller number of countries because some of the required data are not available for the entire sample.

Table A1

Cross-country growth regressions with overall educational attainment and machinery imports, 1970–1997

Dependent variable – differences in log levels of per capita income

	Model 1		*Model 2*		*Model 3*	
Constant	–0.39 (–2.05)[b]	–0.39 (–2.00)[b]	–0.31 (–1.58)	–0.24 (–1.10)	–0.01 (–0.03)	–0.01 (–0.05)
H	0.12 (4.57)[a]	0.12 (4.46)[a]	0.09 (3.31)[a]	0.07 (2.15)[b]		
$Mach_{imp}$	0.08 (6.30)[a]		0.05 (1.87)[c]			
$H * Mach_{imp}$			0.01 (0.83)		0.03 (6.03)[a]	
$MachInd_{imp}$		0.08 (6.03)[a]		0.04 (0.94)		
$H * MachInd_{imp}$				0.02 (1.13)		0.04 (5.52)[a]
dK	0.37 (6.35)[a]	0.39 (6.64)[a]	0.36 (5.87)[a]	0.38 (6.12)[a]	0.36 (5.58)[a]	0.38 (6.10)[a]
dL	–0.27 (–1.17)	–0.29 (–1.18)	–0.31 (–1.30)	–0.35 (–1.42)	–0.37 (–1.65)	–0.40 (–1.77)
R^2	0.80	0.78	0.80	0.78	0.78	0.77
F-stat.	41.2	36.3	32.6	29.2	48.9	45.8
N	46	46	46	46	46	46
Normality P-value	0.80	0.74	0.85	0.92	0.88	0.70

Note: White's heteroskedasticity correction used; t-statistics in parentheses; the superscript ***a*** denotes significance at the 1 per cent, ***b*** at the 5 per cent and ***c*** at 10 per cent confidence level.

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