HUMAN CAPITAL AND DEVELOPMENT

By

Philippe Aghion, Ingvild Almås, and Costas Meghir

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YALE UNIVERSITY
Box 208281
New Haven, Connecticut 06520-8281

http://cowles.yale.edu/

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Philippe Aghion
Collège de France, INSEAD, LSE

Ingvild Almås
University of Zurich, CEPR, IIES

Costas Meghir
Yale University, NBER, CEPR, IFS

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Abstract

Human capital is central to efforts to promote growth, convergence, and the elimination of poverty. Drawing on the seminal macroeconomic frameworks by Nelson-Phelps, Lucas and subsequent developments, alongside macro and microeconomic evidence, we examine the role of human capital in driving innovation and growth. We highlight how different types of human capital, characterized by education level, matter in different stages of development. Despite documented increases in years of schooling, the world's poorest regions still see stagnating outcomes in learning and education quality, potentially creating poverty traps where investments in neither physical nor human capital materialize. We discuss obstacles to human capital accumulation through a simple analytical framework and present evidence from randomized interventions spanning early childhood programs to school-age initiatives, assessing policies that can effectively remove barriers to skill acquisition and establish foundations for sustained growth.

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1 Introduction

According to recent estimates, human capital accounts for 45% of global growth in the decades since 1980 (Gethin, 2025). Therefore, it is safe to say that human capital policies should continue to take center stage in efforts to stimulate growth, achieve convergence with advanced economies, and eliminate poverty (World Bank, 1995, 2011; United Nations, 2000).

The role of human capital in growth rests on a robust theoretical framework, inspired by Becker's human capital theory (Becker, 1964) and developed into a macroeconomic framework by Nelson and Phelps (1966) and Lucas (1988) while Mankiw et al. (1992) operationalized human capital in an augmented Solow model. Since then, there has been a proliferation of empirical work seeking to quantify the role of human capital on growth and addressing complex measurement issues.

Several insights from work such as Krueger and Lindahl (2001), Benhabib and Spiegel (1994), and Vandenbussche et al. (2006) have improved our understanding of the nuanced role of human capital, and the potential role of complementarities with the stage of development and the type of human capital in question. What has become clear is that human capital should not be treated as a homogeneous entity. The type of investment that matters most depends on the stage of economic development: in advanced industrialized countries, the emphasis may lie in promoting higher education and fostering primary research, while in low- or very low-income countries, the priority is often to ensure basic literacy and numeracy as a foundation for escaping poverty and initiating catch-up growth by adopting improved technologies complementary to mid level skills. Relevant heterogeneity, includes the level of education (primary, secondary or higher) and the distinction between cognitive and noncognitive skills (Cunha and Heckman, 2007; Deming, 2017; Heckman et al., 2006).

Beyond the seminal macroeconomic studies mentioned above, important microeconomic work takes a granular look at how education can enable the effective use of innovation (Foster and Rosenzweig, 1996), increase wages and therefore overall productivity (Duflo, 2001),

promote economic restructuring (Porzio et al., 2022), and affect key outcomes, such as delay and reduce fertility and improve health (Duflo et al., 2024; Keats, 2018), among other important contributions. A key implication, particularly in the first of these papers, is that an exogenous innovation can increase the returns to education and promote investments in human capital, but the flip side of this is that education on its own may have little effect on growth, (although it can benefit other dimensions of development, such as health and fertility outcomes) unless accompanied by policies that promote investment and innovation, even in the poorest settings. For example, China's stratospheric growth was accompanied by large increases in education, but would not have been possible without the reforms that promoted entrepreneurship and investment (Zilibotti 2017). And the recent work by Gethin (2025), who attributes 45% of recent global growth to human capital, also emphasizes the role of skill biased technical change. But just as education and innovation can enter a virtuous cycle of growth, progress on either margin risks stalling if the other does not move in tandem. This raises several questions. First, can a poverty trap arise whereby investments in neither physical nor human capital take place? Second, can policy promote human capital investments so as to create the conditions for innovation and physical investments, or should the latter come first? What does a development policy look like when these complementarities are important?

We do not pretend to answer all these questions in this chapter and we do not explicitly discuss policies that promote physical investments and innovation, whose absence could be an indirect obstacle to human capital accumulation. Our focus is on the role of human capital, the obstacles to its accumulation and policies that could enhance its growth. We start by providing an overview of the key macroeconomic results of the role of human capital in growth. Following a discussion of how these may apply in a low-income setting and providing evidence on the importance of human capital for growth in that context, we then discuss the obstacles to human capital accumulation through the lens of a simple model. This allows us to isolate the various channels through which policy can stimulate investments in

skills.

A key practical difficulty is to design policies that can eliminate such obstacles, even in low income settings. We therefore move on to discuss what we have learned from small-scale (randomized) interventions about our ability to promote human capital investments in children starting in the early years and then in school age children. The influential work of Banerjee et al. (2022) shows us how lack of basic skills can be a bottleneck for further development and could inhibit the effectiveness of interventions that address key skills. The seminal Jamaica intervention (Grantham-McGregor et al., 1991) with its long-term follow-up (Gertler et al., 2014), has illustrated the potential power of early intervention, while several interventions targeting school age children, such as Progresa (later Oportunidades) in Mexico (Schultz, 2004), *Plan Apoyo Compartido* in Chile (Bassi et al., 2020) and others have shown the potential for improving both access and quality of schooling. Many of these are highly successful, but the long-term effects are rarely documented. Beyond heterogeneity in the nature and quality of each intervention, their success or failure may have to do with perceived incentives of families to invest in their children, which is related to the issues discussed above. Understanding factors that can induce families to invest more and increase skill acquisition can be a pathway for human capital development, which can then influence the returns to physical investments. Various recent studies have addressed these issues (Dizon-Ross, 2019; Duflo et al., 2015*a*; Jayachandran and Lleras-Muney, 2009; Muralidharan and Prakash, 2017).

There are many aspects of human capital that we do not address in this chapter. This includes remedial vocational programs, on the job and employer provided training and learning by doing. This is not to diminish their importance. However, the success of most of these programs will depend on the solid foundations of conventional primary secondary and possibly tertiary education. Thus, a human capital policy with a focus on growth will have to rely on the solid foundations that only schooling can potentially offer.

Our chapter follows on from the seminal chapters on education in previous handbook

volumes (Behrman, 2010; Schultz, 1988). Our emphasis is different: We explicitly consider the link between human capital and growth, the potential complementarities between policies that promote skill acquisition, physical investments, and innovation, and emphasize the role that human capital interventions can have in mitigating the obstacles to human capital accumulation. However, there are important areas of overlap and thus a continuity in the arguments, with an update based on the research that has happened since.

The chapter proceeds as follows. In Section 2 we discuss models linking growth to human capital. Following that, in Section 3 we discuss the process of accumulation of human capital and obstacles that can prevent it. Section 4 discusses empirical results on interventions designed to identify policies that work in practice and address obstacles we identify, and finally Section 5, offers some concluding remarks.

2 Education and Growth

Does human capital matter for growth and how? In this section we present three basic approaches to this question. The first "Lucas-Becker" approach emphasizes capital accumulation. Within that class, the neoclassical reference is Mankiw et al. (1992) , henceforth MRW, and the AK reference is Lucas (1988). Both papers emphasize *human capital accumulation* as a source of growth. MRW is an augmented version of the Solow model with human capital as an additional accumulating factor of production, and in particular human capital accumulation slows down the convergence to the steady-state by counteracting the effects of decreasing returns to physical capital accumulation. In Lucas, human capital accumulates at a speed proportional to the existing stock of human capital, which in turn leads to a positive long-run growth rate. Whether on the transition path to the steady-state (in MRW) or in steady-state (in Lucas), the rate of growth depends upon the rate of accumulation of human capital, not upon the stock of human capital.

The second "Nelson-Phelps" approach, which goes back to the seminal contribution by

Nelson and Phelps (1966) and the subsequent empirical work by Benhabib and Spiegel (1994), describes growth as being driven by the *stock* of human capital, which in turn affects a country's ability to innovate or to catch up with more advanced countries.[1] By linking the stock of human capital (measured either by the flow of education spending or by school attainment) to the process of technological change, this approach helps answering questions for example on how to maximize growth through a proper design of education spending policy.

The third "Akcigit" approach is more micro and integrates cross-individual heterogeneity, in particular in parental income and/or initial wealth, and in the willingness to pursue research activities. We now proceed to discuss each of these approaches. Before we do so we briefly discuss the Mincer approach to measuring private returns to education, which is the first link between education and growth, rooted in Becker's theory.

2.1 The Mincer approach to measuring the microeconomic returns to education

There is a whole micro literature on how to measure the returns to education. This literature revolves around the so-called "Mincer equation", which is of the form:

$$\ln w_i = \alpha_0 + \alpha_1 n_i,$$

where n_i denotes the number of school years of the corresponding individual i.

We thus measure the return from one additional year of education by its marginal effect

[1] Barro and Sala-i Martín (1995) (1995, chap. 13) also used a large sample of countries during the time period 1965–1985, to regress the average growth rate on several macroeconomic variables, including educational attainment, and public spending on education as a fraction of GDP. Their main findings are: (i) that educational attainment (measured by average years of schooling) is significantly correlated with subsequent growth (with a correlation coefficient at around 0.05), although if we decompose the aggregate measure of educational attainment the impact of primary education remains largely insignificant; (ii) that public spending on education also has a significantly positive effect on growth: a 1.5 percent increase of the ratio of public education spending to GDP during the period 1965–1975 would have raised the average growth rate during the same period by .3 percent per year.

on individual wage, based on the idea that in equilibrium individuals are indifferent between one more year of study or entering the labor market immediately: the opportunity cost of the year of study is equal to the lost salary from not working right away. If people implement this arbitrage correctly, this should thus be equal to the increase in discounted lifetime wages that a worker would receive with one more year of education.

We discuss empirical findings on Mincerian returns to education at a later section. However, the use of this approach to measure the role of human capital in productivity and growth has several potential limitations. First, marginal productivity must be proportional to the wage, which in turn requires competitive markets with price takers. Second, productivity increase induced by one more year of schooling must be directly attributable to the education system; however, the education system also acts as a selection device to select the most talented individuals; now, it is realistic to suppose that education performance is positively correlated with talent. Thus the more talented individuals are those most likely to pursue studies. But then higher wages partly reflect talent, not just schooling per se. On the other hand measurement error in education tends to attenuate the estimated returns. Much of the literature on the Mincerian returns to education find that using Instrumental variables leads to higher - not lower, estimates of the returns to one year of education (See for example, Card, 1993). Another limitation is that a large proportion of workers are self-employed and their hourly wages are difficult to measure, leaving us with a highly selected group of those with observed hourly wages.

However, Mincerian wages provide some useful indication on the marginal value of private investments in education in different fields and at different levels of education, although they may underestimate the social returns. The Mincerian wage does not account for externalities, and in particular (i) for contemporaneous human capital externalities; (ii) for the intertemporal knowledge externalities that lie behind the positive relationship between education and growth and (iii) for knowledge externalities operating through technical progress. That intertemporal externalities matter, is evidenced by the large effects of education on

growth that we discuss later.

More generally, current prices reflect a current state of the economy. They do not inform directly about the growth dynamics that would result for various types of policies. A natural alternative to the above approach, is to use new growth theory to construct empirical relationships which are meant to inform us directly about the impact of different institutions or policies on growth. This is what we try to accomplish in the next three sections.

2.2 The Lucas-Becker Approach

In this section, we present the two main attempts at modeling the relationship between human capital accumulation and economic growth. The Mankiw-Romer-Weil model extends the Solow model by introducing human capital on top of physical capital and raw labor as a third factor of production, assuming decreasing returns to both physical and human capital. The Lucas model assumes constant returns to (human) capital accumulation.

2.2.1 Mankiw et al. (1992)

Mankiw et al. (1992) assume the following aggregate production function:

$$Y = AK^{\alpha}H^{\beta}L^{1-\alpha-\beta}, \tag{1}$$

where A denotes total factor productivity, K denotes the stock of physical capital, H the stock of human capital which *may* also accumulate over time, and L is the stock of raw labor.

For the same reasons as in the Solow model, no long-run growth of per capita GDP is predicted by the MRW model, which again follows from decreasing returns, now to physical *and to human capital* accumulation. However, on the transition path towards the steady-state, growth is positively correlated with the rate of physical *and human* capital accumulation,

since from (1) we immediately have:

$$\Delta Y = \beta \Delta H + u, \tag{2}$$

where Δx denotes the growth rate of x and u includes the growth of other factors.

In the Lucas model we present in the next subsection, the assumption that human capital accumulates at a speed proportional to the existing stock of human capital, leads to a positive long-run growth rate, even in the absence of human capital accumulation by the government.

2.2.2 Lucas (1988)

Inspired by Becker's (Becker, 1964) theory of human capital, Lucas (1988) considers an economy populated by (infinitely lived) individuals who choose at each date how to allocate their time between current production and skill acquisition (or schooling), where skill acquisition increases productivity in future periods. In what follows, we assume a constant population. Thus, if H denotes the current *human capital* stock and u denotes the fraction of time currently allocated to production, the two basic equations of the Lucas model are the following.

$$Y = K^{\beta}(uH)^{1-\beta}, \tag{3}$$

which describes the way human capital affects current production (K denotes the physical capital stock, which evolves over time according to the same differential equation $\dot{K} = Y - C - \delta_k K$, where c is current consumption and δ_k is the depreciation rate), and

$$\dot{H} = \delta H(1-u), \quad \delta > 0, \tag{4}$$

which spells out how current schooling time $(1-u)$ affects the accumulation of human capital.[2] Note that here human capital acquisition does not necessarily involve externalities (or "spillovers") across individuals of a same generation. Yet, the assumption that human capital accumulation involves constant returns to the existing stock of human capital produces a positive growth rate in steady state equal to

$$g = \delta(1-u^*) = \Delta H,$$

where u^* is the optimal allocation of individuals' time between production and education.[3] Education effort $(1-u^*)$ can in turn be shown to depend negatively on the rate of time preference ρ and the coefficient of relative risk-aversion σ and positively on the productivity of schooling measured by δ.

2.3 The Nelson-Phelps approach

The paradigm Nelson and Phelps did not have a model of endogenous growth with endogenous R&D and innovation, but they were already thinking of growth as being generated by productivity-improving adaptations, whose arrival rate would depend upon the stock of human capital. More formally, Nelson and Phelps would picture a world economy in which, in any given country, productivity grows according to an equation of the form:

$$\dot{A} = f(H)(\overline{A} - A),$$

[2] If learning by doing rather than education were the primary source of human capital accumulation, equation (10.2) should be replaced by something like

$$\dot{H} = \delta H u. \tag{10.3}$$

That is, the growth of human capital increases with *production.*

[3] That is, u^* maximizes the representative consumer's intertemporal utility

$$\int_0^\infty \frac{c_t^{1-\sigma}}{1-\sigma} e^{-\rho t} dt$$

subject to: (3), (4) and $\dot{k} = y - c - \delta_k k$ with lower case denoting per capita amounts.

where $\overline{A}$ denotes the frontier technology (itself growing over time at some exogenous rate), and H is the current stock of human capital in the country. A higher stock of human capital would thus foster growth by making it easier for a country to catch up with the frontier technology. Benhabib and Spiegel (1994) tested a slightly augmented version of the Nelson-Phelps model in which human capital does not only facilitate the adaptation to more advanced technologies, but also makes it easier to innovate at the frontier, according to a dynamic equation of the form:

$$\dot{A} = f(H)(\overline{A} - A) + g(H)\gamma A,$$

where the second term capture the innovation component of growth.

Thus if we believe in this Nelson-Phelps approach, then we should expect to see the following kind of equation

$$\Delta Y = \theta H + u \tag{5}$$

to explain by the data on growth across countries.

Using cross country-regressions of the increase in the log of per capita GDP over the period 1965-1985 and including a linear function of the sum of logs of human capital stocks over all the years between 1965 and 1985, Benhabib and Spiegel indeed found a significantly positive correlation between the human capital *stock* H and the growth rate g. Moreover, BS find a larger correlation for countries further below the world technology frontier, which would hint at the catch-up component of growth being the dominant one.

More recently, Krueger and Lindahl (2001) have used cross-country panel data to estimate a combination of the Lucas and Nelson-Phelps paradigms, namely an equation of the form:

$$\Delta Y = \theta_1 \Delta H + \theta_2 H + v \tag{6}$$

These authors find both coefficients θ_1 and θ_2 to be positive and significant when re-

gressing over the whole country sample. However, the significance of the correlation between growth and human capital stocks disappears when restricting the regression to OECD countries. One interpretation of that result, which we refer to as the *Krueger-Lindahl puzzle*, is that human capital stocks only matter for catching-up but not for innovating at the frontier. Another interpretation, is that the above regression is too aggregate or tells an incomplete story. A first attempt along this line, the one recently pursued by Hanushek and Woessmann (2008), is that it is not so much the amount of spending on education that matters for growth, but rather the quality of education. Using test scores to construct an aggregate measure of education quality, Hanushek and Woessmann find a significantly positive correlation between the average growth rate over the period 1960-2000 and the average quality of education over that period.

A remark One remark to conclude this subsection. Suppose indeed that combining the Lucas and Nelson-Phelps approaches to human capital -equation (6)- turns out to be the best specification of the relationship between education and growth. Then, restricting oneself a priori to only the Lucas or only the Nelson-Phelps specification, may lead to underestimating the impact of education on growth.

To see this, suppose that the real world fits the combined approach

$$\Delta Y = \theta_1 \Delta H + \theta_2 H + v$$

and that there is cross-regional convergence in human capital stocks (for example as a result of technology diffusion), so that:

$$\Delta H = a_0 - a_1 H. \tag{7}$$

Then, restricting ourselves to the Nelson-Phelps approach means that we would estimate an equation of the form:

$$\Delta Y = \theta H + u.$$

However, if the world is described by (6) and (7) with $\theta_1 > 0, \theta_2 > 0$ and $a_1 > 0$, then it must be the case that:

$$\theta = \theta_2 - a_1\theta_1,$$

which implies that

$$\theta < \theta_2.$$

In other words, restricting ourselves to a pure Nelson-Phelps specification leads us to underestimate the impact of education on growth.

Similarly, restricting ourselves to a pure Lucas approach by estimating an equation of the form:

$$\Delta Y = \beta \Delta H + w$$

when the world is described by (6) and (7), means that we would end up measuring

$$\beta = \theta_1 - \theta_2/a_1,$$

which implies that

$$\beta < \theta_1,$$

Thus here again the statistician would end up underestimating the effect of education on growth.

The general conclusion is that one must have good reasons to decide a priori to restrict attention to a Lucas or a Nelson-Phelps approach rather than combine the two approaches.

2.4 Bils and Klenow

Bils and Klenow (2000) ask whether the observed correlation between schooling and economic growth across countries reflects a causation from education to growth or a reversed causation or other factors. More precisely, is the fact that countries with higher school enrollment rates

in 1960 experienced faster GDP growth from 1960-1990, truly reflecting an effect of schooling on growth, or can it be instead that higher growth expectations induce a higher demand for schooling? Using a human capital model calibrated with Mincer wage equations from 56 countries, they find that the direct effect of schooling on growth explains less than one-third of the observed correlation between 1960 enrollment and subsequent growth in GDP per worker. And they perform calibrated simulations suggesting that the reverse causality from growth to education also plays an important role in explaining the observed correlation between education and growth. This in turn calls for moving the analysis further. One route is to look at the quality of education measured by test scores. This route has been explored, in particular, by Hanushek and Woessmann (2008) and Angrist et al. (2021). A second avenue, which we explore in the next subsection, is to look at the composition of education spending and enrollment and its effects on productivity growth. A third route is to look for good instruments for education, which would allow to address directly reverse causation.

2.5 Growth and appropriate education policy

Which kind of education investment matters most? How best to allocate public funds between primary, secondary and tertiary education? These are questions that preoccupy governments, and for example it features prominently in the so-called Lisbon Agenda set by countries in the European Union as part of an effort to reduce the growth gap between the EU and the US. A first look at the US versus the EU in 1999-2000 shows that 37.3% of the US population aged 25-64 have completed a higher education degree, against only 23.8% of the EU population. This educational attainment comparison is mirrored by that on tertiary education expenditure, with the US devoting 3% of its GDP to tertiary education versus only 1.4% in the EU. Is this European deficit in tertiary education investment a big deal for growth?

In this subsection we build on Vandenbussche et al. (2006) [VAM], to shed light on these questions. As in Benhabib and Spiegel (1994), productivity growth in VAM can be

generated either by implementing (or imitating) the frontier technology or by innovating on past technologies, and obviously the relative importance of innovation increases as a country or region moves closer to the technology frontier. However, and this is where we depart from Benhabib and Spiegel, different types of education spending lie behind imitation and innovation activities. In particular, higher education investment should have a bigger effect on a country's ability to make leading-edge innovations, whereas primary and secondary education are more likely to make a difference in terms of the country's ability to implement existing (frontier) technologies.

2.5.1 Distance to frontier and the composition of education spending

The starting point of the analysis in VAM, is that, in contrast to the Nelson-Phelps or Benhabib-Spiegel models, human capital does not affect innovation and imitation uniformly: more specifically, primary/secondary education tends to produce imitators, whereas tertiary (especially graduate) education is more likely to produce innovators. This realistic assumption, in turn, leads to the prediction that, as a country moves closer to technological frontier, tertiary education should become increasingly important for growth compared to primary/secondary education (all measured in stocks).

First, note that this provides a solution to the *Krueger-Lindahl puzzle*. Namely, that total human capital stock

$$U + S$$

is not a sufficient statistics to predict growth in OECD countries. For example, take two countries A and B at same distance of world frontier, with same total human capital, but

$$S_A > S_B.$$

The country A will grow faster if the two countries are sufficiently close to the frontier, while the country B will grow faster if both countries are far from the frontier, and yet the two

countries have the same total amount of human capital.

Now, going into slightly greater detail into formalization, VAM focus on the following class of productivity growth functions:

$$A_{it} - A_{it-1} = \lambda[u_{m,i,t}^{\sigma} s_{m,i,t}^{1-\sigma}(\bar{A}_{t-1} - A_{it-1}) + \gamma u_{n,i,t}^{\phi} s_{n,i,t}^{1-\phi} A_{it-1}] \tag{8}$$

where $\bar{A}_{t-1}$ is the frontier technology in period $t-1$, $u_{m,i,t}$ (resp. $s_{m,i,t}$) is the amount of unskilled (resp. skilled) labor used in imitation in sector i at time t, $u_{n,i,t}$ (resp. $s_{n,i,t}$) is the amount of unskilled (resp. skilled) units of labor used by sector i in innovation at time t, σ (resp. ϕ) is the elasticity of unskilled labor in imitation (resp. innovation), and $\gamma > 0$ measures the relative efficiency of innovation compared to imitation in generating productivity growth.

VAM assume that *the elasticity of skilled labor is higher in innovation than in imitation, and conversely for the elasticity of unskilled labor, that is:* $\phi < \sigma$. This assumption in turn implies that a marginal increase in higher education investment S, enhances productivity growth all the more the closer the country is to the world technology frontier, and that a marginal increase in lower education investment U enhances productivity growth all the less the closer the country is from the world technology frontier.

The intuition underlying this proposition, follows directly from the Rybczynski theorem in international trade. Stated in the context of a two sector-two input economy, this theorem says that an increase in the supply of input in the sector that uses that input more intensively, should increase "output" in that sector more than proportionally. To transpose this result to the context of our model, consider the effect of an increase in the supply of skilled labor, keeping the supply of unskilled labor fixed and for given A. Given that skilled workers contribute relatively more to productivity growth and profits if employed in innovation rather than in imitation, the demand for additional skilled labor will tend to be higher in innovation. But then the marginal productivity of unskilled labor should also increase more in innovation

than in imitation; hence a net flow of unskilled workers should also move from imitation into innovation. This in turn will further enhance the marginal productivity of skilled labor in innovation, thereby inducing an ever greater fraction of skilled labor to move to innovation. Now, the closer the country is to the technology frontier (that is, the higher A), the stronger this Rybszynski effect, since a higher A increases the efficiency of both skilled and unskilled labor, in innovation relative to imitation. A second, reinforcing, reason is that an increase in the fraction of skilled labor reduces the amount of unskilled labor available in the economy, hence reducing the marginal productivity of skilled labor in imitation, all the more the closer the country is from the frontier.

VAM confront this prediction with cross-country panel evidence on higher education, distance to frontier, and productivity growth. They consider a panel data set of 22 OECD countries over the period 1960-2000, which they subdivide into five year subperiods. Output and investment data are drawn from Heston et al. (2002) and human capital data from Barro and Lee (2000). The Barro-Lee data indicate the fraction of a country's population that has reached a certain level of schooling at intervals of five years, so they use the fraction that has received some higher education together with their measure of TFP (constructed assuming a constant labor share of .65 across country) to perform the following regression:

$$g_{j,t} = \alpha_0 + \alpha_1 dist_{j,t-1} + \alpha_2 \Lambda_{j,t-1} + \alpha_3 (dist_{j,t-1} * \Lambda_{j,t-1}) + \upsilon_j + u_{j,t},$$

where $g_{j,t}$ is the'growth rate of country j over a five year period, $dist_{j,t-1} \equiv logA_{j,t-1} - log\bar{A}_{j,t-1}$ is the proximity of country j' to the technological frontier at $t-1$ (i.e. 5 years before), $\Lambda_{j,t-1}$ is the lagged fraction of the working age population with some higher education and $\upsilon_{j,t}$ is a country's fixed effect.[4] The closeness and human capital variables are instrumented with their values at $t-2$ and the equation is estimated in differences to eliminate the fixed effect.[5] Before controlling for country-fixed effects, VAM obtains a statistically

[4]We use an identical specification and definition of variables as in the Vandenbussche et al. (2006) paper.
[5]Refer to the original paper for details of the Instrumental Variables estimation approach used.

significant coefficient of -1.87 for the human capital variable and a statistically significant coefficient of 2.37 for the interaction variable, indicating that higher education matters more as a country approaches the frontier. Controlling for country fixed effects removes the significance of the coefficients; however, this significance is restored once country are regrouped into sub-regions and country fixed effects are replaced by group fixed effects.

In Table 1 for completeness we reproduce the last column of Table 3 in VAM with the data updated to 2005 and then to 2015. None of the results change significantly and all conclusions remain the same. When using all the available data to 2015 the parameter estimates remain similar, although less precise, perhaps to be expected given the increased volatility of growth rates following the financial crisis.

Table 1: TFP Growth Equation: Comparison through 2005 and 2015

	Data through 2005	Data through 2015
Proximity	-0.284***	-0.292***
	(0.049)	(0.094)
Fraction	0.160	0.283
	(0.132)	(0.260)
Proximity × Fraction	0.873***	0.983*
	(0.205)	(0.566)
Country dummies	Groups	Groups
Proximity threshold	-0.183	-0.288
	(0.125)	(0.120)
Number of observations	138	164

Note: Each column correspond to the last column (5) of Table 3 in 1. Standard errors clustered at the country level in parentheses. Time dummies included but not reported. *Proximity threshold* refers to the level of proximity beyond which the fraction of higher educated has a positive impact on growth. Group dummies are used instead of individual country dummies. Countries are grouped as follows: Group 1: Belgium, France, Italy, Netherlands; Group 2: Norway, Sweden, Denmark, Finland, Austria, United Kingdom, Switzerland; Group 3: Canada, US Group 4: Australia, New Zealand; Group 5: Portugal, Spain; Group 6: Greece; Group 7: Ireland ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. Data from Barro and Lee (2013) Updated data to 2015 obtained from from https://barrolee.github.io/BarroLeeDataSet/BLv3.html

2.6 Introducing heterogeneity in the relationship between education and innovation

Until now, we have treated innovation like a black box: an abstract individual invested in R&D, and, with a probability that depended on the nature of the investment, he produced an innovation that he could patent and exploit. The reality, however, is more complex.

In particular, not every individual has the same opportunity to become an innovator: the family and social environment, and in particular parents' income, level of education, and professions, affect the individual's propensity to innovate. Intrinsic innovative abilities and talents, which are not distributed equally among individuals, also play a role. Finally, not all individuals have the same willingness to become innovators rather than pursuing alternative careers. Since most of the evidence on this issue comes from advanced economies, we review some of this here, for the broader lessons it offers. In particular, as we see below, it is not simply resources but a culture of innovation that matters.

2.6.1 Who Becomes an Inventor?

To what extent do social and familial factors influence the likelihood of becoming an inventor? Research by Bell et al. (2019) regarding the US, Akcigit et al. (2017) regarding historical data, and Aghion et al. (2023) regarding Finland consistently reveals a J-shaped curve: the probability of obtaining a patent rises sharply only within the highest deciles of parental income. This pattern persists in Finland despite its egalitarian, free education system.

In the US, two main factors explain this. First, while intrinsic ability matters, parental income enables high-potential children to succeed; high-ability children from wealthy families are far more likely to invent than their equally talented but less wealthy peers. Bell et al. (2019) estimate that social origin explains nearly 69 percent of the innovation gap, pointing to financial, knowledge, and cultural barriers. Furthermore, children are more likely to invent if they grow up in innovative geographic zones or have parents working in innovative sectors,

often replicating their parents' specific fields.

Regarding the "Finnish Enigma," Aghion et al. (2023) find that controlling for parental education substantially flattens the J-curve. The correlation between income and invention is largely driven by the fact that wealthier parents tend to be more highly educated. Even within an accessible education system, these parents transmit knowledge and aspirations that prove decisive, illustrating the profound intergenerational effects of education on innovation.

Akcigit et al. (2020) Taking into account the disparities in individuals' access to cutting-edge knowledge, attraction to research careers, and intellectual abilities has direct implications for the relationship between education policy and economic growth. This point has been made most forcefully by Akcigit et al. (2020), henceforth APP, which we view as the most advanced model of innovation-based education and growth to date. The authors start from several facts regarding the relationship between talent, education, and innovation, some of which have already been mentioned above: (i) individuals with a higher IQ are more likely to obtain a PhD; (ii) individuals with higher parental income are more likely to obtain a PhD; (iii) only a fraction of people with a high IQ and high parental income obtain a PhD; (iv) PhDs are far more likely to become inventors than the average individual; (v) conditional on education level, higher IQ people are more likely to innovate; (vi) an increase in the number of PhD slots is associated with a decline in the average IQ of PhDs.

In the APP model, individuals are born heterogeneous with regard to talent, career preferences, and financial wealth. Individuals then decide, depending on their talent, initial wealth, and preferences, whether they want to pursue higher education to become a researcher and innovate. More talented and educated individuals in turn are more likely to innovate. Thus, allocating more talented individuals to higher education and thereafter to research generates more innovation, however some talented individuals might still shy away from research or simply lack the financial resources to pay for the higher education they need to become successful researchers.

In the APP model, the main effect of R&D subsidies is to motivate qualified individuals to choose a career in research and innovation over other careers by making the former more lucrative (in particular, by lowering the cost of access to laboratory equipment and by increasing researchers' salaries). Public investment in education, on the other hand, enables talented individuals from modest backgrounds to pursue higher education that will give them the opportunity to become researchers and innovators. These two policies– public R&D subsidies and public investment in education– therefore have complementary positive effects on innovation and growth because they direct different segments of the population toward research careers.

When a government operates within a limited budget, it will maximize innovation-led growth by investing most of its resources in education. By contrast, if it has greater budgetary resources, the optimal innovation policy will combine public investment in innovation and R&D subsidies, without however sacrificing the former to the latter. Only once a sufficient number of "a priori talented" individuals reach the knowledge frontier and thus have the option of deciding whether to pursue a research career can public R&D subsidies have a significant effect on innovation and growth.

Quantitatively, the benchmark analysis in Akcigit et al. (2020) compares alternative policies using the same government budget of 0.25% of GDP, using their framework. This corresponds approximately to the fiscal cost of R&D subsidies in Denmark between 2000 and 2014. In their model, this budget is equivalent to an R&D subsidy rate of 10%, a common benchmark in the literature. The authors find that allocating this budget to an education subsidy increases innovation by 9.6%, compared to 6.4% for a direct R&D subsidy and 3.8% for an expansion of university slots.

Turning first to R&D subsidies, their model delivers an elasticity of growth with respect to R&D policy that is about 50% lower than in standard creative destruction models. The reason is that several key ingredients—talent heterogeneity, a fixed supply of education slots, career preferences, and financial frictions (through reliance on parental income for higher

education)—dampen the responsiveness of the talent supply to R&D incentives. Intuitively, in their model, an R&D subsidy primarily attracts marginal researchers with lower ability than those already active, which limits the aggregate impact.

By contrast, an education subsidy expands access to higher education for highly talented individuals from disadvantaged backgrounds. These targeted policies improve the allocation of talent by enabling high-ability students who would otherwise be excluded to pursue PhD training. This raises the average quality of researchers, which in turn boosts innovation capacity more strongly than R&D subsidies. However, the paper does not provide a direct comparison of the elasticity of growth to education in their framework relative to the prior literature. Further evidence on the importance and effectiveness of targeting support to high-ability children from low SES backgrounds has also been empirically demonstrated in Abbott et al. (2019): Ability-based grants targeted at children from low-income families were shown to be the most effective policy (relative to expansion of loans or grants targeted just to low-income students) for improving higher education levels and welfare in a general equilibrium framework in the US context.

2.7 Human Capital and Growth in low income countries

Much of the above discussion is general or explicitly addressed to advanced economies. Do these ideas apply more broadly? Should education policy be a priority in low-income countries such as India or those of sub-Saharan Africa? Can this trigger growth? This is of course a central question and one that greatly affects how we view educational interventions in these contexts. The implications of the discussion above is that human capital investments are key and for LMICs and the emphasis should be be on basic skills that allow for catch-up growth. However, the story may be more complex than this, because human capital can only drive growth if other economic and political factors are in place, that allow the development of entrepreneurship and investment more broadly. The key issue here is the potential complementarity between physical and human capital investment. How do the

returns to education vary with physical capital and do the returns to capital and indeed innovation increase with education? Four important papers provide evidence in the context of low income countries.

For the case of India, Foster and Rosenzweig (1996) examine the relationship between innovation, education, and profits resulting from the green revolution that introduced high-yield varieties for rice. The nature of the technology is such that yields are sensitive to the way it is applied and the specific climatic conditions. The authors show that the returns to education increase with the use of the technology and, indeed, that the application of technology is more effective with better educated (literate) farmers. They also show that the green revolution caused an increase in the supply of schooling, indicating that the technology made it worthwhile to acquire skills and individual choices were affected by the new opportunities.

Interestingly, for the specific technology considered, it is the basic skills of primary school that matter and not any higher level of education, which brings us back to VAM: the technology in question was imported, a kind of imitation, and this is best served by lower levels of education than would be required for developing the technology locally: it is literacy and numeracy that are needed to adopt the new high-yielding varieties introduced by the green revolution. and not necessarily high level degrees, which would be more important for innovation. However, without these basic skills catch up growth becomes impossible, emphasizing the importance of complementarities.

In a well-known study Duflo (2001) investigates the impact of a massive school construction program in Indonesia. This increased the amount of education by about a quarter of a year and, more importantly, led to an increase in wages. An interpretation is that offering more education in these low-income contexts can increase productivity and hence growth and can form a justification for educational interventions as part of a policy that will spur development. As in the previous example, this educational expansion led to improvements in basic skills, rather than advanced education that leads to innovation, and is consistent

with intermediate education promoting catch-up growth. However, this study also raises some questions. The author observes wages in the data and estimates a return to education of the order of 10%, which is relatively high, although this is from a very low base, meaning that basic skill prices are very low, implying that in themselves these educational investments are unlikely to account for much convergence in standards of living. Without physical investments that could substantially increase the value of human capital and its share in growth, this would be impossible. When the author extends the analysis to include the self-employed with imputed income, the estimated returns decline to 3.5%. Whether this is a reliable estimate is not clear because of various data issues mentioned in the paper. But if it is, this points to very low returns and reinforces the point that human capital investments alone will not suffice.

Further empirical and theoretical insights into the role of human capital in LMICs are provided by Porzio et al. (2022). They show that as younger cohorts achieve higher levels of education, they increasingly leave agriculture and move into sectors where the returns to schooling are greater. At the same time, productivity gains within agriculture - driven by innovations such as the adoption of high-yielding crop varieties discussed above - reduce the sector's demand for labor. These forces jointly account for the decline in agricultural employment and the reallocation of workers toward more productive activities, highlighting the importance of human capital for structural transformation and by implication for growth and development, and at the same time emphasizing the role of complementary events or actions (innovation and education).

One of the key implications of these studies is that even modest increases in education, particularly those that ensure basic numeracy and literacy, can increase the returns of investment in new technologies. This suggests that education-promoting policies can serve as powerful instruments for development if other investments are not impeded. At the same time, the complementarity between education and innovation gives rise to a potential poverty trap, similar to a hold-up problem: innovation yields higher returns only with an educated

workforce, while the returns to education depend on the presence of innovation. This dynamic helps explain why parents in low-income settings may underinvest in their children's education. Thus, while human capital accumulation is central to growth-oriented policy, economies may remain stuck in a low education, low investment equilibrium. Exogenous shocks, such as the introduction of high-yielding crop varieties or policies that reduce the cost of schooling and improve access may be crucial to breaking out of this poverty trap. Thus the green revolution is a good example of a virtuous cycle of innovation, education and growth.

Lessons can also be learned from the growth of China. China's extraordinary growth was triggered by reforms that encouraged private enterprise and investments, leading to imitation catch-up growth (König et al., 2022; Zilibotti, 2017). We have already argued that such imitation-led growth requires basic skills, and hence human capital should play a role. Indeed, even more so in recent times, when China is transitioning to innovation led growth. So, what has been the contribution of education in accounting for China's growth? As reported in Whalley and Zhao (2010) some earlier studies estimate that growth in human capital accounts for as little as 11.7% of the total. However, when using a measure of human capital that accounts for employment and valued at foregone wages, they estimate a contribution of human capital to China's growth of approximately 39%. Clearly, more work needs to be done here to understand the sources of the extraordinary episode of growth in China. However, it is perhaps another example, where the reforms that allowed investment and innovation combined with a rapid rise in human capital delivered one of the most impressive growth episodes in history, pointing to the importance of complementarity of human capital with the appropriate conditions that allow for investment and innovation.

In a recent paper Gethin (2025) analyzed the role of human capital on growth based on a detailed growth accounting exercise, using microdata from 145 countries. He allows for four types of imperfectly substitutable levels of education[6] as well as endogenous returns that

[6]no education, primary, secondary, and tertiary.

depend on their supply, and accounting for skill biased technical change. He concludes that 45% of global growth in per capita income can be attributed to educational growth. For the lowest 50% in the world distribution of per capita income, the contribution is 43% and, remarkably, in the lowest 20% the contribution increases to 58%, while for the middle 40% the contribution of education growth has been even higher at 69% of total growth. Only in the very top 1% of the per capita global income distribution, education growth accounts for less than 10% of overall growth, as expected. Thus, education accounts for a large part of growth and a reduction in some measure of inequality and indeed poverty.

The general evidence points to human capital as a key factor promoting growth. Importantly, most studies point to complementarities with innovation as a key component of the story. Thus, the conditions that allow for innovation and investment more broadly are likely to be an important factor in generating these results. The green revolution benefited primarily better educated farmers (Foster and Rosenzweig, 1996) but then also induced growth in education and economic restructuring. China's growth points to the importance of structural and market based reforms as the imperative for growth, but without the subsequent increase in education not much would have been achieved. This is all consistent with Akcigit et al. (2020) who prioritize investments in education over R&D subsidies for promoting growth. The inescapable conclusion is that without substantial investments in education growth would be mostly absent or muted at best.

2.8 Human Capital Growth

The discussion above establishes the importance of human capital for economic growth, which should lead to an emphasis on investing in access and quality of education, together with the other necessary ingredients to growth. In fact, schooling has been an emphasis in the Millennium Development Goals (MDG, United Nations, 2000), aiming, for example, at universal primary education and gender educational equality. Educational attainment has certainly increased as we see in Panel A of Figure 1. For example, the average number of

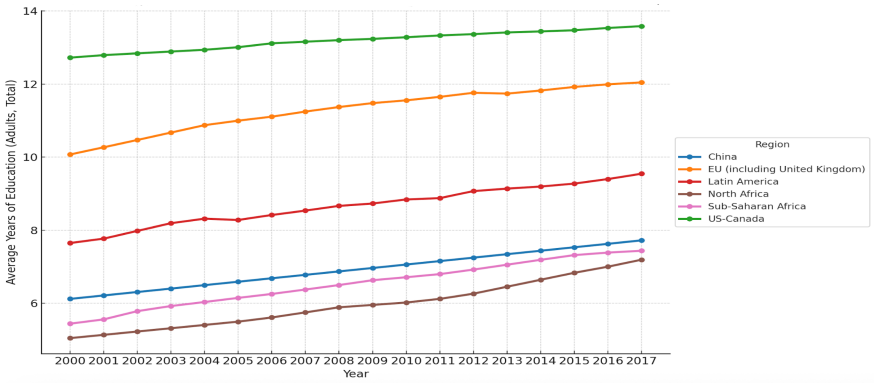
years of schooling increased by about 2 years between 2000 and 2017 in the low education regions, representing between 30%-50% increases. However, while the years of education have grown, learning outcomes tell a different story. In a key paper Angrist et al. (2021) demonstrate convincingly that learning outcomes have not improved. They use various tests, including scores on reading and mathematics tests, which are harmonized to be comparable between countries, to construct learning measures for 164 countries. Some of the key results are shown in Panel B of Figure 1.

Considering the LMIC regions, we see low levels of learning outcomes and no improvement towards closing the gap with European countries and the USA. Even allowing for the fact that the reported growth of HLOs may be biased downward due to composition effects as enrollment is expanding, progress seems nonexistent.

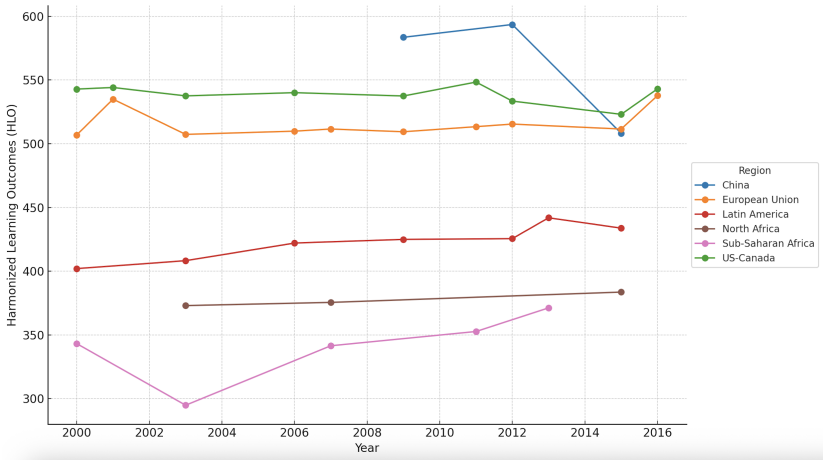
Given the poor state of early childhood development and poor quality of schooling, this should not be a surprise. In terms of ECD McCoy et al. (2016) estimates that in 2010, 43.8% of children 3-4 years of age in sub-Saharan Africa showed low cognitive and socio-emotional development, while the equivalent number in South Asia is 37.7%. Lu et al. (2020) used data from 2010-2016 and concluded that 42% of children in Western and Central Africa were suspected to have developmental delays, with literacy and numeracy particularly low. The picture is similar for East and Southern Africa in general, as well as for South Asia. Latin America and the Caribbean performed much better in this respect, with most registering developmental delays for less than 20% of children.

Conditions do not improve in the schooling period where quality is deficient and learning conditions are poor, as documented in detail in Bold et al. (2017): teacher absenteeism is huge and teacher competence is low. For example, in Africa, on average 44% of teachers were absent from class when they should have been teaching. Children are taught for 51% of the scheduled time and only 66% of teachers are competent with material taught to 4 year olds. Clearly all this adds up to low learning outcomes, which have not been improving over time.

Figure 1: Years of Education and Learning Outcomes over time



(A) Years of Education for selected countries. Data Source: UNDP (2025)



(B) Quality adjusted education across regions. Data Source: Angrist et al. (2021)

Each line in the graph represents a population-weighted regional averages of completed years of education (Panel A) and Harmonized Learning Outcomes - HLO (Panel B) based on the specific countries included in that group. **Sub-Saharan Africa** reflects data from South Africa, Botswana, Ghana, Malawi, Uganda, and Zambia. **North Africa** includes Egypt, Morocco, Tunisia, and Algeria. **Latin America** represents Argentina, Brazil, Chile, Mexico, and Peru. The **European Union** series is computed using France, Germany, Italy, Spain, Poland, and the United Kingdom. US-Canada includes only the United States and Canada. Each regional trajectory therefore reflects the educational quality trends of the specific countries within that grouping. Dots mark the dates where data is available.

What are we to make of these facts? First, there are more children in school and they stay longer. To the extent that some learning is taking place more children have this basic level of education and in that sense aggregate human capital may be increasing, as for example in Latin American countries, where learning outcomes are not as low (although they leave a lot to be desired). In this case, a flat HLO profile with an increasing number of children at that level will correspond to an increase in human capital. However, in several countries, such as those in Africa, learning is hardly taking place, as shown by the particularly low scores[7]. We also know from the Annual Status of Education Report published by Pratham's ASER center (Pratham-ASER-Centre, 2025) that progress in literacy in India is also very slow. In this case, increased enrollment is probably meaningless in terms of human capital and skill acquisition. Given the increasing demand for education and the importance of human capital, there seems to be a missed opportunity to invest in substantial quality improvements. As we discuss below, such improvements can include smaller class sizes (Bowne et al., 2017; Hu et al., 2024; Kim, 2022), better trained teachers (Andrew et al., 2023), scripted lessons to improve teaching practices and support learning (Bassi et al., 2020), incentives for teachers to reduce absenteeism (Duflo et al., 2012) and improve performance (Behrman et al., 2015), and improved basic infrastructure.

3 Understanding Human Capital Accumulation

In many LMICs, despite the increase in years of schooling, both the amount and quality of education remain low, and basic skills such as literacy and numeracy are often lacking as clearly demonstrated by Angrist et al. (2021).[8] So, what are the obstacles that prevent the growth of education and investment in human capital? An answer may lie in an overall context that prevents physical investment, such as excessive labor market regulation (Besley

[7]This statement ignores within group heterogeneity, where some countries are doing a bit better than others. However, the overall picture calls for strong policies that will improve learning

[8]For other examples see the ASER report on basic literacy and numeracy in rural India (Pratham-ASER-Centre, 2025).

and Burgess, 2004; Heckman and Pagés, 2004), which, in turn, makes the returns to education low and dampens the incentives for skill accumulation. Another explanation driving underinvestments in human capital is obstacles to human capital accumulation itself, which may relate to public underinvestments in quality schooling and private constraints in child development and education.

Finally, political instability and high levels of inequality in developing countries have also been shown to inhibit investment in physical and human capital (Aghion et al., 1999; Aisen and Veiga, 2013; Alesina et al., 1996; Alesina and Perotti, 1996). These are not mutually exclusive explanations, and the complementarity between physical and human capital implies that policy must address both.

It is beyond the scope of this chapter to address all these explanations. Thus, against this backdrop, we focus on the process of accumulation of human capital, the obstacles to skill acquisition, the ways in which these can be shaped by parental investments, as well as their incentives to do so, and their interaction with policy. To frame this discussion, we present a simple model of parental investments in child human capital. This framework then allows us to examine the key determinants of skill formation, review what has been learned from various interventions, and highlight the main research gaps.

3.1 Returns to Human Capital

A key driver of investments in human capital and education choices are expected returns. These are the result of economic equilibrium in the labor market and in the marriage market.

The labor market returns will be shaped by available job opportunities and investments in physical capital. In many contexts, job opportunities may be limited due to barriers to geographical mobility, such as those imposed by inadequate transport infrastructure, the complexity of moving with low resources (liquidity constraints), social norms, local networks that provide insurance against risks or other ties to the locality. For example, insurance provided by local networks makes mobility costly because support networks are no longer

available at an alternative location, as argued by Munshi and Rosenzweig (2016). Even temporary migration, which allows for a broader set of economic opportunities, is costly (Meghir et al., 2022). Since returns in rural areas are likely to be lower, such geographical mobility restrictions can imply lower investments in human capital, entrenching poverty, and reducing the opportunities for growth.

A further important reason for potentially lower returns to education are constraints on entrepreneurship, which in turn reduce investments in physical capital. Such restrictions, mentioned above, have been extensively documented in Latin America and India[9] and take the form of labor market regulations that restrict workforce adjustments at the firm level or impose minimum wages that are too high given the productivity. In such environments, formal enterprises are discouraged due to increased costs, and this either stifles investment activity or promotes informality, which in turn shifts business activity to low-productivity sectors (Dix-Carneiro et al., 2021; Meghir et al., 2015). This will also reduce job opportunities for better educated workers and effectively reduce returns to education.

Despite these considerations, several studies have shown substantial returns to schooling, although causality is not always established. These are usually estimated using a version of the Mincer wage equation as in equation 2.1 using ordinary least squares (OLS) and they relate to private returns. Measurement error can attenuate the effects of education and positive selection into education can overstate them. More complex arguments relating to heterogeneous returns can affect the interpretation of the effects when instrumental variables are used, since they may represent a subset of people in the population, namely those induced into education as a result of the instrument (a policy or distance)(Card, 2001; Imbens and Angrist, 1994). In this case there is no clear intuitive explanation or even expectation of the direction of bias. Nevertheless, Gethin (2025) documents that in almost all cases where the results of instrumental variables are compared to those of OLS in Mincer type regressions, the IV results are higher than the OLS.

[9]See Besley and Burgess (2004); Heckman and Pagés (2004)

In Table 3.1 we present estimates obtained from Patrinos and Psacharopoulos (2020), in which the returns to levels of education are shown for low-income countries. They also report an average return per year of schooling of approximately 11% in Latin America and sub-Saharan Africa and 8.1% in South Asia. Duflo (2001) who controls for endogeneity of schooling, reports a return per year of schooling of about 10%, which relates to marginal individuals who attend schooling as a result of a school expansion program, rather than an average in the overall population. This distinction is important because such marginal individuals may have higher returns than the average person. However, when the self employed are included, the estimated returns to education are as low as 3.5%, although this number needs to be regarded with some caution, since it ivolves imputing self-employment income from an alternative data source.

More recently Gethin (2025) has provided detailed information on returns to education worldwide. These are returns based on simple OLS Mincerian regressions. He finds substantial educational returns and, importantly, a convex pattern, with higher levels of education being associated with higher returns per year of schooling. For Latin America, China and sub–Saharan Africa, the returns to a year of primary education are 5%-7%; the returns for a year of secondary vary from 5%-9%, while the returns to a year of education for those with some tertiary education vary from 11%-17%. For India, the contrast is even starker, with a return to a primary year of 1.8% and tertiary 16.1%, with only the rest of Asia and MENA countries[10] having much lower returns from tertiary education (8.5% and 4.2% per year of schooling, respectively). This increasing return to education makes the low education levels even more important to understand. Angrist et al. (2021) argue that the measured returns are biased downward because the observed increases in schooling are not necessarily matched by improvements in learning outcomes. Mendes and Pennings (2025) argue that the return to a quality adjusted year of schooling can be 50% higher. This reinforces the importance of understanding why learning outcomes have not improved in many places.

[10]Middle and North Africa.

Finally, the importance of returns to education must be seen within the relevant context. Often, the base price of human capital (as measured by low skill wages) is very low in a way that an increase of one year of education represents a very small improvement in actual earnings in many of these countries. This again points to the importance of investments for increasing the price of human capital and to enable a catch-up with advanced economies.

Table 2: Returns to education in low-income countries (%).

Educational level	**Private**	**Social**
Primary	25.4	22.1
Secondary	18.7	18.1
Higher	26.8	13.2
Average	23.6	17.8

Note: Based on the full discounting method. The social returns are lower because they account for the subsidies to education.
Source: Patrinos and Psacharopoulos (2020).

Another, often neglected, source of private returns to education is to be found in the marriage market, through the mechanisms of sorting, driven by complementarities in the household production function for children or other public and private goods: the possibility of improving the match provides an incentive itself for investing in human capital. And, moreover, improved matches can have aggregate effects in the economy, beyond improved individual welfare. For example, they could lead to more investments in children leading to an overall increase in human capital, even counting the effect of the costs to couples forming at the low end of the distribution.

In an early analysis of Becker's theory of marriage (Becker, 1981) in the Philippines, Boulier and Rosenzweig (1984) estimate that increases in women's education raise their age at marriage and lead to matches with a higher-earning husband. In the context of an advanced economy, Chiappori et al. (2020) estimate that for women in the UK 58% of the value of college completion and 73% of the value of high school completion are accounted

for by marital returns, while for men the corresponding figures are 21% and 14%.

The marital returns to education also manifest themselves in the way dowries or bride price vary as a function of education (Ashraf, Bau, Nunn and Voena, 2020; Corno and Voena, 2020). Importantly, marital returns to education for women will be positive through these mechanisms, even in contexts where women are typically not expected to work in the labor market, presumably because of their increased skill in home production and child rearing, which then increases their value in the marriage market. Similarly, when dowries are the norm, better educated men can command higher dowries, in part benefiting their parents or the married couple itself (see also, Chiplunkar and Weaver, 2023).

In summary, there is strong evidence that schooling, and even more so quality-adjusted schooling, yields high returns that would justify investments in human capital. Nevertheless, stagnant learning outcomes point to low private and public educational investments. Why this is the case is an important question, and understanding the reasons behind such a deficit can take us a long way to identify some of the factors that impede development. We approach this question by presenting a model of human capital investments during childhood to help us identify potential bottlenecks that can explain underinvestment in human capital. In this context, we discuss the results of interventions that seek to address some of these obstacles and whether they offer promise for promoting human capital growth.

3.2 The Human Capital Production Function

The human capital production function describes the accumulation of skill over the various stages of childhood. Understanding its structure, provides an empirical pathway to designing effective policy for improving human capital at different ages. It depends on the initial conditions of the child, including their genetic endowment and health, on parental investments, public investments through, for example, schools, and on other environmental factors, such as neighborhoods.[11] It is described mathematically by a gender (g) specific production

[11] See, Cunha et al. (2010); Attanasio, Meghir and Nix (2020); Chetty et al. (2016); Ye (2024) among others.

function for age t that we denote by

$$H_{g,t} = F_{g,t}(H_{g,t-1}, M_{g,t-1}, I^m_{g,t}, I^\tau_{g,t}, H^p, X^E_t, u_{g,t}) \tag{9}$$

where $H_{g,t}$ represents the human capital of the child in age t, $I^m_{g,t}$ and $I^\tau_{g,t}$ are parental investments in money and time, that we should think of as taking place between childhood stages t and $t-1$, and X^E_t represents public investments and possibly other environmental factors, including neighborhood characteristics, and H^p represents the human capital of parents, which may include various measures, including cognition and health of the mother and father. $M_{g,t-1}$, represents lagged health of the child and $u_{g,t}$ luck, i.e. random shocks to their development. There is an initial value of human capital $H_{g,0}$, which we may want to think of as the genetic endowment. However, measurement of initial conditions will tend to be made after some environmental factors have materialized, such as in utero nutrition, maternal actions such as smoking, drinking and quality of nutrition, exposure to disease, environmental toxins such as led, etc., all of which are known to affect child development.[12]

Inputs may differ in their effectiveness at different ages. For example, parental stimulation may be a key determinant in the first three years, while public inputs, such as pre-school and school quality, maybe central later on. Child health is likely to be important at various different stages and to affect both the level of investments, such as school attendance (Miguel and Kremer, 2004) and their productivity (Attanasio, Meghir and Nix, 2020). Neighborhoods and peers are key factors in (Chetty et al., 2016; Ye, 2024). The implication is that different interventions may be most effective at different stages. Home visits or groups to promote child stimulation are focused on the first three years; preschool and school interventions from 3+, health interventions throughout childhood.

The structure of the production function and whether it is additively separable in inputs and how it changes from each childhood stage raises important questions and provides an

[12]Some key papers documenting in utero influences of toxins and nutrition on child outcomes include Currie and Neidell (2005); Currie and Schmieder (2009); Aizer et al. (2018); Almond and Mazumder (2013, 2011).

empirical framework to test these based on observational data. The following are two key properties that define how policy should be designed.

Static Complementarities. One important insight from the structure of the human capital production function is that contemporaneous inputs may be complementary. This implies that the productivity of an input may be enhanced if the availability of another input is increased. Cunha et al. (2010) for example use a CES production function that allows for complementarity between the various inputs. In the context of India Attanasio, Meghir and Nix (2020) demonstrate complementarities between child health and parental investments. In other words, malnutrition and other sources of ill health can reduce the productivity of parental investments in cognitive development. This is important because it suggests that packages of interventions are likely to work substantially more effectively than acting on one dimension only. So, for example, a program that promotes health, such as, say, deworming as in Miguel and Kremer (2004) or reducing the incidence of diarrheal diseases while at the same time promoting parental investments, would lead to stronger impacts for each intervention than would have been achieved when implemented on their own. A further key complementarity is between parental investments and parental human capital as shown empirically in several papers (Attanasio, Cattan, Fitzsimons, Meghir and Rubio-Codina, 2020; Attanasio, Meghir and Nix, 2020; Cunha et al., 2010, for example), which can also explain the results reported in our discussion of the "Finish enigma". This is important both for understanding the sources of intergenerational mobility and inequality and for providing a better understanding to target interventions.

Dynamic Complementarities. These refer to complementarities between stages of childhood. The key idea here, studied and promoted by Cunha and Heckman (2007), Cunha et al. (2010) and Heckman (2006) among others, is that the accumulation of child skills in some stage of childhood depends positively on the achievement in earlier stages. The implication is that the productivity of inputs in the stage t is enhanced by the level of accumulation of

previous skills. Dynamic complementarities reflect what the child development literature often refers to as windows of opportunity.[13] The key point is that early development amplifies future potential, while early deficits are difficult to reverse with later remediation. Indeed, the 2024 Lancet series explicitly targets the childhood phase that succeeds the critical 'first 1,000 days.

Most of the evidence on complementarities is based on observational studies, such as those cited above. An exception is Meghir et al. (2023).[14] In this multi-stage experimental study, 192 communities in Odisha, India, were randomly assigned to an early childhood stimulation program (delivered via home visits or group sessions) or a control group. The target children were aged 7 to 16 months. Once this initial two-year stimulation intervention was complete, showing cognitive improvements of approximately 0.3 SD (Grantham-McGregor et al., 2020), the communities were re-randomized. They were assigned to either a higher-quality preschool (lasting from age 3 to school entry between ages 5 and 6) or the status-quo Anganwadi center. This 2x2 design created four groups: no intervention, early intervention only, late intervention only, or both. Cognitive development (IQ) of children who received only enhanced preschool improved by 0.166 SD (SE 0.068). For those who received both interventions, the improvement was 50% larger (0.243 SD, SE 0.077). Although consistent with the complementarity hypothesis, this difference was not statistically significant; thus, the results remain indecisive.

These studies require sufficiently large sample sizes to detect interaction effects and a commitment from sponsors for at least 6–8 years. Yet, to progress beyond small-scale experiments, such multi-stage studies are essential to establish the validity of key policy recommendations. In the meantime, these challenges underscore the continued need for high-quality observational studies in various contexts, both to test such hypotheses and to understand the choices people make and the mechanisms underlying the effects.

In the same way that static complementarities lead us to design packages of interventions,

[13] See the Lancet series on the topic (Engle et al., 2007; The Lancet, 2024).

[14] (See also Heckman et al., 2024; Heckman and Zhou, 2025).

dynamic complementarities lead us to consider human capital policies over the entire childhood. This approach requires understanding the structure of optimal investments alongside the obstacles to accumulation. at every childhood stage. Although important work has been done on access and school participation during adolescence, such as Schultz (2004) andDuflo et al. (2024), more needs to be done to design approaches that will improve quality and learning outcomes at this stage as in the previous ones.

Challenges in the Estimation of the Production Function. Empirical analysis on the technology of skill formation, including the importance of static and dynamic complementarities, requires estimation of the human capital production function. However, doing so is fraught with difficulties. Some of the key issues relate to the measurement of human capital, which is an abstract concept and can only be proxied, for example, by results from various tests, including IQ tests and learning outcomes in mathematics and reading. The approach taken usually is one of dimension reduction through factor analysis, where the various proxies are combined to extract a latent factor that represents human capital (Cunha et al., 2010). However, the value of this approach ultimately rests on an appropriate choice of proxies.

A deeper issue is the dimensionality of human capital. Cunha and Heckman (2008); Cunha et al. (2010) and others have suggested two dimensions, namely cognitive and noncognitive skills (known in the psychology literature as socio-emotional skills). Both have returns in the labor market.[15] From an economic point of view, the dimensionality of human capital is important to the extent that the relative prices of such skills vary over time. If they do not vary, then all of these can be aggregated into one dimension.

Similarly, measuring investments is also complicated both because they are hard to observe and because they may be difficult to characterize. In a broad sense expenditures for children measure investment in resources, while time spent with children measures time in-

[15] Abbott et al. (2019) among many others show returns in cognitive skills inn the labor market for different education levels, while Deming (2017) shows how socio-emotional skills have increased in importance.

puts. However, which expenditures and what time consuming activities should be included is not always clear and depends on their developmental value. For example, time spent with children watching television may not be a productive activity developmentally, while reading books to a child most probably is. On the other hand, watching television may create bonds and improve socio-emotional skills, arguably a different dimension of intelligence (nocognitive skills). Our ability to construct high quality measures of investment depends on quality data collection. Attanasio, Cattan, Fitzsimons, Meghir and Rubio-Codina (2020) are able to use detailed measures of various activities, which they split between material and time investments to construct two latent input factors. Data of such quality is not always available. These are important difficulties that can affect results from empirical work and ultimately our understanding of such investments.

Cunha et al. (2010) show identification of general production functions, with possible nonlinearities, when only proxy measures of human capital are available, and Agostinelli and Wiswall (2025) discuss some of the challenges related to estimating the dynamics of the production function. In practice, research related to these issues will have to combine information from observational studies and experiments such as those of Heckman and Zhou (2025) and Meghir et al. (2023), which examine experimentally static and dynamic complementarities.

3.3 Parental decision making

We present a stripped down model of parental investments in children to make some key observations on their determinants and gain insights in the obstacles for human capital accumulation. In this model there is one type of investment, and we ignore child gender, to which we return later. Parents are assumed to make decisions about the allocation of financial and time resources to the child and themselves. These decisions take the form of investments in child human capital (I). They trade off their own consumption with the cost of investing in children given their own perceptions of the human capital production function

and given their budget constraint.

In the simple model that follows, the household is a collective (Chiappori, 1988, 1992), where each parent has their own preferences ($U_i(c_i) + \mu_i U_c(H)\ i = mother(m),\ father(f)$) over consumption ($c_i$) and child well-being as a function of its human capital ($U_c(H)$). Each parent is altruistically linked to the child with parameter μ_i. The child's lifetime utility $U_c(H)$ is an increasing function of its human capital H. Assuming efficient intrahousehold allocations the household maximizes

$$U = \lambda(U_f(c_f) + \mu_f U_c(H)) + (1-\lambda)(U_m(c_m) + \mu_m U_c(H))$$

subject to the budget constraint

$$Y = c_m + c_f + I \tag{10}$$

where Y is household income, and subject to the human capital production function, which in this simplified setting takes the form

$$H = F(I, H_0, H^p) \tag{11}$$

where H_0 is the initial condition of the child and H^p is the ability of the parents. In the above, λ is the Pareto weight and reflects the bargaining power of the father (and $1-\lambda$ of the mother). It will be a function of variables that determine the relative position of the man and the woman. The combined altruism parameter is $\mu(\lambda) = \lambda\mu_f + (1-\lambda)\mu_m$ and thus depends on the relative bargaining power of the parents.

The first-order condition for monetary investments in child human capital can be written as

$$\mu(\lambda)\frac{\partial U_c}{\partial H}\frac{\partial F}{\partial I} = \lambda U_f' = (1-\lambda)U_m' \tag{12}$$

These look intuitive enough, with the return to human capital investment and the bargaining power of the parents both being important components. However, the interpretation is

complex. This is effectively a version of the collective model with public goods of Blundell et al. (2005), where preferences for public consumption (child investments here) are additively separable from private ones. The key result in that paper is that an increase in the bargaining power of the mother will increase investments in children if the mothers willingness to pay for child investments *is more elastic than the fathers*. The potential ambiguity of the effect on child investments arises from two competing channels. First, if $\mu_m > \mu_f$, i.e., the mother values the utility of the child more than the father, this drives towards more investments in children when her bargaining power increases. However, there is also a redistribution channel that depends on the curvature of the private utilities and the starting point of the bargaining power and intrahousehold distribution. For simplicity, assume that preference for private goods are concave and the same for both parents. Then, when the mother commands almost no bargaining power, a small shift in bargaining power in her favor may decrease child investments because of her high marginal utility of consumption. Only if the marginal utilities of consumption of the two parents are similar can we be sure that a reallocation to the person who values child utility most will also lead to an increase in child investments. This is important because it illustrates that increases in female empowerment may not necessarily increase child investment, particularly if the initial position of the woman is very weak, with a very high marginal utility of consumption. Empirical analysis is needed to shed light on this issue.

One can generalize the model to introduce dynamics, introducing separate developmental stages. Based on the ideas of dynamic complementarities, the productivity of investments in one period (say during school) may increase with investments in earlier periods. This is the key notion underlying the importance of the first three years as a window of opportunity, which has been extensively discussed in the child development literature. In practice, liquidity constraints can prevent parents from allocating investments to children in the optimal time (Carneiro et al., 2021).

Parental Beliefs. A key question is whether parents know the production function in the sense of understanding the returns to investing in children, and perceive the windows of opportunity and the dynamic complementarities, that may be crucially important in developing human capital. Lareau (2003) notes that in low-income settings, parents believe they have a role in protecting their children and allowing for "natural development", but cannot otherwise affect their development trajectory. Further evidence Cunha et al. (2022) develop a method to elicit parental expectations and beliefs about the effectiveness of child investment. They show that mothers have highly heterogeneous expectations associated with income, with higher income mothers having higher expectations on the effectiveness of investments. They also show that these expectations are an important determinant of parental investments.

Following this evidence, a model that would allow for this would explain parental choices on the basis of a modified production function reflecting parental beliefs, instead of the actual technology of child development. In practice, estimating such a model would require estimating the subjectively held production function, say F^{PB}, an exercise carried out in Cunha et al. (2013) and in Attanasio et al. (2019). However, this is complicated in practice if investments and other inputs have multiple dimensions.[16]

3.4 Obstacles to Human Capital Accumulation

We have already documented the lack of progress in learning outcomes of LMICs. Deficits in early childhood development, together with the dynamic complementarities identified in the literature, point to early childhood as an important part of the problem. The issue is illustrated by survey data from Bogota, a capital city in a medium income country, as

[16]This approach can also be used to study the potential difference between mother and father beliefs about returns to different investments, financial and non-financial such as time. This was done in a small study in Tanzania where it was suggested that mothers and fathers' beliefs were similar for high initial condition children, but mothers have – in this context – higher expectations about returns to investment in low initial condition children (Almås et al., 2024). This finding was general in all domains, for example, socio-emotional and cognitive development, as well as in different investment categories such as financial and time investments.

reported in Rubio-Codina et al. (2015). They compare child development across the parental wealth distribution. Focusing on the differences between the top and the bottom wealth quartiles, they show that in the first months after birth the cognitive scores across these two wealth quartiles are already different by 20% of a SD, which is bad enough.[17] However, cognitive development diverges widely thereafter reaching a massive 80% of a SD at 42 months. Similar gaps develop for early language measures.

We now discuss obstacles to child development and the accumulation of human capital, starting with a general overview of the various channels suggested by the model. We distinguish three broad channels: Preferences, household resources, and the perception of the human capital production function by parents.

Household Resources Since Becker and Tomes (1986) it has been well understood that resources can be a key determinant of intergenerational links through the accumulation of human capital. Even if parents fully internalize the interests of the child in the accumulation of skills, they may not have the resources to invest. First, parents may themselves be poor, which would require them to borrow against the income of the child, which is not feasible in practice. Second, even if their lifecycle resources are somehow adequate, their timing may not coincide with the timing of the child's needs (Carneiro et al., 2021), which is where the impact of liquidity constraints becomes important. This would imply that the marginal propensity of parents to invest in their child's skill accumulation will be high, and consequently cash transfers may be an effective tool for directing resources to children. However, in very poor communities, it is the lack of overall resources and the inability to borrow against the human capital of the child that is likely to be the constraining factor in child investments.

The importance of financial resources may vary over the lifecycle. At a very young age, parental investments are not necessarily financially demanding, but do require the mental space to engage with children (Mani et al., 2013). This may explain the null results of

[17]The gap is presumably due to differences in nutrition and other factors starting during pregnancy and due to parenting and environmental factors in the first six months of birth.

unconditional cash transfers in the first years at least in the US (Noble et al., 2025; Duncan et al., 2025). However, in other contexts and older ages resources have been shown to matter in both experimental and observational studies. Examples include (Duflo et al., 2024, 2015*a*; Keats, 2018) and Attanasio, Meghir and Nix (2020) respectively.

Mother's bargaining power, intrahousehold allocations and preferences. Parents affect the development of their child by making several choices, including spending money and taking time to engage with the children and facilitate their educational and formative activities. Investments can take many different forms, including actively engaging the child in play-based learning, purchasing educational materials such as toys and books, and choosing better neighborhoods and higher-quality schools. All these activities cost money and time and, consequently, need to be traded off against the adults' consumption and leisure. The degree to which parents are willing to give up resources and time depends in part on their preferences.

Two important factors will be at play: First, the extent to which parents value the child's future welfare. This depends on the degree of altruism; if this is low, parents will underinvest in their education and development from the child's perspective. If the child could promise to repay the parents and the latter were not liquidity constrained, optimal educational investments could take place, from the perspective of the child. However, it is not possible for the child to commit to repay, and this avenue is not a practical solution to underinvestments.

The second factor is the potentially divergent preferences and beliefs between mother and father and the bargaining power of each. As discussed earlier, the allocation of bargaining power plays an important role in determining investments in children, although it is not always the case that a small shift in bargaining power in favor of women will increase them. This is an empirical question, which we discuss in Section 4.1 below. However, divergent interests and bargaining between parents add an important element to the discussion.

Women's relative bargaining power, is likely to depend on many factors, and it is often assumed that education increases women's empowerment, because it may improve autonomy and labor market earnings, marriage market options and life as a single person. However, measuring empowerment remains empirically difficult. Although the link with education is likely, because of the opportunities education offers both in the labor market and in the ability to operate broadly in society, the relationship is not immediate. Indeed, the study by Behrman et al. (1999) in part speaks to this issue: The green revolution in India increased the labor market opportunities for men but not for women. However, the demand for better educated wives increased due to a greater demand for human capital among children. In turn, better educated wives invested more in children, demonstrating the intergenerational benefits of women's education. Nevertheless, the authors present evidence that this impact is not a result of women's empowerment, but an increase in efficiency of mother's time in raising children. In other words, it is all about static complementarities in the human capital production function between child investments and maternal skill (here literacy). The authors do not claim generality, and the role of education in women's empowerment and hence in child investments may well depend on the context and the outside options that women have.

With these caveats on the link of education and empowerment in mind, we discuss results on the effect of education on women's outcomes and investments in children. Duflo et al. (2024) show that female scholarship recipients in Ghana increased their education, delayed fertility, and had fewer unwanted pregnancies—though total fertility eventually converged to the control group. Moreover, these women also invested more time in actively engaging with their children, who were exposed to significantly more verbal communication. Similarly, studying the effects of universal free primary education in Uganda, Keats (2018) finds that increased women's education led to a delay and decline in fertility, alongside increased early health investments in young children.

Breierova and Duflo (2004) show that the expansion of schooling in Indonesia reduced

fertility; while this study did not observe direct inputs in child rearing (such as time or spending), the simultaneous reduction in early child mortality suggests an increase in effective investment. This pattern is consistent with the standard quantity-quality trade-off (Becker and Lewis, 1973) and the literature on production functions that emphasizes complementarities between maternal skills and child inputs. It also aligns with Thomas (1990), who rejects the unitary household model by showing that women with higher unearned income (and thus greater bargaining power) have fewer children, yet these children enjoy better nutrition and survival rates.[18]

Although women's education seems to improve child outcomes in a variety of contexts, the mechanisms through which this is achieved vary. Further discussion of these issues can be found in Black and Kowalski (2021), Doepke and Tertilt (2019) and others cited above. Women's empowerment is clearly an important goal that needs to be pursued for its many social advantages, including economic growth (since the workforce will increase) and the well-being of the women themselves. Whether women's empowerment in itself will also lead to increased investments in children is an open question.

Parenting Practices and Norms. As mentioned earlier, another key obstacle are parental beliefs about the return to investing in children, represented by a distorted perception of the human capital production function. In fact, the literature on parenting interventions, starting with the Perry preschool experiment (Heckman et al., 2013) and ABCderian (Ramey and Campbell, 1984; Campbell and Ramey, 1994) and the interventions we will discuss below, is based on the idea that parents in low-income settings follow parenting practices that are not consistent with active and stimulating engagement with their children. In the context of LMICs, there is evidence on a limited understanding of the importance of actively engaging children as discussed in Attanasio et al. (2019) and Dupas et al. (2025).

The distorted beliefs are also culturally embedded. An example of this is described in

[18]In the context of the US, causal evidence of the effects of mother's education on a broad range of child human capital outcomes is presented in Carneiro et al. (2013), although it is unclear if this reflects women's increased bargaining power or just improved efficiency in raising children and increased resources.

Weber et al. (2017), who also design an intervention to address the issue. They report that in rural Wolof-speaking communities of Senegal, prevailing norms have traditionally discouraged verbal engagement with infants, which we know to be fundamental for child development. Caregivers often believe that speaking directly to babies is pointless or even dangerous, fearing that doing so might invite evil spirits or mark the adult as "crazy" for talking to someone who "is not there." Contrary to what we understand as stimulating child development, eye contact and direct speech are avoided, and the social expectation is that infants are soothed and physically cared for, but not addressed verbally until they are older and more socially responsive. These beliefs, deeply embedded in local understandings of child development and social propriety, have historically limited the amount of child-directed speech in early life, reinforcing a caregiving environment geared toward protection and survival rather than verbal interaction and cognitive stimulation, and hence limiting human capital accumulation. Of course, it is possible that these norms and beliefs are in tune with local needs and that they could evolve as returns to human capital increase. However, our next example shows that such a transition may not be straightforward even when the economic incentives are strong.

As reported by Munshi and Rosenzweig (2006), lower cast male workers in Mumbai tend to work in blue collar jobs, and indeed these are finely defined by the precise sub-caste to which they belong (*jati*). Jobs are obtained through the caste network, and hence there is a strong incentive to preserve the integrity of the network. They then examine the effects of the rapid rise in the return to English-speaking education, which is a passport for high paying white-collar jobs. A response based on returns should imply a shift from Marathi teaching schools to English speaking ones. And yet, lower caste boys continue to be educated in dead-end Marathi-speaking schools, with no convergence between upper and lower caste boys, even after the dramatic increase in the returns to English. This is an example where the relative security provided by an established network prevents families from taking advantage of increasing but possibly uncertain opportunities in the growing modern sector. It points

to the potential usefulness of social insurance programs that would support the transition to high return education and occupations.

Gender Norms and education. As children reach adolescence, investments in boys' and girls' human capital diverge due to gender norms and incentives arising from the marriage market. Although the drivers of dropout vary by context, economic constraints remain a significant barrier to girls' schooling, particularly when social norms dictate how resources are allocated. Duflo et al. (2015*a*), in an experiment in Kenya, showed that girls' school participation is highly sensitive to subsidies. Similarly, a major evaluation by Duflo et al. (2024) found that young women in Ghana who received scholarships stayed in school longer and delayed both marriage and pregnancy.

Beyond direct economic costs, a set of important papers has analyzed the broader structure of incentives derived from the marriage market, including parental preferences regarding match quality and marriage timing. Corno and Voena (2020) show, for example, that in periods of economic hardship, such as droughts, girls in bride price societies are more likely to drop out of school and marry early, as the resulting bride price helps smooth household consumption. In contrast, in regions where dowry is the norm (e.g., most of India), economic hardship leads to marriage delays. Furthermore, because the bride price norm increases the marital returns to education, a reduction in the cost of schooling significantly increases take-up in bride price areas (Ashraf, Bau, Nunn and Voena, 2020). Indeed, marriage market returns are often the primary driver of female schooling. In hypothetical scenarios in Rajasthan (India), eliminating marital returns to education reduces participation in schooling at age 16 by 60%, and almost all girls drop out by age 18 (Adams and Andrew, 2025).

However, market incentives are not the only factor; a key friction is the agency of girls and how this interacts with social norms. This is addressed by Ashraf, Bau, Low and McGinn (2020); Ashraf et al. (2025) through an intervention that teaches girls to negotiate with their parents. They find that improving negotiation skills led to increased education, as well as

other important benefits, such as delays in initiating sexual activity and smaller age gaps with husbands.

Andrew et al. (2022) experiment with an intervention that explicitly addresses social norms, such as prohibitions on walking to school with boys, staying out past 7 PM, and distorted views about menstruation that restrict girls' schooling. The intervention helps girls avoid internalizing these restrictive norms and equips them with strategies to navigate or challenge them. In a separate experimental arm, they combined this with a community engagement program, organizing meetings where girls raised issues discussed in their groups with community leaders to encourage a shift away from restrictive norms, violence, and harassment. They found that while the girl-focused intervention increased schooling and delayed marriage, mental health improved only when community norms were also addressed, making the girls' new behaviors more socially acceptable. Similarly, Dhar et al. (2022) experiment with engaging adolescents in classroom discussions to shift beliefs; they find that while norms can be shifted, the evidence for improvements in educational outcomes is suggestive but modest.

Finally, mobility constraints related to safety and social reputation are critical barriers. In a particularly interesting policy evaluation in India, Muralidharan and Prakash (2017) show that a program offering bicycles to girls increased secondary school enrollment by 32% (reducing the gender gap by 40%) and increased pass rates on high-stakes exams by 12%, effectively overcoming the cost of distance.

The key takeaway from these studies is that human capital policy must address social norms and beliefs if gender gaps in education are to be closed. In the current context, where many women do not participate in the labor force, the marriage market remains the dominant source of incentives for girls to obtain education.

Similarly, the relationship between gender norms and economic development, with a focus on participation in the labor market, is examined in depth in Field et al. (2025). The authors highlight both the central role of gender norms and the prevalence of biased beliefs about

those norms, and they discuss important measurement challenges. These include how to elicit norms and beliefs while minimizing social desirability bias, as well as how to identify the causal effects of norms on economic outcomes, such as women's labor market participation.

4 Policies in theory and in practice

Although understanding the deficits in the accumulation of human capital and their likely causes is the first step, the overarching aim is to design policies that can mitigate or even eliminate the obstacles. Experimental studies addressing some of these issues have been central in developing policy instruments to stimulate human capital accumulation. They can be particularly useful, in a way that broad observational studies are not, in that they allow a focus on specific solutions, such as particular forms of ECD interventions. However, the difficulty is that the experiments are piecemeal and typically address one or two specific problems at a time. There is a tension between designing effective packages and testing individual interventions. Factorial designs where both individual and combined interventions are tested are often too expensive to implement for the kind of budgets available, and the choice of what should be tested is often arbitrary and based on small pilots.

Even ambitious experiments that test sequences of interventions (Meghir et al., 2023) are in practice limited by cost considerations and the time it takes to implement and obtain results. Ultimately, the strongest feasible approach will be a combination of well-targeted RCTs coupled with structural modeling with the ambition of understanding what the set of policies should be for children and their families throughout childhood.

But even this faces important theoretical and practical difficulties. A model-based structural approach to understanding the process and obstacles in the accumulation of human capital at the individual level provides us with the pathways through which policy may operate. It can also help explain how specific interventions affected the outcomes, further enriching our understanding of policy design (Attanasio, Cattan, Fitzsimons, Meghir and

Rubio-Codina, 2020). However, one limitation of the structural approach that goes through the production function is that it may be too abstract when it comes to understanding what works and what does not. Some interventions, such as cash transfers, are easy to map into a theoretical framework: they improve household resources. How this translates to investment in children is governed by the processes we discussed above. But what do we make of parenting interventions that teach parents to better engage with children, without necessarily spending more time or even resources with them? There may be more effort involved, but how is this measured and how should we price it if we are to incorporate it in a structural economic model of behavior? While the effect of such interventions will be to shift the production function, say by increasing TFP, measuring the (shadow) prices that parents face when deciding to improve parenting is not obvious. This is an open question.

In what follows, we review some of the interventions that have been studied, their results, and how we can use them to learn key policy questions. We follow the progression of childhood and start with early learning, progressing towards policies that enhance school quality. The key conceptual idea here is that we are in possession of evidence based policies that if implemented appropriately and with attention to detail are able to enhance the accumulation of human capital leading to improved learning outcomes and growth.

4.1 Parenting early learning and preschool

Dynamic complementarities imply that the early years are crucial for subsequent human capital accumulation. Yet, among the poorest segments of the population, developmental deficits build up very early in the child's life as as documented earlier, undermining future skill acquisition and the subsequent effectiveness of human capital policies. In fact, a successful early childhood development (ECD) policy can lay the foundations for later success and possibly reduce the fiscal costs of achieving increased skill accumulation.

To address this issue, several experimental studies have been conducted to evaluate whether interventions that improve parenting skills have long-term effects on human capital.

Attanasio, Cattan and Meghir (2022) provide a detailed overview of the evidence. Here, we summarize some key results to provide an understanding of the scope of such interventions.

The Jamaica Study, Grantham-McGregor et al. (1991) This study is the inspiration for much of the ECD work that followed over the next decades and has now generated an approach to child development known as *ReachUp and Learn* (Walker et al., 2018). The program consists of sending a home visitor once a week for two years to work with the mother and her child based on a specially designed curriculum. The target children were specifically chosen to be malnourished, as measured by stunting status (height for age less than two SDs below the WHO mean). The mother is trained to provide psycho-social stimulation during the week by being introduced to several structured activities that address cognitive, language, motor, and socio-emotional development. She is encouraged to integrate such activities in the daily life with the child. Play activities include solving simple puzzles, story telling with age-appropriate books and images, songs, etc. The program is designed as parenting training, where the impact is expected to occur due to a change in the way parents interact with the child, and not simply through the weekly sessions with the home visitor.

TIn the experimental evaluation mother-children pairs were randomly allocated to four groups: a group that received the stimulation intervention, described above, a group that received a nutritional intervention, in the form of powder milk, a group that received both, one group none (control). The nutritional component offered 1 kg of milk-based formula each week for two years to the target child. They also offered cornmeal and skim-milk powder to the other children to deter sharing and diluting the intervention. If the nutritional component, together with the extra nutrition for the adults, is inframarginal and just alleviates the household budget, it could be considered as a cash transfer. In this sense, it offers us a direct experimental comparison of parenting and money. However, the literature on the cash value of in-kind transfers, provides mixed answers about this (Hoynes and Schanzenbach,

2009; Hastings and Shapiro, 2018).

In this sense, it offers us a direct experimental comparison of parenting and money. However, the literature on the cash value of in-kind transfers provides mixed answers about this (Hoynes and Schanzenbach, 2009; Hastings and Shapiro, 2018).

The results are fascinating: At the end of the intervention, the cognitive development of the children receiving stimulation was higher than that of the control group by 80% of a SD. The children were followed up later and some of this effect faded, but still remained about 40% of a SD. A long term follow up 20 years later, when the children were approximately 24 years old, found substantial increases in earnings relative to the control group, of the order of 25% (Gertler et al., 2014). In other words, the early stimulation intervention was transformative, despite no further policy-induced intervention at later stages.

However, the nutrition intervention had small impacts that faded soon. Keeping to our interpretation of this component as effectively a cash transfer, the conclusion of this study is that a parenting intervention can be life-changing, at least for children in extreme poverty who have suffered from malnutrition, but cash itself (or nutritional subsidies) had no effect. The key problem is not just the lack of resources for child investments, but the way parents in such circumstances engage with their children. Understanding the lessons from such an intervention is central to how policy can and should be designed.

Scalable Early Childhood Interventions Inspired by the Jamaican intervention, several studies attempted to replicate these effects with designs that are perhaps easier to bring to scale. Examples include Attanasio et al. (2014) in Colombia, Andrew et al. (2019) in the Indian city of Cuttack, Grantham-McGregor et al. (2020); Meghir et al. (2023) in rural Odisha (India) and Zhou et al. (2023) in China.

A key feature of these interventions is the use of local human resources and, in some cases, existing government infrastructure to implement an ECD program People delivering the program had no specific qualifications and their education levels were similar to those of

the mothers. To be specific, these programs require home visitors to attend the mothers and their children or to run groups where mothers visit with their children, to provide suitable parenting training. Locating and paying trained people (usually women) in these settings is both hard and expensive. The approach followed in Colombia and India is to train local women with a position of trust within the community, but otherwise without any special experience or qualifications. In Colombia the intervention used the Madres Lideres, women who mediated between the beneficiaries of the conditional cash transfer program authorities (Familias en Acción) and the beneficiary families. In India, these were local community workers trained by Pratham, a large educational NGO. In both cases, they were trained by a relatively small number of mentors who had some qualification, such as social work. Their role included training home visitors, providing support throughout the intervention, and monitoring performance. In India, such an intervention still cost USD 135, which at 10% of per capita GDP may be considered high for universal application, or even if just the poorest areas are targeted.

Grantham-McGregor et al. (2020) designed an experiment in which children in 192 communities in Odisha aged 9-16 months at baseline were randomly assigned to a home visit parenting program inspired by the ReachUp program in Jamaica (Walker et al., 2018), a nutritional education program, a new intervention in which ReachUp parenting was delivered in groups of up to 8 pairs of mother-child by a facilitator who coordinated activities between participants, and a control group with no intervention.[19] Although this last intervention was introduced as a cost reduction exercise, surprising results were revealed when it was experimentally compared to the original home visit program. The effectiveness of the the group-based parenting program at 30% of a SD for cognition on an intention-to-treat basis was essentially the same as the home visit model, if not stronger. In fact, once they allowed for compliance (attendance), the effect of treatment on the treated was 0.40 SD for home visits and 0.55 SD for the groups. An interpretation of this surprising result is that moth-

[19]For completeness note that both the home visiting parenting program and the group delivery included a the nutritional education intervention.

ers learn from each other and encourage each other in a context where otherwise they are highly isolated. In fact Andrew et al. (2024) shows that as a result of the intervention, social networks were reinforced among mothers participating in group sessions. This approach reduced the cost to USD35 per child per year, making it a realistic policy option.

The value of these programs rests on the assumption that they have log-term sustained effects. Here the results are mixed. The starting points are prototypical programs such as the Perry preschool program (Heckman et al., 2010; Heckman and Karapakula, 2019) and the ABCderian (Campbell and Ramey, 1994; Garcia et al., 2020) as well as the Jamaica (Gertler et al., 2014) program that have shown extraordinary long-term effects. But this is not universally the case. For example, the effects of the Colombia program faded completely two years out (Andrew et al., 2018). However, the follow-up of a home visit program inspired by the Reach Up intervention in Jamaica (Andrew et al., 2019) showed very strong impacts about five years later (Jervis et al., 2024).

The reason these questions are important for our context is that they highlight the details and difficulties of designing human capital policies in low-income settings. If we cannot get early childhood development right, we will be unable to build a process of skill accumulation that will improve human capital and moderate inequalities. Finding effective and affordable programs with long-term sustainable effects is harder than it sounds.

With this motivation in mind, Meghir et al. (2023) presents an experiment in which the communities in Grantham-McGregor et al. (2020) were rerandomized to a higher pre-school or alternative to the status quo preschool offered by the Indian government (Anganwadi centers). The purpose of the experiment was to measure the complementarity of the early intervention with a subsequent one, as well as the sustainability of the impacts for those who did not receive the second intervention. It created four broad experimental arms over a period of nearly five years: Those receiving both interventions (early stimulation through home visits or groups, followed by enhanced preschool) only the early stimulation, only the enhanced preschool, or none. The experiment showed that all interventions improved child

cognition and the impact was greatest when both interventions were offered, although not significantly. The key idea here, which requires more investigation, is that a sequence of well-designed low-cost interventions can provide the basis for human capital accumulation, counteracting the the obstacles originating in poverty.

Parental decision making and targeted transfers. Early research suggested that improving women's empowerment (as measured by their share of income) can lead to substantial changes in the composition of household spending and possibly increase investment in children (Lundberg et al., 1997; Thomas, 1990). Some more recent studies have also linked women's influence on household decision-making to increases in food expenditure (see e.g., Armand et al., 2020) and specifically to the allocation of food for girls (Duflo, 2003).

Motivated by such findings, many policies, including government child benefits and conditional or unconditional cash transfers, are designed to transfer resources specifically to mothers to improve *parental investments* in children and school attendance (Fiszbein and Schady, 2009; Duflo, 2012; Crosta et al., 2024). However, the theoretical prediction as to whether targeting women raises child-directed spending is not clear; it depends on the woman's initial bargaining power in the household as well as her preferences (see above and Blundell et al., 2005).

Consistent with this theoretical ambiguity, the evidence on whether targeting women raises child-directed spending is mixed, and estimated effects vary substantially by spending category and context (Bastagli et al., 2016; Crosta et al., 2024; Almås et al., 2020). Evidence from PROGRESA/Oportunidades in Mexico highlights these variations. Angelucci and Attanasio (2013) find that transfers to women increase both the share of food expenditure and the quality of the diet, while Tommasi (2019) show that these transfers are associated with reductions in within-household inequality. Regarding non-food expenditures, Bobonis (2009), Attanasio and Lechene (2002), and Rubalcava et al. (2009) find a positive effect of an increase in women's income share on the budget share spent on children's clothing; Rubalcava

et al. (2009) also find a positive effect on the budget share for educational expenditure.

In contrast, evidence from randomized control trials (RCTs) that explicitly vary the gender of the recipient often yields null results. For example, Benhassine et al. (2015) show that a labeled cash transfer in Morocco had the same large, positive effect on schooling regardless of whether it was issued to the father or the mother. Similarly, Almås et al. (2020) find no significant differences in consumption or nutrition between male and female recipients in a highly powered experiment in India, and Haushofer and Shapiro (2016) find similar null results in Kenya.[20]

There are, however, important exceptions. Armand et al. (2020), studying a conditional cash transfer program in Macedonia, find that transferring cash to women increases the food share of expenditure by 4–5 percentage points relative to transfers given to men, though they find no difference in budget shares spent on children's clothing, education, or health. Whether conditionality is the salient difference between the results in this study and those of unconditional cash transfers is still an open question. Conversely, in Burkina Faso, Akresh et al. (2016) find that in times of low rainfall, targeting men actually improves the diet for children compared to targeting women, with no difference in education or health spending.

There are several potential reasons for these mixed results. First, cash transfers might not affect the woman's bargaining power, perhaps because the amounts are too small or the time horizon is too short (Chiappori and Mazzocco, 2017). Second, the assumption that women prefer to spend more on children than men do might be flawed (and particularly so, for marginal changes). To investigate this, a growing literature uses laboratory experiments and preference elicitation. Ringdal and Sjursen (2021) find that in Tanzanian couples, the identity of the decision-maker does not affect allocations to child tutoring. Similarly, Cherchye et al. (2025) conduct an experiment in Nairobi and find that women do not have stronger preferences for children's meals than men. However, using hypothetical questions in Tanzania, Almås et al. (2024) find that mothers allocate significantly more to children (driven

[20]Duflo (2012) reviews the earlier literature on women's empowerment, while Almås et al. (2021, 2023) provide recent surveys on empowerment and household allocations.

by food and clothing) and less to fathers compared to joint decisions, though they find no difference for health and educational expenditure and significantly less for transport.

Complementing these experimental studies, Dunbar et al. (2013) employ a collective model to estimate the share of resources allocated to children. Their work reveals high levels of child poverty and shows that as the number of children increases, the mother decreases her share of consumption to allocate more to the children, while the father's share hardly changes.

In sum, whereas targeting women seems to have a positive effect in some contexts and for specific spending categories such as clothing and food (Lundberg et al., 1997; Armand et al., 2020), studies on the promotion of school attendance typically fail to find any differential effect of targeting mothers versus fathers (Armand et al., 2020).

Childcare and Preschool. In many contexts, young children are placed in a nursery setting from a very young age. This allows women, who are traditionally the principal caregiver, to develop their career, a growth enhancing activity, as well as to offer freedom of choice. It is also an important opportunity to implement policies that improve child development: a recipe for a win-win policy.

Beyond the very young ages, where attendance could be either a complement or a substitute to parenting programs we discussed above, it is becoming standard policy for center-based early learning programs for children from 3 or 4 years old. Such preschool programs are common in advanced economies and are becoming more so in many LMICs.

The experience with these policies has been mixed, which illustrates both the pitfalls and the opportunity to improve the accumulation of human capital. Several studies, whether quasi-experimental or evaluated by randomization, have shown a array of mixed results. The study by Baker et al. (2008) in Canada and the longer term follow up (Baker et al., 2019) shows short- and long-term adverse effects on children's socio-emotional development and in the longer term increases in crime. The adverse effects are particularly pronounced for

children who began attending under the age of two. On the other hand, the US head start program as analyzed by Kline and Walters (2016) leads to large developmental gains for the children, especially when the authors control for the fact that many children substitute into the program from others of comparable quality. Similarly, Cattan et al. (2022) demonstrate the longer term physical and mental health effects of Sure Start, an equivalent UK program. In a study in New Haven (USA) Humphries et al. (2024) while demonstrating large effects on labor supply (as in the Canadian study) find no effects on children (either positive or negative), and this may be attributable to substitution from other similar programs. Finally, Drange and Havnes (2019) shows that children who won a place in a preschool in Oslo through a lottery, entering preschool earlier at about 18 months (instead of 23 months on average for the control group) enjoyed substantial gains by age 7. The lesson from the advanced countries is that center based quality can really matter. Early education is an important tool for enhancing the accumulation of human capital at an early age, and requires appropriate investment in quality.

We also have some evidence in LMICs. In a recent study Meghir et al. (2023) show in a randomized study in Odisha (India) that improving the quality of preschool by adding materials, training the preschool teacher, and offering on the job coaching to improve productive engagement with the children leads to substantial improvements in cognitive development, relative to the status-quo preschool. For example, attending the enhanced pre-school with no previous intervention improved IQ by 17% of a SD (p-value 0.035) after about a year. Interestingly, this is the same as the effect of IQ at that age, for children who only received the early intervention; hence the late intervention allows for catchup. However, the case where the enhanced pre-school followed an early parenting program in the age range 1-3 years, the IQ effect is 24% st. Dev (p-value 0.007), although the difference, while large, is not significant. The counterfactual in this case was a status-quo low-quality government preschool, while the intervention enhanced these government pre-schools.[21] Similarly in a

[21] Using school readiness as a measure, instead of the IQ reported in the main text, does not demonstrate any dynamic complementarity. The ones receiving only the early intervention showed school readiness

randomized control experiment in Colombia (Andrew et al., 2023), positive effects are shown when a government upgrade was combined with professional development of teachers, but not when funding was only spent hiring additional assistants (mainly). Very much like in the Odisha study, it is the training that was critically important. Here we again find that the overwhelming conclusion is that quality matters.

Thus, center-based early learning programs are a critical tool for ensuring the foundations of human capital accumulation and improved learning outcomes later in childhood. However, quality matters and probably explains why some policies expanding child care centers have not improved developmental outcomes. Key ingredients seem to be a well-designed curriculum and teacher manuals, appropriate class sizes for each age, careful training of pre-school workers, and suitable materials to support learning (such as books, puzzles, etc.). Although we need much more research to understand exactly what the key elements are of quality and the trade offs - an understanding of the preschool production function for child development, examples for both wealthy countries and LMICs include Bowne et al. (2017), Hu et al. (2024) and Kim (2022) for the importance of small class sizes in a preschool setting, and Kraft et al. (2018) and Piper et al. (2018) for the importance of training and coaching of teachers. Much else needs to be understood. However, the potential for benefit and harm is huge. All depends on the appropriate investments.

4.2 Schooling and education quality

Although the enormous deficit in learning outcomes that we documented likely owes a lot to poor environments in early childhood, low levels of educational attainment and poor schooling quality are a key component of inadequate skill accumulation (Bold et al., 2017). In countries like Mali and Niger, the average years of schooling were as low as 1.5 years in 2023, compared to a global average of 8.8 years of schooling.[22] And where schooling

improvement o f 0.24 SD (pvalue 0.005, while those receiving both improve by 0.21 SD (pvalue 0.009.

[22]Source: UNDP Human Development Indicators (`https://hdr.undp.org/data-center/human-development-index#/indices/HDI` downloaded August 26, 2025). The definition of Mean

enrollment has increased, it is often the case that learning outcomes remain unacceptably low and stagnant (Bold et al., 2019; Angrist et al., 2021) and illiteracy rates are high. Human capital policies must address the entire childhood period, addressing both the lack of participation and access to schooling, and the egregiously low quality of education that we see in many LMICs. In this section, we review some of the research and policy used to address both questions of participation and quality.

School participation: Incentives and Health Increasing school participation has been a key part of development strategy as seen in the Millennium development goals. Strategies to achieve this include school construction programs (for example, Duflo, 2001) and incentives for parents to send their children to school, such as conditional cash transfer programs, including Progresa/Oportunidades in Mexico (Attanasio et al., 2012; Schultz, 2004; Todd and Wolpin, 2006) and Familias en Acciòn in Colombia (Attanasio et al., 2010). These programs have several advantages because in addition to incentivizing school participation and reducing child labor they act as anti-poverty transfers benefiting both the parent and the child generations with important benefits, including reductions in crime (Attanasio, Cardona-Sosa, Medina, Meghir and Posso-Suárez, 2022), and with substantial spillover effects for their communities as well (Angelucci and De Giorgi, 2009). Similar programs across Latin America and Africa have replicated these positive effects on participation, though learning outcomes often remain unchanged (Adato and Bassett, 2009; De Janvry and Sadoulet, 2006).

Evidence from Malawi (Baird et al., 2012) illustrates that program design strongly influences outcomes. In a randomized comparison of conditional and unconditional cash transfers targeted at adolescent girls, both interventions reduced dropout rates, but the conditional program yielded larger gains in school attendance and literacy. Conversely, the unconditional program had stronger effects on reducing early marriage and teenage pregnancy—highlighting that educational and social objectives may not always align.

years of schooling is the average number of years of education received by people aged 25 and older, converted from education attainment levels using official durations of each level.

Innovations in transfer design can further improve efficiency. Benhassine et al. (2015) demonstrated in Morocco that *labeled cash transfers*—unconditional transfers explicitly framed as education support—achieved nearly the same educational gains as conditional transfers, but at substantially lower administrative cost. In Ecuador, Edmonds and Schady (2012) find that unconditional transfers reduced child labor and delayed workforce entry, while Duflo et al. (2015*a*) show that educational subsidies improved educational attendance and delayed marriage.

Another dimension of the effects of women's bargaining power are gender gaps in spending for human capital. Dizon-Ross and Jayachandran (2023) elicit willingness to pay (WTP) from fathers and mothers in Uganda for various goods. They find that fathers are less willing to spend on girl's human capital than on boys. They then provide a preference based explanation, by showing the fathers' WTP for pleasure goods is also lower for girls than for boys relative to the mothers'. Results like this add to the overall picture by showing how gender gaps may depend on the bargaining power of women. More research is needed to understand the gender dynamics and what this implies for policy.

Beyond access and economic incentives, ill-health is an important impediment to educational achievement. The role of disease burden in development and how this relates to geographical and climatic factors is extensively discussed in Dupas (2025), who also offers multiple references establishing a causal impact from disease burden alleviation to human capital accumulation. An excellent example is given by the seminal paper of Miguel and Kremer (2004). They evaluate the individual and spill-over effects of a large program in which de-worming drugs were randomly phased in to schools. The program reduced school absenteeism in treatment schools by one-quarter and was much cheaper than alternative ways of boosting school participation. De-worming substantially improved health and school participation among untreated children in both treatment and neighboring schools, and these externalities were large enough to justify fully subsidizing the treatment. However, there is no evidence that de-worming improved academic test scores, something that could suggest

that school participation is not necessarily sufficient to increase learning. Long term positive effects of the project were documented by Hamory et al. (2021) who studied the participants up to 20 years after the initial treatment and showed that individuals who received two to three additional years of childhood de-worming experienced a 14% gain in consumption expenditures and 13% increase in hourly earnings . This could of course be an effect of better health, but the authors also argue that it could also be an effect of increased schooling.

In another study Jayachandran and Lleras-Muney (2009) links educational participation and health. They used the sudden decline in mortality in Sri Lanka to show that a decrease in girl's mortality increases the participation in school for girls. Here, the mechanism relates to the expected lifecycle, and hence the period over which educational benefits can be enjoyed.

As shown in Figure 1 progress has been achieved in improving participation. However, schools need to deliver learning, and in this respect the failure is obvious in the stagnant learning outcomes that we documented. As emphasized in e.g., Das et al. (2013), the effectiveness of infrastructure and material inputs depends critically on teacher motivation, governance, and complementary reforms. Programs that fail to address institutional dimensions often yield smaller and less durable impacts. We now discuss research on approaches that could improve quality.

Teaching Material and Pedagogy Early research showed that simply providing schools with more resources—such as textbooks or other supplies—often yielded limited learning gains unless these inputs were accompanied by pedagogical or behavioral changes (see e.g., Glewwe et al. (2009) and Glewwe et al. (2006) for a review). These results motivated a wave of pedagogical innovations aimed at adapting instruction to students' actual learning levels.

Lucas et al. (2014) started with the notion that the rapid increase in primary school enrollment in sub-Saharan Africa had raised concerns about educational quality. To address this, a field experiment evaluated the impact of the Reading to Learn (RtL) program on student achievement in Kenya and Uganda. The program provided teacher training and

instructional materials to randomly selected primary schools in both countries. The results showed that RtL effectively increased the availability of teaching and learning resources. In Uganda, the program led to significant improvements in both written and oral literacy, with gains of nearly 0.20 SDs. In Kenya, a smaller effect of 0.08 SDs was observed, limited to oral literacy. Importantly, schools that implemented the program more closely in line with the RtL model experienced stronger learning gains. However, adherence to the program model varied and was influenced by initial student ability and levels of teacher absenteeism.

In Liberia, *EGRA Plus*—a program that provided teaching guides, reading materials, and continuous teacher feedback—produced some of the largest gains in the literature, increasing oral reading fluency by more than one SD (Piper and Korda, 2011).

A series of influential studies were implemented with the intention of increasing learning for students in schools in urban India. First, Banerjee et al. (2007) study two programs. First, a remedial education program hired young women to teach students who were lagging behind in basic literacy and numeracy skills. It increased average test scores of all children in treatment schools by 0.28 SD, mostly due to large gains experienced by children at the bottom of the test score distribution. Second, a computer-assisted learning program focused on math, increased math scores by 0.47 SD. One year after the programs were over, the children exposed to the computer assisted learning maintained a significant average advantage of 0.1 SD, while for the children exposed to extra tutoring the average impact was insignificant for all but those with a lower baseline level of achievement, who also sustained a significant 0.1 SD advantage.

Following this, a series of programs in India focused on *Teaching at the Right Level* (TARL) an approach pioneered by Pratham in India. In randomized evaluations, grouping children by learning level rather than grade and providing targeted remedial instruction substantially improved basic reading and math skills, and subsequent large-scale implementations integrating the approach into government systems – despite revealing some challenges– showed significant positive results (Banerjee et al., 2017; Banerji and Chavan, 2020).

In Senegal Carneiro et al. (2020) evaluated by RCT a program in which schools received grants to implement pedagogical projects of their own choosing (which did not include infrastructure) but that had been pre-approved by the educational authority. The approach led to an 8% of a SD improvement in overall learning outcomes for children in grades 3 and 5, driven mainly by 12.6% of a SD for children in grade 3. The improvements in children attending these grades a year later was sustained a year later, driven mainly by reading and oral tests, but not mathematics. This demonstrates how a combination of increased resources and a well-defined pedagogical plan can go someway towards improvements in learning and school outcomes.

Incentives for teachers and accountability. We know that teacher quality matters (Hanushek et al., 2004). Chetty et al. (2014) show that replacing a teacher in the bottom 5% of the quality distribution with an average-quality teacher could raise the present value of students' lifetime earnings by around $250,000 per classroom in the US and Bau and Das (2017) show, using data from Punjab, Pakistan, that teacher quality is equally, if not more, critical in this low-income country context. However, for some countries – in particular some sub-Saharan African countries – teacher and school quality has been demonstrated to be very low.

Bold et al. (2017) find that on average teachers in seven African countries were absent from class during 44% of unannounced visits and actively teaching for less than half of the scheduled time. As mentioned earlier, (Bold et al., 2019) highlight that many teachers also lack mastery of the subjects they teach. The authors found that only 66% of language teachers and 68% of mathematics teachers could answer at least 80% of the test questions for their respective grades. Yet, only 6% of language teachers could correctly evaluate 80% of the composition section of the student assessment, which the authors define as the minimum knowledge level for teaching. Bold et al. (2019) suggest that shortfalls in teachers' content knowledge account for 30% of the shortfall in learning relative to the curriculum for the

students in sub-saharan African countries.

Experimental evidence shows that well-designed incentive systems can meaningfully increase teacher presence and improve student performance. Duflo et al. (2012) tested a program in rural India that linked pay to verified attendance using cameras with time stamps. The intervention reduced absenteeism by 21 percentage points and increased student test scores by 0.17 SD. Similarly, Muralidharan and Sundararaman (2011) study teacher performance pay, a large representative sample of governmental employees in the Indian state of Andhra Pradesh. At the end of 2 years of the program, students in incentive schools performed significantly better than those in control schools by 0.27 and 0.17 SD in math and language tests, respectively.

Other reforms have focused on contract teachers and accountability mechanisms to reduce class size and improve teaching. Duflo et al. (2015*b*) showed that contract teachers hired locally to reduce class size were effective in improving student performance. However, government teachers hired centrally shirk in response to the introduction of contract teachers. Moreover, capture by the existing teachers, who promoted their relatives, was reduced when parents were empowered within school governance committees. In a similar vein, Bold et al. (2018) showed that the hiring of local contract teachers under the supervision of an NGO led to learning gains in Kenya of the order of 0.18 SD, but similar government-implemented versions of the same contract produced negligible effects. Their data suggest that there was bureaucratic and political opposition to the contract reform and that this led to implementation delays and a differential interpretation of identical contract terms, and additionally, contract features that produced larger learning gains were not adopted by the government outside of the experimental sample.

These results underscore the difficulties with scaling up programs in general and particularly with limited state capacity, as well as underlining the importance of implementation fidelity institutional capacity and local accountability. It reinforces the need for the recent focus on studying the scalability of different programs and understanding implementation

fidelity can be maintained (see e.g., List, 2022, for a recent discussion).

Community monitoring and local accountability have also shown mixed success. Pandey et al. (2009) find that training community members to monitor schools modestly increased teacher effort. Banerjee et al. (2010) experimented with an intervention informing the community of the existence of village education committees that are supposed to monitor learning, and provided parents testing tools to assess the learning ability of children. This intervention had no effect either on engagement or on reading outcomes. However, volunteer-led reading camps improved literacy outcomes, even when engagement with formal schools remained limited. On the other hand, Pradhan et al. (2014) demonstrate that the combination of strengthened school committees with community participation and elections in Indonesia significantly improved learning outcomes.

Behrman et al. (2015) studies how different types of performance-based incentives influence student learning in Mexican high schools. The authors use evidence from a randomized social experiment in which some schools offered incentives to students, some to teachers, and some to both students and school staff. The findings show that the combined incentive scheme, which involves the entire school community, produced the strongest improvements in student outcomes. Incentives directed only at students generated more modest gains, while incentives targeting teachers alone did not lead to detectable changes in performance.

Finally, Bassi et al. (2020) demonstrate by RCT how improvements in teaching practices and specifically using scripted lessons improved child learning in lower SES schools in Chile. The importance of this lies in showing how training and teaching methods can lead to rapid improvement in schooling outcomes, without need for changes in personnel or other costly and time consuming processes.

Overall, evidence suggests that teacher-focused reforms are most effective when they create clear, credible, and sustained incentives for performance, supported by institutional structures capable of enforcing accountability.

Summary and the the way forward. The accumulated evidence from experimental and quasi-experimental research underscores a central lesson: *improving access is not enough; learning depends on the quality of teaching and institutional incentives.* Material inputs and infrastructure enhance learning when they support effective pedagogy, and teacher incentives work best when embedded in accountable governance systems. Conditional cash transfers reliably increase enrollment, but translating participation into learning requires complementary investments in instructional quality and early childhood development.

As discussed in Duflo et al. (2024) the gains from programs aimed at increasing education and learning, could be larger than the measured effect on the first generation. The authors report on a randomized scholarship program launched in 2008 for Ghanaian adolescents who had been admitted to secondary school but could not afford to enroll. The scholarships increased secondary school completion by 28 percentage points and generated important inter-generational effects: women who received scholarships delayed fertility, experienced fewer unwanted pregnancies, and had children with substantially lower mortality and higher cognitive development by ages 5–7. These gains appear driven not by higher parental income but by better-educated mothers engaging more in preventive care and cognitively stimulating interactions, as confirmed by LENA audio recordings.

The work of Bold et al. (2018) illustrates the importance of focusing on scalability of programs. In order to know whether a policy may work at scale, it is important to study available financial and human resources as well as the infrastructure in place. More research is needed to study scalable educational programs in low income settings. And a better understanding of how scalability should be defined. For example, what program costs should a government expect and how should this be linked to expected returns by the program, because no worthwhile policy is going to be costless.

The whole notion of implementing at scale includes a better understanding of how state capacity matters, how incentives and accountability should be organized and what monitoring systems should be in place. Another neglected aspect are the general equilibrium effects

of implementing a policy at scale. This includes the usual concerns about price changes, but also includes a better understanding of spillover effects and unintended consequences. For example, improving the participation rates in schooling can have virtuous effects through a change in the norms of attending school, but can also dilute quality. On the other hand, improving quality by, say, reducing teacher absenteeism and improving their training, may attract more children to school.

Going forward, there is also a need to further understand how learning at school fits with what is required in the world outside of school. Does the school prepare adolescents for the world outside of school, and are test scores a good measure for this? Studies have documented that skills other than cognition are important to succeed in the labor market in high income countries (Heckman and Rubinstein, 2001; Deming, 2017), and recent studies focus on efficiencies and potential mismatches in low- and middle income countries (Bandiera et al., 2017), but there is still a need to improve our understanding of how schools can better prepare adolescents for the transition to the labor market in settings where the majority of adolescents will neither take higher education, nor work in the formal sector (see e.g., Almås et al., 2025, for a discussion).

Lately we have seen an increased interest in understanding whether policies could also affect the demand for skills and education in low and middle income countries (Carranza and McKenzie, 2024; McKenzie, 2017), but our assessment is that there is a further need to understand the scope and nature for such policies. For example, policies that promote entrepreneurship, investments and an open economy seem crucial for increasing the demand for skills and raising skill prices. Although we have quite a few studies that focus on firms in low income countries (Bloom et al., 2013; Alfonsi et al., 2020, for example,), we believe that there is still a need to better understand the determinants of the demand for skills in low income settings and policies that can stimulate these. Without a simultaneous increase in physical investments, innovation and economic opportunity, human capital investments will not deliver their promise.

More research is needed to understand the inter-generational gains of educational programs, how to design scalable policies, the design of programs that best prepare adolescents for life outside of school, as well as how to improve the demand side for skills and human capital.

5 Concluding Remarks

Human capital is critical for growth, and different types of human capital—distinguished by educational level—become central at different stages of development.These statements are based on a robust theoretical framework and are supported by estimates suggesting that human capital has contributed 45% of global growth in recent decades (Gethin, 2025). Yet human capital alone cannot generate growth in environments where entrepreneurship and investments in physical capital and innovation are impeded by excessive regulation or political instability. Human capital policy is therefore necessary but not sufficient. However, without even basic skills such as literacy and numeracy, adoption of technologies with the capacity to initiate a virtuous cycle of growth and investment—both human and physical—cannot take place.

Despite the importance of investing in human capital, most low- and middle-income countries are failing to catch-up. Although educational attainment, measured in years of schooling, has increased substantially, learning outcomes are often poor and stagnant. Understanding barriers to the accumulation of human capital remains a central research question. Candidate explanations include deficits in early childhood development driven by poverty; low expectations about the value of investing in children; insufficient access to quality preschool driven by government failure to invest in high quality early education; low quality of schooling, potentially due to inadequate resources, low teacher pay and poor training, distorted incentives, and inadequate mechanisms for selecting and retaining high-performing teachers.

Many of these barriers can be addressed by well-designed policies. An expanding knowledge base from research based on experimental and observational studies points to cost effective policy solutions and scalable programs that have the capacity to mitigate many of the obstacles that the last two decades of development economics research has documented. This research has examined the roles of family resources, parenting and cultural factors, teacher incentives, and more. The emerging conclusion is that many of these interventions are effective at boosting human capital at relatively low cost and in a way that is sustained over the medium or longer run; however, the detail of the implementation of these programs seems to matter for effectiveness. With appropriate attention to detail, they therefore offer a promising pathway for policy reform and for improving educational outcomes in low-income settings.

However, the main challenge lies in translating these experimental successes into policies with sustainable impact on a global scale. Successful scaling requires integrating interventions into government systems with appropriate monitoring to ensure durability and understanding how programs tested in isolation might interact when bundled together. General equilibrium effects and spillovers of programs implemented at scale are important aspects that need to be studied and better understood. Finally, it is important to emphasize that policies designed to stimulate growth and development will include both a focus on human capital and a focus on creating conditions that encourage entrepreneurship, investments, and innovation.

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