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# A Primer on Human Capital

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## Abstract

This note summarizes some of the key contributions in the macro- and micro- economic literature on the pathways linking human capital and income growth. Rather than completeness, the objective of this work is to distill some of the most relevant threads in the evolution of these literatures using a human capital lens, with a view to provide a useful yet parsimonious conceptual framework and an update on empirical results. The note first describes the human capital model (section 1). It then outlines the main theoretical elements of growth theory and presents empirical results from the cross-country regressions and development accounting literature to gauge to what extent human capital affects growth at the aggregate level (sections 2, 3 and 4). The note then reviews the micro empirical literature estimating labor income returns of human capital investments (sections 5 and 6). The conclusion draws comparisons between the two empirical approaches and provides a brief critical assessment on how to interpret the empirical results. Investing in human capital is a promising strategy to attain stable and positive growth. The magnitude of the effects is country-specific and varies depending on the population of interest, the policy under consideration, and the human capital component considered.

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# A Primer on Human Capital[*]

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# 1. Introduction

Human capital and growth are linked by numerous pathways and threads. Investing in human capital affects productivity, productivity affects growth and growth feeds back to human capital opportunities. Moreover, human capital is a broad concept, which includes not only education and training but also many other aspects of individual human development such as medical care, early childhood interventions, intergenerational mobility.

A complete review of all the relevant literatures and of all the important policy implications in this area is a daunting task. Instead, this note distills some of the most relevant threads in the evolution of these literatures using a human capital lens. It provides two main contributions: a parsimonious conceptual framework that summarizes the theoretical contributions and a review of the empirical results that integrate macro and micro literature. The conceptual framework is used to integrate the two strands of the empirical literature, to provide an interpretation of the results and to guide the policy implications.

The note is organized as follows. The next Section provides a definition of human capital and a description of the standard human capital model. Section 3 presents the conceptual framework, first describing a general model of output growth and then adding human capital. Section 4 reviews the empirical literature, presenting results from both the macro and micro literature. The first set of results covers cross-country regressions and development accounting; the second reports evidence following the life-cycle of individual agents. The section also draws comparisons between the macro and micro empirical approaches and provides a brief critical assessment on how to interpret the empirical results.

The last Section contains the main lessons learned from this review: Investing in human capital is a promising strategy to attain stable and positive growth but the magnitude of the effects is country-specific and varies depending on the population of interest, the policy under consideration, and the human capital component considered. The use of micro data tailored to evaluate the specific policy of interest in the country under consideration, in conjunction with economic models able to aggregate the micro-level effects is suggested as the best methodology to inform policy action.

# 2. What is Human Capital?

## 2.1 Definition

*Human capital includes education, training, medical care, and other additions to knowledge and health […] accumulated work and other habits, even including harmful addictions such as smoking and drug use*
*(Gary Becker, Nobel Prize Lecture: "The Economic Way of Looking at Life", 1992)*

As such, investing in human capital is akin to investing in physical capital: one can invest in the human factor of production with the expectation of economic returns just as one can invest in the factor of production physical capital.[1] Moreover, since human capital includes "*education, training, medical care, and other additions to knowledge and health*", any policy affecting these areas affects human capital and, ultimately, growth.

The empirical literature, both at the micro and macro level, has measured different aspects of human capital, mainly focusing on education and years of schooling as the main component of *general* human capital and on on-the-job training as the main component of *specific* human capital. More recently, there has been a recognition of the importance of health in affecting general human capital and of the effectiveness of early childhood investments.[2] General human capital is valued at all firms and jobs and it is therefore portable across all potential employers. Specific human capital, instead, is not valued at all firms and jobs since it involves skills and knowledge that have productive value only in a specific job or firm. As a result, it is not portable across all potential employers. Given these crucial differences, the incentive to acquire the two types of human capital and the externalities they may generate are significantly different. Broadly speaking, both the individual worker and the economy as a whole have an incentive to acquire general human capital (for example, schooling), while only the firm interested in a specific production process has an incentive to invest in specific human capital (for example, on-the-job training about a firm-specific software).[3]

A different but related question is whether human capital is the same as knowledge. Romer's recent contributions [Jones and Romer (2010); Romer (2015)] highlight the important difference between human capital and knowledge where the first - which is stored in neural connection in the brain - is a rival and excludable good; while the second (to be understood as codified knowledge, for example knowledge stored in a document or a book) is a non-rival and partially excludable good.

### 2.2 The Human Capital Model

The key intuition behind the human capital model [Becker (1962), Becker (1993)] is that individuals decide on the "additions to knowledge" that constitute human capital. Decisions are taken in order to maximize a payoff which includes not only earnings and labor market performance but also cultural and other nonmonetary gains. Knowledge additions has both direct and opportunity costs. *Direct cost* are the actual expenses incurred in the investment activity such as school tuition or health costs. *Opportunity costs* are the forgone benefits

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[1] This view is now shared by most economists and many other social scientists and policy makers but it was quite controversial at the time (the first influential papers by Becker and his first book on human capital are from the early 1960's: see Becker (1962) and Becker (1993 3ed, 1ed 1964)). Famously, Schultz in his presidential address to the American Economic Association meeting in 1961 said that "free people should not be equated with property and marketable assets."

[2] See Section 4 for empirical evidence on education, health and early childhood. Section 4.1 focuses on evidence at the macro level and Section 4.2 on evidence at the micro level.

[3] This difference was already emphasized in the early work by Becker (1962). More recent work has tried to empirically disentangle the importance of general and specific human capital. See Sanders and Taber (2012) for a review.

that could have been obtained in the time that was instead invested in schooling. For example, full time college participation prevents students from earning a wage for full-time work in the labor market.

Human capital investment decisions have an intertemporal nature, i.e. they typically involve an investment today in order to obtain a payoff in the future. These decisions, therefore, involve quite complex expectations about the future and may introduce inefficiencies through hold-up problems, any time frictions or market failures are present. For example, schooling investment are typically made before a worker enters the labor market and is matched with a specific firm. If all the firms pay marginal productivity, then the only uncertainty is about aggregate changes in labor market conditions. But if firms retain some rents because markets are not perfectly competitive - for example due to search frictions - then agents are also uncertain about the employer they are going to meet. As a result, they are uncertain about how much of the increase in productivity due to their human capital investment they can obtain through wages. This in turn affects their decision of how much education to obtain [Acemoglu and Shimer (1999); Flinn and Mullins (2015)].

The inherent dynamic of human capital investment decisions also generates interactions between different types of human capital. *Dynamic complementarities* imply that a given investment in human capital today not only affects future payoffs but also subsequent accumulation of human capital [Cunha, Heckman and Schennach (2010); Manuelli and Seshadri (2014)]. For example, investments in the health and nutrition of children in the early years of life have a large impact on how effective schooling will be in increasing their future cognitive skills and knowledge. Dynamic complementarities may be so strong, that early investments may not be productive at all if they are not followed by later investments [Cunha et al. (2006)].

Dynamic interactions extend also beyond the life of the individual, involving the *intergenerational transmission* of human capital and the importance of *family backgrounds* in affecting human capital investments [Becker and Tomes (1986)]. There are two major sources of individual heterogeneity which may lead agents to make different human capital investment choices: personal attitudes and talents (*ability*) and costs involved in investing today in order to obtain a future benefit (*intertemporal discount rate*). Both characteristics are significantly affected by family backgrounds. For example, good child-rearing parental practices can help a child to reach her full potential in terms of cognitive and non-cognitive abilities and thus affect ability. Conversely, imperfect capital markets may make the opportunity cost of giving up current wages in order to study simply too high for low income families. As stressed early on by Becker [Becker (1993 3ed, 1ed 1964)], if the returns to human capital exhibit decreasing marginal returns, this type of dynamics may be a powerful explanation for persistent inequality. For example, consider the investment in years of schooling. A simplified version of the human capital model implies that a given agent will invest in schooling in order to maximize the present value of lifetime earnings. Since in the simplified model the only cost is the opportunity cost, the agent goes to school until the marginal rate of return to schooling equals the intertemporal discount rate. Since the returns to schooling are decreasing, individuals from disadvantaged families will stop accumulating schooling earlier because, with imperfect capital markets, they face higher discount rates. By accumulating less schooling, they will earn lower wages and provide lower family background to their offspring, thus perpetuating inequality.

Human capital theory models individual agents' behavior, but the impact on aggregate outcomes and growth has been an early concern [Schultz (1963)]. The key distinction here is between *private* and *social rate of return* to human capital investments [Becker (1993); Heckman et al. (2006); Krueger and Lindahl (2001)]. The private rate of returns is the return enjoyed by the individual agent taking the decision. Typically, it does only include monetary benefits and, as implied by the example above, is the return obtained by equating the (net) present value of life-time earnings to the net present value of the human capital investment cost. However, this return not only ignores cultural and other non-monetary gains at the individual level but also ignores aggregate gains or loss that may be generated by the investment's positive or negative externalities (the social return). The sources of externalities are numerous and intuitive. For example, a health initiative introducing mass vaccinations not only has health benefit for vaccinated individuals but also for those who are not. Similarly, good schools in crime-prone areas not only improve the lifetime opportunities of the students attending them but also reduce crime rates improving society as a whole.

## 3. Conceptual Framework.

### 3.1 Where does output growth come from?

**The Basic Framework**. The basic building block of growth theory is a production function where output (or GDP, usually denoted by Y) is a function of technology (A), physical capital (K) and labor (L).

$$Y = A\,F(K, L) \qquad [1]$$

The most common functional form for the production function is the Cobb-Douglas constant returns to scale formulation:

$$Y = A\,K^{\alpha} L^{\beta} \qquad [2]$$

If $\alpha<1$ and $\beta<1$, there are marginal decreasing returns to each factor. In competitive markets, ß is the (constant) share of output that goes to labor.

In equation 1, there are three sources of growth in aggregate output: technological innovation affecting *A*, capital accumulation increasing *K*, and population growth or changes in the participation rate of the population increasing *L*. Population growth may be achieved both by increasing fertility and by increasing life expectancy. Therefore, in this setting, the role of human development policies is limited to health and fertility interventions. In this basic framework, *L* is the stock of labor used in production, often normalized for some labor supply intensity (participation rate, part-time or full-time work). However, each unit of *L* is essential a body, without much consideration for the fact that different individuals may have different skills and productivities or that the same individual may acquire additional skills and therefore change her productivity over her life-time.

**Adding Human Capital.** A more general formulation of the previous production function which takes the role of acquiring skills into account is the following:

$$Y = A\ F(K, H) \qquad [3]$$

where output (Y) is a function of technology (A), physical capital (K) and *human capital* (H). In this world, there still are three ways to increase income but the third one is much richer. Increases in the factor of production labor (H) are not only determined by demographic changes but also (and in many contexts, mainly) by *human capital investments.* Here investment in human capital allow for per-capita growth without necessarily resorting to technological innovation or physical capital accumulation.

### 3.2 How does Human Capital affect Growth?

**The Direct Channel.** The first impact of human capital on growth is the direct impact implied by its accumulation. This is an impact analogous to physical capital accumulation. Following Lucas (1988), we can rewrite the production function as:

$$Y = A\ F(K, vH) \qquad [4]$$

where $v$ denotes the portion of the current stock of human capital devoted to production and ($1$-$v$) the portion devoted to skill acquisition. We can think $v$ and $(1\text{-}v)$ as *proportion of each unit of time* that the representative agent devotes to the two activities. As a result, the optimal decision of the agent is characterized by the same trade-off of the original Becker model. Investing in human capital (skill acquisition) comes at the opportunity cost of not using the time in production. The implication is a law of motion of human capital that parallels the law of motion of investment in physical capital. Just as the output that is not consumed (net of depreciation) increases the capital stock, so the human capital that is not consumed in production increases the human capital stock. Empirically, this means that we expect GDP growth to be a function of the growth of human capital.

In addition to quantity, also the quality of human capital matters. A simple way to allow for heterogeneous human capital is by introducing the distinction between skilled ($S$) and unskilled ($U$) workers. Then, the production function assumes the following more general formulation:

$$Y=A\ F(K, v_S H_S, v_U H_U)$$

where the investment decisions $v_S$ and $v_U$ are now skill-specific. Human capital accumulation laws of motion will then also be skill-specific.

**The Impact on A**. The second impact of human capital on growth is through its influence on technological progress, as represented by the stock of knowledge $A$. In the long run, economic growth depends on $A$'s growth. In Solow's model, this process is exogenous to the economic forces described in the model. In endogenous growth models, long-run economic growth (*A*'s growth) is endogenously determined, including as a function of human capital. As a result, growth goes on indefinitely because the returns to a broad class of capital goods do not diminish as the economy develops [see Barro and Sala-i-Martin, 1998, page 12 and Howitt (1998)].

This *endogenous growth* process, can be described by the following production function:

$$Y = AF(K, \varphi H) \qquad [6]$$

$$\mathrm{A} = G[(1-\varphi)H] \qquad [7]$$

where [7] defines the knowledge component as a function of human capital. In other words, human capital is an input that can be used to produce new knowledge *A*, which then increases *Y*. In this notation, a proportion of human capital φ is invested in production and *(1- φ)* in knowledge generation.

Broadly speaking there are two classes of endogenous growth models: 1) "*AK*" models where human and physical capital are not explicitly distinguished and K exhibits constant marginal product, driving long run growth [Frankel (1962); Romer (1986)]; 2) models where endogenous growth is innovation-based, i.e. where intellectual capital is distinct from human and physical capital. The literature identifies various channels through which innovation generates productivity growth: by increasing the variety of intermediate products [Romer (1990)]; and by rendering products obsolete through a Schumpeterian process of creative destruction where the probability of innovation depends on R&D expenditure [Aghion and Howitt (1992)]. In these models, human capital is an input to produce knowledge *A*. Therefore, an important question is "what type of human capital" is necessary to develop this type of growth. The literature stresses different element as key - literacy, secondary, or tertiary education, specialization. Romer (1990) and then Mokyr (2005) identify in research engineer and engineering-minded technicians, respectively, the key to innovation. In a recent paper, Maloney and Valencia Caicedo (2016) argue that the density of engineers in 1880 captures well historical differences in innovative capacity, which in turn explain a significant fraction of the Great Divergence in the Americas.

Recently, Jones and Romer (2010) and Romer (2015) emphasized that the direction of the impact may also go the other way, from *A* to *H*. For example, the education process can be seen as a form of increasing the human capital stock *H* by leveraging the accumulated knowledge *A*. A similar direction of causation can result from technological innovations rewarding differently different qualities of human capital. Consider for example the heterogeneous human capital model in which labor can be broadly divided in skilled and unskilled. The so-called *skill-biased technical change* [see Acemoglu (2002) and Violante (2009) for a review] is an innovation in the production technology that increases the relative productivity of skilled labor with respect to unskilled labor. The consequence is a change in relative demand and therefore relative prices between the two types of labor, which in turn changes the human capital accumulation process. Hsieh and Klenow (2010) take this reasoning further and add to heterogeneous human capital the presence of different sectors. They document the presence of different levels of *A* over these different sectors and argue that these differences can influence the incentive to accumulate physical and human capital because they affect the price of capital and schooling relative to the price of output.

**The Interaction of H and K**. The main interaction between human and physical capital is the impact of the quantity of physical capital on labor productivity. Equation [3] shows that the productivity of a human capital investment depends on the level of physical capital used in the production process. Formally, this means that the first derivative of output with respect to human capital is, itself, a function of *K*.

The interaction between human and physical capital also extend to the *type* of capital used in production on top of its quantity. Krusell et al. (2000) argue that the substantial cheapening of equipment capital (notably, computers and information technologies) that occurred in the 80s has led to an increase in the stock of capital. Since skilled labor is relatively more complementary to equipment capital than unskilled labor, this process is also one of the sources of the skilled-biased technical change described in section 3.2. There is now a large literature on capital-skill complementarity and on its impact on inequality, productivity and, ultimately, growth.[4] Recently, Duffy et al. (2004) has found support for capital-skill complementarity on a large sample of developed and developing countries. This interaction may also lead to changes in the share of labor and capital in production. For example, Kouraboubanis and Neiman (2014) document a decline in the labor share in the last thirty years and they attribute it to the decrease in relative prices of investment goods.

## 4. The empirical Evidence

### 4.1 The Macro evidence

The macroeconomic literature has used two main methodologies to assess the relationship between human capital and growth: cross-country regressions and development accounting.

#### 4.1.1 Cross-country regressions

This literature flourished in the 1990s and was initially motivated by testing the implications of growth convergence models. Growth convergence predicts that countries starting at lower income levels should converge to income levels of richer countries in some version of the Solow–Swan model (1956) augmented with human capital. In the *conditional* convergence literature, a country would grow faster the further away it is from its own steady state level of income. The earlier literature focused on physical capital while the following and more recent literature also includes a more complete set of state variables

[4] Griliches (1969) is the classic reference; Goldin and Katz (1998) and Katz and Krueger (1998) provide empirical support of capital-skill complementarity using technological change over time as identification strategy; Acemoglu (1998) provides theoretical support focusing on technology upgrading.

such as population growth and human capital accumulation. The next frontier is the inclusion of two additional variables: ideas and institutions [Jones and Romer (2010)].

A typical empirical contribution in this area estimates the correlation between different measures of human capital (such as years of schooling and life expectancy) and GDP per capita growth. The question they try to answer is: *If a country were to increase investment in a given human capital component, by how much would income growth change?*

**Early findings.** Barro and Sala-i-Martin's book summarizes some of the key results of these estimations. They report that educational attainment is positively correlated with growth across countries: 1 standard deviation increase in male secondary schooling (equivalent to 0.68 years of schooling) is associated with an increase in the growth rate by 1.1 percentage points per year. When education is decomposed in primary, secondary and higher, it is secondary and higher education that are responsible for the positive impact on growth (Barro and Sala-i-Martin (1995), chapter 12, page 431.) Subsequent work has not always confirmed these results. For example, Pritchett (2001) uses data on 91 countries and does not find a significant association between a rise in educational attainment and the rate of growth of output per worker.

Increases in life expectancy are also found to be positively correlated with growth: 1 standard deviation increase in in life expectancy (13 years) is associated with an increase in the growth rate of GDP by 1.4 percentage points (Barro and Sala-i-Martin (1995), chapter 12, page 432). More recently, Barro (2015) reports that growth is positively associated with lower mortality rate, lower fertility and higher female relative to male school attainment for those aged 15+, while he finds that the impact of a general increase in attainment is not significantly different from zero. Zaman and Tiwari (2017) find that an increase in social protection spending is positively correlated with growth: Moving from 0 to 2% of GDP spending on SP increases growth by 0.1-0.4 percentage points.

**Identification, measurement, and reverse causation.** There are many interpretation on the estimates of a coefficient of GDP growth when regressed on the level of education and change in education. As discussed in Benhabib and Spiegel (1994) and Krueger and Lindhal (2001), level of schooling could be a proxy for steady state income, or could change the steady state growth rate by enabling the work force to develop and adopt new technologies (as in Nelson and Phelps, 1966 and Romer, 1990), or reflect an exogenous change in returns to education, or could reflect reverse causality of increased education in anticipation of future growth.

Importantly, a consensus around this literature is that obtaining unbiased estimated coefficients in cross-country setups has proven problematic due to potential omitted variables issues; reverse causality; heterogeneous effects, and measurement error. Acemoglu and Johnson (2007) use instrumental variables to address some of the identification problems in these types of regressions. They exploit international health improvements from the 1940s to estimate the effect of life expectancy on economic performance. They find that longer life expectancy increases population. It also increases GDP, but not enough to compensate the population effect so there is no impact on GDP per capita growth. However, finding valid instruments is difficult, see for example the discussion of Acemoglu and Johnson (2007) in Bloom et al. (2014).

Many have also argued that measurement error may plague the estimation results (Kruger and Lindhal, 2001). A recent contribution by Barro and Lee (2013) overcomes some of the limitations of the original perpetual inventory-based education dataset (Barro and Lee, 1993) and improves data accuracy by using information from consistent census data, disaggregated by age group, along with new estimates of mortality rates and completion rates by age and education level. A related question is whether using average years of schooling is the right measure for human capital. Recent work by Hanushek and Woessman (2015) shows that using school attainment as proxy for human capital fails to account for differences in quality of education across countries and thus is unlikely to provide a reasonable estimate of the role of human capital. They thus propose the use of scores from international tests of mathematics, science and reading achievement.[5] Based on an aggregate value of skills for about fifty countries, they concludes that it is learning – rather than schooling –that matters.

A further concern with cross country regressions is that causality might run both ways, from human capital to growth and back. Weil (2013) explicitly discusses this with reference to health and reviews different mechanisms through which income - or economic dynamics associated with income growth - might affect health. These include improved sanitation, which is associated with better health (though with a lag); and higher urbanization, which is often associated with a negative impact on health.

### 4.1.2 Development accounting

Growth accounting - i.e. the decomposition of income growth rates into the contribution of different factors - was first applied to the growth time series of the US by Solow in the fifties. Later, a similar methodology has been applied on cross-sections of countries, leading to the *development accounting* literature. This methodology decomposes income differences across countries into their measurable components: physical capital (*K*), human capital (*H*), and a residual which is interpreted as Total Factor Productivity (*A* or *TFP*). This work tries to answer the question: *What share of aggregate income differences can be attributed to variation in K and H and how much can be attributed to the efficiency with which these two factors are used (TFP)?*

Accurately measuring income and factors and properly choosing the production function's functional form are the two key steps of development accounting. Efficiency is obtained as a residual. Traditionally, large part of this literature is dedicated to understanding this residual, which is often referred to as the "measure of our ignorance" [Abramovitz (1957), cited in Caselli (2005)].

[5] Barro and Lee (2013) show a high correlation between their measure of school attainment and Hanushek and Woessman (2009)'s measure of human capital quality, though they note that human capital quality is quite diverse for countries with similar levels of educational attainment.

In the past two decades, the literature has obtained mixed results. Mankiw et al. (1992) use secondary school enrolment to proxy for the investment rate in human capital and attribute 50% of income differences in their sample of 98 non-oil countries to differences in human capital. Klenow and Rodriguez-Clare (1997) use years of schooling *attainment* as inputs to a human capital aggregator and find instead that human capital accounts for 10 to 30 percent of income differences. When taking into account various measures of school quality, Caselli (2005) concludes that improving measurement of human capital by including school quality changes only slightly the conclusion that human capital explains a small share of income differences. Caselli and Ciccone (2013) compute the maximum impact that can be obtained by giving to the country under examination the same level of schooling as the US and they find similar results as Caselli (2005). For example, if Brazil, India, and Mexico were to move to the same education attainment of the US, the output gap that would be covered would only be equal to, respectively, 22.4%, 5.4% and 20.1%.[6] These are estimated as upper bounds, resting on the assumption of perfect substitutability of skilled and unskilled labor.

Contributions removing the perfect substitutability assumption arrive at different conclusions. Jones (2014) advocates the use of more general form of human capital aggregators than those used in the previous development accounting literature. Human capital aggregators are those functions that aggregate the heterogeneous human capital in the economy in one factor of production to be inserted in the production functions described by equation [1] and [2]. He proposes aggregators taking into account the different returns of the different types of human capital as a function of: (i) their relative scarcity, and (ii) the possible complementarities between them. Using the same data used by Caselli (2005), Jones (2014) estimates that physical and human capital variations can fully explain output differences between countries. Malmberg (2016) follows a similar approach by removing other restrictions from the standard development accounting model and by using different functional forms inspired by theory. Specifically, he allows for imperfect substitutability between skilled and unskilled labor and uses a broader definition of skills which is not simply based on education levels but also on the skill contents of specific occupations as described in the *Occupational Employment Statistics* (OES) survey maintained by the US Bureau of Labor Statistics (BLS).[7] He concludes that the human capital accounts for the majority of income differences across countries.

Development accounting has also been used to study the impact of other human capital components in addition to education and schooling. Health is an area of recent interest. For example, Galasso and Wagstaff (2016) compute that the per capita income penalty a country incurs for not having eliminated stunting when today's workers were children is, on average, 6% of GDP per capita. Weill (2013) uses a decomposition à la Caselli (2005) and estimates that the cross-section income variance explained by health is about 10%.

[6]All data refer to the year 2000.

[7] Sasso and Ritzen (2016) use cognitive skills data from the *Programme for the International Assessment of Adult Competences* (PIAAC) and confirm the importance of a definition of skills that goes beyond the simple education level when performing developing or growth accounting exercises.

## 4.2 The Micro evidence

### 4.2.1 Introduction

The most popular micro-level approach uses observations at the individual level - typically at the level of the worker, the student or the household - to run regressions of individual wages or earnings on individual levels of human capital plus some additional controls. The human capital returns obtained in this way are returns for a given individual as a result of human capital investment on herself. The impact on overall growth is therefore generated through the impact on wages and labor market performance. The standard specification is log linear:

$$lnw_i = \beta_0 + \beta_1 hc_i + x'_i\beta + \varepsilon_i \qquad [7]$$

where a measure of labor income ($w_i$) is regressed on the human capital variable of interest ($hc_i$) and a set of controls ($x_i$). The relative return to the human capital investment, the coefficient of interest in the regression, is $\beta_1$.

Empirically, there are advantages of using this micro-level approach. First, micro-level regressions use variation at the level of the individual workers instead of aggregating at the country level. Second, they can estimate more flexible specifications because each country (sometime different groups of workers within a country, such as men and women) is allowed to have a different return to the specific human capital component under study. Third, the range of additional controls that can be added to the specification is larger thanks to the richer amount of information included in the survey data used in this context. Fourth, they may take into account the individual heterogeneity which is an integral part of the original human capital model. The original human capital model posits an investment decision in human capital made *by the individual agent*. If individuals are different, they may make different decisions. Estimates based on micro-evidence allows to take into account at least some of these individual-agent level differences while the macro evidence has to aggregate over them.

The main disadvantage of using the micro-level approach is that the link to the variable of interest, growth, is less direct. The issue is sometime referred to as the difference between *private returns* and *social returns*. The macro-evidence presented in Section 4.1 uses as dependent variable a measure of GDP either in levels or growth rates. This measure is a direct proxy for the total output variable considered in all growth models. Assessing impacts of human capital investments on GDP is assessing the overall aggregate impact of the investment: the *social return*. The micro-evidence presented in this Section uses as dependent variable a measure of individual labor income which is the payoff based on which the individual agent is making the choice: the *private return*.[8]

[8] In both cases, there can be non-pecuniary returns that are not captured either by GDP or by labor income measures. Some of these returns may be captured by taking into account the externalities we discuss in the rest of the paper. Other returns go beyond growth rates and while very important will not be discussed in the paper.

The wedge between private and social returns may be significant. The first reason is that labor income is only one component of GDP, even if a relevant one. The second, most important reason is that human capital investment generate *externalities*. For example, as seen in Section 3, human capital investments may generate technological progress which in turn increases productivity of *any* production inputs. Other examples of typical positive externalities are: education investments reducing aggregate crime rates or health investments in mothers making their children healthier [Kruger and Lindhal (2001); Glewwe (2000)]. The presence of positive externalities does not necessarily mean that the social return of a given human capital investment is always higher than the private return. In many countries investment in education is highly subsidized: if the subsidy is too high, the private return may exceed the social return and lead to overinvestment in education [Heckman and Klenow (1997)]. What it means, though, is that looking at wages instead of GDP may under- or over-estimate the overall impact of human capital investments on growth. The micro-evidence is well equipped to estimate private returns to human capital investments. How these private returns exactly relate to the social returns at the center of the growth literature depends on the human capital investment under consideration, the specific country, the specific time period, the growth model assumptions used to interpret the results. Still, impacts on wages are relevant since they are systematically correlated with growth in GDP.

The second issue with the micro level evidence concerns the identification of the effects of interest. Both econometric issues related to the quality of the estimates and modeling issues related to the interpretation of the results are as important in the micro evidence as in the macro evidence. Both concerns are discussed in Section 4.2.3.

The third and final issue concerns measurement errors. In Section 4.1 we already pointed out the importance of a correct measure of human capital variables. In the empirical micro literature, measurement errors issues also involve the outcome variables: wages and earnings. Validation studies have shown the presence of measurement errors in self-reported wages in economies with well-developed labor markets [Bollinger (1998); Bound et al. (2001)]. The problem is only amplified in less developed labor markets where the informal sector is large or the agricultural sector employs a large proportion of the labor force [Jacoby and Skoufias (1997)]. Possible solutions to measurement errors issues are the implementation of validation studies able to cross-check different data sources and the use of administrative data. In economies with large agricultural sectors, proposed solutions include changing the outcome variable by using consumption data or production data instead of labor income data.

### 4.2.2 Review of Empirical Results

Human Capital investment is a dynamic process, involving a variety of decisions covering the entire life cycle. The following section presents empirical evidence on some of the most popular human capital investments involved in this process. It starts with early childhood investments and continues with education decisions, skills acquisition, on-the-job components. It closes with investments in health.

**Returns to Early Childhood Development Investments.** Recognizing the major dynamic complementarities discussed in Section 2.2 has led to a renewed interest in early childhood investments.[9] A given investment in human capital today not only affects future payoffs but also influences subsequent accumulation of human capital. The result is that human capital accumulation and skill formation should really be seen as a life-cycle, life-long process where returns on early investments are high while remediation later in life is difficult [Cunha et al. (2006)]. Such dynamic complementarity is so strong that early human capital investments and early accumulation of both cognitive and noncognitive skills seem to sort individuals into different paths of lifetime outcomes [Doyle et al. (2009)].

Interventions in this area are varied: they range from childcare programs to nutrition programs, from programs targeting children to programs targeting mothers. They also vary in quality with success crucially dependent on implementation. García et al. (2016) estimate a rate of return of 13% per year for a high-quality early childhood program in the US.[10] Bernal and Fernandez (2013) study the impact of a subsidized community-based childcare program in Colombia[11] finding positive impacts on cognitive development and socioemotional skill (about 0.2 of a standard deviation) but no impact on nutrition. Elango et al. (2016) revisits the evidence on early childhood education concluding that the quality of the service provided is crucial. They estimate that only high-quality means-tested programs are socially efficient (i.e. generates positive net returns at the aggregate level). Berlinski and Schady (2016) provide a review and an interpretation of the evidence in Latin America, confirming the importance of quality. Focusing on two types of programs - home visits and daycare programs - they report positive effects on cognitive skills for all home visit interventions (ranging from 0.2 to 1.2 standard deviations) while both positive and negative effects for day care programs (ranging from –0.2 to 0.2 standard deviations).

While the quality of the intervention matters and the benefit-cost ratios vary for different program, the consensus in the literature is that investing in *comprehensive* birth-to-five early childhood programs leads to significant returns in the accumulation of subsequent human capital, in labor market outcomes, in health outcomes and in positive social behavior. [Elango et al. (2016); Berlinski and Schady (2016); Heckman and Mosso (2014).]

**Returns to Education Investments.** Returns to education are one of the most estimated coefficient in empirical microeconomics. They have been estimated on a large number of

[9] Elango et al. (2016) survey early childhood education; Berlinski and Shady (2016) interpret early years interventions in Latin America; Heckman and Mosso (2014) focuses on the economics of human development and social mobility emphasizing the importance of early life conditions; Cunha et al. (2010) provide methods to estimate skill formation starting from early childhood; and Cunha et al. (2006) review and interpret the empirical evidence.

[10] The Carolina Abecedarian Project (ABC) and the Carolina Approach to Responsive Education (CARE).

[11] Hogares Comunitarios de Bienestar (HCB).

countries and over long time periods.[12] In a typical specification, the human capital investment of interest is represented by the number of years of schooling completed. Other specifications look at the highest degree completed, occasionally at the type of degree within the same level. Typical controls include a quadratic term in labor market experience (generating the so called *mincerian regression,* from Mincer (1974)) and demographic variables such as marital status and gender. For case studies on specific countries the set of controls may become particularly large, including measure of individual ability (such as test scores) or family background variables (such as parents' education).

Particularly relevant for the growth literature are papers estimating returns to education on a large number of countries using comparable data.[13] Working with micro data from 149 countries, Montenegro and Patrinos (2014) estimate that, on average, one additional year of schooling is associate with a 9.7% increase in earnings; with higher increases for women than men (11.4% with respect to 9.1%). However, they find wide variations between countries and over time: returns range from more than 25% to less than 1%. Similar results are found by Caselli (2015) which collects estimation results from different authors on 87 countries in the mid-1990s and 91 countries in the mid-2000s. Regional patterns by world regions over time show stable returns in Europe and Central Asia (about 7%) and in Africa and the Middle East (about 8%); a decrease in returns in Latin America and the Caribbean (from more than 10% in the 1990s to about 8% in the 2000s); and an increase in returns in South-East Asia and the Pacific (from about 8% in the 1990s to more than 10% in the 2000s.) Again, country variation within world regions is substantial. A different way to summarize estimates extracted from a large set of different papers is proposed by Ashenfelter et al. (2001). They acknowledge the importance of potential bias in returns to schooling estimates, collecting works using different samples and estimation method. They then conduct a meta-analysis based on about a hundred estimates on nine different countries. The meta-analysis aggregates the estimation results using different weight based on estimation method and publication bias. The average returned obtained is comparable to those reported above: about 7% from estimates based on ordinary least squares (OLS) and about 9% from estimates attempting to reduce estimation bias (instrumental variable estimators (IV) and estimators based on sample of twins).

Given the importance accorded to education in building human capital, the empirical literature has also attempted to estimate the interaction between education and other human capital components. Heckman, Humphries, and Veramendi (2016) estimate causal consequences of schooling decisions on health status and smoking behavior using a dynamic model of investment in schooling. Two main results emerge from their work. First, returns to schooling investments are very heterogeneous in the population. For high-ability individuals, completing High School or College has not only high direct returns but also improves the option of acquiring additional valuable schooling. For low-ability

[12] A partial list of important contributions include: Griliches (1977); Mincer (1974); Card (2001); Heckman, Lochner, and Todd (2006); Goldin and Katz (2008).

[13] Recent examples presenting estimates for a variety of world regions include Caselli (2015), Montenegro and Patrinos (2014) and World Bank (2012). Peet, Fink and Fawzi (2015) present results on 25 developing countries. Flabbi, Paternostro, and Tiongson (2008) focus on 8 ECA countries and estimate returns over two decades.

individuals, a significant direct effect is still present but the positive impact on future options is negligible. Second, returns to schooling on health outcomes are significant: Completing College with respect to dropping out from High School reduces the probability of smoking by more than 17%. Lochner (2011) is a complete review of empirical works in economics attempting to estimate what are labeled as the *non-production benefits* of education. They include impacts on crime, health, and good citizenship. Some of the results report very large effects. For example, Lochner and Moretti (2004) propose both an OLS and IV estimation strategy concluding that an extra year of completed schooling is associated with a 10-15% reduction in incarceration rates. Brunello et al. (2013) estimate that years of schooling have a causal effect on the body mass index (BMI) of women living in nine European countries: one additional year of schooling reduces the BMI by 1.84%.

Finally, a last important interaction between education and human capital concerns the transmission of the accumulated human capital to the next generation. The empirical literature has found strong correlations between income and human capital of parents and children.[14] The theoretical literature has pointed out the importance of the intergenerational transmission of human capital and the role that family backgrounds play in affecting human capital investments [Becker and Tomes (1986)]. The literature on education mobility is vast and finds positive and significant impact of mother's education on children outcomes. The evidence on father's education is more mixed. The impact of policy interventions aiming at reducing the importance of family background in favor of equality of opportunities in education is also very well developed.[15] Family backgrounds and policy interventions may also play a role in explaining the persistence of human capital over time. Rocha, Ferraz, and Soares (2017) is a particularly relevant contribution in this literature because it is able to link individual-level human capital investment with regional-level long-term development.

Despite the large variation in estimated returns and the problems in identifying causal impacts, returns to schooling estimated on micro data provide some valuable lessons:

1. Returns are different in magnitude but they are positive in virtually all countries and periods;
2. Returns are systematically different not only by country and region but also by demographic groups (notably, gender, cohort of birth and ethnic groups);
3. Returns are different over time within the same country. High income countries exhibit more stable returns than developing countries;
4. Returns to education decisions are not limited to income but include non-production benefits, such as impacts on health, crime and political participation. These returns are estimated to be positive and significant.

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[14] A classic references on the intergenerational transmission of income is Solon (1992); a recent contribution is Lefgren et al. (2012). On human capital intergeneration transmission, see Black, Devereux, and Salvanes (2005). International comparisons are provided in Chevalier, Denny, and McMahon (2003) and Hertz et al. (2007).

[15] For a review on Europe, see Dolton, Asplund, and Barth (2009). For the impact of school tracking and intergenerational mobility in education, see Dustmann (2004) and Checchi and Flabbi (2007).

**Returns to Skills.** Human capital investments produce returns only if they generate valuable skills. Unpacking the process moving from investments to skills formation to returns implies measuring these skills at different points of the accumulation process.

Many empirical works in this area use the *Programme for the International Assessment of Adult Competences* (PIAAC) survey to measure adult skills. PIAAC is developed by the OECD to measure cognitive skills that are considered necessary to be a productive worker and a participating member of society. PIAAC also provides measures that are comparable internationally. Hanusheck et al. (2016) perform cross-country regressions on 31 countries. They estimate increases in gross hourly wages as a result of a standard deviation increase in the numeracy score. The estimated returns range from 9.4% (with full controls) to 19.9% (with only country fixed effects controls). OECD (2016) uses the same survey on all 33 participant countries in 2014-2015 concluding that one standard deviation more on the literacy scale increase the probability to be employed by 0.8 percentage point and is associated with a 6% increase in wages.

However, cognitive skills are just one of the possible skills relevant in the human capital accumulation process. Recently, economists have followed other social scientists in recognizing the importance of personality traits, or non-cognitive skills, as important components of human capital and, ultimately, labor productivity.[16] Non-cognitive skills can be defined as components of human behavior, including thoughts and feelings, which are important in inter-personal and social interactions. A typical taxonomy adopted from Psychologists includes the *Big Five* of personality traits: openness, conscientiousness, extraversion, agreeableness, and neuroticism (emotional stability). Specific traits that have proved to be particular important for labor productivity are self-esteem and locus of control, which are strongly associated with conscientiousness and emotional stability [Almlund et al. (2011)]. Glewwe et al. (2016) is one of the first contribution considering both cognitive and non-cognitive skills measured in the early years as predictors of outcomes in a developing country. They focus on China's poorest provinces estimating that both types of skills are important to predict education attainment. When education attainment is controlled for, however, they are not strong predictors of early labor market outcomes.

**Returns to Experience and Seniority.** Human capital accumulation continues once individuals transit from schooling to the labor market since working at a given job involves important learning processes. A standard proxy used to capture the overall return of this human capital accumulation is the years of work experience accumulated by a given worker. A typical specification is the so called *Mincerian regressions* [Mincer (1971)] where log wages are regressed on years of schooling $s_i$ and years of work experience $e_i$, linear and squared:

$$lnw_i = \beta_0 + \beta_1 s_i + \beta_2 e_i + \beta_3 e_i^2 + \varepsilon_i \qquad [8]$$

[16] For a review, see Almlund et al. (2011). For an early example applied to labor productivity, see Heckman et al. (2006). For an important data collection initiative focusing on middle- and low-income countries see the World Bank's *STEP Skills Measurement Program* (STEP) [Pierre et al. (2014)].

Years of work experience enter the specification in a quadratic form to allow for the return to be decreasing for high values of experience. This is one of the important empirical regularities originally found by Mincer. The human capital model may explain this regularity. Over their career, individuals are subject to two processes: accumulation of new human capital through learning on the job but also depreciation of the human capital previously acquired. Eventually, the second process dominates leading to a reduction and possibly a reversal of returns to experience.[17] Returns to experience estimates are almost as common as returns to years of schooling estimates since they are frequently jointly estimated in a specification similar to equation [8]. In Montenegro and Patrinos (2014) the estimate for potential experience is centered around 3.1% a year in a large sample of countries. Potential experience is positively correlated with returns to schooling and its variation across countries is large, with some countries registering returns twice as large while others almost zero. The recent literature has also focused on the evolution of returns to experience over time. Kambourov and Manovskii (2008) focus on the US showing a flattening of experience profiles over the birth cohorts 1950-1970. Returns to experience may also change together with other human capital characteristics, such as education [Card and Lemieux (2001)].

An important characteristic of at least some of the human capital accumulation on-the-job is being *specific* to that job, becoming not easily portable to another job. The first original contributions by Becker, see for example Becker (1962), were emphasizing this argument by distinguishing between *general* and *specific* human capital. In this terminology, years of schooling are an example of general human capital while years of experience in a given firm (tenure or seniority) are an example of specific human capital. Typical estimates for a high-income country such as the U.S. are about 11% wage increase for ten additional years of seniority at a given firm [Flabbi and Ichino (2001)]. Between the overall experience accumulated in the labor market and the more specific experience accumulate in a given firms, recent literature has shown the importance of intermediate categories. Kambourov and Manovskii (2009) emphasizes the importance of experience accumulated in a specific occupation or industry. They estimate on US data that 5 years of experience in the same 3-digit occupation increase wages 12% to 20% a year. Sanders and Taber (2012) provide a review of the contributions trying to empirically disentangle the importance of general and specific human capital. They conclude that no human capital accumulation on the job can be fully described as general or specific. Rather, the empirical evidence fits better a model of task-specific human capital which is not fully industry-specific nor occupation-specific. Autor and Handel (2013) estimate that one standard deviation increase in abstract task content within the same occupation leads to a 7% increase in wages.

There is also a large literature claiming that returns to seniority are not related to productivity increases.[18] These contributions challenge the human capital interpretation of the positive coefficients estimated on measures of experience and seniority in equations

[17] Mincer, however, did not share this human capital interpration of his results: see Heckman et al. (2006) for a recent reconsideration of his arguments.

[18] The literature started with Medoff and Abraham (1980) who had the idea of using supervisors' evaluations to control for productivity differences in wage equations and continued with Altonji and Shakotko (1987). More recent contributions are Flabbi and Ichino (2001); Dohmen (2004): Buchinsky et al. (2010).

similar to [8]. They propose explanations based on deferred compensation, match-specific productivity in presence of search frictions, personnel networks within the firm.

**Returns to Health Investments.** Individual health status is an important component of human capital but it is more difficult to measure at the micro level than schooling or labor market experience. This section reviews some of the variables that have been used in the literature to proxy individual health and discusses their estimated returns.

An important component of individual health which is frequently collected in household surveys is *disability status*. Disability is typically defined as "a physical, mental, or other health condition that limits the kind or amount of work" an individual can perform.[19] Gilleskie and Hoffman (2014) use this measure to estimate the impact of health capital on wages. To reduce endogeneity, they develop a model of joint health and labor market decisions. Their estimates on U.S. data show that the direct effect of moderate disability on wages is significant but relatively small (about $0.30 per hour).[20] However, they find strong impacts on labor market transitions: moderately disabled workers are 23% more likely to make an occupation or employment transition than nondisabled workers. Since the returns to these transitions are estimated to be lower for individuals affected by disability and since the disability induces more of them, the overall impact of disability accrues over time, generating much larger impact on wages in the medium-long run. Campolieti and Krashinsky (2006) use Canadian data to study the impact of accidents on the job. They similarly show the important interaction between disability and job mobility. Their estimates suggest larger wage losses for disabled workers who did not return to work with their time-of-accident employer than for those who did return, with the latter earning 27% more.

Another component related to health status that is receiving increasing attention is *body mass*. Thomas and Strauss (1997) is one of the first contribution studying the impact of health on wages in Brazil. They estimate a significant association between Body Mass Index (BMI) and wages of males, in particular among the less-educated. Harris (2014) estimates the full labor market impact of BMI by allowing long-run effects to take place. He uses a life-cycle model similar to Gilleskie and Hoffman (2014) estimating that a reduction in an individual's initial body mass by 10% leads to a 4% increase in wages after age 30. Brunello et al. (2009) focus on obesity confirming the significant negative correlation between obesity and wages in a review of a large number of European countries.

Finally, *stunting* is an important marker of health and cognitive status for children. A child is affected by stunting when she is being excessively short for her age (2 standard deviations below the median of a healthy reference population). The review presented by Hoddinott et al. (2013a) looks at the impact of stunting in the 1000 days after conception throughout the life cycle. Using a range of estimates for a variety of countries, they conclude that the prevention of one fifth of stunting would increase income by 11%. Victora et al. (2008) use a long cohort study on Brazil estimating that a one standard

[19] This is the definition used by one of the most important survey used in the U.S. literature, the Survey of Income and Program Participation (SIPP) conducted by the United States Census Bureau.
[20] They use the 1996 SIPP which covers individuals up to the year 2000.

deviation increase in the height-for-age score at age 2 increases annual income by 8% for both men and women. Hoddinott et al. (2013b) use data for Guatemala. They estimate that being stunted at age 2 decreases wages by 16% for men and 14% for women. When using an IV strategy to reduce endogeneity bias the impact becomes much larger for men (65%) and slightly larger for women (18%) but it is less precisely estimated. Finally, the comprehensive review provided by Galasso and Wagstaff (2016) confirms the large impact of stunting on income by performing a meta-analysis on program evaluations of nutrition interventions.

Despite the difficulty in measuring health investments and the problems in identifying causal impacts, returns to health are potentially a large component of individual human capital. If some of the earlier literature focused on dramatic impacts on health, such as disability, the most recent literature is working on outcome variables more susceptible to marginal changes, such as body mass indexes.

### 4.2.3 Interpretation of the results

Does the estimated 9.7% return in earnings for one additional year of schooling mean that if a policy manages to increase education by one year for the entire population the overall income will increase by 9.7%? Based on the estimate that a reduction in an individual's initial body mass by 10% leads to a 4% increase in wages, is it possible to conclude that a national nutrition policy able to achieve that objective for the entire population will lead to a 4% increase in overall wages? The answer is generally *no* due to two main reasons: *biased estimates* and *equilibrium effects*. The first relates to the possible bias affecting the estimates of the parameters of interest. The second relates to the difficulty of building counterfactual policy experiments able to take into account behavioral responses.

**Biased Estimates.** In virtually all the settings described in the previous review of the empirical results the parameters of interest are at risk of estimation bias. In a regression context, the issue is frequently framed as lack of identification: the estimates of the parameters of interest are not really *causal* but may simply represent a conditional correlation or a potentially spurious empirical association. The two main sources of bias are *unobserved individual heterogeneity* and *reverse causation*.

*Unobserved individual heterogeneity* refers to relevant individual-level variables affecting the relation of interest but not available in the data used in estimation. This omission generates endogeneity either directly as a standard *omitted variables bias* or indirectly by implying not-random *sample selection*. Unobserved individual heterogeneity may also mask important heterogeneous effects, i.e. the fact that the relation of interest is very different between individuals in the population. If this is the case, the estimated parameters may only be reporting a distorted average of them.

Consider once again equation [7] presented at the beginning of this section. Assume that the human capital variable of interest is the years of schooling completed $s_i$:

$$lnw_i = \beta_0 + \beta_1 s_i + x'_i\beta + \varepsilon_i \qquad [9]$$

The parameter of interest is $\beta_1$ which could be interpreted as the *return* (in term of wages $w_i$) of an additional year of schooling. Now assume the presence of unobserved individual heterogeneity. For example, that individuals are heterogeneous in their level of *ability* $a_i$. Higher ability makes individuals more productive on the job increasing their wages. Since ability is not observed, will enter the wage equation through the error term which becomes equal to:

$$\varepsilon_i = a_i + u_i$$

where $u_i$ is the usual uncorrelated random error. If one additionally assumes, as in the original model by Becker, that higher ability also induces higher schooling levels then ability will also be correlated with the years of schooling completed $s_i$. As a result, a simple regression of log wages $lnw_i$ on schooling $s_i$ and controls $x_i$ generates biased estimates. The intuition is straightforward: the higher wages observed for individuals with higher schooling may be due both to their higher level of schooling and to their higher level of ability but it is not possible to disentangle the two separate effects. Formally, the variable of interest is correlated with the error term:

$$Cov(\varepsilon_i, s_i) > 0$$

and therefore schooling is endogenous and the OLS estimator is biased.
When this is the case, it becomes difficult to derive sensible policy implications. Consider a simple version of individual heterogeneity where the population is composed of only two types of individuals: High ability and Low ability individuals. High ability individuals complete College earning a wage $w_{High}$; low ability individuals complete only High School earning a wage $w_{Low}$. Suppose a policy is implemented in order to increase education at the level of College for all the individuals with only High School. Based on OLS estimates, one would expect a return equal to ($w_{High}$ - $w_{Low}$) for each individual. However, the actual return would be much lower because $w_{High}$ is the wage earned by individuals completing college *and* endowed with High ability. From the estimates, we cannot predict what the wage of individuals completing college *and* endowed with Low ability is and therefore we cannot evaluate the impact of the policy.

*Reverse causation* refers to situations in which the direction of the causation is ambiguous. Again, consider the log wage regression equation presented earlier. Assume that the human capital variable of interest is a measure of individual health $h_i$:

$$lnw_i = \beta_0 + \beta_1 h_i + x'_i\beta + \varepsilon_i \qquad [10]$$

The parameter $\beta_1$ can be considered the wage return of health investments. A positive estimated coefficient suggests that a healthier individual is a more productive worker, therefore earning a higher wage. However, the opposite direction of causation may also be true. If health, productivity and returns are jointly determined one cannot exclude the fact that it is the higher wage the cause of the higher health index. Since higher wages are associated with the possibility of buying healthier, more nutritious food and with the availability of better health services, there is a genuine causal channel from higher wages to better health. This may well be the true reason behind the positive estimated coefficient.

*Solutions.* Both sources of biased estimates have been acknowledged by the literature early on.[21] The two main econometric solutions are the use of exogenous variation in order to eliminate the source of endogeneity and the use of economic modeling in order to explicitly trace the channels of the endogeneity. The two methods are almost always used in combination but specific applications emphasize one or the other. Contributions emphasizing economic modeling are presented in the next section, when they will be combined with a discussion of equilibrium effects. What follows is a brief discussion of contributions emphasizing exogenous variation in a setting very similar to the one just described in equation [7] to [10]. The approach is the following. Since the source of bias is the correlation between the human capital variable of interest ($hc_i$) and the error term:

$$Cov(\varepsilon_i, hc_i) \neq 0$$

it is important to isolate variation in $hc_i$ which is *not* correlated with the error term. A common way to implement this is finding a variable $z_i$ (called instrumental variable) which is correlated with the variable of interest but not with the error term:

$$Cov(z_i, hc_i) \neq 0 \qquad [11]$$

$$Cov(z_i, \varepsilon_i) = 0 \qquad [12]$$

The fact that the variable is correlated with the variable of interest (condition [11]) allows for the identification of the effect of the interest. The fact that the variable is not correlated with the variable of interest (condition [12]) is the exogeneity condition necessary to solve the bias. The returns to schooling literature is particularly rich with examples of instrumental variable. Starting from the 1990s, these instrumental variables have been inspired by so called *natural experiment*, i.e. institutional changes or similar events able to mimic a quasi-random assignment to a different level of schooling or human capital. A classic example from the labor literature is the Viet Nam era draft lottery [Angrist and Krueger (1992).] A classic example from the development literature is the roll out of school construction in Indonesia [Duflo (2001).] A recent example using a reform of wage setting in Israeli kibbutzim is able to estimate directly the responsiveness of schooling investment to changes in their returns [Abramitzky and Lavy (2015)] The last fifteen years have also seen a flourishing of Randomized Control Trials (RCT) where the exogeneity of the source of variation is assured by construction by randomly assigning individuals (or household or villages) to a treatment or to a control group. A recent application randomly assigns women in rural India to three years of recruiting services providing information about requirements and remunerations of relatively skilled jobs [Jensen (2012).] Estimation results show that schooling acquisition increased when women were informed about the labor market opportunities available with those skills.

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[21] See for example the classic Griliches (1977) applied to returns to schooling. A more recent review is Card (1999) and a simple interpretative framework is provided in Card (2001).

**Equilibrium Effects.** Even in the presence of unbiased estimated parameters, one additional problem remains. The parameters are estimated on data extracted from a given economy, with given prices and policy parameters. Evaluating a policy, or even simply trying to give an interpretation to a given return, requires imagining or simulating a counterfactual environment where some of these fundamentals change. For example, suppose to have estimated returns to schooling in a country with 12 years of average completed schooling. A relevant policy question may be asking what the average wage or the overall wage distribution in the country would be when the average years of schooling completed in the population is increased to 16. The answer is not obvious since it cannot simply use the wage regression parameters estimated in the pre-policy environment. If more people complete more education, the supply of skilled workers in the labor market increases. But if the supply increases, the wages for skilled workers will fall. As a result, the pre-policy returns cannot be simply transferred to the post-policy environment.

These general equilibrium effects are difficult to fully incorporate in empirical micro-model while they are more common in many macro-models performing quantitative exercises using calibrated or estimated parameters.[22] Still, interesting examples exist. Kahanna (2016) uses a large expansion of the public-school system together with a model of human capital accumulation. Both elements are embedded in a model of the labor market for skills in order to study returns to schooling once general equilibrium effects are taken into account. The estimated returns are in the usual range (13.4% return for an additional year of education) but the equilibrium impact of adding more educated work force to the labor market is shown to depress the returns to skill reducing the economic benefit of the human capital investment.

If general equilibrium effects are important when considering large scale policies, they may be less crucial when the policy intervention is more limited. But even if this is the case, there can still be partial equilibrium effects due to changes in workers' behavior. Two examples from the literature on search models of the labor market[23] estimated on micro data [Eckstein and Wolpin (1995); Flinn and Mullins (2015)] illustrate this point. They assume that that markets are not completely competitive so that it requires time and effort to meet a firm offering a job.

Eckstein and Wolpin (1995) study returns to schooling in the US. They make the point that accepted wages may be different from wages offered to the agents during the search process. Returns estimated from wage regressions such as equation [8] use observed wages, i.e. wages at which agents have accepted to work. However, each agent may have received and rejected many wage offers before the one observed in the data. Agents reject wage offers in the hope of receiving a better offer at the next meeting with an employer. How selective workers are in accepting a wage offer depends on the schooling level but also on

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[22] The debate dates back at least to the so called Lucas critique [Lucas (1976)]. Recent examples include Dynamic Stochastic General Equilibrium (DSGE) models (see Sbordone et al. (2010) for a review aimed at policy makers) and macro search model of the labor market incorporating endogenous job creation (see Rogerson et al. (2005) for a review.)

[23] See for example the reviews by Rogerson et al. (2005) focusing on macro search and by Eckstein and van den Berg (2007) focusing on empirical micro search.

other factors. Consider a simplified economy where there are just two types of job searcher: a College educated agent assumed to receive high utility from leisure and a High School educated agent assumed to receive low utility from leisure. The High School agent will receive lower job offers because she has completed less schooling. Despite this, she will be likely to accept them because she does not value leisure very much. The College agent will receive higher job offers because she has completed more schooling. On top of that she will be very picky before accepting them because working will force her to give up at least a portion of the leisure she so much values. The differential in accepted wages between the two workers will then be driven by two different forces: the difference in schooling level, which is a genuine return to schooling, and the difference in preferences for leisure, which should not be factored in as return. Genuine returns to schooling should be computed based on wage offers not accepted wages. Recovering the wage offer distribution becomes necessary in order to evaluate the actual returns to schooling. Eckstein and Wolpin (1995) estimate the differences between returns estimated on accepted wages and returns estimated on wage offers to be significant. Using NLSY79 data on men, they estimate the internal annual rate of return for completing College relative to only completing High School to be 31.5% for blacks and 17.0% for whites. The same returns would be much lower if only accepted wages were considered: respectively, 9.4% for blacks and 11.9% for whites.

Flinn and Mullins (2015) show how the previous considerations are also important when building counterfactuals to evaluate policy experiments. They study school subsidies taking into account that any change in them, even if small scale, will have an impact on the reservation wage of all the individuals participating in the market. But if reservation wages change, then it is not enough to know the current accepted wages: the evaluation of the policy requires predicting the accepted wages in the new policy environment. In order to predict the new accepted wages the primitive wage offers need to be recovered. They accomplish this thanks to the structure of the search model together with some parametric assumptions. They conclude that a schooling subsidy financed by a lump-sum tax improves overall welfare, reduces aggregate unemployment, and increases production in the economy. A school subsidy covering about 10% of the cost of schooling will increase output by about 4.6%.

## 5. Conclusion

Human capital is a broad concept including "*education, training, medical care, and other additions to knowledge and health*" [Becker (1992)] but also neural connections in the brain [Romer (2015)]. The importance of human capital in affecting growth has long been recognized by the literature [Lucas (1988); Romer (1990).] The paper summarizes it by describing three main pathways:

1. *The direct impact*, responsible for increasing the stock and accumulation of the factor of production labor;
2. *The impact on technological progress*, able to increase the productivity of all the factors of production.

3. *The interaction between physical and human capital*, affecting the returns of a given mix of the two main production factors.

As a result of this framework, any policy related to education, job training, health but also early childhood development and other areas influencing the productivity of an individual in the economy affects human capital accumulation and, ultimately, growth.

If the direction of the impact is unambiguously positive - the accumulation of human capital is associated with positive growth - the magnitude of the impact - what is the return of a given human capital investment - is much more difficult to evaluate. Two strands of the literature attempt to provide an answer. The empirical macro literature takes a direct approach, considering output (GDP) as the dependent variable of interest and using aggregate measures of human capital investments as inputs. The typical example are cross-country regressions where GDP is the dependent variable. Observed measures of human capital investments (such as years of schooling and life expectancy) are the regressors of interest [Barro and Sala-i-Martin (1995).] Equally relevant is the literature on development accounting where output growth is decomposed into the growth of its measurable components (physical capital and human capital) with the residual interpreted as TFP [Caselli (2005).] The empirical micro literature takes a more indirect route because the dependent variable is typically a measure of labor income observed at the level of the individual agent. If the impact on growth is more indirect (wages or labor income are only one component of overall GDP) there are numerous advantages of using this approach. First, since they do not need to aggregate at the country level, micro-level estimates use all the information available in the data. Second, they can estimate more flexible specifications. For example, each country is allowed to have different returns to human capital investments. Third, the range of additional controls that can be added to the specification is larger because survey data typically include more detailed information than aggregate level data. Fourth, micro level estimates may better incorporate the individual heterogeneity which is an integral part of the original human capital model.

The paper provides a survey of quantitative results in both the empirical macro and micro literature, considering human capital components ranging from years of schooling to disability indexes, from early childhood development indicators to multidimensional measures of skills.

Both theory and evidence show that investing in human capital is a promising strategy to attain stable positive growth. But the magnitude of the effects remains country-specific, varying based on the population of interest, the policy under consideration, and the human capital component considered. As a result, the paper suggests the use of micro data tailored to evaluate the specific policy of interest in the country under consideration, in conjunction with economic models able to aggregate the micro-level effects.

## References


**Abramitzky, Ran, and Victor Lavy (2014).** "How responsive is investment in schooling to changes in redistributive policies and in returns?." *Econometrica* 82 (4): 1241-1272.

**Acemoglu, Daron, (1998).** "Why do new technologies complement skills? Directed technical change and wage inequality," *The Quarterly Journal of Economics* 113 (4): 1055-1089.

__ **(2002).** "Technical Change, Inequality and the Labor Market," *Journal of Economic Literature* 40: 7-72.

__ **and Simon Johnson, (2007).** "Disease and Development: The Effect of Life Expectancy on Economic Growth," *Journal of Political Economy* 115 (6): 925-985.

__ **and Robert Shimer, (1999).** "Holdups and Inefficiencies with Search Frictions," *International Economic Review* 40: 827-849.

**Altonji, J., Shakotko, R., (1987).** "Do wages rise with job seniority?" *Review of Economic Studies* 54, 437–459

**Angrist, Joshua D., and Alan B. Krueger, (1992).** "Estimating the payoff to schooling using the Vietnam-era draft lottery." *NBER Working paper* No. w4067.

**Almlund, M., A. Duckworth, J. Heckman, and T. Kautz. (2011).** "Personality Psychology and Economics", in: E. Hanushek, S. Machin, and L. Woessman (eds.) *Handbook of the Economics of Education*, Vol. 4, Amsterdam: Elsevier, pp. 1-181.

**Ashenfelter, Orley, Colm Harmon, and Hessel Oosterbeek, (2001).** "A Review of Estimates of the Schooling/Earnings Relationship, with Test for Publication Bias," *Economic Journal* 111: 791-820.

**Attanasio, Orazio, Arlen Guarín, Carlos Medina, and Costas Meghir, (2015)**. "Long term impacts of vouchers for vocational training: Experimental evidence for Colombia," NBER Working Paper w21390, National Bureau of Economic Research.

**Autor, David H., and Michael J. Handel. (2013)** "Putting tasks to the test: Human capital, job tasks, and wages." *Journal of Labor Economics* 31.S1: S59-S96.

**Baird, Sarah, Joan Hamory Hicks, Michael Kremer, and Edward Miguel, (2016)**. "Worms at work: Long-run impacts of a child health investment," *The Quarterly Journal of Economics* 131 (4): 1637-1680.

**Barro, Robert J. (2015)** "Convergence and modernisation." *The Economic Journal* 125, no. 585: 911-942.

**__ , and Jong Wha Lee. (2013)** "A new data set of educational attainment in the world, 1950–2010." *Journal of development economics* 104: 184-198.

**__ , and Xavier Sala-i-Martin. (1995)** "Economic growth." *McGrawHill, New York*.

**__ , and Jong-Wha Lee. (1993)** "International comparisons of educational attainment." *Journal of monetary economics* 32, no. 3: 363-394.

**Becker, Gary S**., **(1962).** "Investment in Human Capital: A Theoretical Analysis," *Journal of Political Economy* 70 (5): 9–49.

**__ , (1993).** "Nobel Lecture: The Economic Way of Looking at Behavior," *Journal of Political Economy* 101 (3): 385–409.

__ , **(1993).** *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*, University of Chicago Press.

**Ben-Porath, Yoram, (1967).** "The production of human capital and the life cycle of earnings," *Journal of Political Economy* 75 (4): 352-365.

**Berlinski, Samuel and Norbert Schady (Ed.), (2016).** *The early years: child well-being and the role of public policy*, DIA Series-IDB, Springer.

**Bernal, Raquel and Camila Fernández, (2013).** "Subsidized child care and child development in Colombia: Effects of Hogares Comunitarios de Bienestar as a function of timing and length of exposure," *Social Sciences & Medicine* 97: 241-249.

**Bils, Mark, and Peter J. Klenow, (2000).** "Does schooling cause growth?" *American Economic Review* 90 (5): 1160-1183.

**Black, Sandra E., Paul J. Devereux, and Kjell G. Salvanes. (2005)** "Why the apple doesn't fall far: Understanding intergenerational transmission of human capital." *American economic review* 95, no. 1: 437-449.

**Bleakley, Hoyt**, **(2007).** "Disease and Development: Evidence from Hookworm Eradication in the American South," *Quarterly Journal of Economics* 122 (1): 73-117.

**____, (2010).** "Malaria eradication in the Americas: A retrospective analysis of childhood exposure," *American Economic Journal: Applied* 2 (2): 1-45.

**Bollinger, C. (1998).** "Measurement Error on the Current Population Survey: A Nonparametric Look", *Journal of Labor Economics*, 16(3), pg. 576- 594.

**Bound, J., C. Brown and N. Mathiowetz (2001).** “Measurament Errors in Survey Data”, in: J.J. Heckman and E.E. Leamer (eds.), *Handbook of Econometrics*, Volume 5, Amsterdam: Elsevier Science. ☒

**Brunello, Giorgo, Daniele Fabbri, and Margherita Fort**, **(2013).** "The Causal Effect of Education on Body Mass: Evidence from Europe, " *Journal of Labor Economics* 31 (1): 195-223.

**Brunello, Giorgio, Pierre-Carl Michaud, and Anna Sanz-de-Galdeano, (2009)**. "The Rise of Obesity in Europe: An Economic Perspective," *Economic Policy* 24 (59): 551-96.

**Buchinsky, M., Fougere, D., Kramarz, F., & Tchernis, R. (2010).** "Interfirm mobility, wages and the returns to seniority and experience in the United States." *The Review of economic studies*, *77*(3), 972-1001.

**Campolieti, Michele, and Harry Krashinsky, (2006)**. "Disabled workers and wage losses: some evidence from workers with occupational injuries," *ILR Review* 60 (1): 120-138.

**Card, David**, **(1999).** “The Causal Effect of Education on Earnings,” in Orley C. Ashenfelter and David Card (Ed.), *Handbook of Labor Economics*, Elsevier.

**__ , (2001).** “Estimating the Return to Schooling: Progress on Some Persistent Econometric Problems,” *Econometrica* 69 (5): 1127–1160.

**__ , Jochen Kluve, and Andrea Weber (2015)**. “What works? A meta-analysis of recent active labor market program evaluations,” NBER Working Paper w21431, National Bureau of Economic Research.

**__ , and T. Lemieux (2001)** “Can Falling Supply Explain the Rising Return to College for Younger Men? A Cohort-Based Analysis,” *The Quarterly Journal of Economics*, 116, pp. 705–746.

**Carneiro, Pedro, and James J. Heckman, (2004).** "Empirical estimates of the returns to schooling," *Mimeo*, University of Chicago.

**Carneiro, Pedro, Michael Lokshin, and Nithin Umapathi, (2016).** “Average and Marginal Returns to Upper Secondary Schooling in Indonesia,” *Journal of Applied Econometrics* 5.

**Caselli, Francesco, (2015).** *Technology Differences Over Space and Time*, CREI Lecture, Princeton University Press.

__ , **(2005).** “Accounting for cross-country income differences,” in Aghion and Durlauf (Ed.), *Handbook of Economic Growth*, Elsevier Science.

__ , **and Antonio Ciccone. (2013)** "The contribution of schooling in development accounting: Results from a nonparametric upper bound." *Journal of Development Economics* 104: 199-211.

**Cawley, John, (2004).** “The Impact of Obesity on Wages,” *The Journal of Human Resources* 39 (2): 451–474.

**Checchi, Daniele and Flabbi, Luca, (2007)** "Intergenerational Mobility and Schooling Decisions in Germany and Italy: The Impact of Secondary School Tracks." *IZA Discussion Paper* No. 2876.

**Chevalier, Arnaud, Kevin Denny, and Dorren McMahon. (2003)** "A multi-country study of inter-generational educational mobility." *ISSC University of Dublin WP* 2003/06.

**Crépon, Bruno, Esther Duflo, Marc Gurgand, Roland Rathelot, and Philippe Zamora, (2013).** "Do labor market policies have displacement effects? Evidence from a clustered randomized experiment," *The Quarterly Journal of Economics* 128 (2): 531-580.

**Cunha, Flavio, James J. Heckman, Lance Lochner, and Dimitriy V. Masterov, (2006)**. "Interpreting the evidence on life cycle skill formation," *Handbook of the Economics of Education* 1: 697-812.

**__ , James J. Heckman, and Susanne M. Schennach, (2010)**. "Estimating the technology of cognitive and noncognitive skill formation," *Econometrica,* 78 (3): 883-931.

**Dhaliwal, Iqbal, Esther Duflo, Rachel Glennerster, and Caitlin Tulloch, (2011)**. "Comparative cost-effectiveness analysis to inform policy in developing countries: a general framework with applications for education," *Education Policy in Developing Countries*, University of Chicago Press.

**Dohmen, Thomas J. (2004)** "Performance, seniority, and wages: formal salary systems and individual earnings profiles." *Labour Economics* 11.6: 741-763.

**Dolton, Peter, Rita Asplund, and Erling Barth. (2009)** *Education and inequality across Europe*. Edward Elgar Publishing.

**Doyle, Orla, Colm P. Harmon, James J. Heckman, and Richard E. Tremblay. (2009)** "Investing in early human development: timing and economic efficiency." *Economics & Human Biology* 7, no. 1: 1-6.

**Duffy, John, Chris Papageorgiou, and Fidel Perez-Sebastian, (2004)**. "Capital-Skill Complementarity? Evidence from a Panel of Countries," *Review of Economics and Statistics* 86 (1): 327-344.

**Duflo, Esther, (2001)**. "Schooling and Labor Market Consequences of Schooling Construction in Indonesia," *American Economic Review* 91 (4): 795-813.

**Dustmann, Christian (2004)** "Parental Background, Secondary School Track Choice, and Wages", *Oxford Economic Papers*, no. 56, , pages 209-230.

**Eckstein, Zvi and Gerard van den Berg, (2007).** "Empirical labor search: A survey," *Journal of Econometrics* 136: 531-564.

**__ , and Kenneth Wolpin, (1995).** "Duration to First Job and the Return to Schooling: Estimates from a Search-Matching Model," *The Review of Economic Studies* 62 (2): 263-286.

**Elango, Sneha, Jorge Luis García, James J. Heckman, and Andrés Hojman, (2016).** "Early Childhood Education," in Robert Moffitt (Ed.), *Economics of Means-Tested Transfer Programs in the United States*, University of Chicago Press.

**Evans, David, and Arkadipta Ghosh, (2008)**. "The Cost Effectiveness of Education Interventions in Poor Countries," *Policy Insight* 2 (4).

**___ , and Anna Popova, (2014).** "Cost-effectiveness measurement in development: Accounting for local costs and noisy impacts," Policy Research working paper WPS 7027, World Bank Group.

**Flabbi, Luca, Stefano Paternostro, and Erwin R. Tiongson. (2008)** "Returns to education in the economic transition: A systematic assessment using comparable data." *Economics of Education Review* 27, no. 6: 724-740.

**___ , and Andrea Ichino, (2001)** "Productivity, seniority and wages: new evidence from personnel data." *Labour Economics* 8.3: 359-387.

**Flinn, Christopher and Joseph Mullins, (2015).** "Labor Market Search and Schooling Investment," *International Economic Review* 56 (2), 359-398.

**Galasso, Emanuela and Adam Wagstaff**, **(2016).** "The Economic Costs of Stunting and how to Reduce Them," Policy Research Note, World Bank Group (forthcoming).

**García, Jorge Luis, James J. Heckman, Duncan Ermini Leaf, and María José Prados, (2016).** "The Life-cycle Benefits of an Influential Early Childhood Program," NBER Working Paper w22993, National Bureau of Economic Research.

**Gautier, Pieter, Paull Muller, Ban van der Klaauw, Michael Rosholm, and Michael Svarer, (2012).** "Estimating Equilibrium Effects of Job Search Assistance," Tinbergen Institute Discussion Paper 12-071/3.

**Gilleskie, Donna and Denise Hoffman, (2014).** "Health Capital and Human Capital as Explanations for Health-Related Wage Disparities," *Journal of Human Capital* 8 (3): 235-279.

**Glewwe, Paul, Qiuqiong Huang, and Albert Park. (2016)** "Cognitive Skills, Noncognitive Skills, and School-to-Work Transitions in Rural China," *Journal of Economic Behavior & Organization*.

**Goldin, Claudia, and Lawrence F. Katz, (1998).** "The origins of technology-skill complementarity," *The Quarterly Journal of Economics* 113 (3): 693-732.

**Griliches, Zvi, (1969)**. "Capital-skill complementarity," *The Review of Economics and Statistics* 51 (4): 465-468.

**___, (1977).** "Estimating the Returns to Schooling: Some Econometric Problems," *Econometrica*, 1977, 45 (1), 1–22.

**Hanushek, Eric A., Guido Schwerdt, Simon Wiederhold, and Ludger Woessmann, (2016).** "Coping with change: International differences in the returns to skills," NBER Working Paper w22657, National Bureau of Economic Research.

**Harris, Matthew C., (2014).** "What Is the Full Cost of Body Mass in the Workplace? A Dynamic Stochastic Model of Occupational Choice, Hours Worked, and Body Mass over the Life Cycle," Working paper, University of Tennessee.

**Heckman, James J., John Humphries, and Gregory Veramendi, (2016).** "Returns to Education: The Causal Effects of Education on Earnings, Health and Smoking," NBER Working Paper w22291, National Bureau of Economic Research.

**__ , Lance J. Lochner, and Petra E. Todd**, **(2006).** "Earnings Functions, Rates of Return and Treatment Effects: The Mincer Equation and Beyond," in E. Hanushek and F. Welch (Ed.), *Handbook of the Economics of Education* 1, Elsevier Science.

**__, and Stefano Mosso, (2014).** "The economics of human development and social mobility," *Annual Review of Economics* 6 (1): 689-733.

**__, J. Stixrud, and S. Urzua (2006).** “The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior,” *Journal of Labor Economics*, 24(3): 411–82.

**Hertz, Tom, Tamara Jayasundera, Patrizio Piraino, Sibel Selcuk, Nicole Smith, and Alina Verashchagina. (2007)** "The inheritance of educational inequality: International comparisons and fifty-year trends." *The BE Journal of Economic Analysis & Policy* 7, no. 2.

**Hoddinott, John, Harold Alderman, Jere R. Behrman, Lawrence Haddad, and Susan Horton (2013a)**. "The Economic Rationale for Investing in Stunting Reduction," GCC Working Paper Series 13-08.

**__ , Jere R Behrman, John A Maluccio, Paul Melgar, Agnes R Quisumbing, Manuel Ramirez-Zea, Aryeh D Stein, Kathryn M Yount, and Reynaldo Martorell, (2013b).** “Adult consequences of growth failure in early childhood,” *American Journal of Clinical Nutrition* 98 (5): 1170-1178.

**Hsieh, Chang-Tai and Peter J. Klenow (2010)**. “Development Accounting,” *American Economic Journal: Macroeconomics* 2 (1): 207-223.

**Hanushek, Eric and Ludger Woessman (2015).** *The Knowledge Capital of Nations: Education and the Economics of Growth*, MIT press.

**Jacoby, Hanan G., and Emmanuel Skoufias (1997).** "Risk, financial markets, and human capital in a developing country." *The Review of Economic Studies* 64.3: 311-335.

**Jensen, Robert (2012).** “Do labor market opportunities affect young women's work and family decisions? Experimental evidence from India.” *The Quarterly Journal of Economics,* 127 (2): 753-792.

**Jones, Benjamin F. (2014).** “The human capital stock: a generalized approach,” *The American Economic Review* 104.11: 3752-3777.

**Jones, Charles I., and Paul M. Romer (2010).** “The new Kaldor facts: ideas, institutions, population, and human capital,” *American Economic Journal: Macroeconomics* 2.1: 224-245.

**Kambourov, Gueorgui, and Iourii Manovskii (2009).** “Occupational specificity of human capital,” *International Economic Review* 50.1: 63-115.

**Kambourov, Gueorgui, and Iourii Manovskii. (2008).** “Rising Occupational and Industry Mobility in the United States: 1968-1997,” *International Economic Review*, 49.1: pp. 41-79

**Karabarbounis, Loukas and Brent Neiman, (2014).** "The Global Decline of the Labor Share," *Quarterly Journal of Economics* 129 (1): 61-103.

**Katz, Lawrence F., and Alan B. Krueger, (1998).** "Computing inequality: have computers changed the labor market?" *The Quarterly Journal of Economics* 113 (4): 1169-1213.

**Khanna, Gaurav (2016).** "Large-scale Education Reform in General Equilibrium: Regression Discontinuity Evidence from India," mimeo, UC-San Diego.

**Klenow, Peter J., and Andres Rodriguez-Clare. (1997)** "Economic growth: A review essay." *Journal of monetary economics* 40, no. 3: 597-617.

**Krueger, Alan and Lindhal, M., (2001).** "Education for Growth; Why and for Whom*?,"* *Journal of Economic Literature* 39: 1101-1136.

**Krusell, Per, Lee E. Ohanian, José-Víctor Ríos-Rull, and Giovanni L. Violante, (2000)**. "Capital-skill complementarity and inequality: A macroeconomic analysis," *Econometrica* 68 (5): 1029-1053.

**Lefgren, Lars, David Sims, and Matthew J. Lindquist.** "Rich dad, smart dad: Decomposing the intergenerational transmission of income." *Journal of Political Economy* 120, no. 2 (2012): 268-303.

**Lochner, Lance**, **(2011).** "Nonproduction Benefits of Education: Crime, Health, and Good Citizenship," in E. Hanushek, et al. (Ed.), *Handbook of the Economics of Education* 4, Elsevier Science.

**__ , and Enrico Moretti, (2004).** "The Effect of Education on Crime: Evidence from Prison Inmates, Arrests, and Self-Reports," *American Economic Review* 94 (1): 155-189.

**Lucas, Robert, (1976).** "Econometric Policy Evaluation: A Critique," in K. Brunner and A. Meltzer (Ed.), *The Phillips Curve and Labor Markets,* Carnegie-Rochester Conference Series on Public Policy, Elsevier.

**Maloney and Valencia Caicedo (2016).** "Innovative Capacity and Development in the Americas," mimeo.

**Malmberg, Hannes, (2016).** "Human Capital and Development Accounting Revisited," *Job Market Paper*, IIES Stockholm University.

**Mankiw, N. Gregory, David Romer, and David Weil, (1992).** "A contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 107 (2): 407-37.

**Manuelli, Rodolfo E. and Ananth Seshadri**, **(2014).** "Human Capital and the Wealth of Nations," *American Economic Review* 104 (9): 2736-2762.

**Miguel, Edward and Michael Kremer, (2004)**. "Worms: Identifying impacts on education and health in the presence of treatment externalities," *Econometrica* 72 (1): 159-217.

**Mincer, Jacob A. (1974).** *Schooling, Experience, and Earnings*. Boston: NBER.

**Montenegro, Claudio E. and Harry Anthony Patrinos**, **(2014).** "Comparable Estimates of Returns to Schooling around the World," Working Paper 7020, World Bank Group.

**OECD, (2016).** "Skills Matter: Further Results from the Survey of Adult Skills," *OECD Skills Studies*, OECD Publishing.

**Peet, Evan, Günther Fink, and Wafaie Fawzi, (2015).** "Returns to education in developing countries: Evidence from the living standards and measurement study surveys," *Economics of Education Review* 49: 69-90.

**Pierre, Gaelle; Sanchez Puerta, Maria Laura; Valerio, Alexandria; Rajadel, Tania. (2014)**. "STEP Skills Measurement Surveys: Innovative Tools for Assessing Skills," *Social Protection and Labor Discussion Paper*, No. 1421.

**Raveh, Ohad and Ariell Reshef, (2016).** "Capital imports composition, complementarities, and the skill premium in developing countries," *Journal of Development Economics* 118: 183-206.

**Rocha, Rudi, Claudio Ferraz, and Rodrigo R. Soares. (2017)** "Human capital persistence and development." *American Economic Journal: Applied Economics* 9, no. 4: 105-136.

**Rogerson, Richard, Robert Shimer, and Randall Wright, (2005).** "Search-Theoretic Models of the Labor Market: A Survey," *Journal of Economic Literature* 43 (4): 959-88.

**Romer, Paul M. (2015).** "Human Capital and Knowledge," Blog post on the 25th Anniversary of the publication of Romer (1990).

**__ , (1990).** "Endogenous technological change." *Journal of political Economy* 98, no. 5, Part 2 (1990): S71-S102.

**__ , (1986).** "Increasing returns and long-run growth." *Journal of Political Economy* 94, no. 5: 1002-1037.

**Sanders, Carl and Christopher Taber, (2012).** "Life-cycle wage growth and heterogeneous human capital," *Annual Review of Economics* 4 (1): 399-425.

**Sasso, Simone and Jo Ritzen, (2016).** "Sectoral Cognitive Skills, R&D, and Productivity: A Cross-Country Cross-Sector Analysis," IZA Discussion Paper 10457.

**Sbordone, Argia, Andrea Tambalotti, Krishna Rao, and Kieran Walsh, (2010).** "Policy Analysis Using DSGE Models: An Introduction," *Economic Policy Review, Federal Reserve Bank of New York*, 16 (2).

**Schultz, Theodore**, **(1963).** *The Economic Value of Education*, Columbia University Press.

**Solon, Gary. (1992)** "Intergenerational income mobility in the United States." *The American Economic Review*, 393-408.

**Thomas, Duncan, and John Strauss, (1997)**. "Health and wages: Evidence on men and women in urban Brazil," *Journal of Econometrics* 77 (1): 159-185.

**___, Elizabeth Frankenberg, Jed Friedman, Jean-Pierre Habicht, Mohammed Hakimi, Nathan Jones Jaswadi, and Gretel Pelto, (2006).** "Causal Effect of Health on Labor Market Outcomes: Experimental Evidence," Online Working Paper Series, California Center for Population Research.

**Victora, Cesar G, Linda Adair, Caroline Fall, Pedro C. Hallal, Reynaldo Martorell, Linda Richter, and Harshpal Singh Sachdev, (2008).** "Maternal and child undernutrition: consequences for adult health and human capital," *The Lancet* 371 (9609): 340-357.

**Violante, Giovanni L. (2016).** "Skill-Biased Technical Change," in L. Blume and S Durlaf (Ed.), *The New Palgrave Dictionary of Economics*, McMillan.

**Zaman H. and S. Tiwari (2017)**. "Can Safety Nets Contribute to Economic Growth?," *Mimeo,* World Bank Group, *work in progress*.