UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

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No. 154

June 2001

DISCUSSION PAPERS

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The author is grateful to William Choa, S. Mansoob Murshed and Holger C. Wolf for their helpful comments and suggestions on an earlier version, and to Nelly Berthault for extracting the trade data from COMTRADE.

UNCTAD/OSG/DP/154

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Keywords: Technology transfer; human capital; economic development.

JEL classification: O10, O30, F15, O47.

CONTENTS

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Jörg Mayer

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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)*):

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

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

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

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

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

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:

$$\frac{\dot{A}(t)}{A(t)} = g(H) + f(H)\left[\frac{T(t) - A(t)}{A(t)}\right] \qquad g'(H)>0,\ \varphi'(H)>0 \qquad (4)$$

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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