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► **To cite this version:**

Carmen Camacho, Fernanda Estevan. Intergeneration Human Capital Transmission and Poverty Traps. 2023. halshs-04075431

HAL Id: halshs-04075431

<https://shs.hal.science/halshs-04075431>

Preprint submitted on 20 Apr 2023

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WORKING PAPER N° 2023 – 14

Intergeneration Human Capital Transmission and Poverty Traps

**Carmen Camacho
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JEL Codes: I14, I24, J13, J24, O4.

Keywords: Poverty trap, Human capital, School quality, Intergenerational transmission, Longevity.



Intergeneration Human Capital Transmission and Poverty Traps*

Carmen Camacho[†] and Fernanda Estevan[‡]

April 6, 2023

Abstract

We use an overlapping generations model to investigate the role of parental health investment and children's schooling on the aggregate level of human capital and inequality. In our model, parental longevity affects children's human capital since it impacts human capital transmission. When poor parents cannot afford to invest in health, poverty traps may arise as human capital levels remain low in the long run. Both health costs and public school quality are crucial in determining whether households fall into the poverty trap. We demonstrate that high-quality schools ensure that successive generations become more educated, eventually attaining a higher human capital steady state. However, public health investments are particularly effective, as they affect household income and schooling and allow for human capital transmission through generations. We calibrate our model for Brazil and Chile and show that our model predicts that a poverty trap will arise in Brazil but not in Chile.

Keywords: poverty trap, human capital, school quality, intergenerational transmission, longevity.

JEL Codes: I14, I24, J13, J24, O4.

*Financial support from the Sao Paulo Research Foundation (FAPESP grant # 2015/21640-3 and 2019/25033-5), CNPq and grant ANR-17-EURE-0001 are gratefully acknowledged.

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1 Introduction

Schooling is essential in human capital formation and intergenerational mobility (Bowles and Nelson, 1974; Card et al., 2022). As a result, many public policies have targeted investments in public school quality. However, there is also an increasing notion that parental inputs play a crucial role in determining children’s educational outcomes (Altonji and Dunn, 1996; Bowles and Gintis, 2002; Heckman and Mosso, 2014). This role becomes particularly evident in contexts where adult mortality is high, as in less developed countries. Consequently, parental health investments and public school quality improvements can affect children’s human capital and increase intergenerational mobility.

We build an overlapping generations model for the household to investigate the impact of public school quality and parental health investments on the aggregate level of human capital and inequality. In our two-period model, human capital transmission to children occurs proportionally to parents’ lifespan. Moreover, parental longevity is endogenous, and parents can increase their lifetime by investing in health.

Our paper relates to the vast literature investigating the impact of (endogenous) adult mortality on human capital accumulation. A shorter lifespan is typically associated with less human capital accumulation since it lowers education returns (Chakraborty, 2004; Castelló-Climent and Doménech, 2008; Goenka and Liu, 2020), bequests for children (Chakraborty and Das, 2005a), investments in early life (Birchenall, 2007), and leads to increases in the opportunity cost of education (Chakraborty and Das, 2005b).

We consider an additional important channel: parental mortality reduces human capital transmission from parents to children and generates a trade-off between investing in children’s human capital and adults’ health. In our model, parental human capital transmission affects the marginal return to the child’s schooling due to their complementarity in the human capital production function. Indeed, empirical evidence shows that parental time investment in children is crucial to their future productivity (Guryan et al., 2008; Gayle et al., 2015; Zumbuehl et al., 2021). There is also extensive evidence that parents’ death and health shocks negatively impact children’s education level.¹ In particular, Bar and Leukhina (2010) suggest that learning from parents leads to increased skills, and Ainsworth et al. (2005) show that guardians may not be perfect substitutes for parental human capital transmission. More recently, Kristiansen (2021) documents that children exposed to parental health shocks achieve lower educational attainment, especially those from underprivileged households.

In our model, parents decide on their (private) health investment and their children’s schooling levels, which depend on education quality. Children who do not attend school full-time can work and contribute to the household’s revenue. Although children are not as productive as adults, their labor is valuable. Of course, the less time spent in school, the lower children’s human capital in

¹See, for example, Gertler et al. (2004); Soares (2006); Grant (2008); Rocha and Soares (2010); Sun and Yao (2010); Bratti and Mendola (2014); Baranov and Kohler (2018).

the future.²

We first present our analysis in a partial equilibrium framework, which allows us to show a tractable model and obtain results and directions regarding the steady state of households. We show that households tend to optimally prioritize health investments to the detriment of their children’s schooling. Increasing parental lifespan contributes to household income and allows for the intergenerational transmission of human capital, raising the marginal return to schooling. Our results also show the existence of poverty traps, in particular when school quality is low and health care is costly, leading to low social mobility. At a higher level of school quality, it is unlikely that households will be in a poverty trap unless out-of-pocket health costs are extremely high. Importantly, our setting allows us to consider the relative merits of different public policies, such as investments in public school quality and public health infrastructure. While providing a full cost-benefit analysis of both strategies is out of this paper’s scope, our results suggest that reducing health costs is more effective than improving public school quality.

We then show that our results naturally extend to a general equilibrium setting. To better grasp its properties and dynamics, we numerically simulate our model. While one can easily calibrate our model using publicly available data, we use Brazil and Chile as examples. Interestingly, both countries have similar parameters and fit into the low-quality school setting, where poor households are prone to poverty traps. However, in Chile, unit wages and the level of human capital associated with primary schooling are higher. Consequently, even households starting with low levels of human capital can fully invest in health and schooling over one or two generations, and inequality disappears over time. In contrast, poor Brazilian households can never invest in health and schooling and remain with low levels of human capital even in the long run.

Related to our work, [Stark and Wang \(2005\)](#) also consider intergenerational transmission’s role in human capital formation. Parental transmission and educational investments are substitutes in their setting, but the former is relatively cheaper. Thus, an increased parental lifespan leads to more human capital accumulation. Apart from considering a different human capital production function, our work is highly complementary to [Stark and Wang \(2005\)](#), as we allow parents to invest in their health to prolong their adult lives.

Our study also relates to extensive literature that exploits the mechanisms behind the demographic transition.³ While these models typically indicate channels connecting life expectancy and human capital accumulation, they do not exploit the precise mechanisms of action operating through household decisions, school quality, and parental transmission of human capital as we do here. Instead, they focus on the role of fertility, a channel we intentionally leave aside in our analysis. If anything, introducing fertility decisions in our model would delay the convergence process, rendering the poverty trap more challenging to escape. Our analysis describes an empirically rele-

²The fact that children work is not essential for our findings. Alternatively, we could consider any cost related to schooling.

³The contributions to this literature include [Blackburn and Cipriani \(2002\)](#); [Galor \(2005\)](#); [Cervellati and Sunde \(2005\)](#); [Soares \(2005\)](#); [Lord and Rangazas \(2006\)](#); [Angeles \(2010\)](#); [Cervellati and Sunde \(2011a,b, 2013\)](#); [de la Croix and Licandro \(2013\)](#); [Murtin \(2013\)](#); [Varvarigos and Zakaria \(2013\)](#).

vant channel behind the established negative link between life expectancy and economic growth.⁴ More generally, we also contribute to the literature showing how poverty traps may arise in the absence of perfect markets (see, e.g., Galor and Zeira, 1993; Galor, 1996; Hazan, 2009).

We organize our paper as follows. In Section 2, we present the basic framework, and in Section 3, we calculate the optimal behavior and steady states. Section 4 discusses the model’s implications in a general equilibrium framework. We present our numerical simulations and calibration in Section 5 and the conclusion in Section 6.

2 The Model

The economy comprises agents who live for up to two periods: childhood and adulthood. Population size is constant, as each adult has one child. The child’s future human capital depends on the time spent at school, public school quality and human capital directly transmitted by the parent. The adult supplies labor inelastically and makes all decisions, including the amount invested in her health, the child’s time at school, and household consumption. The adult health investment affects her longevity and human capital transmission to her child.

We study the utility maximization problem of a representative agent (an adult) characterized by a human capital level, h_t , which determines her earning capabilities and is transmitted during the adult’s lifetime to her offspring.

As regards health investment, m_t , we assume there exists an upper bound M , so that $0 \leq m_t \leq M$. In our setting, an investment of M would avoid preventable anticipated mortality.⁵ Note that the lower the value of this upper bound, the more affordable it is to ensure longevity. We assume a linear longevity function for analytical convenience. The fraction of time the parent lives as an adult is:

$$\lambda(m_t) = \frac{m_t}{M}. \quad (1)$$

Thus, while agents have one unit of time endowment during childhood, the time endowment is $0 \leq \lambda(m_t) \leq 1$ in adulthood.

The parent values the household’s expected consumption and the child’s human capital, h_{t+1} . We assume that there is a minimum amount of human capital that all children acquire. In most middle-income countries, this level would correspond to primary education, which is nearly universal nowadays. Therefore, apart from choosing health investment, the adult decides on the fraction of their one-unit time endowment their child spends at secondary and tertiary education, s_t , and at work, $1 - s_t$. These decisions are made based on the expected longevity given by (1) and are carried

⁴See, for instance, de la Croix and Licandro (1999); Sala-i Martin et al. (2004); Acemoglu and Johnson (2007); Ferreira and Pessoa (2007); Lorentzen et al. (2008); De la Croix (2010); Ferreira et al. (2011); Oster et al. (2013). Another strand of the literature exploits the impact of child mortality on education decisions, a complementary approach to the one we adopt in this paper, e.g., Strulik (2004); Azarnert (2006); Estevan and Baland (2007); Kalemli-Ozcan (2008), among others.

⁵Additionally, we could assume an exogenous probability of unanticipated mortality. We do not include that possibility in our analysis for simplicity, but our qualitative results remain as long as unpreventable mortality is not under the individual’s control.

out independently of the parent's survival.

Similar to [de la Croix and Doepke \(2003\)](#), we assume a Cobb-Douglas human capital production function:⁶

$$h_{t+1} = B [\lambda (m_t) h_t]^\beta [E + Qs_t]^{1-\beta}, \quad (2)$$

where B is a technology parameter, $\beta \in (0, 1)$ is the share of parental transmission in human capital formation, E is the education level a child acquires in primary education, and Q is public school quality in secondary and tertiary education.⁷

Household consumption depends upon the adult's longevity:

$$c_t = \lambda (m_t) w h_t + w^c (1 - s_t) - m_t, \quad (3)$$

where w and w^c are adult and child unit wages, respectively. We represent adult's preferences by a logarithmic utility function:

$$\ln c_t + \delta \ln h_{t+1}, \quad (4)$$

where δ measures altruism towards the offspring's human capital, which will determine her future income.

Combining equations (1)-(4), the optimization problem of the household becomes:

$$\max_{l_t, m_t} \ln \left[\frac{m_t}{M} w h_t + w^c (1 - s_t) - m_t \right] + \delta \ln \left[\left(\frac{m_t}{M} h_t \right)^\beta (E + Qs_t)^{1-\beta} \right], \quad (5)$$

subject to $0 \leq s_t \leq 1$, and $0 \leq m_t \leq M$.

There is a single consumption good, and its production only requires labor. The good and labor markets are assumed to be perfectly competitive. Child and adult labor are perfect substitutes, but children are less productive than adults by a factor of γ , where $\gamma < 1$, as in [Basu and Van \(1998\)](#) and [Strulik \(2004\)](#). The condition that ensures equilibrium in the labor market is:

$$w^c = \gamma w, \quad (6)$$

so that the firm is indifferent between hiring adults or children.

⁶The only difference is that we do not include society's average human capital level in (2), which would create an additional source of convergence in the model. We disregard this channel to focus on the role of longevity, education quality, and schooling.

⁷Throughout the paper, we disregard the possibility of private education since we are mainly interested in the trajectories of relatively poor households. However, including private education would raise household costs, possibly delaying convergence.

3 Optimal Behavior and the Steady States

The characterization of the optimal solution and the corresponding steady states depends on whether:

$$I = \frac{Q}{E} \frac{\delta(1-\beta)}{1+\beta\delta} \quad (7)$$

is larger or smaller than 1. Note that $\frac{\delta(1-\beta)}{1+\beta\delta} < 1$, so that $I < 1$ means that Q , secondary and tertiary education quality, is not significantly higher than E , primary school quality. As a result, we can identify $I < 1$ with a low-quality secondary and tertiary schooling setting. On the contrary, $I > 1$ would prevail in an economy with high-quality secondary and tertiary education.

3.1 Low-Quality School Setting

We start by analyzing the case where school quality is low. We derive optimal conditions for m_t and s_t and show that they depend upon the household's initial level of human capital. When the human capital endowment is very low, households cannot invest in their children's education and only partially invest in health. For relatively higher levels of human capital, households tend to privilege investment in health. It contributes to household income, and the parent's longer lifespan also allows intergenerational transmission of human capital. There is full schooling for high levels of human capital, even with low-quality schools. Thus, well-off households fully invest in secondary and tertiary education besides health, even if the quality of schools available is low.

When making optimal decisions, four categories of households arise depending on their human capital, denoted by low, low intermediate, high intermediate, and high. Proposition 1 shows all optimal decisions.

Proposition 1. *When school quality is low, $I < 1$, and depending on the level of the household human capital, h_t , four possible optimal solutions emerge:*

h_t		H_1	H_2	H_3
m_t	$0 < \frac{Mw\beta\gamma\delta}{(M-h_t w)(1+\beta\delta)} < M$	M	M	M
s_t	0	0	$0 < 1 - \frac{(E+Q)w\gamma+Q(M-h_t w)(1-\beta)\delta}{Qw\gamma(1+(1-\beta)\delta)} < 1$	1
h_{t+1}	$(\frac{m_t}{M} h_t)^\beta E^{1-\beta}$	$h_t^\beta E^{1-\beta}$	$h_t^\beta (E + Qs_t)^{1-\beta}$	$h_t^\beta (E + Q)^{1-\beta}$
	low	low intermediate	high intermediate	high

Table 1: Low School Quality. Optimal decisions.

The threshold levels of human capital defining these categories are given by $H_1 = \frac{M}{w} - \frac{\beta\gamma\delta}{1+\beta\delta}$, $H_2 = \frac{M}{w} + \gamma \left(\frac{E}{\delta Q(1-\beta)} - 1 \right)$, and $H_3 = \frac{M}{w} + \frac{\gamma(E+Q)}{\delta Q(1-\beta)}$.

Proof. See Appendix B. □

Not surprisingly, health expenditures, m_t , and schooling, s_t , increase with human capital. The low regime corresponds to low health expenditures and no schooling. In the low intermediate

regime, when h_t is above H_1 , the agent invests the maximum amount on health, but the child does not attend school yet. Intuitively, the agent's income is insufficient to afford a high health investment and education level, precluding secondary and tertiary schooling. For values of h_t above H_2 , children start attending school, but full schooling is only attained in the high regime when $h_t > H_3$.

The three thresholds for human capital increase with M . Indeed, $\frac{\partial H_i}{\partial M} = \frac{1}{w}$, $i = 1, 2, 3$. Hence, if out-of-the-pocket health costs decrease, the low regime shrinks, becoming less likely. The intermediate regimes are displaced downwards, keeping their sizes. As a result, the high regime starts at lower values for human capital, becoming more probable.

A remarkable consequence for policymakers is that if out-of-pocket health costs decrease, not only does life expectancy improve, adult labor and human capital transmission increase, but households can change regimes, afford health costs and increase schooling.

Note that the relative distance of the thresholds defined above depends on γ , which relates to the opportunity cost of schooling, and E , the quality of primary education. If $\gamma = 0$, then children's wage is zero, and there is no child labor simply because it is not profitable for the household. In this case, there is still a threshold value for human capital, $\frac{M}{w}$. Households with human capital above $\frac{M}{w}$ invest the maximum in health. As γ increases, H_1 lowers and the gap between H_2 and H_3 diminishes. The low and high intermediate regimes shrink. Increasing γ makes secondary and tertiary schooling less attractive, allowing parents to invest more in health as household income increases. An increase in E raises the child's human capital in all regimes. However, it also affects the thresholds H_2 and H_3 that move to the right by the same amount. This makes the low intermediate regime more likely, increasing the human capital required for secondary and tertiary schooling.

We now investigate whether these regimes are sustainable in the long run by analyzing the steady states associated with them and their stability. In the low regime, $h_t < H_1$, there is no analytical solution for the steady state of h_t , so we restrict our analysis to the three other cases. As will be shown, the existence of a steady state within each of these regimes crucially depends on out-of-the-pocket health costs, M . It is convenient to define three threshold levels for M , $M_1 = w \left(E + \gamma - \frac{E\gamma}{Q(1-\beta)\delta} \right)$, $M_2 = w \left(E + \frac{\beta\gamma\delta}{1+\beta\delta} \right)$ and $M_3 = (E + Q) w \left(1 - \frac{\gamma}{Q(1-\beta)\delta} \right)$.⁸ The next proposition summarizes our findings:

Proposition 2 (Steady state when school quality is low). *In the low intermediate regime, a unique steady state $h^{il} = E$ exists and is stable for $M \in [M_1, M_2]$. In the high regime, the unique steady state $h^h = E + Q$ is stable whenever $M < M_3$.*

Proof. See Appendix C. □

For illustration purposes, let us assume that $M_2 < M_3$.⁹ Table 2 summarizes the stable steady states:

⁸While $M_1 < M_2$ and $M_1 < M_3$, we cannot place M_2 relatively to M_3 without imposing further hard-to-justify

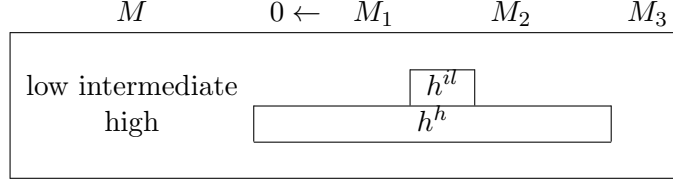


Table 2: Low School Quality. Steady states for households' human capital.

We now discuss the results obtained in Proposition 2 by focusing on the three cases for which we have analytical solutions for the steady state. First, when out-of-the-pocket health costs are relatively low, i.e., $M < M_1$, there is only one steady state characterized by maximum health expenditures and full-time secondary and tertiary schooling. Human capital transmission is enhanced since many households can afford to invest the maximum amount in health, given its low cost. Over time, all households converge to the highest level of sustainable human capital in the long run. Additionally, this phenomenon leads to strong human capital accumulation.

Second, for moderate levels of M , i.e., $M_1 < M < M_2$, two steady states coexist, h^{il} and h^h , and the distribution of human capital exhibits a high degree of persistence. Hence, decreasing out-of-the-pocket health costs will enhance equality, adult survival, and human capital accumulation. More precisely, social mobility is low, except for the households in the upper tail of the distribution, i.e., in the high intermediate and high regimes, which converge to h^h . Households in the low intermediate regime converge to the stable low-level steady-state h^{il} , which is a poverty trap as defined in Azariadis (1996) and Azariadis and Stachurski (2005).

Finally, when M is relatively large, i.e., $M_2 < M < M_3$, there is a unique stable steady state in the high regime. However, only the households that start in the high regime remain there, while the others converge to a steady state in the low regime. As a result, only the most educated can afford medical costs when out-of-the-pocket health care is expensive. For substantial levels of M , $M > M_3$, no steady state exists in any of the four regimes under consideration.

There are some open questions left that we explore in our numerical simulations. The first is whether a steady state exists in the low regime and whether it is stable. If it is stable, it can be considered a poverty trap. The second question concerns the long-run behavior of households initially endowed with human capital in the high-intermediate regime. Indeed, recall that there exists dynamical indeterminacy in this case so that depending on the initial human capital endowment, the household may converge towards the low intermediate or high regime.

restrictions on the parameters.

⁹Depending on the values of the parameters, we can have either case. If instead $M_2 > M_3$, then the high regime steady state is stable for low and intermediate values of M , while the low intermediate holds for intermediate and relatively high values of M . In the numerical simulations, we have that $M_2 < M_3$, so we focus our analysis in that parameter range.

3.2 High School Quality

We now discuss the results under the assumption that school quality is high, i.e., $Q > \frac{1+\beta\delta}{\delta(1-\beta)}E$. There are two main differences concerning the low school quality setting. First, the low intermediate regime, in which $m_t = M$ and $s_t = 0$, does not exist when Q is high. Second, providing children with some secondary and tertiary schooling is always optimal, whichever the parameter configuration. Proposition 3 summarizes the optimal behavior in the different regimes.

Proposition 3. *When school quality is high, there are three possible optimal regimes conditional on the level of human capital h_t :*

h_t	H_4	H_5
m_t	$0 < \frac{M(E+Q)w\beta\gamma\delta}{Q(M-h_t w)(1+\delta)} < M$	M
s_t	$0 < \frac{(E+Q)(1+\beta\delta)}{Q(1+\delta)} < 1$	0
h_{t+1}	$\left(\frac{m_t}{M}h_t\right)^\beta (E + Qs_t)^{1-\beta}$	$h_t^\beta (E + Q)^{1-\beta}$
	low	intermediate
		high

Table 3: High School Quality. Optimal decisions.

where $H_4 = \frac{M}{w} - \frac{(E+Q)\beta\gamma\delta}{(1+\delta)Q}$ and $H_5 = \frac{M}{w} + \frac{\gamma(E+Q)}{\delta Q(1-\beta)}$.

Proof. See Appendix B. □

As in the low-quality school setting, the high regime has full-time schooling and maximum health expenditures. The intermediate regime also features an interior level of s_t increasing in h_t and maximum health expenditures. Finally, in the low regime, the agent chooses interior levels of both s_t and m_t . Thus, when school quality is high, households always find it optimal to send their child to secondary and tertiary school, at least part of the time.

We now investigate under which regimes and conditions our model has a steady state. As before, we cannot study the low regime analytically. Therefore, in what follows, we concentrate on the two last regimes.

Proposition 4 (Steady state when school quality is high). *In the high regime, there is a unique and stable steady state $h^h = E + Q$ if $M < M_5 = (E + Q)w \left(1 - \frac{\gamma}{Q(1-\beta)\delta}\right)$.*

Proof. See Appendix D. □

Since school quality is high, households always find sending their children to school optimal. When out-of-the-pocket health costs are low, we expect that human capital rapidly increases and converges to the high regime.

In the intermediate regime, there is an unstable steady state given by $h^{ih} = \frac{(1-\beta)((E+Q)w\gamma - MQ)\delta}{w(\gamma - (1-\beta)(Q-\gamma)\delta)}$ only when $M \in [M_4, M_5]$, where $M_4 = (E + Q)w\delta \frac{Q(1-\beta) + \beta\gamma}{Q(1+\delta)}$. Hence, the intermediate regime shows dynamical indeterminacy, as in the low-quality school case. That means that depending on

the initial level of human capital and the parameter set within the same regime, some households' human capital could increase until they reach the high regime. In contrast, other households could decrease to join the low regime. Nevertheless, it could also be the case that all households in the intermediate regime increase their human capital with time (or decrease it).

3.3 Comparison between Low and High School Quality

For reasonable out-of-the-pocket health costs, households outside the high regime will always prefer to live in a society with high-quality public secondary and tertiary schools. We have already underlined that we cannot study the low regime dynamics analytically. Still, we know that $\bar{h} = 0$, the absolute poverty trap, is a steady state with low or high school quality. We have seen that when Q is high, the intermediate regime presents dynamic indeterminacy. This means that for reasonable values of out-of-the-pocket health costs, M , households with human capital in the low regime will increase until they reach the intermediate and continue rising until they attain the high regime. Then why do we claim that poor households should prefer a high-quality school society? Because in the low-quality school society, for the same value of M , they would have been stuck in the low intermediate regime forever since the steady state of the intermediate regime is stable.

The threshold defining the high regime in both the low and high-quality school cases is the same increasing function of Q . The higher the secondary and tertiary school quality, the more human capital a household needs to be in the high regime. Still, even in this case, households would prefer an economy with high-quality schools. For high Q , children attend school at least partially so that human capital increases over time. Households will trespass thresholds; although it may take longer, they will attain the high regime. Note that along the way, full-time secondary and tertiary education arises.

Additionally, convergence towards the high regime is faster if out-of-the-pocket health costs decrease. Indeed, as in the low-quality case, thresholds in the high school regime are increasing functions of M . Furthermore, although it may take longer to reach the high regime when school quality is high, children obtain secondary and tertiary education at least partially for all levels of human capital.

4 General Equilibrium

Up to now, we have focused on a partial equilibrium analysis that allowed us to obtain explicit analytical results and directions regarding the steady state of households in the long run. We now complement our analysis by investigating the general equilibrium properties of our model.

Let us assume there exists a unique firm that operates the following technology:

$$Y_t = AL_t^\alpha, \tag{8}$$

with $A \geq 0$, $0 < \alpha < 1$ and where L_t is aggregated labor. Assuming that the unique final good is

the numeraire, we can solve the firm's profit maximization problem and obtain salaries at time t as:

$$w_t = A\alpha L_t^{\alpha-1}.$$

Let us define the equilibrium of this economy:

Definition 1. *Given an initial distribution of human capital $G_0(h_0)$, an equilibrium consists of sequences of salaries $\{w_t\}_{t=0}^{\infty}$, aggregate labor $\{L_t\}_{t=0}^{\infty}$, distribution of human capital $\{G_{t+1}(h_{t+1})\}_{t=0}^{\infty}$ and decision rules $\{c_t, m_t, l_t, h_{t+1}\}_{t=0}^{\infty}$ such that:*

- i) The household's decision rules $\{c_t, m_t, l_t, h_{t+1}\}_{t=0}^{\infty}$ maximize utility (4) subject to the household constraints (2), (3) and (6);*
- ii) The firm choice, L_t , maximizes profits;*
- iii) The price w_t is such that the labor market clears;*
- iv) Considering the optimal decisions, human capital evolves as described in Tables 1 and 3, depending on whether Q is low or high. The distribution of human capital will evolve accordingly.*

When Q is low, the labor market clears when:

$$\begin{aligned} L_t = & \int_0^{H_1} \left(\frac{\beta\gamma\delta}{1+\beta\delta} \frac{w_t h_t}{M - w_t h_t} + \gamma \right) dF(h_t) + \int_{H_1}^{H_2} (h_t + \gamma) dF(h_t) \\ & + \int_{H_2}^{H_3} \left(h_t + \frac{\gamma(E+Q)}{Q(1+\delta(1-\beta))} \frac{\delta(1-\beta)}{1+\delta(1-\beta)} \frac{M-h_t}{w_t} \right) dF(h_t) + \int_{H_3}^{\infty} h_t dF(h_t), \end{aligned} \quad (9)$$

where the thresholds H_1, H_2 and H_3 are defined in Proposition 1. If Q is high, then:

$$\begin{aligned} L_t = & \int_0^{H_4} \left[\frac{(E+Q)\beta\gamma\delta}{Q(1+\delta)} \frac{w_t h_t}{M - w_t h_t} + \frac{E+Q}{Q} \frac{1+\beta\delta}{1+\delta} \gamma \right] dF(h_t) \\ & + \int_{H_4}^{H_5} \left[h_t + \gamma \frac{E+Q}{Q} \frac{1}{1+(1-\beta)\delta} + \frac{(1-\beta)\delta}{1+(1-\beta)\delta} \frac{M-h_t w_t}{w_t} \right] dF(h_t) + \int_{H_5}^{\infty} h_t dF(h_t), \end{aligned} \quad (10)$$

where thresholds H_4, H_5 are defined in Proposition 3.

Unfortunately, and for obvious reasons that follow from the study of equations (9) and (10), we cannot provide general theoretical results. We could easily compute wages if all households had a human capital endowment above H_3 in the low school quality setting (above H_5 if school quality is high). We could conclude in this case that the economy had a unique steady state and that the steady state was stable. From Proposition 2, optimal decisions do not depend on w_t when the household's human capital is high enough. Hence we knew the existence of this steady state from our previous analysis.

5 Numerical simulations: Brazil and Chile

In this section, we numerically explore the importance of health in economic development in two Latin American countries: Brazil and Chile. While we can simulate our model for virtually any country, since it requires only publicly available data, we chose these two countries since they have similar public educational spending levels and relative earnings per education level. Moreover, our calibration shows that their parameters place them in the low-education-quality setting. Still, Chile is an upper-income country with a per capita GDP 53 percent larger than Brazil, an upper-middle-income country. As a result, the households in the low regime converge to starkly different steady states in these countries. In Chile, these households eventually converge to the high regime, while in Brazil, they fall into the poverty trap. Consequently, Brazil has a much higher income and life expectancy inequality in the long run than Chile.

We divide this section into two subsections. The first subsection provides details on the calibration strategy. Then, in a second subsection, we discuss our results for the evolution of households' life expectancy, school attendance, human capital, GDP, and the Gini coefficients of income in each country.

Calibration strategy

We calibrate our model using data from the World Bank (World Bank, nd, 2021; van der Weide et al., 2021), Barro and Lee (2013), Feenstra et al. (2015), Groningen Growth and Development Centre (2023), and OECD (2017). Due to data availability, we center our calibration in 2015.¹⁰ Since we employ an OLG setting, we multiply by 35 all annual values to obtain the value for one generation, understood here as 35 years. All monetary values are in thousands of current US dollars. We present the raw data and the data sources in Table A.1.

We borrow two parameters, α and β , from the existing literature. Regarding the final good production function, we use the Penn World Table (Feenstra et al., 2015) to set α , the labor share, to 0.58 and 0.44 for Brazil and Chile, respectively.

We obtain the share of parental transmission in human capital formation, β , from the GDIM (Global Database on Intergenerational Mobility) database (World Bank, 2021; van der Weide et al., 2021). The database contains estimates of intergenerational mobility in education for different cohorts using country-specific household surveys.¹¹ For cohorts born between 1940 and 1989, the GDIM database provides the β coefficient, corresponding to the coefficient obtained from regressing children's on parents' years of schooling. Averaging the available cohorts, we obtain that β is 0.67 and 0.54 for Brazil and Chile, respectively.

We then calibrate M and the initial value of the unit wage, $w(1)$. M is the maximum health

¹⁰Data on intergenerational mobility in education is available for 2014 and 2013 for Brazil and Chile, respectively. However, we expect these variables to be persistent over a short-term horizon.

¹¹For Brazil, the estimates are based on the 2014 Brazilian National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios*, PNAD). For Chile, the data used is from the 2013 Chile National Socioeconomic Characterization Survey (*Encuesta de caracterización socioeconómica nacional*, CASEN).

investment, and we assume that it would generate a life expectancy of 100. We compute M as the current health expenditure per capita/(life expectancy/100) in 2015 and extracted from [World Bank \(nd\)](#). Thus, M equals 1.05 and 1.39 per year (36.65 and 48.72 per generation) in Brazil and Chile, respectively. We obtain the average initial unit salary as the GDP per capita/(life expectancy/100) \times average years of schooling. The variable ‘average years of schooling’ is extracted from [Barro and Lee \(2013\)](#) for 2015. This yields an annual unit salary of 1.34 and 1.56, and a generation value of 46.94 and 54.55 in Brazil and Chile, respectively. Hence, at the generation level, $M/w(1)$ equals 0.78 and 0.89 for Brazil and Chile, respectively.

Next, we need to calibrate the remaining two parameters γ and δ , and the human capital thresholds H_i , $i = 1, 2, 3$. Note that we need to calibrate five elements, and we only have three equations defining the human capital thresholds in [Proposition 1](#):

$$\begin{cases} H_1 = \frac{M}{w} - \frac{\beta\gamma\delta}{1+\beta\delta}, \\ H_2 = \frac{M}{w} + \gamma \left[\frac{E}{\delta Q(1-\beta)} - 1 \right], \\ H_3 = \frac{M}{w} + \frac{\gamma(E+Q)}{\delta Q(1-\beta)} \end{cases}, \quad (11)$$

Since we are interested in the role of education differences in inequality, we can focus on relative human capital thresholds. We assume that human capital thresholds can be written as $H_i = \mathcal{H}_i L$, where \mathcal{H}_i is the group i 's income share and L is a common factor, like a scale parameter. We then use data on relative earnings by education level, available from [OECD \(2017\)](#), to define all \mathcal{H}_i at time 0. We consider that \mathcal{H}_1 is below the upper secondary level, \mathcal{H}_2 corresponds to the upper secondary level, and \mathcal{H}_3 is a bachelor's or equivalent education. [Table 5](#) presents the values for relative earnings considering these definitions:

	Brazil	Chile
\mathcal{H}_1	62.24	68.23
\mathcal{H}_2	100	100
\mathcal{H}_3	248.66	236.71

Table 3: Relative earnings by education level ([OECD, 2017](#)).

Before solving [\(11\)](#), we need to calibrate E and Q considering the per-student spending levels in primary and secondary/tertiary education, respectively. To reconstruct these levels, we use data on government expenditure per student in primary, secondary, and tertiary education as a percentage of GDP per capita and GDP per capita. As a result, we obtain that E and Q correspond to 1.77 and 4.81 (or 61.87 and 168.34 over a generation) in Brazil and 2.05 and 4.73 (or 71.73 and 165.56 over a generation) in Chile, respectively.

Under these assumptions, we can solve [\(11\)](#) as a system of three equations and three unknowns: L , δ , and γ . We obtain that for Brazil, $L = 0.0121$, $\delta = 0.3191$ and $\gamma = 0.1710$. For Chile, we have

that $L = 0.0124$, $\delta = 0.4163$ and $\gamma = 0.2716$.

We then use data on educational attainment in 2015 from [Barro and Lee \(2013\)](#) to distribute the population into the four human capital groups defined by these thresholds. Table 4 shows the population distribution in each human capital group.

		Brazil	Chile
θ_1	No schooling	0.0837	0.0734
θ_2	Primary (Total) or less	0.2954	0.0558
θ_3	Secondary (Total)	0.4773	0.6424
θ_4	Tertiary (Total)	0.1435	0.2284

Table 4: Population share by highest educational level attained in 2015 ([Barro and Lee, 2013](#))

Importantly, the technology parameters A and B are unknown. We set $B = 1$ and compute A to obtain the abovementioned first-period salaries for Brazil and Chile. Technically speaking, we know that salaries are determined at equilibrium according to the following:

$$w_t = A\alpha L_t^{\alpha-1},$$

and this for every t . Then, if we use the definition above to obtain A , we first need to compute aggregate labor.

We use the market clearing condition given by equation (9) for the case of low quality (the program checks that we are in this regime beforehand) to compute total labor given the distribution of human capital obtained from [Barro and Lee \(2013\)](#) (see Table 4), with the thresholds H_1, H_2 and H_3 defined and calibrated above. Since we assume that all households in the same human capital category have the same human capital and that there are θ_i households in category i , we can write a discrete version of (9):

$$\begin{aligned} L_1 &= \theta_1 \left(\frac{\beta\gamma\delta}{1+\beta\delta} \frac{w_1 h_1(1)}{M - w_1 h_1(1)} + \gamma \right) + \theta_2 [h_1(2) + \gamma] \\ &+ \theta_3 \left(h_1(3) + \frac{\gamma(E+Q)}{Q[1+\delta(1-\beta)]} \frac{\delta(1-\beta)}{1+\delta(1-\beta)} \frac{M - h_1(3)}{w_1} \right) + \theta_4 h_1(4). \end{aligned} \quad (12)$$

As w_1 enters the definition of L_1 , our program solves a non-linear equation in A . Table 5 summarizes our parameter values:

Results

As mentioned above, under the model calibration, Brazil and Chile fall into the school low-quality category described in our model.

Our results show very different trajectories. In a nutshell, and before getting into the details, note that while inequalities in human capital, schooling, income, and life expectancy disappear

		Brazil	Chile
α	Labor share	0.5812	0.4396
β	Parental transmission share in human capital	0.6692	0.5362
w(1)	First generation salary	46.94	54.55
M	Maximum health investment	36.65	48.72
L	Threshold common factor	0.0121	0.0124
δ	Altruism parameter	0.3191	0.4163
γ	Children's productivity	0.1710	0.2716
Q	Secondary and tertiary education quality	223.45	222.83
E	Primary education quality	6.75	14.46
A	Final good production technology	384.23	1277.4
B	Education technology	1	1

Table 2: Parameters values.

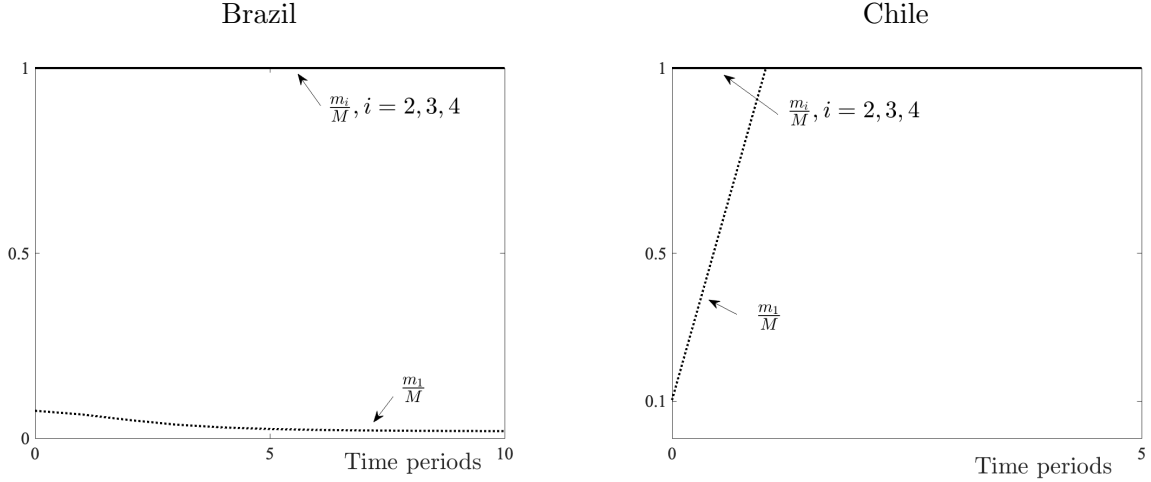
with time in Chile, the group with the lowest human capital remains in a poverty trap in Brazil.

Despite the similarity of many parameters between the two countries, some crucial differences exist. For example, primary education quality is almost twice as good in Chile than in Brazil, and the implied technology A is also almost three times higher, as shown in Table 5. Also, while 87 percent of the adult population in Chile has an upper secondary education or beyond, only 52 percent does in Brazil. These differences are determinant since they imply that unit salaries are much higher in Chile than in Brazil, allowing Chile's lower-income group not to fall into the poverty trap and to catch up with the other groups.

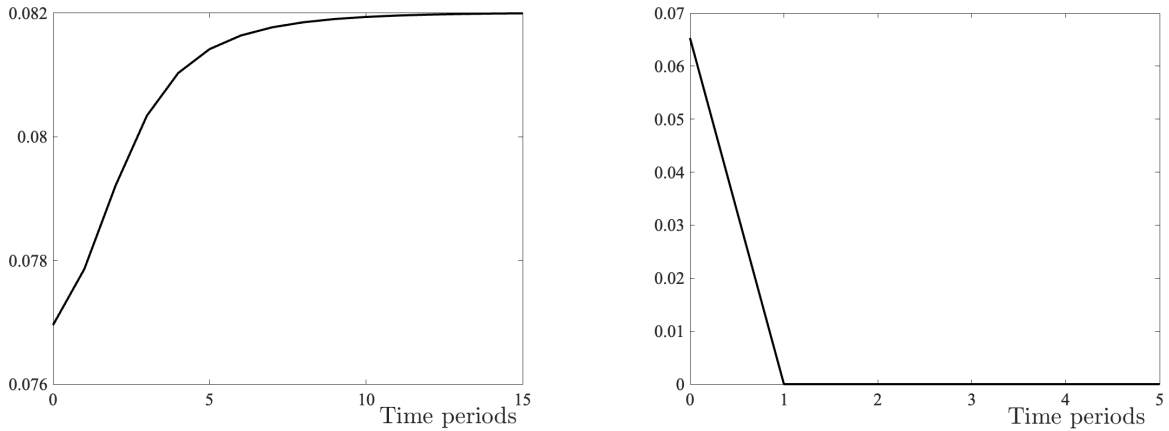
In both countries, the three groups with the highest levels of human capital always invest the maximum level in health, as shown in Figure 1, panel (a). However, low human capital households in Brazil invest little in health and experience declines in life expectancy over time. In contrast, even households with the lowest human capital levels in Chile can fully invest in health after one generation due to higher unit wages. Thus, while inequalities in life expectancy disappear in Chile, they not only remain in Brazil but widen over time (Figure 1, panel (b)).

Figure 2 presents the evolution of school attendance for both countries. All groups but the lowest in Brazil rapidly converge towards full-time schooling. In Brazil and Chile, it takes only one generation for the second group to pass from no schooling to full-time schooling. It takes two generations for the lowest group in Chile to pass from no schooling to full-time schooling. These results show that the groups quickly move across the three first human capital groups.

The combination of parental life expectancy, school attendance, and parents' human capital levels determines the evolution of human capital in both countries. Figure 3 shows that the three upper groups converge towards the upper steady state of human capital, which take similar values for both countries ($\bar{h}_{Brazil}^h = 228$ and $\bar{h}_{Chile}^h = 237.2$). These results illustrate Proposition 2 on the stability of the steady state in the low-quality case. Recall that stability hinges on the value of M relative to three threshold levels for health investment. Using the parameter values in our calibration, we check that the maximum value of out-of-the-pocket health costs is below the first threshold for both countries ($M_{1,Brazil} = 2,881.5$ and $M_{1,Chile} = 3,894.2$).



Panel (a): Life expectancy



Panel (b): Life expectancy Gini coefficient

Figure 1: Life expectancy and Life expectancy Gini coefficient.

According to Proposition 2, the steady state in the low intermediate regime is unstable, and that in the upper regime is stable. Indeed, our simulations show that, in both examples, the steady state in the high regime is stable, and the three more educated groups converge to that level. In contrast, the intermediate regime's steady state is unstable since the second group quits its initial regime and converges towards the high steady state. To conclude, note that while differences in human capital in Chile between the three more educated groups remain almost constant for seven generations, the distance between the second and the lowest group first increases. Then the gap starts closing after eight generations. Finally, all groups exhibit the same level of human capital after twelve generations.

Given the human capital and life expectancy dynamics, income inequality in Chile decreases and disappears with time. At the same time, it remains positive (although at low levels) in Brazil

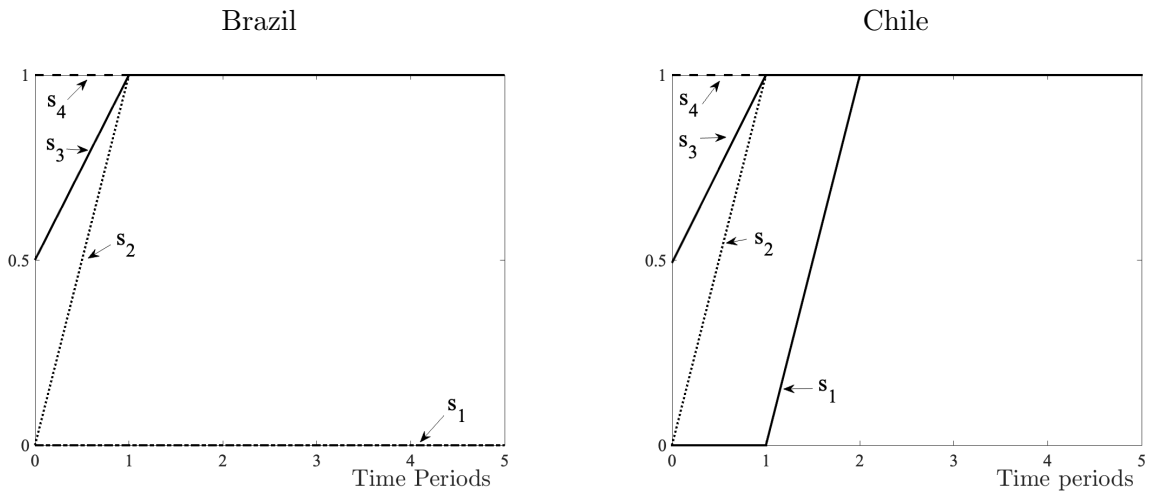


Figure 2: School attendance.

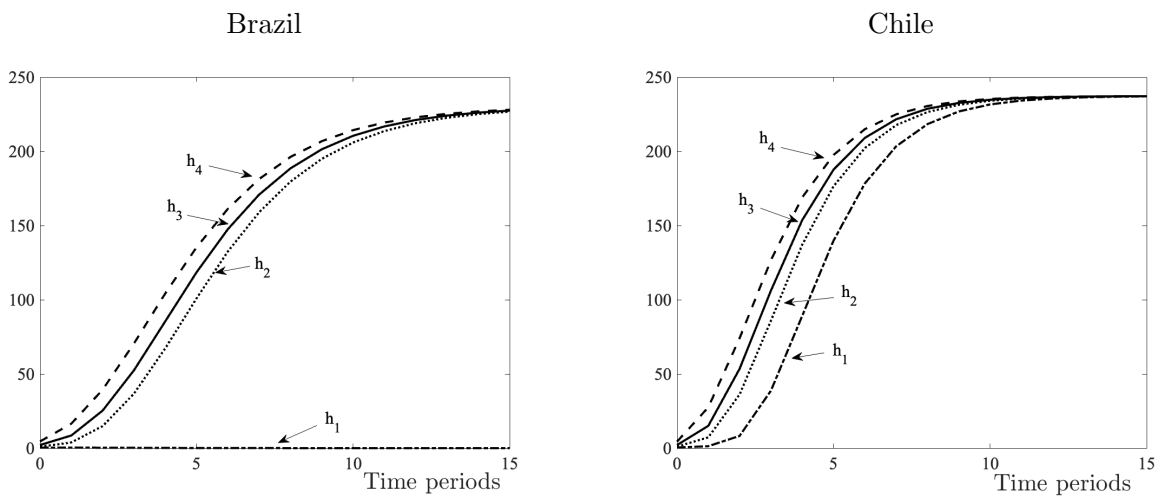


Figure 3: Human capital.

due to the lowest group's stagnation, as shown in Figure 4.

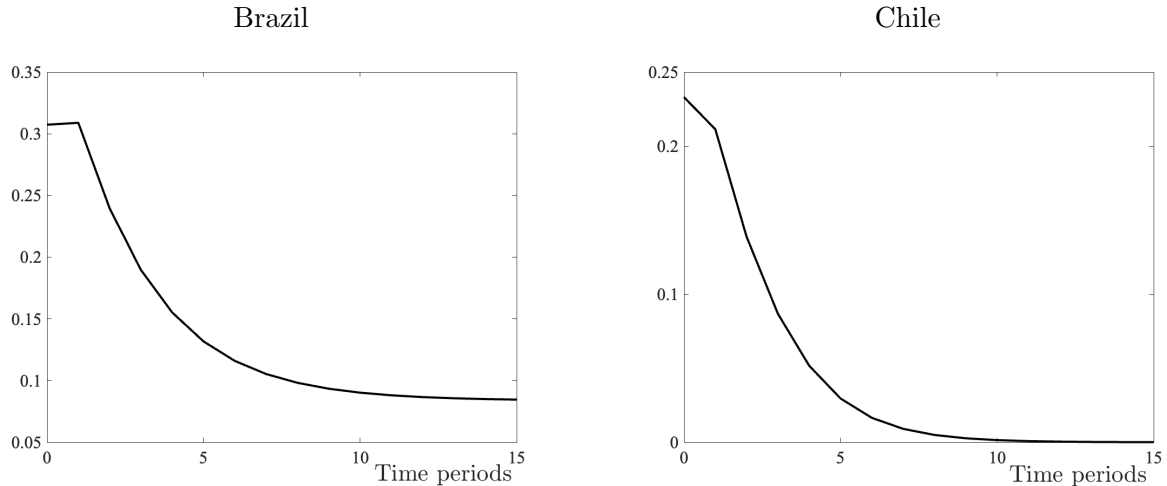


Figure 4: Income Gini coefficient.

6 Conclusion

In this paper, we use an overlapping generations model to consider the role of parental human capital transmission on the aggregate level of human capital and inequality. We show that poverty traps may arise in a framework where parents choose their health investment and their children's schooling/child labor levels. Public policy may be crucial in avoiding poverty traps by supplying high-quality public education and reducing the need for private health expenditures that mainly burden low-income households.

We show very little social mobility in societies with low school quality unless out-of-the-pocket health costs are affordable, which could correspond to a situation with high levels of public health investment. However, if public school and health investments are low, initially, poor households are prone to remain in a poverty trap. When large private health investments are needed to ensure a high life expectancy, households will find it optimal to choose some schooling only when public school quality is high.

We illustrate our analytical results by simulating our model using data from Brazil and Chile. While both countries present similar parameter values, they crucially differ regarding unit wages and the human capital level of poor households. Consequently, low human capital households in Chile eventually converge to high levels of human capital, while in Brazil, they remain in a poverty trap.

While our framework does not allow us to compare public policies targeting education and health, our results suggest that subsidizing out-of-the-pocket health costs may be the most effective way to change the human capital paradigm and converge into a high human capital society in the long run. Indeed, improving adults' life expectancy affects household income, leading to more schooling and the transmission of human capital from parent to child. Taken together, they confirm

that health may differ from other types of human capital, as suggested by Grossman (1972), and that improving public health conditions may be more urgent than investing in education for promoting development (Hazan and Zoabi, 2006; Schultz, 1999). More generally, our results indicate the complementarity between health and education expenditures as in Clark and Royer (2013) and Sarkar and Sarkar (2016).

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A Additional Tables

	Brazil	Chile	Year	Variable name	File	Source
Share of labor income in GDP	0.5812	0.4396	2015	L.ABSH	pwt1001.xlsx	Groningen Growth and Development Centre (2023)
Coefficient from regressing respondents' years of schooling on parents' years of schooling				BETA		
1940 cohort	0.9386	0.7124	2014/2013	BETA	GDIM_2021_09.csv	World Bank (2021)
1950 cohort	0.8061	0.6041	2014/2013	BETA	GDIM_2021_09.csv	World Bank (2021)
1960 cohort	0.6286	0.5025	2014/2013	BETA	GDIM_2021_09.csv	World Bank (2021)
1970 cohort	0.5475	0.4609	2014/2013	BETA	GDIM_2021_09.csv	World Bank (2021)
1980 cohort	0.4254	0.4015	2014/2013	BETA	GDIM_2021_09.csv	World Bank (2021)
Current health expenditure per capita (current US\$)	785.26	1,127.02	2015	SH.XPD.CHEX.PC.CD	-	World Bank (nd)
Life expectancy at birth, total (years)	74.99	79.65	2015	SP.DYN.LE00.IN	-	World Bank (nd)
GDP per capita (current US\$)	8,813.99	13,495.01	2015	NY.GDP.PCAP.CD	-	World Bank (nd)
Government expenditure per student (% of GDP per capita)						
Primary	20.05	15.19	2015	SE.XPD.PRIM.PC.ZS	-	World Bank (nd)
Secondary	21.53	16.64	2015	SE.XPD.SECO.PC.ZS	-	World Bank (nd)
Tertiary	33.04	18.41	2015	SE.XPD.TERT.PC.ZS	-	World Bank (nd)
Average years of total schooling	8.76	10.70	2015		BL_v3_MF2564.xls	Barro and Lee (2013)
Highest level attained (Total, % of population aged 25 and 64)						
No schooling	8.37	7.34	2015		BL_v3_MF2564.xls	Barro and Lee (2013)
Primary	29.54	5.58	2015		BL_v3_MF2564.xls	Barro and Lee (2013)
Secondary	47.73	64.24	2015		BL_v3_MF2564.xls	Barro and Lee (2013)
Tertiary	14.35	22.84	2015		BL_v3_MF2564.xls	Barro and Lee (2013)
Relative earnings						
Below upper secondary education	62.24	68.23	2015			OECD (2017)
Upper secondary education	100.00	100.00	2015			OECD (2017)
Tertiary education	248.66	236.71	2015			OECD (2017)

Table A.1: Calibration Raw Data

B Optimal Behavior. First-Order Conditions

The Lagrangian associated with the household maximization problem is:

$$\begin{aligned} L(s_t, m_t, \mu_1, \mu_2, \mu_3, \mu_4) &= \ln \left[\frac{m_t}{M} (wh_t + w^c(1 - s_t) - m_t) + \left(1 - \frac{m_t}{M}\right) (w^c(1 - s_t) - m_t) \right] \\ &\quad + \delta \ln \left[\left(\frac{m_t}{M} h_t \right)^\beta (E + Qs_t)^{1-\beta} \right] \\ &\quad + \mu_1(1 - s_t) + \mu_2 s_t + \mu_3 m_t + \mu_4 (M - m_t), \end{aligned}$$

where μ_i , $i = 1, \dots, 4$ are the Lagrangian multipliers associated to the constraints:

$$1 - s_t \geq 0, \quad s_t \geq 0, \quad m_t \geq 0, \quad \text{and} \quad M \geq m_t, \quad (13)$$

respectively. The first-order conditions of the Lagrangian with respect to s_t and m_t are:

FOC(s_t):

$$\frac{\gamma M w}{h_t m_t w + \gamma M w(1 - s_t) - m_t M} + \frac{\delta(1 - \beta)Q}{E + Qs_t} - \mu_1 + \mu_2 = 0, \quad \text{and} \quad (14)$$

FOC(m_t):

$$\frac{\frac{h_t w}{M} - 1}{\frac{m}{M} h_t w + \gamma w(1 - s_t) - m_t} + \frac{\beta \delta}{m_t} + \mu_3 - \mu_4 = 0, \quad (15)$$

respectively, plus the slackness conditions associated to the constraints on s_t and m_t in (13):

$$\begin{aligned} \mu_1(1 - s_t) &= 0, \mu_1 \geq 0, \\ \mu_2 s_t &= 0, \mu_2 \geq 0, \\ \mu_3 m_t &= 0, \mu_3 \geq 0, \quad \text{and} \\ \mu_4(M - m_t) &= 0, \mu_4 \geq 0. \end{aligned}$$

In order to obtain the first order conditions, we need to examine very carefully all possible cases, considering both interior and corner solutions:

Case 1: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = 0$, $0 < s_t < 1$, $0 < m_t < M$.

In this case, the optimal values for s_t and m_t are:

$$\begin{aligned} s_t &= 1 - \frac{E + Q}{Q} \frac{1 + \beta \delta}{1 + \delta}, \quad \text{and} \\ m_t &= \beta \gamma w \frac{\delta}{1 + \delta} \frac{E + Q}{Q} \frac{M}{M - h_t w}. \end{aligned}$$

These conditions are well-defined whenever:

$$h_t < \frac{M}{w} - \beta \gamma \frac{\delta}{1 + \delta} \frac{E + Q}{Q}, \quad (16)$$

and school quality is sufficiently high: $Q > \frac{1+\beta\delta}{\delta(1-\beta)}E$. Hence, the pure interior solution is optimal only for households whose human capital is below a certain threshold and whenever school quality is above a certain threshold.

Case 2: $\mu_1 = \mu_2 = \mu_3 = 0; \mu_4 > 0, 0 < s_t < 1, m_t = M$.

The optimal value for s_t is:

$$s_t = 1 - \frac{(E+Q)w\gamma + \delta Q(1-\beta)(M-h_t w)}{Qw\gamma(1+\delta(1-\beta))}, \text{ and} \quad (17)$$

$$\mu_4 = \frac{1}{M} \left(\beta\delta + \frac{M-h_t w}{M-w[h_t + \gamma(1-s_t)]} \right). \quad (18)$$

Imposing the conditions that $0 < s_t < 1$ and $\mu_4 \geq 0$, we conclude that this case is possible whenever:

2.i) If $Q < \frac{1+\beta\delta}{\delta(1-\beta)}E$, then human capital must verify that:

$$\frac{M}{w} - \gamma \left(1 - \frac{E}{Q\delta(1-\beta)} \right) < h_t < \frac{M}{w} + \frac{E+Q}{Q} \frac{\gamma}{\delta(1-\beta)}. \quad (19)$$

2.ii) If $Q > \frac{1+\beta\delta}{\delta(1-\beta)}E$, then:

$$\frac{M}{w} - \gamma\beta \frac{E+Q}{Q} \frac{\delta}{1+\delta} < h_t < \frac{M}{w} + \frac{E+Q}{Q} \frac{\gamma}{\delta(1-\beta)}. \quad (20)$$

Case 3: $\mu_2 = \mu_3 = 0; \mu_1, \mu_4 > 0, s_t = 1, m_t = M$.

The optimal values for μ_1 and μ_4 are:

$$\mu_1 = \frac{\gamma w}{M-h_t w} + \delta(1-\beta) \frac{Q}{E+Q}, \quad \text{and} \quad (21)$$

$$\mu_4 = \frac{1+\delta\beta}{M}. \quad (22)$$

This case is possible whenever $h_t \geq \frac{M}{w} + \frac{\gamma}{\delta(1-\beta)} \frac{E+Q}{Q}$.

Case 4: $\mu_1 = \mu_3 = \mu_4 = 0; \mu_2 > 0, s_t = 0, 0 < m_t < M$.

Here the optimal values for m_t is:

$$m_t = \gamma \frac{\beta\delta}{1+\beta\delta} \frac{Mw}{M-h_t w}, \quad (23)$$

and for the co-state variables:

$$\mu_2 = \frac{Mw\gamma}{w\gamma M - m_t(M-h_t w)} - \delta(1-\beta) \frac{Q}{E}. \quad (24)$$

This case arises whenever $h_t < \frac{M}{w} - \gamma \frac{\beta\delta}{1+\beta\delta}$ and $Q < \frac{1+\beta\delta}{\delta(1-\beta)}E$.

Case 5: $\mu_1 = \mu_3 = 0$, $\mu_2, \mu_4 > 0$, $s_t = 0$, $m_t = M$.

Here:

$$\mu_2 = \frac{w\gamma}{w(\gamma + h_t) - M} - \delta(1 - \beta)\frac{Q}{E}, \quad \text{and} \quad (25)$$

$$\mu_4 = \frac{1 + \beta\delta}{M - w(h_t + \gamma)} - w\frac{h_t + \beta\delta(\gamma + h_t)}{M[M - w(h_t + \gamma)]}. \quad (26)$$

This case arises when $Q < \frac{1+\beta\delta}{\delta(1-\beta)}E$, and:

$$\frac{M}{w} - \gamma\frac{\beta\delta}{1 + \beta\delta} < h_t < \frac{M}{w} - \gamma\left(1 - \frac{E}{Q\delta(1 - \beta)}\right). \quad (27)$$

The second-order condition for optimality holds in all cases.

Summarizing, we have found that when school quality is low, $Q < \frac{1+\beta\delta}{\delta(1-\beta)}E$, there are four regimes defined by the following thresholds for human capital $H_1 = \frac{M}{w} - \frac{\beta\gamma\delta}{1+\beta\delta}$, $H_2 = \frac{M}{w} + \gamma\left(\frac{E}{\delta Q(1-\beta)} - 1\right)$, and $H_3 = \frac{M}{w} + \frac{\gamma(E+Q)}{\delta Q(1-\beta)}$.

When school quality is high, $Q > \frac{1+\beta\delta}{\delta(1-\beta)}E$, there are three regimes defined by the following thresholds for human capital $H_4 = \frac{M}{w} - \frac{(E+Q)\beta\gamma\delta}{(1+\delta)Q}$ and $H_5 = \frac{M}{w} + \frac{\gamma(E+Q)}{\delta Q(1-\beta)}$.

C Steady State. Low School Quality.

Whenever possible, we replace the optimal choices for s_t and m_t into the law of accumulation of human capital h_{t+1} . Then, the resulting function should express h_{t+1} as a function of h_t and the model parameters. In the low intermediate regime we obtain $\bar{h}_{il} = E$ and in the high regime $\bar{h}_h = E + Q$. We cannot obtain analytical results for the other regimes. In the low intermediate regime:

$$\frac{\partial h_{t+1}}{\partial h_t} = \beta h_t^{\beta-1} E^{1-\beta}, \quad (28)$$

which evaluated at its steady state:

$$\frac{\partial h_{t+1}}{\partial h_t} \Big|_{SS} = \beta < 1, \quad (29)$$

so that \bar{h}_{il} is asymptotically stable. Similarly, in the high regime:

$$\frac{\partial h_{t+1}}{\partial h_t} = \beta h_t^{\beta-1} (E + Q)^{1-\beta}, \quad (30)$$

which evaluated at its steady state:

$$\frac{\partial h_{t+1}}{\partial h_t} \Big|_{SS} = \beta < 1, \quad (31)$$

proving that this steady state is asymptotically stable.

D Steady State. High School Quality.

As with low school quality, we can only obtain analytical results when $h_t > H_5$. In that case, $\bar{h}_h = E + Q$. If we study the stability of this steady state, we need to take the derivative of h_{t+1} with respect to h_t :

$$\frac{\partial h_{t+1}}{\partial h_t} = \beta h_t^{\beta-1} (E + Q)^{1-\beta}, \quad (32)$$

which evaluated at its steady state:

$$\frac{\partial h_{t+1}}{\partial h_t} |_{SS} = \beta < 1, \quad (33)$$

proving that this steady state is asymptotically stable.