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Barriers to capital accumulation in a model of technology adoption and schooling ☆

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ABSTRACT

Standard growth models require large differences in barriers to capital accumulation to reproduce the observed disparities in the wealth of nations. I introduce technology adoption and schooling decisions into a standard growth model and show that the required differences in barriers implied by this model are much smaller. In particular, a calibrated version of the model implies per capita income differences 3 times larger than a standard model. Per capita income differences are amplified by two reinforcing factors: schooling capital differences and aggregate total factor productivity differences. The results suggest caution in the role of factor inputs derived from standard development accounting exercises. A development policy that subsidizes education is not optimal in the presence of barriers to capital accumulation, removing barriers can replicate educational outcomes and generate higher income levels by several orders of magnitude.

1. Introduction

Why does a typical worker in a rich country produce 20–30 times more than a typical worker in a poor country? In this paper, I argue that the complementarity between schooling and technology adoption decisions is important for understanding cross-country income differences. While there is abundant empirical evidence supporting this complementarity, it has been abstracted in most studies of international income differences.

Standard growth models require large differences in barriers to capital accumulation to produce the observed disparities in the wealth of nations. I introduce technology adoption and schooling decisions into a standard growth model and show that the required barriers are much smaller. The amplification effect of barriers on income is given by the endogenous aggregate total factor productivity differences generated by the model and by schooling capital differences. Therefore, ignoring the complementarity of technology adoption and schooling decisions has important implications for the role of factor inputs in standard income accounting exercises. To assess the strength of this amplification result, I calibrate a version of the model with reasonable barriers and show that the model implies income differences 3 times larger than a standard model.[1] The model suggests an important role of human capital in development. However, subsidies to education are not optimal in the face of barriers to capital accumulation in this environment.

☆ This is a substantially revised version of Chapter 2 of my dissertation at the University of Minnesota. A version of the paper previously circulated under the title "Technology Adoption and Schooling: Amplifier Income Effects of Policies across Countries." I would like to thank V.V. Chari for comments and advice. I have also benefited from the comments of Andres Erosa, Ig Horstmann, Pat Kehoe, Narayana Kocherlakota, Lee Ohanian, Ed Prescott, Jim Schmitz, Carlos Urrutia, Gustavo Ventura, Xiaodong Zhu, and seminar participants at several conferences and universities. All remaining errors are my own.

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[1] An alternative way of presenting the result would be to show the required barriers needed to reproduce international income differences for a reasonable capital share. I prefer not to present quantitative results in this way since the relationship between income and barriers is highly non-linear in

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Table 1
No schooling population and average years of schooling – 1985.

Region (# of countries)	No schooling	Some schooling	AYS	AYS2
Developing countries (73)	49.7	50.3	3.6	7.2
OECD countries (23)	3.3	96.7	8.9	9.2
Middle Eastern countries (12)	52.8	47.2	3.5	7.4
Latin American countries (23)	22.4	77.6	4.5	5.8

Note: Barro and Lee (1993), Table 6, pp. 383–4. Regional averages are weighted by each country's population aged 25 and over. No schooling refers to adults that have not completed 1 year of formal education. AYS is average years of schooling of the entire adult population and AYS2 is average years of schooling of the adult population with some schooling.

I consider a model where a single good can be produced with either a modern or a traditional technology. An important distinction between these technologies is that schooling is a productive input in the modern technology but not in the traditional technology. In this environment, technology adoption refers to the adoption of the modern technology, and technology adoption and schooling decisions are related since the adoption of the modern technology requires schooling investment in equilibrium.

There is strong evidence that the complementarity between technology adoption and schooling decisions is quantitatively important. A large fraction of the adult population has zero years of completed formal schooling in poor countries, while a negligible fraction has zero schooling in rich countries. Table 1 reports the fraction of the adult population that has not completed a year of formal schooling, the fraction that has completed at least 1 year, and the average years of schooling for different groups of countries. There are remarkable differences across these groups. Even more striking differences emerge when considering individual countries. Fig. 1 reports the fraction of the adult population with zero years of formal schooling: in rich countries virtually all the adult population has some schooling, while in poor countries up to 90% of the adult population has zero schooling. If the no schooling population roughly measures the usage intensity for traditional technologies, then explicitly allowing for this possibility in the model is crucial for understanding the data, in particular for poor countries.

The complementarity between technology adoption and schooling has received a great deal of attention in the early development literature. Welch (1970) and Schultz (1975, 1980) show that incentives to undertake educational investments are higher in environments where more advanced technologies are being adopted. More recently, Dunne and Schmitz (1995) and Doms et al. (1997) show that plants using more advanced technologies have more educated workers. Rosenzweig (1995) summarizes empirical evidence regarding the relationship between education and technology. He argues that investments in education are not optimal everywhere, but investments in education are productive in environments with substantial technical change or with changing market and political institutions. A rough approximation of the connection between technology adoption and education is presented in Fig. 2. It documents the positive relationship between average years of schooling in the adult population and a measure of total factor productivity from Hall and Jones (1999).

A central element in the recent economic growth literature is to develop quantitative models that are consistent with the large differences in per capita income across countries. One approach is to consider broader notions of capital as in Mankiw et al. (1992) and Chari et al. (1997). In particular, a quantitative literature has developed to assess the significance of human capital in amplifying international income differences, e.g., Manuelli and Seshadri (2014), Erosa et al. (2010), and Cubas et al. (2013).[2] Another approach is to consider other features of the standard model that can amplify the effects of barriers to capital accumulation on income disparity. Some research in this direction includes Parente and Prescott (1994), Zeira (1998), Jovanovic and Rob (1998), Parente et al. (2000), Parente and Prescott (1999), and Armenter and Lahiri (2012).

Parente et al. (2000) introduce home-production into a standard growth model, obtaining important amplification income effects for the case with highly substitutable market and non-market goods, and a low capital intensity home technology. An implication of their model is that a large portion of the amplification effect is due to unmeasured non-market consumption. I find that introducing technology adoption and schooling into a standard growth model generates a large amplification income effect without unmeasured output. The reason is that, contrary to the home production story, my model generates aggregate total factor productivity differences. This paper is also related to Restuccia and Vandenbroucke (2014) who analyze the role of productivity differences on cross-country schooling in the presence of income effects and a switch from home to market production and from work to leisure.

The need for theories of total factor productivity differences across countries has been emphasized by Prescott (1998) and Parente and Prescott (2000). Parente and Prescott (1999) develop a model of monopoly rights to the use of technologies capable of generating quantitatively relevant TFP differences across countries. An important distinction with Parente and Prescott's model is that in my model aggregate TFP differences are tied to educational investments and barriers to capital accumulation. In a quantitative experiment below I show that my model can generate substantial aggregate TFP differences.

(*footnote continued*)
these models, i.e., for high income differences, barriers needed are enormously large, while for reasonable barriers the implied income differences are not as large.

[2] See also the related approach of measuring human capital differences across countries in Hendricks (2002) and Schoellman (2012).