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Technology adoption, human capital formation and income differences

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ABSTRACT

The paper presents a model of technology adoption with endogenous supply of human capital. I investigate the effects of skill bias technical change in the frontier economies on the evolution of output, the quantity and quality of human capital in the adopting countries. The framework introduces a novel feature by connecting the direction of technology adoption to a sequential process of skill accumulation, where the returns of advanced human capital depend on the quality of basic education. I find that moderate skill bias at the frontier produces convergence in output per capita, while strong skill bias generates two convergence clubs among adopting countries. In the latter case, a further increase in skill bias leads to a larger disparity in output between clubs. Furthermore, the countries in the low income club converge to a new steady-state characterized by a higher quantity and lower quality of skilled labor.

1. Introduction

This paper investigates how changes in frontier technologies affect the evolution of output and human capital in the adopting countries. The analysis uncovers new trade-offs that arise when the type of technologies adopted are conditioned by a sequential process of skill accumulation, where the returns of advanced human capital depend critically on the quality of basic education. Skill-biased technical change (SBTC henceforth) occurring in the frontier countries alters both the incentives to adopt technologies and the returns to investment at different stages of education in the follower countries. In this paper I ask the following questions: How does SBTC in the frontier economies affect the technological progress and the quantity and quality of different types of human capital in the adopting economies? How do countries at different stages of development respond to such a technological shock? What are the implications for the evolution of the world income distribution?

I show that the strength of the frontier skill bias can change the nature of the long-run distribution of income across adopting countries: while moderate skill bias produces convergence in output per capita, strong skill bias leads to formation of convergence clubs, with the emergence of a rich club of adopters. The main result of the paper shows that in the polarizing regime, a marginal increase in the skill bias at the frontier leads to a greater divergence in income levels between the rich and the poor clubs in the long-run. Interestingly, the countries in the low income club reach a new steady-state characterized by a higher quantity but lower quality of skilled labor.

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The paper develops an overlapping generations model of a developing economy that endogenizes both the investment in advanced education and the direction of technology adoption. A key ingredient of the framework is the hierarchical nature of human capital formation: there is a first stage of education, which builds basic or unskilled human capital and an optional advanced stage that produces skilled human capital. An individual can invest in advanced education only if her basic preparation exceeds a certain threshold, a feature that is intrinsic to the sequential nature of any education process, e.g. in order to learn calculus, one needs to master algebra. Consequently, both the quantity and the quality of skilled workers and the returns of skilled human capital depend on the overall effectiveness of basic education, which in turn varies positively with the level of development.

This process of human capital accumulation is further embedded in a general equilibrium model of a production economy with two sectors employing different types of labor (skilled and unskilled, respectively) together with skill-specific technologies. The new technologies in both sectors are developed in the frontier countries and are available for adoption in the developing economy. The evolution of the frontier technologies is independent of the conditions in the developing world. Each period, firms in the adopting economy choose a level of technology that is appropriate for the quality and quantity of sector-specific skills available. Consequently, the direction of technical change at the frontier generates changes in the direction of technical adoption in the developing countries.

I use the model to study (1) the joint determination of technologies and investment in different types of education along the development process and (2) how the resulting equilibrium changes with the strength of skill bias in technology at the frontier. There are two forces at work, the technology-skill complementarity and the endogenous selection of workers in the two sectors. Higher SBTC produces larger increases in productivity in the skilled sector in relatively richer adopting economies as they have both a higher quantity and quality of skilled human capital to be matched with the new adopted technologies. Richer economies also tend to have a larger market size for skilled technologies. When the skill bias at the frontier is low, these effects are small and thus the decreasing returns in factors insure the neoclassical convergence in output per capita.[1] However, if the frontier skill bias is large, the productivity gains from investing in skills become significantly larger in relatively more developed economies. This produces larger increases in future output and the quality and quantity of skilled workers. Consequently, the nature of the long-run equilibrium changes, with the emergence of a rich club of economies that converge to a steady-state where skill premium, enrollment in advanced education and output per capita are high, and a poor club of "left behind" countries which do not have a large enough skilled sector in order to benefit from the adoption of skill biased technologies. The calibration of the model with plausible parameter values produces the two-club equilibrium, consistent with the lack of convergence in income and higher education attainments in the developing world during the last decades.

The model provides some interesting insights on dynamic effects of SBTC on output and the quality and quantity of education across countries. Consider, for example, the polarizing regime. A further marginal increase in the skill bias leads to a greater divergence in income levels between the rich and the poor club in the long-run. An increase in the skill bias has two opposing short-run effects on output. First, there is a positive effect from the immediate increase in enrollment in advanced education and implicitly the size of the skilled sector. Second, the increase of the skilled labor force generates a reallocation of human capital from the unskilled to the skilled sector in all adopting economies. Thus, there is a negative effect on output stemming from the reduction of the market size for the unskilled technologies. Moreover, the increase in enrollment in higher education reduces the average ability of the unskilled workers and thus their capacity to adopt new skill-specific technologies. In the "trapped" economies the negative effect from an increase in the skill bias outweighs the gains in productivity in the skilled sector. As a result, in the short-run there is a reduction in output, despite the increase in the skilled workforce. This translates into a lower quality of education next period, which further depresses the adoption capabilities. In the long-run, the economies in the poor club converge to a long-run equilibrium with lower output. Although the quantity of skilled labor is higher in the new steady-state, its quality is lower. Within the rich club, further SBTC leads to a steady-state with higher output and a larger and better prepared skilled labor force.

The study connects a few strands of literature. The first is a small but growing literature studying the connection between growth and human capital, where the human capital accumulation is viewed as a multi-stage process (see, for example, Su, 2004; Blankenau, 2005; Blankenau et al., 2007; Arcalean and Schiopu, 2010, Gilpin and Kaganovich, 2012). While most of this literature analyzes the implications for inequality, output and/or welfare of various educational policies in terms of budget level or allocation across stages, this paper is focused on the relationship between investment in different types of skills and technology adoption. Previous research has studied various microeconomic frictions, such as borrowing constraints (Fernandez and Gali, 1999) or informational problems (Blankenau and Camera, 2006) that can generate equilibria characterized by a disparity between educational attainment and the quality of human capital. This paper proposes a different mechanism that can generate such a result, focusing on dynamics produced by SBTC along the level of development.

The paper is also related to the theoretical literature on underdevelopment traps (see, for example, Skiba, 1978; Azariadis and Drazen, 1990; Galor and Zeira, 1993). Earlier papers like Barro and Becker (1989), Becker et al. (1990), Palivos (1995) and Palivos (2001) have studied the role of the quantity and quality trade-off of human capital for economic growth. Some of them have obtained multiple balanced growth paths. Complementary to these studies, this paper emphasizes a different

[1] The steady-state in levels is chosen just for analytical convenience. In Section 2 of Appendix B I present a version of the model that generates a balanced growth path in per capita output along which the enrollment in advanced education is constant. Results hold in this framework as well.