Policy Research Working Paper 9418

Life Expectancy at Birth and Lifetime Education and Earnings

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WORLD BANK GROUP
Education Global Practice
September 2020

Policy Research Working Paper 9418

Abstract

Exploiting cross–birth cohort and cross-country variation from a pool of 188 household surveys from 111 countries, this paper measures how life expectancy at birth affects lifetime education and earnings. On average, individuals add one year of schooling for every 8.3 years of increased life expectancy at birth. Lifetime earnings increase by 1.7 percent per year of added life expectancy at birth. The estimates imply that rising life expectancy at birth explains 75 percent of the increase in average years of schooling worldwide for birth cohorts between 1922 and 1987 and 38 percent of the increase in average gross domestic product per capita in the 20th century.\.

This paper is a product of the Education Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at cmontenegro@worldbank.org.

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JEL Classification: I12, I15, I21, J24, O11, O15
Key Words: Health, Education, Human Capital, Human Development, Life Expectancy, Return to Education

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Life Expectancy at Birth and Lifetime Education and Earnings

1. Introduction

Improvements in nutrition, education, transportation, sanitation, and knowledge of diseases have had a dramatic effect on life expectancy worldwide. Vallin and Meslé (2009) have estimated that various improvements in knowledge and technology increased potential life expectancy at birth by 0.33 year per year from 1885 to 1960 and by 0.2 year per year thereafter. A woman born in 2000 is expected to live 33 years longer than a woman born in 1885.[1] This 63% increase in expected length of life has been accompanied by improved health status and enhanced physical abilities which, in turn, should have had profound effects on life-cycle investments in skills, the application of skills to the labor market, and the ability to enjoy life.

Ben-Porath (1967) and Becker (1993) posited that increased length of life would have an unambiguously positive effect on investments in human capital. Both models limited agents to choices of working versus acquiring additional human capital, ignoring the possibility that individuals would consume more leisure rather than spending more time working or learning. Heckman (1976) extended the model to allow both time and financial investments in human capital production and to allow agents to choose labor supply and the consumption of goods and leisure over the life cycle. Still, his model predicts that increased life expectancy at birth would cause individuals to increase also their lifetime human capital production.

[1] Vallin and Meslé (2009) focused on women's life expectancy to avoid the effects of war and the higher probability of violent or accidental deaths in their analysis of vital statistics. Potential life expectancy is based on the highest country life expectancy in each of the years they evaluated between 1750 and 2000.

The link between health and human capital investment has been examined intensively in previous research and at different points in the life-cycle. Shocks to fetal or infant health have been shown to lower educational investments or returns. These include maternal malnutrition (Field et al. 2009; Maluccio et al. 2009; Almond and Majumder 2011); low birth-weight (Behrman and Rosenzweig 2004); excessive or insufficient rainfall during the first year of childhood (Maccini and Yang 2009; Shah and Steinberg 2014); exposure to diseases (Almond 2006; Currie and Vogl 2013); and famine during early childhood (Almond and Currie 2011; Gorgens et al. 2012). Exogenous shocks from exposure to environmental pollution or hazards (Chay and Greenstone 2003; Foster et al. 2009; Jayachandran 2009; Almond et al. 2009), and exposure to violence or civil war (Akresh et al. 2011; Camacho 2008; Blattman and Annan 2010; Leon 2012; Yuksel 2014) have also reduced educational attainment and labor market earnings.

While the link between these shocks and education might be due to health or related income shocks, past studies have been able to isolate the effects of health on human capital investments. Exploiting variation in the timing and intensity of hookworm and malaria eradication in the American South and in developing countries, Bleakley (2007, 2010a) and Lucas (2010) demonstrated improved education and earnings outcomes for populations with early, compared to later, exposure to the public health interventions. Miguel and Kremer (2004) found that children who received treatment for intestinal worms in Kenya were absent 25% less frequently than students in the schools that were randomly assigned to receive the treatment 2-3 years later. Follow-up surveys of these students reveal that those students from the treatment schools worked 13% more hours and earned 20%-29% more than those from the control schools (Karlan and Appel 2011). Bhalotra and Venkataramani (2012) found that the availability of antibiotics to combat pneumonia at the time of infancy increased education and earnings when those infants reached adulthood.

A few studies have examined the role of life expectancy on education. Jayachandran and Lleras-Muney (2009) used improvements in maternal health to instrument for presumed endogenous life expectancy of children and found that an additional year of expected life increased schooling by 0.11 year. Oster et al. (2013) used information on when individuals learned that they had the fatal Huntington's disease as the measure of a life cycle shock and found that schooling increased by 0.17 year for every additional year of expected life.

Studies that examine the effect of increased life expectancy on human capital investment have had more mixed results. Acemoglu and Johnson (2006, 2007) found no effect of increasing life expectancy due to improved control of infectious disease on schooling. They argued that because improved length of life effectively increases cohort size, returns to human capital may fall due to rising labor supply outpacing any growth in demand for skills. Bloom, Canning and Fink (2014) found that the Acemoglu and Johnson result reverses, however, when controls for initial health are added. Hazan (2009) argued that this Ben-Porath model requires an increase in lifetime labor supply for the gain in life expectancy to increase investments in human capital. Given that American men born between 1840 and 1970 actually reduced lifetime labor supply, he concluded that life expectancy has either a negligible, or possibly even, a negative effect on investments in education. His subsequent analysis (Hazan 2012) found no correlation between life expectancy at age 5 and educational attainment.[2] However, other analyses of similar

[2]Following Soares (2005), Hazan included "post demographic transition countries," which are basically a group of countries that exhibited life expectancy at birth above 50 in 1960. He preferred life expectancy at age 5 or 10 instead of that at birth since the later displayed widespread variability due to high infant mortality.

country-level data still found a positive correlation between life expectancy and schooling (Cervellati and Sunde 2013; Hansen 2013; Cohen and Leker 2014).

This paper makes several improvements over the previous cross-country studies of life expectancy's effect on human capital investments. First, the analysis is based on a much larger number of 111 developed and developing countries. The analysis is conducted at each cohort level so that there is a one-to-one correspondence between a cohort's year of birth in a country and the corresponding life expectancy at birth. Secondly, the schooling attainment of each cohort per country was calculated from household survey data for each country in place of the noisier approximations based on school enrollment data, extrapolated estimates for missing values, and *ex post* adjustments for mortality that were used in previous studies. Estimates are generated separately for men and women and for urban and rural residents to establish the robustness of the findings. Thirdly, estimates of parental life expectancy at birth are incorporated into the analysis to examine evidence of the intergenerational transmission of human capital from parent to child. Finally, we estimate the impact of life expectancy on both lifetime years of schooling and lifetime earnings. We find that an additional year of life expected at time of birth increases years of schooling by 0.12 year and earnings by about 1%. The implied Wald estimate of returns to schooling are 9.9% for men, 4.3% for women, 10.2% for urban residents and 2.9% for rural residents. These cross-country results are very consistent with the findings based on individual data.

The next section applies Heckman's (1976) model of life-cycle earnings, learning, and consumption to the question of how increased life expectancy at birth will affect lifetime schooling and earnings. Section 3 explains how we utilize these implications to derive the reduced form specifications for our estimations. Section 4 elaborates on the data sources, and section 5 specifies the empirical model. Section 6 reports the findings and presents some robustness tests, and section 7 presents the individual analysis. Section 8 discusses and interprets the findings and draws some conclusions.

2. Theoretical Framework

Heckman (1976) developed a life cycle model of earnings, learning, and consumption by merging the theory of labor supply with that of human capital production. His model relaxes several assumptions of the Ben-Porath (1967) model that are important to our analysis, including that labor supply decisions are endogenous, that budgets can be used to consume leisure and invest in human capital as well as to purchase market goods and services, and that initial endowments of assets and human capital can alter the entire trajectory of consumption, investment and labor supply. This study uses Heckman's framework to motivate the analysis of how life expectancy at birth will alter lifetime human capital investments and earnings.

At each instant, the individual is endowed with one unit of time, which s/he allocates among leisure $L(t)$, investment in human capital $I(t)$, and work $(1 - L(t) - I(t))$. Human capital *H(t)* augments individual time in the production of additional human capital in income generation and in leisure consumption. Human capital is accumulated at the rate

$$\dot{H}(t) = F[I(t)H(t), D(t)] - \sigma H(t) \quad (1)$$

$$H(0) = H_0 \quad (2)$$

where $I(t)$ is the time allocated to human capital production, and $D(t)$ is the input of market goods into human capital production in period *t*. *F* is a concave production function. No human capital is produced unless time is allocated to it, *i.e.*, $I(t) > 0$. Human capital depreciates at the rate of σ in every period.[3]

Consumers' income in period *t* comes from two sources: interest earnings from assets accumulated and wage earnings conditional on accumulated human capital. The market price for a unit of human capital is R. Labor income in period *t* can be at most $RH(t)$ if the individual devotes no time to human capital production or leisure. Income can be allocated to direct investment in education goods ($D(t)$) and to consumption of durable and nondurable goods ($X(t)$) at price P. Given an endowment of initial assets A_0 and the human capital endowment H_0, an individual will accumulate wealth $A(t)$ according to

$$\dot{A}(t) = rA(t) + RH(t)[1 - I(t) - L(t)] - PD(t) - PX(t), \quad (3)$$

$$A(0) = A_0. \quad (4)$$

In equation (3), *r* is the risk-free rate of return on accumulated assets. The individual's instantaneous utility function takes the form

$$U[X(t), L(t)H(t)],$$

where utility is concave in its arguments $X(t)$ and $L(t)H(t)$. Note that $L(t)$ is leisure in natural units of time while $L(t)H(t)$ is the human capital augmented leisure. The individual seeks to maximize lifetime utility as

$$\int_0^T e^{-\rho t} U[X(t), L(t)H(t)]dt. \quad (5)$$

This is maximized subject to the constraints (1)-(4).[4] The current value Hamiltonian of the above problem is

[3] Although human capital might exhibit a differentiated rate of depreciation at older ages, we adopt Heckman's assumption that σ is constant throughout life. This will not change the implication of the model for our setting.
[4] We ignore the bequest motive for simplicity. Bequests do not make much sense in a model without hierarchical families.

$J(t)\colon e^{-\rho t}U[X(t), L(t)H(t)] + \lambda(t)\{ rA(t) + RH(t)[1 - I(t) - L(t)] - PD(t) - PX(t)\} +$

$\mu(t)\{F[I(t)H(t), D(t)] - \sigma H(t)\},$

(6)[5]

where $\lambda(t)$ is the shadow value of an additional unit of wealth and $\mu(t)$ is the shadow value of an additional unit of human capital in period *t*. The first-order conditions are

$$J(t)_{X(t)}\colon U_1(t) = \lambda(t)e^{\rho t}P. \quad (7)$$

$$J(t)_{L(t)}\colon U_2(t)H(t) = \lambda(t)e^{\rho t}RH(t). \quad (8)$$

$$J(t)_{I(t)}\colon \mu(t)F_1(t)H(t) = \lambda(t)RH(t). \quad (9)$$

$$J(t)_{D(t)}\colon \mu(t)F_2(t) = \lambda(t)P. \quad (10)$$

$$J(t)_{A(t)}\colon \dot{\lambda}(t) = -r\lambda(t). \quad (11)$$

Equation (11) is a first-order differential equation in $\lambda(t)$. The solution for $\lambda(t)$ is

$$\lambda(t) = \lambda(0)e^{-rt}. \quad (12)$$

The last first-order condition is

$$J(t)_{H(t)}\colon \dot{\mu}(t) = \sigma\mu(t) - R\lambda(t). \quad (13)$$

The terminal condition for human capital is

$$\mu(T) = 0, \quad (14)$$

while the assumption of non-satiation $\lambda(T) > 0$, together with the "no Ponzi scheme" condition $A(T) \geq 0$, implies that the terminal condition for wealth is

$$\lambda(T)A(T) = 0. \quad (15)$$

In equation (12), $\lambda(0)$ is the shadow value or marginal utility of wealth at the beginning of life. It is also period 0's shadow value of lifetime earnings. Since resources are finite and an

[5] For simplification, we assume that there is no income tax in the model. Heckman assumed a tax rate of (1-α) so that a households could keep only a fraction (α) of the income.

assumption of non-satiation holds, $\lambda(0)$ must be positive. To simplify the analysis further, we define the shadow value of human capital in terms of wealth, that is, the ratio of the shadow value of human capital to that of assets: $g(t) = \frac{\mu(t)}{\lambda(t)}$. Along with equation (14), this yields the first-order differential equation for $g(t)$,

$$\dot{g(t)} = (\sigma + r)g(t) - R.$$

Utilizing the terminal condition for the shadow value of human capital, as stated in equation (14), the solution for $g(t)$ is

$$g(t) = \frac{R}{(\sigma+r)}\left[1 - e^{(\sigma+r)(t-T)}\right]. \tag{16}$$

Since the two basic assumptions of the model are strict concavity and differentiability of the utility and production functions, we can invert equations (7), (8), and (12) to obtain the $\lambda(0)$ constant demand function for consumption good $X(t)$ and effective leisure $L(t)H(t)$:

$$X(t) = X\left[\lambda(0)e^{(\rho-r)t}P,\ R\lambda(0)e^{(\rho-r)t}\right], \tag{17}$$

$$H(t)L(t) = HL\left[\lambda(0)e^{(\rho-r)t}P,\ R\lambda(0)e^{(\rho-r)t}\right]. \tag{18}$$

Similarly, the demand functions for the two human capital investment inputs can be obtained by inverting equations (9) and (10).

$$D(t) = D\left[\frac{P}{g(t)}, \frac{R}{g(t)}\right]. \tag{19}$$

$$I(t)H(t) = IH\left[\frac{P}{g(t)}, \frac{R}{g(t)}\right]. \tag{20}$$

$g(t)$ gets smaller as $t \rightarrow T$, so the price of purchased educational inputs and the opportunity cost of time devoted to human capital production increase as an individual ages. As a result, time invested in human capital production, $I(t)$, decreases as an individual ages and approaches zero at *T*. Before time *T*, human capital production takes place in every period to offset human capital depreciation.

The stock of human capital at any period *t*, *H(t),* is the depreciation-weighted accumulated investments in human capital through period *t*, plus the depreciated initial stock. Human capital stock at period *t* is specified as follows,

$$H(t) = \int_0^t e^{\sigma(\tau - t)} F[I(\tau)H(\tau), D(\tau)]d\tau + H(0)e^{-\sigma t}. \quad (21)$$

Thus, the lifetime human capital stock is the accumulated human capital over a lifetime *T* is

$$H(T) = \int_0^T e^{\sigma(\tau - T)} F[I(\tau)H(\tau), D(\tau)]d\tau + H(0)e^{-\sigma T}. \quad (22)$$

The value of human capital is equal to the earnings generated from selling this human capital in the market in each period, net of its explicit and implicit production costs. The shadow value of human capital in terms of wealth, *g(t)*, can be used to convert human capital into wealth. The value of the lifetime accumulated human capital evaluated at the initial period is

$$V = g(0)H(0) + \int_0^T e^{-rt}\{g(t)F[I(t)H(t), D(t)] - PD(t) - RIH(t)\}\, dt. \quad (23)$$

The term within the integral is the lifetime net earnings from human capital investments.

2.1 Comparative dynamics from increase in life expectancy at birth T

This section derives the effect of changes in life expectancy, *T*, on human capital investment decisions, lifetime human capital production, and lifetime earnings from human capital investments.

Proposition 1: The shadow value of human capital in terms of wealth, $g(t)$, increases when life expectancy, *T*, increases.[6] This happens for all $t \in [0, T]$ as $\frac{\partial g(t)}{\partial T} = Re^{(\sigma + r)(t - T)} > 0$.

As $g(t)$ increases, the effective cost of the inputs into human capital production falls, as expressed in equations (18-19), leading us to proposition 2.

[6] All proofs to these propositions are presented in Appendix A.

Proposition 2**:** As life expectancy at birth, T, increases, purchases of educational investment goods, $D(t)$, and effective time investment, $I(t)H(t)$, increase in every period of life $t < T$.

Proposition 3: As life expectancy at birth, T, increases, the human capital stock $H(t)$ accumulated by time t increases in every period $t \in [0, T]$, as does the total human capital $H(T)$ accumulated over the lifetime. This is a direct consequence of the increased use of $D(t)$ and $I(t)H(t)$ in every period t, as governed by the production function $F[I(t)H(t), D(t)]$.[7]

Proposition 4: As life expectancy at birth, T, increases, lifetime labor income increases.

Proposition 5: As life expectancy at birth, T, increases, the marginal utility of lifetime wealth at the beginning of life, $\lambda(0)$, decreases.

Proposition 6: As life expectancy at birth, T, increases, the consumption of leisure in human capital-adjusted efficiency units, $HL(t)$, increases. However, measured hours of leisure, $L(t)$, may increase or decrease. The proof in Appendix A shows that an increase in life expectancy at birth has two opposing effects on the units of leisure. Effective leisure becomes cheaper due to a fall in the marginal utility of wealth; at the same time, the opportunity cost of hours spent in leisure increases due to rising human capital investments. It is possible that lifetime leisure will rise or fall as T increases, contrary to the assertion made by Hazan (2009).

3. Reduced Form and Econometric Specifications

The model predicts that in every period of life, increased life expectancy at the start of life will increase accumulated human capital and will raise lifetime earnings. Simultaneously solving the first-order conditions given by equations (7-15) results in reduced-form solutions of

[7] We are assuming that the per unit value of human capital is not bid downward due to the outward shift of the supply of skilled workers. As we demonstrate, the estimated impact of increased life expectancy on human capital investment is sufficiently small in magnitude that the positive effects of human capital on income have dominated the downward pressure from increased supply.

the lifetime sequences of the expected paths of goods consumption, investments in human capital, leisure consumption, and planned accumulations of assets and human capital in every period, conditional on available information on the exogenous variables at time 0. The exogenous variables include the rates of interest (*r*) and human capital depreciation (σ), the price of human capital inputs (*P*), the rental rate of human capital (*R*), the endowments of human capital and assets (H_0, A_0), and life expectancy at birth (*T*). At the time of birth, the individual can set the optimal trajectory of the human capital stock at every point in the life cycle based on information available at that time Ω_0 :

$$E[H(t)|\Omega_0] = f^H\big(r, \sigma, P, R, H_0, A_0, T, g(t)\big)\ \forall t \in [0, T]. \qquad (24)$$

The investment trajectory for time and goods inputs into human capital investment in each period is set by the expected paths of the shadow values of assets and human capital,

$$g(t) = g(0)e^{(\sigma+r)t} + \frac{R}{(\sigma+r)}\left[1 - e^{(\sigma+r)t}\right] = \frac{\mu(0)}{\lambda(0)}e^{(\sigma+r)t} + \frac{R}{(\sigma+r)}\left[1 - e^{(\sigma+r)t}\right]. \qquad (25)$$

A change in T increases the projected lifetime wealth at the beginning of life, causing the marginal utility of wealth at birth, $\lambda(0)$, to fall. That increases $g(0)$, the value of human capital relative to wealth at the start of life, and this increase in $g(0)$ increases all the subsequent values of $g(t)$, as given by equation (25).

While the planned sequence of $g(t)$ is based on information available at time 0, unanticipated shocks to the exogenous variables in equation (24) will cause the individual to reconsider investments and the sequence of $g(t)$ evolves. Critically, however, the new information will be orthogonal to the information set Ω_0. As a result, changes to the sequence of $g(t)$ will be uncorrelated with Ω_0. For example, suppose at time *t'* the individual finds out that life expectancy has changed from *T* to *T'*. The individual will re-optimize, including new values of the $g(t)$ sequence from *t'* through the end of life at *T'*. However, $E[\mathscr{g}(t) - g(t)|\Omega_0] =$

$0 \; \forall \; t > t'$ where $g(t)$ represents the re-optimized sequence of relative shadow values of human capital to assets. That means that changes made to planned sequences of human capital investments, labor supply, and lifetime consumption paths from the plans made at time 0 will be uncorrelated with the values of the exogenous variables at time 0, including the life expectancy at birth.[8]

This result has important implications for estimating lifetime human capital investments and earnings as a function of life expectancy at birth. Suppose that the planned human capital stock at time *t* conditional on initial information is $H(t|T)$, and the updated plan after changes in information on life expectancy is $\mathcal{H}(t|T')$. A survey will reveal information on actual human capital investments $\mathcal{H}(t)$, but $E[\mathcal{H}(t|T') - \mathcal{H}(t)|\Omega_0] = 0$ and so the projection of observed $\mathcal{H}(t)$ on T will yield the effect of life expectancy at birth on planned human capital investments at birth. On the other hand, $E[(\mathcal{H}(t|T') - H(t)|\Omega_0, T'] \neq 0$ and so a regression of $\mathcal{H}(t)$ on T' will not generate the unbiased effect of life expectancy on planned human capital investments. In particular, if individual decisions made after birth due to new information on any of the exogenous variables result in changes in life expectancy, the observed human capital outcomes $\mathcal{H}(t)$ and the observed life expectancy T' will be jointly determined. A similar argument suggests that to derive the effect of life expectancy on lifetime earnings, one should also regress observed earnings on life expectancy at birth and not life expectancy at later ages.

[8] Hazan (2012) proposed that life expectancy at age five instead of life expectancy at birth is more suitable to explain human capital investment decisions due to the selection problem with respect to who survives infancy or early childhood. In practice, by the time a child reaches age five, parents or government or both have made significant investment in the child, which makes life expectancy at age five higher compared to what it was at birth, and thus makes life expectancy at five an endogenous variable.

4. Data

We require data with considerable variation in life expectancy at birth and information on lifetime human capital investment and earnings. We exploit the World Bank's *International Income Distribution Database (I2D2)* for this purpose. I2D2 is a harmonized collection of household surveys conducted in 111 countries from all regions and income groups. A list of the countries and survey years is presented in Table B1 in Appendix B. Of our 111 countries, 30 are developed countries, 11 in Asia and Pacific, 17 in Central Asia and Eastern Europe, 23 in Latin America, 4 in the Middle East and North Africa, and 26 in Sub-Saharan Africa and South Asia.

From each survey, we include only those individuals who have complete information on both education and wages. Since our interest lies in how life expectancy at birth affects human capital accumulation and earnings, we focus on those individuals who were working at the time of the survey and reported positive incomes. We limit our analysis to the age group 25-60 years. Focusing on individuals over age 25 limits the probability that they would still in school;[9] the upper bound of 60 years avoids selection issues related to retirement and rising mortality with age.

Because life expectancy at birth sets the trajectory for lifetime human capital investment and earnings, we do not aggregate across individuals with different life expectancies, but instead define each cohort in each country as the unit of observation. Our earliest available survey is in 1970 and the latest is in 2012. To fit our age range of 25-60, we include 77 birth cohorts born between 1911 and 1987.

Many of the countries have multiple surveys, giving us repeated observations for many cohorts. However, completed schooling will be the same for the same cohort across surveys.

[9] Both Barro and Lee (2010) and Cohen and Soto (2007) assume that years of schooling are fixed by age 25.

We opted to use the earliest available survey for each country to limit mortality bias in the estimated completed schooling and then the most recent survey to capture the completed schooling for the youngest cohorts in the country. In total, we used 188 surveys from 111 countries to generate 4,670 cohort observations covering almost 4 million individual observations. We further disaggregate the cohorts by gender, and if possible, also by urban and rural residence. For each birth cohort, we computed average years of schooling, average earnings, and incidence of marriage. To compare lifetime earnings across countries, we require a common unit of time. Across the 188 surveys, wages are measured per hour, day, week, month, quarter, or year. These surveys are internally consistent, so a survey dummy variable standardizes both time units and currency units. The survey dummy variable also controls for country-specific effects. In effect, the source of identification in our estimates is the variation in schooling and earnings across cohorts within surveys.

The data on life expectancy at birth by country were compiled from 1950 from the United Nation's population database.[10] For earlier birth cohorts, GapMinder constructs a measure of life expectancy at birth for almost 200 countries back to 1900. Figure 1 shows the pattern of life expectancy at birth by birth cohort starting in 1910. Worldwide life expectancy has risen from 38 to 72 years over the 90-year period. Over that same period, the global average years of schooling rose from 6.8 to 12.4 years. As shown in Figure 2, these patterns are common across regions and income groups.

As life expectancy increases, the fraction of the birth cohort that enters working age increases. If workers of different ages are not perfect substitutes for one another, members of unusually large working-age cohorts will face depressed earnings (Welch, 1979). We use the

[10] The UN database is available at http://data.un.org/Default.aspx.

number in the cohort relative to the total population as our measure of the relative cohort supply. Figure 3 shows the path of average wages across birth cohorts after netting out the survey fixed effect.[11] Starting with the oldest cohorts, average earnings rise over birth cohorts until the mid-1950s when the average earnings begin to decline. The reversal is due to the declining age of the more recent birth cohorts, illustrating that we will need to control for position in the life cycle to remove the effects of age on lifetime earnings. As we demonstrate in the next section, using quadratic terms in age of the cohort or using cohort-specific fixed effects serves to correct for the age effect on earnings.

5. Empirical Specification

The theory suggests that the reduced-form equation for completed schooling and earnings will depend on conditions known at the time of birth, plus changes to those variables conditioned on information orthogonal to the variables known at birth. We specify the equations for completed years of schooling S_{jct} and log earnings $\ln(Y_{jct})$ for cohort j, country c, and survey year t as

$$S_{jct} = \gamma_0 + \gamma_L LE_{jc} + \gamma_R RUR_{jct} + \gamma_M MALE_{jct} + \gamma_{PL} LE_{jc}^P + a_j + \theta_{Sct} + \varepsilon_{jct}, \tag{26}$$

$$\text{Ln}(Y_{jct}) = a_0 + \beta_L LE_{jc} + \beta_R RUR_{jct} + \beta_M MALE_{jct} + \beta_{PL} LE_{jc}^P + \sum_{p=1}^{J} \beta_p \boldsymbol{Z}_{jct} + a_j + \theta_{Yct} + \omega_{jct}. \tag{27}$$

The focus on years of schooling is a matter of convenience in that we know that human capital investment will rise in every period t as life expectancy for cohort j, LE_{jc}, rises, but schooling is the most readily observable and consistent measure of human capital investment

[11] The survey fixed effects give us an estimate of average wages net of fixed factors such as the home currency; the time unit used for wages, whether hourly, weekly, monthly or annually; country-specific fixed effects; and inflation. The wages are presented on a logarithmic scale.

across countries and time. As it is also a form of human capital investment that is fixed at a relatively young age, we can assume that for birth cohorts aged 25 and over, years of schooling are fixed for the rest of their lives. In equations (26) and (27), a_j includes cohort-specific effects that are known at birth and common across countries, and θ_{Sct} and θ_{Yct} are survey-specific fixed effects that also incorporate country-specific effects that are common across cohorts within a country. $MALE_{jct}$ and RUR_{jct} are, respectively, the average proportion male and average proportion rural in cohort *j*, country *c*, and survey year *t*. We also include an approximation of the life expectancy at birth for each birth cohort, which we assume as the 25-year lagged life expectancy at birth in a country. Our rationale is evidence of intergenerational transmission of human capital (Lindahl et al. 2015) and life expectancy (Björkegren et al. 2019) that may suggest a further gain from improving health conditions on lifetime schooling and earnings.[12]

The log earnings equation (27) shares many of the same features as equation (26). Unique elements in $\boldsymbol{Z}$ include the cohort-specific marriage incidence rate and size of the cohort within a country-survey year. Cohort-specific fixed effects a_j will correct for position in the life cycle.

Alternatively, we can conserve on parameters and specify the lifetime log earnings function as

$$\ln(Y_{jct}) = a'_0 + \beta'_L LE_{jc} + \beta'_A AGE_{jct} + \beta'_{AA}(AGE_{jct})^2 + \beta'_R RUR_{jct} + \beta'_M MALE_{jct} + \sum_{p=1}^{J} \beta_p \boldsymbol{Z}_{jct} + \theta'_{Yct} + \omega'_{jct}, \tag{28}$$

[12] Our findings of intergenerational transfers through parental life expectancy were not overly sensitive to the assumption of the lag length.

where the quadratic terms in the age of the cohort control for position in the life cycle. We can compute the returns to schooling applying the Wald estimator: $\frac{dlnY}{dS} = \frac{\frac{\partial lnY}{\partial LE}}{\frac{\partial S}{\partial LE}} = \frac{\beta_L}{\gamma_L}$. This estimate uses life expectancy at birth as an instrument for completed years of schooling by cohort. We can compare it with the traditional estimate using the Mincerian earnings function specification,

$$\ln(Y_{jct}) = \varphi_0 + \varphi_S(SchoolYears_{jct}) + \varphi_A(AGE_{jct}) + \varphi_{AA}(AGE_{jct})^2 + \varphi_R RUR_{jct} + \varphi_M MALE_{jct} + \varphi_{Yct} + \vartheta_{jct}, \quad (29)$$

which yields biased estimates of the returns to schooling due to presumed endogeneity of the schooling choice (Card, 1999).

Observations are weighted to reflect the cohort-survey cell share of the total population in the country. We further weighted the data by the square root of the cell-size to correct for differences in measurement error variance between thin and thick cell samples.[13] Finally, we cluster all errors at the country level to correct for likely correlated errors across cohorts within a country.

6. Results

6.1 Life expectancy at birth and years of schooling

Table 1 reports the estimates obtained from regression equations (26). We start with the simplest bivariate specification relating life expectancy at birth and lifetime schooling. All of the specifications include a survey fixed effect which controls for country fixed factors, cyclical factors related to the timing of the survey, and survey type (i.e., household expenditure survey vs. labor force survey). We also control for common birth cohort-specific effects across

[13] Cell size is the total number of observations belonging to a specific cohort in a survey. We divide the cell size by how many times each cohort appears and use that to construct the weight to be applied in the regression. In our sample of 111 countries, for 77 countries we add younger birth-year cohorts from the most recent survey.

countries.[14] In specification IV, we include cohort dummies, where cohort is defined by the year of birth to control for time-varying factors across countries. [15]

The coefficient of life expectancy at birth, γ_L in equation (26), is always positive and statistically significant. The effect ranges from 0.094 to 0.12 year of schooling per additional year of life expectancy. The 30-year increase in world life expectancy between the 1922 and 1987 birth cohorts (Figure 1) by itself would have increased completed schooling by 2.8 to 3.6 years. The coefficient of parental life expectancy in specification IV suggests that there is also an intergenerational channel through which parental health affects children's education. The effect of parental life expectancy is 22% of the own life expectancy effect, raising the combined effect of rising life expectancy to 3.4 to 4.4 years of schooling.

The effect of life expectancy gain at birth might have different effects on different groups. We investigate this by estimating equation (26) for four subsamples separately: (i) males, (ii) females, (iii) urban residents, and (iv) rural residents (Table 2). Across all specifications, we observe a larger effect of life expectancy gain at birth on women's schooling than on men's schooling, but there is little difference in this life expectancy effect between rural and urban residents. For all four groups, the parental life expectancy effect is positive but not statistically significant.

6.2 Life expectancy at birth and earnings

Table 3 reports estimates obtained from regression equations (27) and (28). The first column implies a negative coefficient on life expectancy at birth, but as shown by the inverted

[14] Cohorts born during the Great Depression or during World War II might experience common shocks to schooling availability. Similarly, there were several United Nations programs and activities to improve health and education across the countries, implying that cohorts born after the 1960s in the low-income countries might have been exposed to similar global campaigns for education.

[15] Later, in the robustness section, we include cohort dummies defining cohorts by five-year birth range.

U-shaped plot of log of wages across birth cohorts in Figure 3, we need to control for the age of the cohort when we observe its wage. The latest birth cohorts will be observed early in their life cycle when their ages are low, even as their life expectancy is high. Once we control for lifecycle effects by including age or cohort-fixed effects and other potential confounders, the coefficient of life expectancy at birth reverses sign: the effect of life expectancy at birth on log of wages turns out to be positive and statistically significant. Increasing life expectancy at birth by one year increases lifetime earnings by roughly 1%. In all the specifications, the log of earnings increases with age at a decreasing rate. Consistent with the findings in the literature, married people and urban residents earn relatively more compared to their unmarried and rural counterparts. A larger cohort size lowers cohort earnings, consistent with the presumption that unusually large cohorts receive depressed earnings.[16] As with schooling, there is an intergenerational gain from parental life expectancy that is statistically significant in all of the specifications with cohort fixed effects. The parental life expectancy effect is 60%-88% as large as the own life expectancy effect.

In Table 4, we report separate estimates by gender and region. The returns to life expectancy are somewhat larger for men than women and for urban than rural residents. However, for males, the life expectancy coefficient turns out to be statistically significant only in specification III where we control for lifecycle position by birth-year fixed effect. For rural residents, life expectancy at birth is never statistically significant. Parental life expectancy retains a small positive effect on the earnings of their children, but the effect is statistically significant for men, women and rural residents, and only in the specification with the birth-year fixed effect.

[16] Cohort-specific dummies would absorb this effect if one specific cohort experiences a surge in population across the world.

Using the worldwide increase in life expectancy at birth of 30 years between 1922 and 1987, these estimates suggest that rising life expectancy increased lifetime earnings by 27%. The gains are largest for males (36%) and smallest for rural residents (21%).

6.3 Returns to schooling

The Mincerian earnings function (29) generates a measure of the returns to education. This can be compared to the Wald estimator.[17] Estimates from the Mincerian earnings function are reported in Table 5, and these estimates are compared to the corresponding Wald estimators in Table 6.

In Table 5, additional schooling increases lifetime earnings irrespective of the specification used. For the pooled sample, the coefficient of years of schooling shows that one additional year of schooling increases lifetime earnings by 11.8% in the simple specification I; this shrinks to 9.4% once we include a broad set of controls.[18] The estimates on the age terms, percentage male, percentage urban-rural, percentage married, and cohort size exhibit the usual signs. The estimates of the earnings function by gender and urban-rural residence do not show any notable variation across groups. Specification II reveals that one additional year of schooling increases lifetime earnings for males, females, urban, and rural groups by 10.6%, 7.3%, 9.5%, and 8.8%, respectively.

In Table 6, the Wald estimate of the returns to schooling is obtained by dividing the life expectancy coefficients from specification IV in Table 3 by the life expectancy coefficient from specification IV in Table 1. Similarly, for the male, female, urban, and rural groups, we divide the group-specific life expectancy coefficient obtained from specification II in Table 4 by the life

[17] The Wald estimator for $Return\ to\ Education = \frac{return\ to\ lifetime\ earnings\ from\ 1\ year\ gain\ in\ life\ expectancy\ at\ birth}{return\ to\ schooling\ from\ 1\ year\ \ gain\ in\ life\ expectancy\ at\ birth}$.

[18] In all specifications reported in Table 5, we have used survey fixed effects to facilitate comparison across countries and time periods.

expectancy coefficient from specification IV in Table 2. The standard errors for the Wald estimates are obtained from 500 bootstrap replications with the corresponding sample. In the pooled sample, the Wald estimates are 16% lower compared with the Mincerian estimates (7.90% vs. 9.40%). The Wald estimate is slightly higher for urban residents (10.21% vs. 9.50%), but it is lower for males (9.90% vs. 10.60%), females (4.30% vs. 7.30%), and rural residents (2.90% vs. 8.8%). For both Mincerian and Wald estimates, the return to schooling is always higher for males than females, and higher for urban than rural residents.

6.4 Robustness checks

We reexamine our findings using several estimation methods and samples. We re-estimated the models (i) without weights, (ii) using a different sample consisting only of data from one survey per country, (iii) using an alternative definition of parents' life expectancy,[19] (iv) including cohort fixed effect with an alternative definition of cohort,[20] (v) using a sample consisting only of young age groups, and (vi) using a higher-order age variable to wipe out all age effects while estimating the life expectancy effects on earnings.[21] These robustness checks generate similar estimates of life expectancy effects on schooling and earnings. In most cases, the sign and statistical significance of the life expectancy coefficient is positive and statistically significant. The results for all robustness checks are briefly discussed and reported in Appendix C.

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[19] Previously, parents' life expectancy was constructed by taking a 25-year lag of life expectancy at birth. The youngest cohort in our survey was born in 1987. In the 1980s, in many regions, especially in Sub-Saharan Africa and South Asia, mother's age at first child birth was less than 20. For example, in Niger half of the women had given birth by age 18 (Source: http://www.unicef.org/pon95/fami0009.html). An alternative measure of parents' life expectancy assumed a 15-year lagged value of own life expectancy.

[20] While constructing the five-year birth cohorts, we collapse all individuals aged 25-59 into different five-year birth cohorts, except for the first and last cohorts. In total, we define 13 cohorts based on 5-year birth groups. Since the number of observations before 1930 is too thin, we group those observations into one cohort. Similarly, all individuals who were born during 1985-87 were collapsed to form the youngest cohort.

[21] In addition to those attempted for schooling, we try one additional robustness check for lifetime earnings. Following Card (1999) and Murphy and Welch (1990), we add higher-order age terms to sponge out all age effects.

The final check of robustness involves adding exogenous variables that vary by country and cohort at the time of birth, and substituting life expectancy at birth by life expectancy measured at older ages. The theory predicts that the effect of life expectancy at birth is exogenous to any random shock realized in a later period in life. To demonstrate the validity of this, we incorporate average temperature and average precipitation that was observed for a birth-cohort at the time of birth in its country of origin. Note that similar to life expectancy at birth, average temperature and average precipitation also vary by birth-year and country. The results and discussion on this are presented in Appendix C. In sum, the estimates reveal that the statistically significant positive association of life expectancy at birth with schooling and earnings is not altered even after inclusion of these exogenous variables.

Concerns related to high infant and child mortality rates led some recent papers to argue against using life expectancy at birth. Hazan (2012) suggests that life expectancy beyond early childhood is more appropriate to capture its true effect on human capital investment decisions since parents make schooling decisions for their children at age five or later.[22] However, by the time a child reaches age five or ten, the parents have made substantive investments in the child's health based on new information on the child's survival prospects. That makes life expectancy at ages 5 or 10 endogenous responses to observed child survival, making their use inappropriate as explanatory variables for other parental investments in children. However, results using life expectancy at higher ages still have positive and significant effects on years of schooling and lifetime earnings, as reported in Appendix C. These findings contrast with Hazan's (2012) finding that life expectancy at older ages does not exhibit any statistically significant association with schooling years using a cross-country panel database.

[22] The argument is based on the observation that cross-country life expectancy at birth exhibits more variation compared to life expectancy at five due to high infant and child mortality.

7. Individual-level analysis

We extend the analysis utilizing individual-level observations instead of cohort-level mean observations as reported above. Since the theoretical model suggests that life expectancy at birth is exogenous in determining human capital investment and lifetime earnings, an individual-level analysis will confirm if country-cohort specific unobservables are contaminating the cohort-mean based empirical results. We estimate three equivalent specifications of equations 26, 28, and 29 using individual-level data:

$$S_{ict} = \gamma_0 + \gamma_L LE_{jc} + \gamma_R RUR_{ict} + \gamma_M MALE_{ict} + a_j + \theta_{Sct} + \varepsilon_{ict}, \quad (26a)$$

$$\ln(Y_{ict}) = a_0' + \beta_L' LE_{jc} + \beta_A' AGE_{ict} + \beta_{AA}'(AGE_{ict})^2 + \beta_R' RUR_{ict} + \beta_M' MALE_{ict} + \sum_{p=1}^{J} \beta_p \boldsymbol{Z}_{ict} + \theta_{Yct}' + \omega_{ict}, \quad (28a)$$

$$\ln(Y_{jct}) = \varphi_0 + \varphi_A(AGE_{ict}) + \varphi_{AA}(AGE_{ict})^2 + \varphi_S(SchoolYears_{ict}) + \varphi_R RUR_{ict} + \varphi_M MALE_{ict} + \varphi_{Yct} + \vartheta_{ict}. \quad (29a)$$

We do not observe individual life expectancy at birth, but a cohort's life expectancy at birth, an average measure of individual life expectancies at birth within a cohort ($LE_{jc} = \frac{\sum_{i=1}^{N} LE_{ijc}}{N}$), is exogenous to an individual's completed years of schooling or lifetime earnings. Group means are often used to instrument for endogenous variables in empirical analysis using individual-level data.[23] In the above specifications, $LE_{ijc} = LE_{jc} + \mu_{ij}$, which states that individual i's life expectancy at birth in country c deviates from cohort j's mean life expectancy by μ_{ij} which, by construction, is orthogonal to the mean. Since μ_{ij} will be contained in the error term, the following conditions hold:

[23] Royalty (2000) used the state tax rate as an instrument for marginal tax rate in explaining employees' health insurance eligibility. Similarly, a series of studies following Ruhm (2000) exploited variation in state or county level unemployment rate while explaining individual health behavior during a recession.

$Cov(\varepsilon_{ict}, LE_{jc}) = 0$, $Cov(\omega'_{ict}, LE_{jc}) = 0$, and $Cov(\vartheta_{ict}, LE_{jc}) = 0$.

In contrast to the cohort-mean level analysis in the previous sections, to save time and space here, we estimate one specification each for the pooled sample and for the male-female, rural-urban subsamples.[24] As Table 7 shows, the estimates conform to those obtained from the cohort-mean level analysis: life expectancy at birth exhibits a positive and statistically significant association both with completed years of schooling and lifetime earnings. The life expectancy effects on schooling reveal a similar pattern to those obtained from the cohort-mean level analysis reported in Tables 1 and 2. However, except for the urban subsample, the life expectancy effects on earnings are always larger compared to similar estimates using cohort-mean level analysis. In the pooled sample, a one-year gain in life expectancy at birth leads to 0.12 year more completed years of schooling and to 1.3% higher lifetime earnings. The largest effect on earnings is observed for the male subsample—a 1.5%-increase in lifetime earnings for each additional year in life expectancy at birth.

Panel (b) of Table 6 reports the Wald estimates of the returns to schooling based on the estimates in Table 7 along with the related returns to schooling in the Mincerian earnings function estimated using the individual sample. The detailed results from the Mincerian earnings function estimations are reported in Table B2 in Appendix B. The Mincerian returns to schooling estimates are about 10%. The Wald estimates exhibit more variation among the groups—for example, the return to schooling is 15% for males, compared to 7.8% for females.. Except for the female subsample, the Wald estimates of the return to schooling exceed the corresponding Mincerian estimates. The Mincerian returns to schooling are similar to those estimated using the birth cohort-level data. However, the Wald estimates based on the individual-level data are

[24] We choose specification IV from Table 1 for schooling, and specification IV from Table 3 for earnings.

somewhat larger with the overall return to schooling rising to 11.2% per year of schooling compared to 7.9% using the cohort-level data.

In contrast to the cohort-mean level analysis, the findings from individual-level empirical analysis consistently suggest that parents' life expectancy has a statistically significant positive influence on both human capital investments and lifetime earnings in the pooled sample as well as in the male, urban and rural subsamples. Parents' life expectancy effects on years in school are 19%-26% of the cohort's own-life expectancy effect; the effects on earnings are even larger—38.5% to 54.5% of the own-life expectancy effect. This is strong evidence of an intergenerational transfer effect with respect to increases in life expectancy at birth. Such high transmission across generations is not uncommon considering the recent findings by Lindahl et al. (2015) of intergenerational persistence in human capital and lifetime earnings across several generations.

7.1 Instrumental Variables Estimation

Thus far, we have assumed that life expectancy at birth is exogenous. This assumption may be supportable by evidence that, in Sweden, all of the persistence in mortality across generations is attributable to pre-birth factors (Björkegren et al. 2019), and yet findings for one country is hardly generalizable. We investigate the possible biases due to endogenous life expectancy at birth by using a plausible instrument in equations (24) and (25): the observed mortality rate of children of age five or less. The presumption is that parents use the prevailing under-5 mortality rate as a signal of a newborn's expected length of life when they make their fertility decisions, and so it should be a reasonable indicator of the exogenous component of the health endowment, H_0.

The instrumental variables estimates for completed years of schooling are presented in panel (a) of Table 8 while those for earnings are presented in panel (c). To facilitate a comparison of these IV estimates with the OLS estimates obtained from the corresponding sample, related OLS estimates on completed years of schooling and earnings are presented in panels (b) and (d), respectively. In all first stages, the under-5 mortality rate shows a statistically significant negative relationship with life expectancy at birth, and the first-stage F-test statistics imply that our estimates are not subject to weak instrument bias. The reported IV estimates suggest that a one-year gain in life expectancy is associated with 0.146 additional year of completed schooling versus 0.113 additional year in the OLS estimates. An additional year of life expectancy raises lifetime earnings by 1.7% using the IV specification versus 1.2% using the OLS specification. The schooling estimates are larger for females than for males, and larger for rural than urban birth cohorts. The gain in lifetime earnings is higher for males than for females, and higher for urban than for rural workers. Applying the historical increase in life expectancy at birth, the implied gain in education and earnings for the 1987 birth cohort over the 1922 birth cohort is 4.4 more years of schooling and 51% higher lifetime earnings.

We report the Wald estimates of the returns to schooling based on the IV estimates at the bottom of Table 6. The overall return to schooling rises to 12% per year of schooling. Returns for males and urban residents increase while returns to females and rural residents become smaller. However, the overall result from all of these estimates is that our Wald estimates correspond to consensus estimates from the very large literature on returns to schooling of about 10% per year, somewhat larger for men and urban residents and somewhat smaller for women and rural residents.

7.2 Selection bias due to the labor force participation decision

Our analysis for lifetime earnings includes those who are in the labor force at the time of the survey. If life expectancy at birth affects an individual's labor force participation decision, our estimates will be subject to bias and the direction of that bias is uncertain. Note that Hazan (2009) observed that a gain in life expectancy at birth was associated with a decrease in the labor force participation of U.S. males born between 1840 and 1970. We investigate the labor force selection issue with individual-level data in two ways: (i) first, by including a birth-year specific correction measure for selection in each survey, which is constructed as the proportion of individuals in that cohort participating in the labor force in a survey, and (ii) by estimating a two-step Heckman selection correction for an individual's labor force participation status. To fulfill the exclusion criterion, the selection equation includes household size (number of household members) and the interviewee's relationship to the household head.[25] These estimates are done separately for the pooled sample and the male, female, urban and rural subsamples.

The results are reported in Tables 9 and 10. After controlling for the proportion of the birth-year cohort in the labor force, neither the pooled sample nor any of the subsamples shows a different pattern in the effect of a gain in life expectancy at birth on lifetime earnings from that obtained without addressing the selection issue, as reported in Table 7. However, estimates obtained following Heckman's two-step procedure (Table 10) in which we utilize information on individual-level labor force status are positive and statistically significant in the second stage equation, and are larger in magnitude compared to those obtained without any selection correction.[26] The life expectancy effects on lifetime earnings for the pooled sample and the male and rural subsamples are larger in magnitude than our estimates without correcting for selection.

[25] In the first stage, we estimate a fixed effects logit model of labor force participation decision including age, gender, urban/rural residence, marital status, life expectancy at birth, parents' life expectancy, household size, relationship to the household head, and survey/country fixed effects. Using the parameters from the logit model, we calculate a linear predicted probability which we then convert into normal densities to construct the inverse Mills ratio used in the second stage for selection correction.

[26] Replicating the analysis in Table 10 on the same sample but without including the selection correction term produces life expectancy coefficients of 0.13, 0.15, 0.12, 0.12 and 0.10 for the pooled, male, female, rural, and urban samples.

For the urban subsample, the selection correction does not alter the life expectancy effects on lifetime earnings. Household size and the individual's relationship to the household head, our identification variables in the selection equation, always turn out to be statistically significant predictors of individual labor force participation.

The life expectancy coefficient in the selection equation is positive and statistically significant, except in the rural subsample, though it is smaller in magnitude. Since we control for the life cycle stage in the selection specification, this positive association suggests that a gain in life expectancy at birth influences labor force participation marginally at any stage of the lifecycle. In the earnings equation, the negative and statistically significant inverse Mills ratios suggest a negative selection bias: individuals with jobs have lower wages compared with those for whom we do not observe wages. This is not the case for the urban subsample. Controlling for selection, the corresponding coefficient for urban residents is lower by 9%, suggesting that those urban residents with complete wage information are drawn from a relatively higher income group than those urban residents without wage information. One possible explanation for this disparity is that the urban residents without wage information include not only those whose shadow price of labor is higher than the market wage offer but also those residents who work in the informal sector or those who own large businesses. Overall, the effects of a gain in life expectancy at birth on lifetime earnings without correcting for selection bias tend to be conservatively lower using a cohort-based analysis.

8. Conclusion

Using time-series data on birth cohorts from 111 countries, we find that gains in life expectancy at birth increase both investments in human capital and lifetime earnings. An individual completes an additional 0.12 year of schooling for each year added to life expectancy at birth. This estimate is comparable to the estimate of 0.11 year by Jayachandran and Lleras-Muney (2009) for Sri Lanka and to 0.17 year by Hansen (2013) using a 70-country study. In our data, global average life expectancy at birth increased 29.7 years between the 1922 and 1987 birth cohorts. Based on our results, this gain implies an increase of 3.6 years in completed schooling. The actual years of schooling in our sample increased by 4.8 years for the same cohorts, so our results suggest that increased life expectancy at birth explains 75% of the increase in average schooling worldwide.

We have also estimated the effect of an additional year of life expectancy at birth on lifetime earnings and find this to be a gain of 1.7%. Global per capita GDP increased by 380% or by 1.3 log points between 1900 and 2000. Our analysis implies that real earnings increase by 1.7% per year of added life expectancy, or by 0.50 log points evaluated at the average gain in life expectancy. Thus, the gain in life expectancy alone explains 38% of the gain in per capita GDP. We illustrate the effect in Figure 4.

In the U.S., estimates by Steckel (2002) suggest that life expectancy at birth rose 31.4 years between 1870 and 1990. This gain in life expectancy alone would have increased years of schooling by 3.8 years according to our results, or by 45% of the 8.3 years increase noted by Lee and Lee (2016) for that period. Steckel (2002) also reported that per capita GDP rose 2.25 log points; based on our results, we can tie 0.53 of this increase to rising life expectancy at birth. Hence, while the gains in human capital and lifetime earnings are largest for poorer countries, they can be substantial even for much richer countries.

9. References

Acemoglu, D., and S. Johnson 2007. "Disease and Development: The Effect of Life Expectancy on Economic Growth." *Journal of Political Economy* 115(6): 925–985.

Acemoglu, D., and S. Johnson. 2006. "Disease and Development: The Effect of life expectancy on economic growth." *NBER Working Paper*, No. 12269.

Akbulut-Yuksel, M. 2014. "Children of War: The Long-Run Effects of Large-Scale Physical Destruction and Warfare on Children." *Journal of Human Resources* 49(3): 634-662.

Akresh, R., and D. de Walque. 2011. "Armed Conflict and Schooling: Evidence from the 1994 Rwandan Genocide." *World Bank Policy Research Working Paper* No. 4606.

Almond, D. 2006. "Is the 1918 Influenza Pandemic Over? Long-term Effects of *in utero* Influenza Exposure in the Post-1940 U.S. Population." *Journal of Political Economy* 114 (4): 672-712.

Almond, D., L. Edlund L, and M. Palme. 2009. "Chernobyl's Subclinical Legacy: Prenatal Exposure to Radioactive Fallout and School Outcomes in Sweden." *Quarterly Journal of Economics* 124(4): 1729–1772.

Almond, D., and J. Currie. 2011. "Killing Me Softly: The Fetal Origins Hypothesis." *Journal of Economic Perspectives* 25(3): 153-72.

Almond, D., and B. Mazumder. 2011. "Health Capital and the Prenatal Environment: The Effect of Ramadan Observance during Pregnancy." *American Economic Journal: Applied Economics* 3(4): 56-85.

Barro, R., and J-W Lee. 2013. "A New Data Set of Educational Attainment in the World, 1950–2010." *Journal of Development Economics* 104: 184–198.

Becker, G. S. 1993. *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education, 3rd edition*. Chicago: University of Chicago Press.

Behrman, J. R., and M. R. Rosenzweig. 2004. "Returns to Birthweight." *Review of Economics and Statistics* 86(2): 586–601.

Ben-Porath, Y. 1967. "The Production of Human Capital and the Life Cycle of Earnings." *Journal of Political Economy* 75(4, Part I): 352–365.

Bhalotra, S., and A. Venkataramani. 2012. "Shadows of the Captain of the Men of Death: Early Life Health Interventions, Human Capital Investments, and Institutions." *unpublished manuscript,* University of Bristol.

Björkegren, E., M. Lindahl, M. Palme, and E. Simeonova. 2019. "Pre- and Post-Birth Components of Intergenerational Persistence in Health and Longevity: Lessons from a Large Sample of Adoptees." *Journal of Human Resources,* 0318-9421R1.

Blattman, C., and J. Annan. 2010. "The Consequences of Child Soldiering." *Review of Economics and Statistics* 92(4): 882-98.

Bleakley, H. 2007. "Disease and Development: Evidence from Hookworm Eradication in the American South." *Quarterly Journal of Economics* 122(1): 73–11.

Bleakley, H. 2010. "Malaria Eradication in the Americas: A Retrospective Analysis of Childhood Exposure." *American Economic Journal: Applied. Economics* 2(2): 1–45.

Bloom, D., D. Canning, and G. Fink. 2014. "Disease and Development Revisited." *Journal of Political Economy* 122(6):1355-1366.

Card, D. 1999. "The causal effect of education on earnings." In O. Ashenfelter and D. Card (ed.), *Handbook of Labor Economics,* Edition 1, volume 3, chapter 30, pages 1801-1863. Elsevier.

Cervellati, M., and U. Sunde. 2013. "Life Expectancy, Schooling, and Lifetime Labor Supply: Theory and Evidence Revisited." *Econometrica* 81(5): 2055–2086.

Chay, K.Y., and M. Greenstone. 2003. "The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession." *Quarterly Journal of Economics* 118(3): 1121-1167.

Camacho, A. 2008. "Stress and Birth Weight: Evidence from Terrorist Attacks." *American Economic Review*, *Paper and. Proceedings*. 98(2): 511-515.

Cohen, D., and M. Soto. 2007. "Growth and Human Capital: Good Data, Good Results." *Journal of Economic Growth* 12(1): 51–76.

Cohen, D., and L. Leker. 2014. "Health and Education: Another Look with the Proper Data." Available at *http://www.parisschoolofeconomics.eu/docs/cohen-daniel/cohen-leker-health-and-education-2014.pdf* (*last accessed on July 17th, 2015*).

Currie, J., and T. Vogl. 2013. "Early-life Health and Adult Circumstance in Developing countries." *Annual Review of Economics* 5(1):1-36.

Dell, M., B.F. Jones, and B. A. Olken. 2014. "What Do We Learn from the Weather? The New Climate-Economy Literature." *Journal of Economic Literature* 52(3): 740-798.

Field, E., O. Robles, and M. Torero. 2009. "Iodine Deficiency and Schooling Attainment in Tanzania." *American Economic Journal: Applied Economics* 1(4): 140–169.

Finis, W. 1979. “Effect of Cohort Size on Earnings: The Baby Boom Babies’ Financial Bust.” *Journal of Political Economy* 87(5): S65-S97.

Foster, A., E. Gutierrez, and N. Kumar. 2009. "Voluntary Compliance, Pollution Levels, and Infant Mortality in Mexico." *American Economic Review* 99(2): 191-97.

Gørgens, T., X. Meng, and R. Vaithianathan. 2012. “Stunting and Selection Effects of Famine: A Case Study of the Great Chinese Famine.” *Journal of Development Economics* 97(1): 99–111.

Halla, M., and M. Zweimüller. 2014. “Parental Response to Early Human Capital Shocks: Evidence from the Chernobyl Accident.” *Discussion Paper 7968*, Institute for the Study of Labor.

Hansen, C. W. 2013. “Life Expectancy and Human Capital: Evidence from the International Epidemiological Transition.” *Journal of Health Economics* 32(6): 1142–1152.

Hazan. M. 2009. “Longevity and Lifetime Labor Supply: Evidence and Implications.” E*conometrica* 77(6): 1829–1863.

Hazan. M. 2012. "Life Expectancy and Schooling: New Insights from Cross-Country Data." *Journal of Population Economics* 25(4): 1237-1248.

Heckman, James J. 1976. “A Life-cycle Model of Earnings, Learning, and Consumption.” *Journal of Political Economy* 84(4, Part 2): S9–S44.

Jayachandran, S., and A. Lleras-Muney. 2009. “Life Expectancy and Human Capital Investments: Evidence from Maternal Mortality Declines.” *Quarterly Journal Economics* 124(1): 349–398.

Jayachandran, S. 2009. “Air Quality and Early-life Mortality Evidence from Indonesia’s Wildfires.” *Journal of Human Resources* 44(4): 916–54.

Karlan, D., and J. Appel. 2011. *More than Good Intentions: How a New Economics is Helping to Solve Global Poverty.* New York: Dutton.

Lee, J.-W., and H. Lee. 2016. “Human Capital in the Long Run.” *Journal of Development Economics* 122: 147-169.

León, G. 2012. “Civil Conflict and Human Capital Accumulation: Long-term Consequences of Political Violence in Perú.” *Journal of Human Resources* 47(4): 991-1023.

Lucas, A. M. 2010. “Malaria Eradication and Educational Attainment: Evidence from Paraguay and Sri Lanka.” *American Economic Journal: Applied Economics* 2(2): 46-71.

Maccini, S., and D. Yang. 2009. “Under the Weather: Health, Schooling, and Economic Consequences of Early-life Rainfall.” *American Economic Review* 99(3): 1006–1026.

Maluccio, J. A., J. Hoddinott, J. R. Behrman, R. Martorell, A.R. Quisumbing, and A. D. Stein. 2009. "The Impact of Improving Nutrition during Early Childhood on Education among Guatemalan Adults." *Economic Journal* 119(537): 734–63.

Lindahl, M., M. Palme, S.S. Massih, and A. Sjögren. 2015. "Long-Term Intergenerational Persistence of Human Capital: An Empirical Analysis of Four Generations." *Journal of Human Resources* 50(1): 1-33.

Miguel, E., and M. Kremer. 2004. "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities." *Econometrica* 72(1): 159-217.

Murphy, K. M., and F. Welch. 1990. "Empirical Age-Earnings Profiles." *Journal of Labor Economics* 8(2): 202-229.

Oster, E., I. Shoulson, and R. Dorsey. 2013. "Limited Life Expectancy, Human Capital and Health Investments." *American Economic Review* 103(5): 1977–2002.

Royalty, A.B. 2000. "Tax Preferences for Fringe Benefits and the Health Insurance Offered by Employers." *Journal of Public Economics* 75(2): 209-227.

Ruhm, C.J. 2000. "Are Recessions Good for Your Health?" *Quarterly Journal of Economics* 115 (2): 617–650.

Shah, M., and B. M. Steinberg. 2014. *"*Drought of Opportunities: Contemporaneous and Long-term Impacts of Rainfall Shocks on Human Capital.*" Working Paper No. 19140,* NBER.

Soares, R. R. 2005. "Mortality Reductions, Educational Attainment, and Fertility Choice." *American Economic Review* 95(3): 580–601.

Steckel, R. 2002. "A History of the Standard of Living in the United States" in R. Whales (ed.), *EH.Net Encyclopedia* Economic History Association.

University of East Anglia Climatic Research Unit (CRU); [Ian Harris]. Climatic Research Unit (CRU) Year-by-Year Variation of Selected Climate Variables by Country (CY), [Internet]. NCAS British Atmospheric Data Centre, 2013, *25th August, 2014*. Available at http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__DE_56531370-2613-11e3-9fca-00163e251233

Vallin, J., and F. Meslé. 2009. "The Segmented Trend Line of Highest Life Expectancies." *Population and Development Review* 35(1): 159-187.

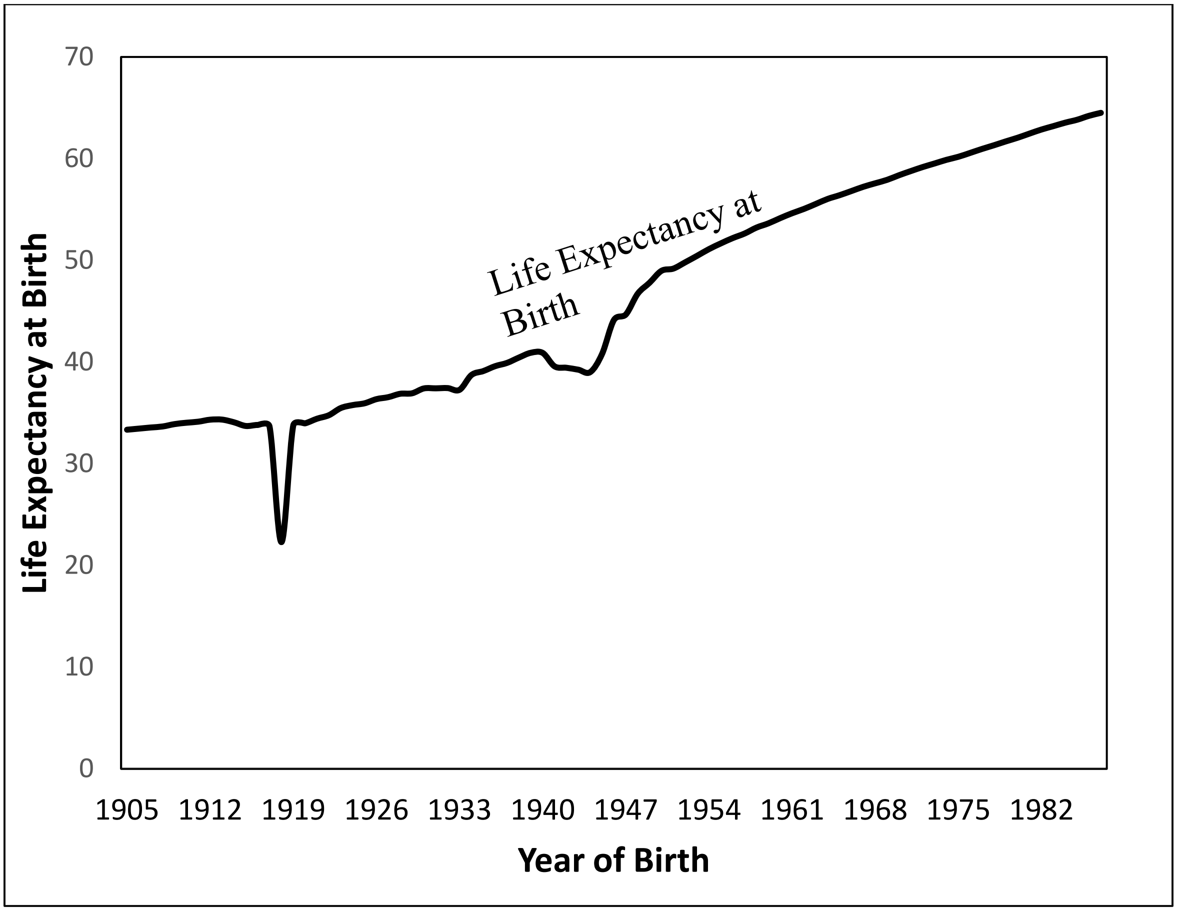


Figure 1: Life Expectancy at Birth across Cohorts, World Average

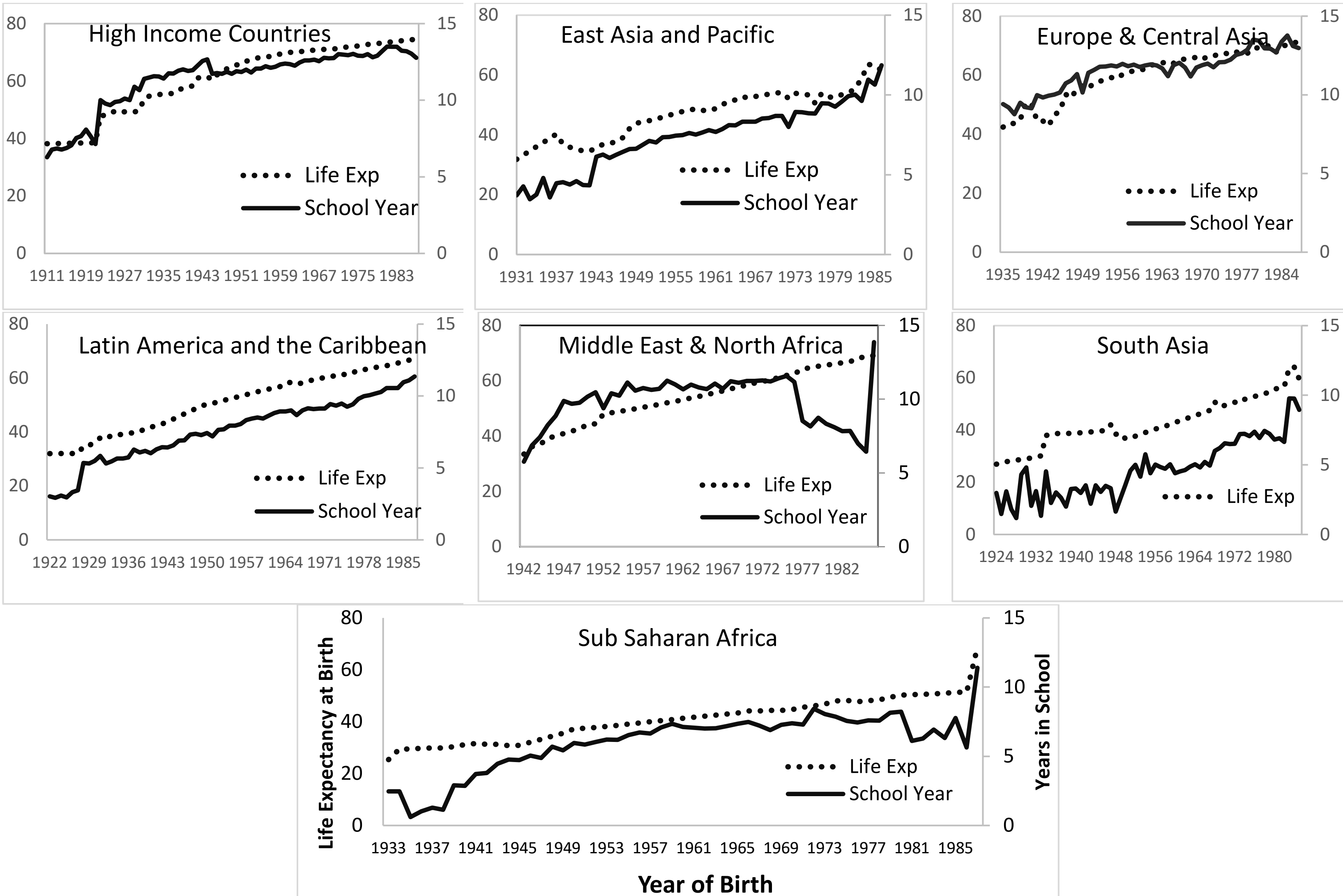
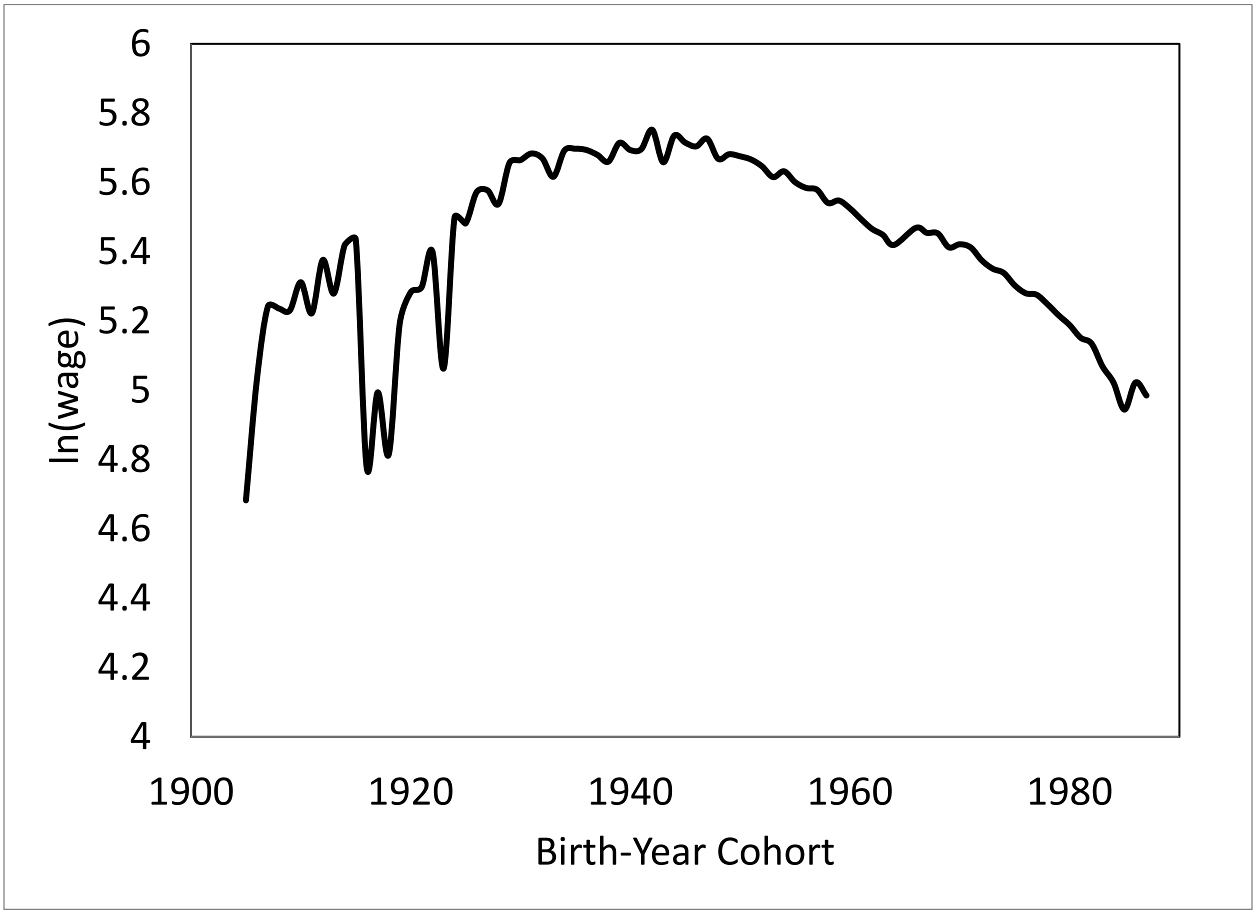
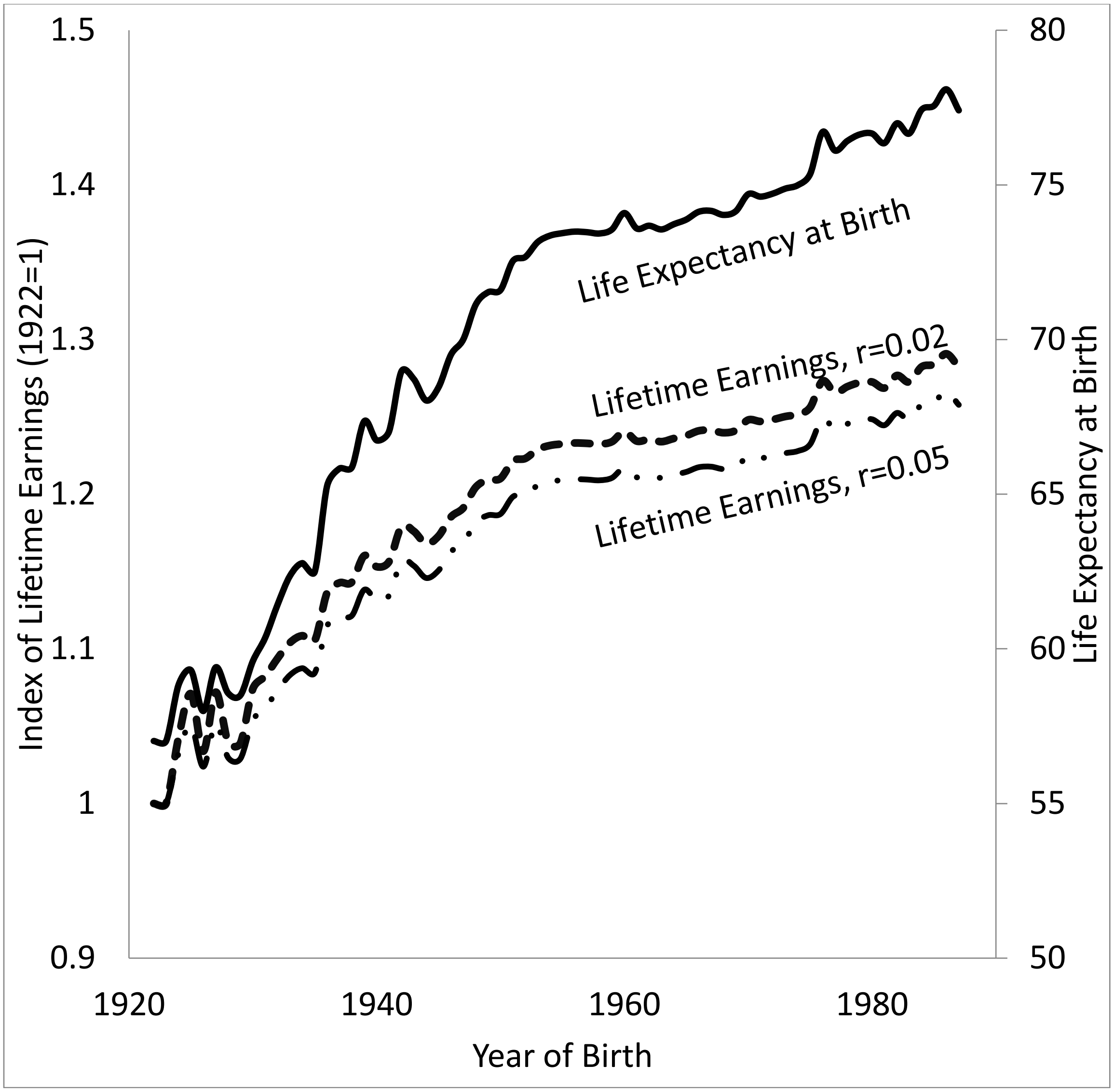


Figure 2: Life Expectancy and Schooling by Birth Cohort across Regions



Note: The birth-year specific wages are the coefficients of Birth-Year dummies in the regression of log (wages) on birth-year dummies and survey dummies, where the survey dummies are taking care of across survey differences in exchange rates, inflation, unit of wages, differences in survey instruments.

Figure 3: Log(wage) by 1905-1987 Birth-year Cohorts, World Averages



Note: We assume 1922 as the base year. We plot the implied present value of lifetime earnings (adjusted for the base year) from the specification II in Table 3 against the Birth Year. The lifetime earnings estimates are assumed for male residing in urban areas. The life expectancy at birth numbers are the maximum life expectancy enjoyed by a cohort across the countries, which is to capture what an average person would expect to enjoy staying on the frontier of health technology at the time of birth. While calculating the net present value of log of lifetime earnings, we try two different discount rates 2% and 5%. The period in the figure ranges from 1922 to 1987 as prior to 1922, the information on urban/rural residence is missing.

Figure 4: World Average Life Expectancy at Birth and Implied Lifetime Earnings Index

Table 1: Life Expectancy at Birth and Schooling

	I	II	III	IV
Life expectancy at birth	*0.120****	*0.097****	*0.094****	*0.117****
	[0.015]	*[0.014]*	*[0.008]*	*[0.026]*
% Urban		6.009***	6.043***	6.737***
		[1.687]	[1.748]	[1.057]
% Male		-1.212	-1.342	-0.858*
		[1.047]	[0.922]	[0.516]
Parents Life Expectancy			0.004	0.026*
			[0.019]	[0.014]
Birth Year Fixed Effects				YES
Survey Fixed Effects	YES	YES	YES	YES
Constant	3.476***	1.574	1.625	-1.748
	[0.916]	[2.298]	[2.455]	[2.256]
N	4670	4185	3861	3861
Adjusted R-square	0.987	0.985	0.985	0.987

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

Table 2: Heterogeneity in Effects of Life Expectancy at Birth on Schooling

	Males				Females			
	I	II	III	IV	I	II	III	IV
Life Expectancy at Birth	***0.098****	***0.082****	***0.084****	***0.107****	***0.157****	***0.141****	***0.135****	***0.157****
	[0.015]	***[0.013]***	***[0.009]***	***[0.028]***	***[0.018]***	***[0.018]***	***[0.014]***	***[0.032]***
% Urban		5.679***	5.766***	5.958***		4.249***	4.351***	4.737***
		[1.860]	[1.911]	[1.155]		[0.845]	[0.927]	[0.645]
% Male								
Parents Life Expectancy			-0.005	0.02			0.007	0.019
			[0.022]	[0.017]			[0.018]	[0.015]
Birth Year FE				YES				YES
Constant	4.420***	1.801	1.888	-1.172	1.622	-0.419	-0.52	-3.001
	[0.905]	[1.713]	[1.949]	[2.288]	[1.148]	[1.491]	[1.755]	[2.623]
N	4690	4204	3878	3878	4622	4149	3822	3822
Adjusted R-square	0.984	0.98	0.98	0.983	0.983	0.981	0.982	0.982
	Urban				Rural			
Life Expectancy at Birth	***0.112****	***0.103****	***0.097****	***0.108****	***0.129****	***0.119****	***0.114****	***0.118****
	[0.018]	***[0.018]***	***[0.011]***	***[0.028]***	***[0.017]***	***[0.011]***	***[0.010]***	***[0.029]***
% Urban								
% Male		-0.25	-0.291	-0.106		-0.56	-0.68	-0.448
		[0.807]	[0.707]	[0.441]		[0.548]	[0.576]	[0.467]
Parents Life Expectancy			0.007	0.02			0.01	0.012
			[0.016]	[0.013]			[0.019]	[0.018]
Birth Year FE				YES				YES
Constant	4.539***	5.461***	5.492***	3.861*	2.195**	2.567***	2.444**	1.785
	[1.104]	[1.433]	[1.513]	[2.167]	[0.996]	[0.884]	[1.202]	[2.510]
N	4684	4200	3874	3874	4446	3959	3657	3657
Adjusted R-square	0.982	0.963	0.963	0.965	0.992	0.987	0.988	0.988

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

Table 3: Effect of Life Expectancy at Birth on Earnings

	I	II	III	IV	V	VI
Life Expectancy at Birth	***-0.017**** [0.005]***	***0.010** [0.006]***	***0.011** [0.006]***	***0.009** [0.005]***	***0.013*** [0.005]***	***0.009*** [0.004]***
Age		0.091*** [0.015]	0.094*** [0.015]	0.077*** [0.013]		
Age square*(1/100)		-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]		
% Urban		1.303*** [0.421]	1.396*** [0.423]	1.112*** [0.196]	1.348*** [0.323]	1.087*** [0.186]
% Male		0.409*** [0.111]	0.412*** [0.116]	0.206* [0.118]	0.154 [0.130]	-0.059 [0.145]
Parents Life Expectancy			0.004 [0.003]	0.003 [0.003]	0.008** [0.003]	0.008** [0.003]
% Married				0.471*** [0.153]		0.610*** [0.124]
Cohort Size				-8.577*** [1.534]		-7.733*** [1.544]
Birth Year FE					YES	YES
Constant	8.490*** [0.331]	3.738*** [0.746]	3.341*** [0.819]	4.206*** [0.671]	5.278*** [0.481]	5.637*** [0.415]
N	4670	4185	3861	3861	3861	3861
Adjusted R-square	0.996	0.998	0.998	0.998	0.998	0.998

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

Table 4: Heterogeneity in Effect of Life Expectancy at Birth on Earnings

	Males			Females		
	I	II	III	I	II	III
Age	0.103***	0.084***		0.069***	0.054***	
	[0.018]	[0.018]		[0.011]	[0.007]	
Age-squared*(1/100)	-0.10***	-0.10***		-0.10***	-0.10***	
	[0.000]	[0.000]		[0.000]	[0.000]	
% Urban	1.252***	0.947***	0.892***	0.907***	0.933***	0.949***
	[0.475]	[0.201]	[0.154]	[0.121]	[0.130]	[0.151]
% Male						
Life expectancy at birth	***0.011***	***0.010***	***0.012****	***0.009****	***0.007****	***0.009*****
	[0.008]	***[0.007]***	***[0.006]***	***[0.004]***	***[0.003]***	***[0.003]***
Parents' life expectancy		0.002	0.008*		0.001	0.004*
		[0.004]	[0.004]		[0.003]	[0.002]
% Married		0.472**	0.578***		0.429***	0.434***
		[0.180]	[0.144]		[0.125]	[0.074]
Cohort size		-12.837***	-12.065***		-9.243	-10.247
		[0.643]	[1.059]		[7.188]	[7.816]
Birth-year Fixed Effects			YES			YES
Constant	3.796***	4.350***	5.671***	4.596***	4.905***	5.708***
	[0.893]	[0.980]	[0.562]	[0.370]	[0.334]	[0.324]
N	4204	3878	3878	4149	3822	3822
Adjusted R-square	0.997	0.998	0.998	0.997	0.998	0.998
	Urban			**Rural**		
Age	0.096***	0.083***		0.069***	0.054***	
	[0.012]	[0.010]		[0.013]	[0.015]	
Age-squared*(1/100)	-0.10***	-0.10***		-0.10***	-0.10***	
	[0.000]	[0.000]		[0.000]	[0.000]	
% Urban						
% Male	0.495***	0.377***	0.103	0.193	0.124	0.074
	[0.091]	[0.074]	[0.091]	[0.140]	[0.133]	[0.147]
Life expectancy at birth	***0.012*****	***0.011*****	***0.010*****	***0.002***	***0.003***	***0.007***
	[0.004]	***[0.003]***	***[0.003]***	***[0.008]***	***[0.009]***	***[0.007]***
Parents' life expectancy		0.002	0.005		0.007	0.011**
		[0.002]	[0.003]		[0.006]	[0.005]
% Married		0.294***	0.501***		0.534**	0.592***
		[0.089]	[0.095]		[0.237]	[0.124]
Cohort size		-7.169*	-5.264		-7.316***	-6.624***
		[4.065]	[3.542]		[1.637]	[2.369]
Constant	4.337***	4.653***	6.396***	5.706***	5.380***	5.988***
	[0.543]	[0.473]	[0.336]	[0.900]	[1.086]	[0.642]
N	4200	3874	3874	3959	3657	3657
Adjusted R-square	0.998	0.999	0.998	0.996	0.996	0.996

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

Table 5: Mincerian Earnings Functions and Returns to Schooling

	Pooled sample		**Males**		**Females**		**Urban**		**Rural**	
	I	II	I	II	I	II	I	II	I	II
Age	0.081*** [0.007]	0.072*** [0.006]	0.088*** [0.008]	0.077*** [0.008]	0.069*** [0.005]	0.054*** [0.005]	0.087*** [0.007]	0.081*** [0.005]	0.073*** [0.009]	0.049*** [0.009]
Age-squared *(1/100)	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0. 10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.000*** [0.000]
Years of schooling	***0.121*** [0.025]***	***0.094*** [0.013]***	***0.137*** [0.028]***	***0.106*** [0.020]***	***0.093*** [0.012]***	***0.073*** [0.008]***	***0.102*** [0.018]***	***0.095*** [0.010]***	***0.096*** [0.022]***	***0.088*** [0.024]***
%Urban		0.528*** [0.172]		0.406** [0.171]		0.604*** [0.093]				
%Male		0.363*** [0.116]						0.392*** [0.099]		0.244** [0.108]
% Married		0.329*** [0.110]		0.308*** [0.097]		0.341*** [0.127]		0.172* [0.103]		0.406** [0.182]
Cohort size		-5.78*** [1.208]		-7.35*** [1.141]		-6.91 [6.369]		-4.073* [2.291]		-4.967*** [1.486]
Constant	4.291*** [0.337]	4.243*** [0.307]	4.135*** [0.373]	4.416*** [0.335]	4.665*** [0.211]	4.748*** [0.126]	4.302*** [0.343]	4.352*** [0.230]	4.746*** [0.348]	5.110*** [0.386]
Survey Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	4670	4185	4690	4204	4622	4149	4687	4201	4446	3959
Adjusted R-square	0.998	0.998	0.998	0.998	0.997	0.998	0.998	0.999	0.996	0.996

Note: Standard errors in brackets. Significance levels: *p<0.05, ** p<0.01, ***p<0.001.

Table 6: Comparison of Returns to Schooling using Mincerian and Wald Estimators

	Pooled sample	**Males**	**Females**	**Urban**	**Rural**
Panel a. Birth cohort data					
Mincerian earnings function	9.40%***	10.60%***	7.30%***	9.50%***	8.80%***
[std. error]	[0.013]	[0.020]	[0.008]	[0.010]	[0.024]
Wald estimate [std. error]	7.90%***	9.90%***	4.30%***	10.21%***	2.90%
	[0.018]	[0.024]	[0.011]	[0.017]	[0.026]
Panel b. Individual-level data					
Mincerian earnings function	9.7%***	8.9%***	10.7%***	8.6%***	10.0%***
[std. error]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Wald estimate	11.2%***	15.0%***	7.8%***	10.6%***	10.1%***
[std. error]	[0.004]	[0.003	[0.003]	[0.004]	[0.004]
Wald estimate using IV	12.02.%***	17.2%***	7.4%***	13.8%***	9.4%***
estimator	[0.003]	[0.004]	[0.004]	[0.004]	[0.004]
[std. error]					

Note: The Mincerian return to schooling estimates are taken from specification II for each group in Table 5 while the Wald estimates for pooled sample is derived by dividing the coefficients of life expectancy at birth from specification IV in Table 3 by the coefficient of life expectancy at birth in specification IV in Table 1. Similarly, for each gender and Rural-Urban group, the Wald estimates are obtained by dividing the life expectancy coefficients from specification II in Table 4 by life expectancy coefficients from specification IV in Table 2. Standard errors for Wald estimates are obtained by 500 bootstrap replications.

Table 7: Life Expectancy at Birth Effects on Schooling and Earning, Individual-Level Analysis

	Pooled Sample		**Males**		**Females**		**Rural**		**Urban**	
	Schooling	Earnings	Schooling	Earnings	Schooling	Earnings	Schooling	Earnings	Schooling	Earnings
Urban	-1.621*** [0.087]	-0.424*** [0.017]	-1.812*** [0.087]		-1.253*** [0.074]			-0.483*** [0.016]		-0.396*** [0.017]
Male/Female	0.247*** [0.032]	-0.366*** [0.010]		-0.358*** [0.012]		-0.355*** [0.008]	0.0932* [0.041]		0.287*** [0.031]	
Life expectancy at birth	***0.115*** [0.008]***	***0.013*** [0.001]***	***0.103*** [0.008]***	***0.015*** [0.002]***	***0.150*** [0.011]***	***0.012*** [0.002]***	***0.120*** [0.009]***	***0.012*** [0.002]***	***0.0996*** [0.007]***	***0.011*** [0.001]***
Parents' life expectancy	0.0219*** [0.006]	0.005*** [0.001]	0.0270*** [0.007]	0.008*** [0.002]	0.008 [0.006]	0.002 [0.001]	0.0233** [0.007]	0.006*** [0.002]	0.0233*** [0.006]	0.006*** [0.001]
Age		0.077*** [0.004]		0.087*** [0.005]		0.060*** [0.005]		0.064*** [0.003]		0.081*** [0.005]
Age square*(1/100)		-0.10*** [0.000]		-0.10*** [0.000]		-0.10*** [0.000]		-0.10*** [0.000]		-0.10*** [0.000]
Marital status		-0.107*** [0.008]		-0.245*** [0.008]		0.024 [0.015]		-0.100*** [0.008]		-0.113*** [0.009]
Cohort size		-2.483*** [0.286]		-2.666*** [0.357]		-1.270*** [0.375]		-1.771*** [0.335]		-2.497*** [0.279]
Constant	3.315*** [0.645]	4.925*** [0.217]	3.749*** [0.640]	4.474*** [0.279]	2.112* [0.835]	4.979*** [0.245]	1.297 [0.796]	5.062*** [0.218]	4.242*** [0.569]	4.838*** [0.225]
Birth-Year Fixed Effect	YES		YES		YES		YES		YES	
Survey Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	2725213	2543741	1589055	1473199	1136158	1070542	872016	832947	1853197	1710794
Adjusted R-square	0.444	0.898	0.442	0.916		0.869	0.589	0.888	0.340	0.904
F-statistic	36.730	1371.40	39.200	1040.50	49.770	350.70	39.120	292.50	30.190	468.70

Note: Standard errors in brackets. Significance levels: *p<0.05, ** p<0.01, *** p<0.001.

Table 8: Instrumental Variables Estimation using Infant Mortality as an Instrument for Life Expectancy at Birth

	Pooled sample		**Male**		**Female**		**Urban**		**Rural**	
	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
Panel a: Dependent Variable in Stage 1 is life expectancy at birth; in stage 2, years of completed schooling										
Death rate for under-5 children	**-0.864*** **		**-0.848*** **		**-0.889*** **		**-0.791*** **		**-0.954*** **	
	[0.106]		[0.116]		[0.088]		[0.095]		[0.113]	
Life expectancy at birth		**0.146*** **		**0.138*** **		**0.176*** **		**0.128*** **		**0.152*** **
		[0.028]		[0.028]		[0.036]		[0.032]		[0.029]
Parents' life expectancy	**-0.117*** **	**0.039*** **	**-0.122*** **	**0.040** **	**-0.110*** **	**0.034*** **	**-0.079** **	**0.042*** **	**-0.163*** **	**0.038** **
	[0.037]	[0.014]	[0.037]	[0.016]	[0.038]	[0.012]	[0.037]	[0.012]	[0.046]	[0.018]
Urban	0.006	-1.520***	0.011**	-1.698***	-0.003	-1.186**				
	[0.004]	[0.580]	[0.005]	[0.583]	[0.005]	[0.489]				
Gender	0.009	0.278**					0.010*	0.316***	0.008	0.14
	[0.005]	[0.117]					[0.006]	[0.091]	[0.007]	[0.214]
First Stage F-Statistic (Weak Identification Test)	67.067		53.721		101.876		69.877		71.851	
Panel b: Corresponding OLS Estimates (Life expectancy at birth is exogenous for individual schooling)										
Life expectancy at birth		**0.113*** **		**0.103*** **		**0.141*** **		**0.090*** **		**0.124*** **
		[0.02]		[0.02]		[0.04]		[0.02]		[0.03]
Parents' life expectancy		**0.037** **		**0.036** **		**0.032** **		**0.042*** **		**0.031***
		[0.01]		[0.02]		[0.01]		[0.01]		[0.02]
Panel c: Dependent Variable in Stage 1 is life expectancy at birth, in stage 2, it is log of wage										
Death rate for under-5 children	**-0.818*** **		**-0.807*** **		**-0.835*** **		**-0.752*** **		**-0.900*** **	
	[0.087]		[0.092]		[0.081]		[0.072]		[0.105]	
Life expectancy at birth		**0.017*** **		**0.024*** **		**0.013*** **		**0.018*** **		**0.014** **
		[0.005]		[0.008]		[0.004]		[0.005]		[0.007]
Parents' life expectancy	**-0.092** **	**0.007*** **	**-0.099** **	**0.009*** **	**-0.082***	**0.003*** **	**-0.06**	**0.007*** **	**-0.130** **	**0.007***
	[0.046]	[0.002]	[0.048]	[0.003]	[0.043]	[0.001]	[0.040]	[0.001]	[0.062]	[0.004]
Urban	0.002	-0.361***	0.006	-0.352***	-0.005	-0.352***				
	[0.003]	[0.063]	[0.004]	[0.071]	[0.006]	[0.046]				
Individual age	-0.077	0.074***	-0.094	0.085***	-0.056	0.055***	-0.062	0.079***	-0.098	0.061***
	[0.088]	[0.009]	[0.100]	[0.012]	[0.072]	[0.008]	[0.091]	[0.009]	[0.099]	[0.011]
Individual age-squared	-0.002*	-0.001***	-0.002*	-0.001***	-0.002**	-0.001***	-0.002*	-0.001***	-0.002*	-0.001***
	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]
Gender	0.011	-0.415***					0.011*	-0.387***	0.014	-0.476***
	[0.007]	[0.060]					[0.006]	[0.057]	[0.012]	[0.072]
Married	0.035	0.123***	0.044	0.258***	0.031	-0.038	0.017	0.121***	0.053	0.124***
	[0.029]	[0.014]	[0.033]	[0.050]	[0.031]	[0.028]	[0.020]	[0.012]	[0.039]	[0.022]
Cohort size	11.325*	-2.645***	10.407**	-2.894***	13.286*	-1.370**	8.9	-2.821***	13.778*	-1.833***
	[5.824]	[0.531]	[5.076]	[0.539]	[7.778]	[0.621]	[5.476]	[0.695]	[7.399]	[0.204]
First Stage F-Statistic (Weak Identification Test)	95.603		83.083		**114.28**		108.877		73.451	
Panel d: Corresponding OLS Estimates (Life expectancy at birth is exogenous for individual wage earnings)										
Life expectancy at birth		**0.012*** **		**0.015*** **		**0.011*** **		**0.011*** **		**0.011** **
		[0.00]		[0.01]		[0.00]		[0.00]		[0.00]
Parents' life expectancy		**0.006*** **		**0.009*** **		**0.003*** **		**0.007*** **		**0.006***
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]

Note: Standard errors reported in brackets are clustered at the country level. Significance levels: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. All covariates are at the individual level except life expectancy at birth and infant mortality rate, which are birth-year level means. All of the specifications include country fixed effects and birth year fixed effects. Specifications under panel (b) & (d) are to facilitate comparison with estimates obtained from IV and reported in panels (a) and (c).

Table 9: Life Expectancy at Birth Effects on Lifetime Earnings with Correction for Selection including Cohort Size in Labor Force

	Pooled sample	Males	Females	Rural	Urban
Life expectancy at birth	***0.013****** ***[0.003]***	***0.015****** ***[0.004]***	***0.013****** ***[0.003]***	***0.013****** ***[0.004]***	***0.010****** ***[0.003]***
Age	0.077*** [0.011]	0.090*** [0.015]	0.060*** [0.009]	0.062*** [0.012]	0.083*** [0.012]
Age-squared*(1/100)	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]
Rural	-0.367*** [0.066]	-0.360*** [0.073]	-0.357*** [0.050]		
Male	0.431*** [0.017]			0.486*** [0.016]	0.403*** [0.018]
Marital status	-0.103*** [0.021]	-0.240*** [0.046]	0.076*** [0.029]	-0.114*** [0.034]	-0.096*** [0.019]
Cohort size	-2.564 [3.161]	-0.009 [4.284]	-1.548 [2.835]	-3.384 [4.292]	-1.228 [3.315]
Parents' life expectancy	0.005*** [0.002]	0.008*** [0.003]	0.002 [0.001]	0.006*** [0.003]	0.006*** [0.002]
Correction term for selection (Proportion of birth-year cohort in labor force)	0.202 [4.499]	-4.038 [6.217]	0.984 [4.005]	2.349 [6.324]	-1.619 [4.074]
Constant	4.473*** [0.475]	4.467*** [0.698]	4.898*** [0.301]	4.552*** [0.593]	4.398*** [0.425]
N	2478294	1434525	1043769	822189	1656105
Adjusted R-square	0.899	0.918	0.869	0.888	0.906

Note: Standard errors in brackets. Significance levels: *p<0.05, ** p<0.01, *** p<0.001.

Table 10: Life Expectancy at Birth Effects on Lifetime Earnings with Correction for Selection Due to Participation in Labor Force

	Pooled Sample		Male		Female		Rural		Urban	
	Selection Equation	Earnings Equation	Selection Equation	Earnings Equation	Selection Equation	Earnings Equation	Selection Equation	Earnings Equation	Selection Equation	Earnings Equation
Household size	-0.039*** [0.001]		0.002 [0.001]		-0.075*** [0.001]		-0.022*** [0.001]		-0.056*** [0.001]	
Respondent is household head	0.787*** [0.003]		0.862*** [0.007]		0.538*** [0.004]		0.721*** [0.006]		0.810*** [0.004]	
Life expectancy at birth	***0.003*** [0.000]***	***0.014*** [0.004]***	***0.002** [0.001]***	***0.018*** [0.007]***	***0.007*** [0.000]***	***0.012*** [0.003]***	***-0.006*** [0.001]***	***0.014*** [0.005]***	***0.016*** [0.001]***	***0.010*** [0.003]***
Age	0.204*** [0.001]	0.045*** [0.005]	0.203*** [0.002]	0.035*** [0.009]	0.209*** [0.001]	-0.005 [0.016]	0.199*** [0.002]	0.046*** [0.006]	0.209*** [0.002]	0.043*** [0.006]
Age-squared*(1/100)	-0.3*** [0.000]	-0.0*** [0.000]	-0.3*** [0.000]	0 [0.000]	-0.3*** [0.000]	0 [0.000]	-0.3*** [0.000]	-0.0*** [0.000]	-0.3*** [0.000]	-0.0*** [0.000]
Rural	0.106*** [0.003]	-0.378*** [0.062]	-0.061*** [0.006]	-0.351*** [0.076]	0.172*** [0.003]	-0.401*** [0.037]				
Male	1.691*** [0.003]	0.154*** [0.036]					1.851*** [0.006]	0.301*** [0.047]	1.630*** [0.004]	0.105** [0.041]
Marital status, never married	0.070*** [0.004]	-0.116*** [0.031]	-0.914*** [0.007]	-0.026 [0.035]	0.558*** [0.005]	-0.122** [0.056]	-0.030*** [0.007]	-0.108*** [0.036]	0.109*** [0.005]	-0.121*** [0.030]
Cohort Size (Proportion of birth-year cohort in labor force)		-2.286*** [0.749]		-2.471*** [0.839]		-0.666 [0.950]		-1.761*** [0.273]		-2.120** [0.972]
Parents' life expectancy	0.007*** [0.000]	0.004** [0.002]	-0.001 [0.001]	0.008*** [0.003]	0.010*** [0.000]	-0.001 [0.001]	0.012*** [0.001]	0.005 [0.003]	-0.002*** [0.000]	0.007*** [0.002]
Inverse Mills Ratio		-0.742*** [0.278]		-1.575*** [0.566]		-1.077*** [0.390]		-0.443** [0.214]		-0.849** [0.325]
Constant	-3.420*** [0.038]	5.356*** [0.297]	-0.742*** [0.084]	5.262*** [0.511]	-4.003*** [0.045]	6.872*** [0.569]	-3.137*** [0.058]	5.034*** [0.483]	-3.747*** [0.050]	5.497*** [0.266]
N	4453600	2478294	2149376	1434525	2304224	1043769	1831164	822189	2622436	1656105
Adjusted. R square		0.9		0.919		0.871		0.888		0.907
F-statistics		344.508		130.152		319.203		61.128		201.815

Note: Standard errors in brackets. Significance levels: *p<0.05, ** p<0.01, *** p<0.001. From the selection equation, we calculate the linear predicted probabilities, and then convert these into normal densities to calculate the inverse Mills ratio. The group-specific inverse-mills ratios are used in the earnings specifications, which is estimated only on those who are in the labor force, to correct for the selection.

Appendix A. Proofs of Propositions in Section III

Proposition 1: The shadow value of human capital in terms of wealth, $g(t)$, increases when life expectancy, *T*, increases.

Proof: differentiation of equation (15) w.r.t. *T* yields

$$\frac{dg(t)}{dT} = \frac{d}{dT}\left(\frac{R}{(\sigma+r)}\left[1 - e^{(\sigma+r)(t-T)}\right]\right)$$

$$= \frac{R}{(\sigma+r)}\left[-(\sigma+r)(-e^{(\sigma+r)(t-T)})\right]$$

$$= R\left[(e^{(\sigma+r)(t-T)})\right].$$

Since market rental rate of human capital $R > 0, \frac{dg(t)}{dT} = R\left[(e^{(\sigma+r)(t-T)})\right] > 0.$

Proposition 2: If life expectancy at birth, *T*, increases, purchases of educational-investment goods, *D(t)*, and effective time investment, *I(t)H(t)* would increase in every period of life.

Proof: from equation (19)-(20), we note that price of *D(t)* is $\frac{P}{g(t)}$, and price of *I(t)H(t)* is $\frac{P}{g(t)}$. *P* and *R* are assumed to be constant over lifetime. Therefore, $g(t)$ determines the movement of prices in the demand functions for investment goods. Proposition 1 shows that $\frac{dg(t)}{dT} > 0$. So, in response to a rise in *T*, prices of both *D(t)* and *I(t)H(t)* would decrease as well. Since both of these inputs are assumed normal, own price decrease would increase purchase of both inputs $\forall\, t \in [0, T]$ *i.e.*, $\frac{dD(t)}{dT} > 0$ and $\frac{dI(t)H(t)}{dT} > 0$. We explicitly show the case for $D(t)$.

$$D(t) = D\left[\frac{P}{g(t)}, \frac{R}{g(t)}\right] \forall\, t \in [0, T]$$

$$\frac{dD(t)}{dT} = -\frac{P}{[g(t)]^2} * D_1 * \frac{dg(t)}{dT} - \frac{R}{[g(t)]^2} * D_2 * \frac{dg(t)}{dT}$$

$$\frac{dD(t)}{dT} = -\left[\frac{P}{g(t)} * D_1 + \frac{R}{g(t)} * D_2\right] * \frac{\frac{dg(t)}{dT}}{g(t)}.$$

Strong concavity and twice differentiability of production function implies that

$\frac{P}{g(t)} * D_1 + \frac{R}{g(t)} * D_2 < 0$, and from proposition 1, $\frac{dg(t)}{dT} > 0$. These together imply that $\frac{dD(t)}{dT} > 0$.

Proposition 3: If life expectancy, *T*, increases, total human capital stock accumulated over lifetime increases as well.

Proof: From equation 21, human capital stock at any time *t* is

$$H(t) = \int_0^t e^{\sigma(\tau-t)} F[I(\tau)H(\tau), D(\tau)]d\tau + H(0)e^{-\sigma t}.$$

$$\frac{d}{dT}[H(t)] = \frac{d}{dT}\left[\int_0^t e^{\sigma(\tau-t)} F[I(\tau)H(\tau), D(\tau)]d\tau + H(0)e^{-\sigma t}\right]$$

$$=\int_0^t e^{\sigma(\tau-t)} \frac{d}{dT}\{F[I(\tau)H(\tau), D(\tau)]\}d\tau + \frac{d}{dT}(H(0)e^{-\sigma t})$$

$$=\int_0^t e^{\sigma(\tau-t)} \left\{F_1 \frac{\delta I(\tau)H(\tau)}{\delta T} + F_2 \frac{\delta D(\tau)}{\delta T}\right\} d\tau.$$

Proposition 2 demonstrates that $\frac{dD(t)}{dT} > 0$, and $\frac{dI(t)H(t)}{dT} > 0$. Again, $F[I(\tau)H(\tau), D(\tau)]$ is increasing in both of its argument if $I(\tau) > 0$. So, the term in braces inside the integral is positive, *i.e.*, $\left\{F_1 \frac{\delta I(\tau)H(\tau)}{\delta T} + F_2 \frac{\delta D(\tau)}{\delta T}\right\} > 0$. These together imply that $\frac{d}{dT}[H(t)] > 0$.

Since in response to a rise in life expectancy at birth, human capital increases $\forall\, t \in [0, T]$, lifetime human capital stock, $H(T) = \int_0^T \left[e^{\sigma(\tau-t)} F[I(\tau)H(\tau), D(\tau)]d\tau + H(0)e^{-\sigma T}\right]dt$, will increase as well. Further, since lifetime accumulation of human capital increases, the value of the stock would change as well in response to a rise in life expectancy. Proposition 4 below explains this.

Proposition 4: If life expectancy *T* increases, lifetime labor income increases.

Proof: the present value of lifetime labor earnings, as stated in equation 23, is

$$V = g(0)H(0) + \int_0^T e^{-rt}\{g(t)F[I(t)H(t), D(t)] - PD(t) - RIH(t)\}\, dt,$$

where the term inside the integral is the time *0* present value of net profits from human capital accumulation as of time *t*. Differentiating w.r.t *T* yields

$$\frac{dV}{dT} = H(0)\frac{d}{dT}\left[\frac{R}{(\sigma+r)}\left[1 - e^{(\sigma+r)(-T)}\right]\right] + \frac{d}{dT}\left[\int_0^T e^{-rt}\{g(t)F[I(t)H(t), D(t)] - PD(t) - RIH(t)\}\, dt\right].$$

Applying the Leibniz Rule on the above yields

$$\frac{dV}{dT} = H(0)\left[R\left[e^{(\sigma+r)(-T)}\right]\right] + \left[\int_0^T e^{-rt}\frac{d}{dT}\{g(t)F[I(t)H(t), D(t)] - PD(t) - RIH(t)\}\, dt\right] + e^{-rT}[g(T)F[I(T)H(T), D(T)] - PD(T) - RIH(T)],$$

$$\frac{dV}{dT} = H(0)\left[R\left[e^{(\sigma+r)(-T)}\right]\right] + \left[\int_0^T e^{-rt}\left\{\left[g(t)F_1\frac{\delta I(\tau)H(\tau)}{\delta T} + g(t)F_2\frac{\delta D(\tau)}{\delta T}\right] + F[I(t)H(t), D(t)]\frac{dg(t)}{dT} - P\frac{dD(t)}{dT} - R\frac{dH(t)}{dT}\right\} dt\right] + e^{-rT}[g(T)F[I(T)H(T), D(T)] - PD(T) - RIH(T)].$$

From the first order conditions (9), we substitute $g(t)F_1 = R$, and from (10), $g(t)F_2 = P$ into the above equation to yield

$\frac{dV}{dT} = H(0)\left[R\left[e^{(\sigma+r)(-T)}\right]\right] + \left[\int_0^T e^{-rt}\left\{R\frac{\delta I(\tau)H(\tau)}{\delta T} + P\frac{\delta D(\tau)}{\delta T} + F[I(t)H(t), D(t)]\frac{dg(t)}{dT} -\right.\right.$
$\left.\left. P\frac{\delta D(\tau)}{\delta T} - R\frac{\delta I(\tau)H(\tau)}{\delta T}\right\} dt\right] + e^{-rT}[g(T)F[I(T)H(T), D(T)] - PD(T) - RIH(T)],$
$\frac{dV}{dT} = H(0)\left[R\left[e^{(\sigma+r)(-T)}\right]\right] +$
$\left[\int_0^T e^{-rt}\left\{F[I(t)H(t), D(t)]\frac{dg(t)}{dT}\right\} dt\right] + e^{-rT}[g(T)F[I(T)H(T), D(T)] - PD(T) - RIH(T)].$

In the RHS of the above equation, clearly the first term $H(0)\left[R\left[e^{(\sigma+r)(-T)}\right]\right] > 0$. Since $\frac{dg(t)}{dT} > 0$ from proposition 1, the middle term $\left[\int_0^T e^{-rt}\left\{F[I(t)H(t), D(t)]\frac{dg(t)}{dT}\right\} dt\right]>0$. Finally, the last term $e^{-rT}[g(T)F[I(T)H(T), D(T)] - PD(T) - RIH(T)]$ is the present value of net profit from human capital investment in the last period *T*. Although, Heckman assumes that human capital investment might be taken even at a financial loss because of nonmarket benefit of education, in the current setting, condition 14 states that shadow value of human capital is *0* in the last period *T*. It implies that an individual at her last stage of life would not invest in human capital since she will not survive in periods after T to reap the benefits of the investment. Accordingly, in the last period *T*, $D(T) = 0$, and, therefore, the last term is 0. It suggests that lifetime labor income from human capital investment is positive, i.e., $\frac{dV}{dT} > 0$.

Proposition 5: If *T* increases, marginal utility of lifetime wealth, $\lambda(0)$, decreases.

Proof*:* Since $\lambda(0)$ is the marginal utility of wealth or shadow value of lifetime wealth as of period 0, and utility function follows concavity, it would decrease if lifetime wealth increases. Throughout the lifetime, wealth comes from two sources-labor income from exploiting human capital in the labor market and initial asset. Proposition 4 shows that lifetime labor income increases in response to gain in *T*. However, *T* does not affect initial endowment of assets $A(0)$. These together imply that an increase in *T* would increase lifetime wealth, which, in turn, suggests that $\lambda(0)$ falls when life expectancy at birth increases.

Proposition 6: If life expectancy *T* increases, consumption of leisure in human capital adjusted efficiency units, i.e., effective leisure $HL(t)$ increases. However, measured hours of leisure, $L(t)$, responds in an ambiguous manner.

Proof: Since leisure is by assumption a normal good and an increase in life expectancy at birth (*T*) increases lifetime income, value of leisure should increase $\forall\ t \in [0, T]$. From equation 17, $H(t)L(t) = HL\left[\lambda(0)e^{(\rho-r)t}P,\ R\lambda(0)e^{(\rho-r)t}\right]$.

Since proposition 5 shows that $\frac{d\lambda(0)}{dT} < 0$, when *T* increases effective leisure becomes cheaper through reduced value for $\lambda(0)$. It implies that in response to gain in *T*, for an individual value of leisure increases at all ages. However, the direction of change in consumption of leisure in natural units of time, $L(t)$, is not quite clear. For exposition, note that effective leisure can be expressed as

$$InL(t) = InHL(t) - InH(t)$$

$$\frac{d}{dT}[InL(t)] = \frac{d}{dT}[InHL(t)] - \frac{d}{dT}[InH(t)],$$

$$= \frac{d[InHL(t)]}{d\lambda(0)} * \frac{d\lambda(0)}{dT} - \frac{d[InH(t)]}{dT}.$$

Since leisure is a normal good, $\frac{d[InHL(t)]}{d\lambda(0)} * \frac{d\lambda(0)}{dT} > 0$, and in proposition 3, we have already shown that the second term $\frac{d[InH(t)]}{dT} > 0$. Therefore, we cannot sign $\frac{d}{dT}[InL(t)]$. If $\frac{d[InHL(t)]}{d\lambda(0)} * \frac{d\lambda(0)}{dT} > \frac{d[InH(t)]}{dT}$, $L(t)$ increases in response to a rise in *T* and *vice versa*.

Appendix B

Table B1: List of Countries and Years of Surveys

Country	Survey Year	Country	Survey Year
Afghanistan	2007	Latvia	2004, 2012
Albania	2003	Moldavia	2002, 2005
Argentina	2012	Maldives	1998, 2004
Austria	2004, 2012	Mexico	1989, 2012
Azerbaijan	1995	North Macedonia	2003, 2005
Belgium	2004, 2011	Malta	2009, 2012
Burkina Faso	1994, 2009	Mongolia	2002, 2011
Bulgaria	2003, 2012	Mozambique	2002
Bosnia-Herzegovina	2001, 2004	Mauritius	1999, 2012
Belarus	1998	Malawi	2004, 2010
Belize	1993, 1999	Namibia	1993
Bolivia	1992, 2012	Niger	1995, 2011
Brazil	1981, 2012	Nigeria	1993
Canada	1981, 2001	Nicaragua	1993, 2009
Switzerland	2011	Holland	2005, 2012
Chile	1987, 2011	Norway	2004, 2012
China	2002	Pakistan	2010
Cameroon	2001	Panama	1989, 2012
Colombia	2001, 2012	Peru	1997, 2012
Costa Rica	1989, 2009	Philippines	2003, 2011
Cyprus	2005, 2012	Poland	2005, 2012
Czech Republic	2005, 2012	Puerto Rico	1970, 2005
Germany	2005, 2012	Portugal	2004, 2012
Denmark	2004, 2012	Paraguay	1990, 2011
Dominican Republic	1996, 2011	Romania	1994, 2012
Ecuador	1994, 2012	Russian Federation	1994, 2009
Spain	2004, 2012	Senegal	2011
Estonia	2004, 2012	Solomon Islands	2005
Ethiopia	2005	Sierra Leone	2003, 2011
Finland	2004, 2012	El Salvador	1991, 2009
France	2004, 2012	Serbia	2008
Micronesia, Fed. States.	2000	São Tomé and Príncipe	2000, 2010
Gabon	2005	Surinam	1999
United Kingdom	2005, 2012	Slovak Republic	2003, 2012
Greece	2004, 2012	Slovenia	2005, 2012
Guatemala	2000, 2011	Sweden	2004, 2012
Guyana	1992	Eswatini	2000
Honduras	1991, 2011	Chad	2003
Croatia	2004, 2012	Togo	2006
Haiti	2001	Thailand	1990, 2009
Hungary	2004, 2012	Tajikistan	2003
Indonesia	1998, 2010	Turkmenistan	1998
India	1983, 2007	Timor-Leste	2001, 2007
Ireland	2004, 2009	Tunisia	2001
Iceland	2004, 2012	Turkey	2002
Italy	2004, 2012	Tanzania	2000
Jamaica	1990, 2002	Uganda	1992
Jordan	2002, 2010	Ukraine	2000, 2005
Kenya	2005	Uruguay	1989, 2012
Kyrgyzstan	1997	United States	1990, 2010
Cambodia	1997, 2008	Venezuela, RB	1989, 2006

Lao PDR	1997, 2008	Vietnam	2002, 2010
Lebanon	2011	West Bank and Gaza	1998, 2008
Sri Lanka	1993, 2009	Zaire	2005
Lithuania	2005, 2012	Zambia	1998, 2010
Luxembourg	2004, 2012		

Note: Total of 188 surveys from 111countries spanning the years 1970-2012.

Table B2: Return to Schooling from Mincerian Earnings Functions: Individual Level Analysis

	Pooled Sample	Males	Females	Rural	Urban
Years of Schooling	***0.097*** [0.001]***	***0.089*** [0.001]***	***0.107*** [0.001]***	***0.086*** [0.001]***	***0.100*** [0.001]***
Age	0.062*** [0.003]	0.068*** [0.004]	0.052*** [0.004]	0.052*** [0.003]	0.066*** [0.004]
Age- squared *(1/100)	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]	-0.10*** [0.000]
Urban residence	-0.222*** [0.004]	-0.210*** [0.006]	-0.231*** [0.004]		
Male	-0.450*** [0.014]			-0.493*** [0.016]	-0.427*** [0.015]
Marital status	-0.061*** [0.006]	-0.204*** [0.006]	0.073*** [0.012]	-0.067*** [0.007]	-0.062*** [0.007]
Cohort size	-0.326 [0.203]	-0.417 [0.260]	0.083 [0.294]	-0.331 [0.274]	-0.348* [0.197]
Constant	5.102*** [0.075]	5.164*** [0.096]	4.573*** [0.093]	5.444*** [0.059]	4.865*** [0.084]
Survey Fixed Effect	YES	YES	YES	YES	YES
N	2572536	1491901	1080635	842749	1729787
Adjusted R-square	0.912	0.928	0.888	0.901	0.919
F	3299.304	2002.804	3300.83	1117.629	2029.129

Note: Standard errors in brackets. Significance levels: *p<0.05, ** p<0.01, *** p<0.00

Appendix C. Robustness Checks

Table C1 reports the first set of robustness results for schooling. In general, estimates of life expectancy's effect on schooling from all of the specifications for robustness show similar patterns as we observed: the coefficients of life expectancy at birth always turn out to be positive and statistically significant at less than the 1 percent level. The estimates lie in the range of 0.04-0.111. Life expectancy's effect on schooling is smaller in magnitude both in the un-weighted case, and when a young group sample is used. The estimates are similar in magnitude when we use only one survey per country (the latest possible survey), or we replace parents' life expectancy by a 15-year lagged value of life expectancy at birth. Similar to previously reported estimates, if life expectancy at birth increases by one year, the birth-year cohort will spend 0.1 year more time in school.

For lifetime earnings, Table C2 reports that the positive and statistically significant relationship between life expectancy at birth and earnings is robust across samples consisting only young-age group, controls through higher order age terms, alternative definition of parents' life expectancy, and alternative assumption on cohort fixed effect. In contrast to that for schooling, we fail to notice any statistical significance for un-weighted regression and sample consisting only one survey per country. Incorporating higher order age terms in our specification, we obtain a 0.8% increase in income from an additional year of gain in life expectancy at birth, which is similar to what we observe in our main specification (specification IV in Table 3). Including cohort fixed effects by defining each cohort as a five-year birth range shrinks the life expectancy effect on lifetime earnings, as reported in column IV. Parents' life expectancy constructed by taking a 15-year lag does not affect the life expectancy effect on earnings. Next, we restrict our sample on young working group by including only those who are in age group 25-

45. The coefficient of life expectancy at birth now shrinks further in magnitude (1.6% per year of added life expectancy) and still remain statistically significant. Although we do not report in Table C2, the coefficient of life expectancy at birth turns out to be positive and statistically significant if we alternatively define the young working group to be those in the age ranges of 25-50 or 25-40.

Life expectancy at birth or something else?

The literature finds that weather shocks impact well-being through multifaceted channels including reduced labor productivity, agricultural output shock, mortality due to disease outbreak, and political instability instigating civil war (Dell et al. 2014; Maccini and Yang 2009). As a control for other factors prevailing at the time of birth, we incorporate country-cohort specific average temperature and average precipitation. The weather attributes that prevailed at the time of birth appear to be exogenous. This robustness check will give us an indication of whether the positive and statistically significant positive association of life expectancy at birth with schooling and lifetime earnings is truly an exogenous impact of life expectancy at birth, or it is actually due to any cohort and country specific omitted or unobserved factors which influence both health and human capital.[27]

The time series on country averages on yearly temperature and precipitation is compiled from CRU-CY data set, produced and maintained by Climate Research Unit at the University of East Anglia, UK. [28] The CRU-CY data set maintains information on monthly, seasonal or annual

[27] For illustration, while one was in the womb, if there was a severe flood in his/her locality, which caused food scarcity and high infant mortality in that area, then any life expectancy effects we observe in our model would actually be the true effect of weather shocks.

[28] The underlying data set behind the construction of the CRU-CY data set is the CRU TS data set. The construction is described as "*The original data (CRU TS 3.21) took the form of a value for each month and each box on a 0.5 degree latitude/longitude grid. CRU assigned each box to a single country. For each country CRU calculated the weighted mean of the values from its constituent grid boxes for each month in turn. Each grid box was weighted by surface area, using the cosine of the latitude. The seasonal and annual values are the means of their constituent months. The CRU TS dataset prioritizes completeness, and has no missing data over land. Where observations are*

spatial averages on 10 climate variables including temperature and precipitation. We utilize annual averages of these two variables- temperature and precipitation. The first two columns in Table C3 report the results from the earnings specifications with weather variables while the last two columns report those for years in school.

The estimates show that the inclusion of birth-year-and-country specific weather variables do not alter the impact of life expectancy at birth on either schooling or lifetime earnings compared to what we observed above. Controlling for any possible weather shock at the time of birth, we observe that one additional year gain in life expectancy increases investment in schooling by 0.11 year and lifetime earnings by 0.8%. We do not observe any such independent effects of temperature and precipitation on either schooling or earnings in our complete specification. However, specifications excluding life expectancy variables in column II and IV reveal that any possible temperature shock at the time of birth is associated with lifetime earnings but not schooling, while high precipitation at the time of birth leads one to spend more time in school.

Life expectancy at older ages

Some recent papers question the appropriateness of use of life expectancy at birth emphasizing on concerns related to high infant and child mortality rate. We check the strength of our findings to life expectancy at ages beyond infancy by incorporating life expectancy at age five and ten in place of that at birth in our empirical analysis. However, since life expectancy at age 5 and 10 are not available before 1950 for most of the countries in our sample, we use a truncated sample of what we have used so far. Data on life expectancy at age 5 and 10 is available from world population prospects (2012) published by Population division, Department

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unavailable, the 1961-90 monthly climatic mean is used as a substitute. In data sparse regions of the world, this can lead to repeated values, and this can show up in derived products such as CRU CY."

of Economic and Social Affairs, United Nations. [29] Note that these data are available at 5-year range, for example, those who were born between 1950 and 1955 in Brazil share the same life expectancy at five or ten. So, in this empirical exercise life expectancy at age five or ten varies by five-year-cohort within a country, whereas previously it varied by birth-year. Other variables would remain the same and will vary by birth-year. To consistently assign life expectancy measures at higher ages, for a birth-year cohort we assign a five-year forwarded value as measures of life expectancy at five, and ten-year forwarded value as measure of life expectancy at ten.

The columns I-III in Table C4 reports the results for schooling while columns IV-VI for lifetime earnings. To facilitate a comparison of the coefficients of life expectancy at birth with life expectancy at five and ten, we also estimate one specification with life expectancy at birth. The impact of life expectancy at age five or ten on time spent in school is similar to what we observe for life expectancy at birth. An additional year of life expectancy at birth increases school-years by 0.11 year while an additional year of gain in life expectancy at age five and ten increases years in school respectively by 0.115 and 0.10 year. Overall, we observe estimates in similar magnitudes compared to our estimates in Tables 1 and 2. Similarly, the impact of life expectancy at higher ages, at five and ten, on lifetime earnings is positive and statistically significant in this truncated sample. An additional year of life expectancy gain at age five or ten increases lifetime earnings by 1.1% and 1.3%, which is close to the 0.9% effect that we have observed for life expectancy at birth.

[29] Various region, gender and age specific life expectancy data are available at http://esa.un.org/wpp/Excel-Data/mortality.htm (last accessed on November 13th, 2014).

Table C5 reports the results from a replication of Table C4 with individual level data.[30] In this table, both for schooling and earnings, as we move from life expectancy at birth to higher ages, the coefficient of life expectancy at birth increases in magnitude. An additional year of gain in life expectancy at age 10 increases schooling by 0.129 years, which is 16% larger compared to the effect of life expectancy at birth. For earnings, the life expectancy at age 10 exhibits a 61% larger effect compared to similar effect from life expectancy at birth. One interesting finding from this robustness exercise is that parents' life expectancy turns out to be positive and statistically significant in almost all the specifications with life expectancy at higher ages for both of schooling and earnings. It implies that parents with higher life expectancy are healthier, possibly more educated and richer and that these characteristics are transmitted to their children either through better health or more investments in children.

[30]To facilitate a comparison of the coefficients of life expectancy at birth with those for life expectancy at ages five and ten, we also replicate Table C5 exclusively for the sample for which life expectancies at ages five and ten are available. The estimates from the balanced and unbalanced samples are close.

Table C1: Life Expectancy at Birth and Schooling- Robustness Check with Different Weighting, Surveys and Sample Groups

	I	II	III	IV	V
	No Weight	Single Survey (Oldest)	Alternative Definition of Parents Life Expectancy	Alternative Definition of Cohort Fixed Effect	Sample Consisting only Young Group (Age 25 to 50)
% Urban	3.811***	6.028***	6.477***	6.737***	6.237***
	[0.654]	[1.415]	[1.234]	[1.057]	[1.464]
% Male	0.991*	-1.336**	-0.896*	-0.858*	-0.182
	[0.526]	[0.643]	[0.476]	[0.516]	[0.483]
Life expectancy at birth	***0.039****	***0.104*****	***0.107*****	***0.117*****	***0.111*****
	[0.017]	***[0.023]***	***[0.021]***	***[0.026]***	***[0.023]***
Parents' life expectancy (lagged 25 years)	-0.008	-0.008		0.026**	0.031***
	[0.010]	[0.009]		[0.014]	[0.010]
Parents' life expectancy (lagged 15 years)			0.026***		
			[0.010]		
Cohort Fixed Effects	YES	YES	YES	YES	YES
Constant	4.896***	1.566	-1.064	-1.748	-1.681
	[1.111]	[1.841]	[1.617]	[2.256]	[1.777]
N	3861	3022	3977	3861	3090
Adjusted R-square	0.945	0.986	0.987	0.987	0.988

Note: Standard errors in brackets. Significance levels: * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The Young Age group specific analysis is robust to age group 25-45 and 25-40. In column IV, instead of cohort level defined at five-year birth range, birth-year fixed effect is assumed.

Table C2: Life Expectancy at Birth and Earnings: Robustness Check with Different Weighting, Specification and Survey Selection

	I	II	III	IV	V	VI
	No Weight	Single Survey (Oldest)	Higher Order Age Variable	Alternative Definition of Cohort Fixed Effect	Alternative Definition of Parents Life Expectancy	Sample Consisting only Young Group (Age 25 to 45)
Age	0.068***	0.072***	-0.094		0.079***	0.089***
	[0.007]	[0.012]	[0.168]		[0.014]	[0.009]
Age-squared	-0.001***	-0.001***	0.006		-0.001***	-0.001***
	[0.000]	[0.000]	[0.006]		[0.000]	[0.000]
% Urban	0.883***	1.006***	1.109***	1.043***	1.118***	0.953***
	[0.101]	[0.206]	[0.193]	[0.221]	[0.203]	[0.166]
% Male	0.480**	-0.007	0.210*	-0.11	0.210*	0.363**
	[0.186]	[0.145]	[0.121]	[0.155]	[0.111]	[0.140]
Life expectancy at birth	0.004	0.005	0.008*	0.005*	0.008*	0.016***
	[0.003]	[0.005]	[0.005]	[0.003]	[0.004]	[0.006]
Parents' life expectancy (lagged 25 years)	0.00 [0.003]	-0.001 [0.003]	0.003 [0.003]	0.004 [0.003		0.008** [0.004]
Parents' life expectancy (lagged 15 years)					0.005 [0.004]	
% Married	0.249***	0.491***	0.491***	0.779***	0.446***	0.305**
	[0.063]	[0.169]	[0.179]	[0.200]	[0.152]	[0.138]
Cohort size	-5.843***	-10.320***	-8.636***	-7.792***	-8.684***	-7.948***
	[2.105]	[1.624]	[1.513]	[1.785]	[1.352]	[1.619]
Age cubed			0			
			[0.000]			
Age^4			-0.094			
			[0.168]			
Constant	4.943***	5.184***	5.881***	6.072***	4.087***	3.241***
	[0.477]	[0.565]	[1.747]	[0.316]	[0.700]	[0.712]
Cohort Fixed Effect				YES		
Survey Fixed Effect	YES	YES	YES		YES	YES
N	3861	3022	3861	3861	3977	2638
Adjusted R-square	0.995	0.998	0.998	0.998	0.998	0.999

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001. Specification VI is robust to age group 25-40 and 25-50. In column IV, position in the life cycle is controlled by including cohort fixed effect while defining cohort at 5-year birth range.

Table C3: Life Expectancy at Birth, Earnings and Years in School: Robustness Check including Temperature and Precipitation

	Log Wage		Years in School	
	I	II	III	IV
Age	0.077***	0.071***		
	[0.013]	[0.011]		
Age-squared*100	-0.10***	-0.10***		
	[0.000]	[0.000]		
% Urban	1.107***	1.082***	6.772***	6.737***
	[0.198]	[0.207]	[1.233]	[1.355]
% Male	0.212*	0.035	-0.981**	-3.303***
	[0.122]	[0.166]	[0.506]	[1.223]
Life expectancy at birth	***0.008****		***0.112******	
	[0.005]		***[0.023]***	
Average precipitation at the time of birth	-0.007	-0.01	0.028	0.071***
	[0.005]	[0.006]	[0.036]	[0.023]
Average temperature at the time of birth	0.004	0.007**	-0.003	0.006
	[0.004]	[0.003]	[0.010]	[0.012]
Parents' life expectancy	0.003	0.002	0.024**	0.013
	[0.003]	[0.003]	[0.011]	[0.012]
% Married	0.477***	0.549***		
	[0.156]	[0.164]		
Cohort size	-8.680***	-8.503***		
	[1.494]	[1.616]		
Constant	4.256***	5.133***	-1.624	6.885***
	[0.623]	[0.314]	[1.605]	[1.412]
Cohort Fixed Effect	YES	YES	YES	YES
Survey Fixed Effect	YES	YES	YES	YES
N	3751	3751	3751	3751
Adjusted R-square	0.998	0.998	0.987	0.982

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

Table C4: Life Expectancy, Schooling and Earnings: Robustness Check with Life Expectancy at Higher Ages

	Years in School			Log of Earnings		
	I	II	III	IV	V	VI
% Urban	6.715***	5.633***	5.777***	1.112***	0.834***	0.902***
	[1.220]	[1.143]	[1.323]	[0.196]	[0.146]	[0.150]
% Male	-0.932*	-1.136*	-1.444*	0.206*	0.296***	0.261**
	[0.495]	[0.573]	[0.756]	[0.118]	[0.098]	[0.106]
Life expectancy at birth	***0.112****			***0.009****		
	[0.023]			***[0.005]***		
Life expectancy at age 5		***0.115****			***0.011****	
		[0.045]			***[0.004]***	
Life expectancy at age 10			***0.101****			***0.013****
			[0.044]			***[0.004]***
Parents' life expectancy	0.023**	0.048***	0.039**	0.003	0.007**	0.005*
	[0.011]	[0.018]	[0.018]	[0.003]	[0.003]	[0.003]
Age				0.077***	0.085***	0.082***
				[0.013]	[0.012]	[0.013]
Age squared				-0.10***	-0.10***	-0.10***
				[0.000]	[0.000]	[0.000]
% Married				0.471***	0.298***	0.369***
				[0.153]	[0.103]	[0.110]
Cohort size				-8.577***	-6.136***	-6.368***
				[1.534]	[1.719]	[1.916]
Cohort Fixed Effect	YES	YES	YES			
Survey Fixed Effect	YES	YES	YES	YES	YES	YES
Constant	-1.198	-1.834	-0.091	4.206***	3.856***	3.814***
	[1.736]	[3.447]	[3.117]	[0.671]	[0.610]	[0.650]
N	3861	3341	3546	3861	3341	3546
Adjusted R-square	0.987	0.984	0.984	0.998	0.999	0.999

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001. Although not reported here, life expectancy at age 15 results in similar estimate for both of schooling and earnings as those of life expectancy at age 5 or 10.

Table C5: Life Expectancy, Schooling and Earnings: Robustness Check with Life Expectancy at Higher Ages using Individual-Level Data

	Years in School			Log of Earnings		
	I	II	III	I	II	III
Age				0.077***	0.079***	0.081***
				[0.004]	[0.006]	[0.006]
Age Square				-0.001***	-0.001***	-0.001***
				[0.000]	[0.000]	[0.000]
% Urban	-1.621***	-1.612***	-1.625***	-0.366***	-0.361***	-0.365***
	[0.087]	[0.209]	[0.202]	[0.010]	[0.022]	[0.022]
% Male	0.247***	0.329***	0.296***	-0.424***	-0.387***	-0.402***
	[0.032]	[0.069]	[0.068]	[0.017]	[0.037]	[0.036]
Life Expectancy at Birth	***0.113****			***0.013****		
	[0.008]			***[0.001]***		
Life Expectancy at Age 5		***0.126****			***0.015****	
		[0.025]			***[0.003]***	
Life Expectancy at Age 10			***0.129****			***0.021****
			[0.026]			***[0.003]***
Parent's Life expectancy	0.020***	0.048***	0.041***	0.005***	0.008***	0.007***
	[0.007]	[0.010]	[0.010]	[0.001]	[0.002]	[0.001]
Marital Status				-0.107***	-0.118***	-0.115***
				[0.008]	[0.018]	[0.018]
Cohort Size				-2.483***	-1.729***	-1.770***
				[0.286]	[0.388]	[0.379]
Cohort Fixed Effect	YES	YES	YES			
Survey Fixed Effect	YES	YES	YES	YES	YES	YES
Constant	3.718***	1.221	1.810	4.925***	4.564***	4.259***
	[0.635]	[1.775]	[1.765]	[0.217]	[0.286]	[0.279]
N	2726329	2345389	2478221	2543741	2222008	2333455
Adjusted R-Square	0.444	0.418	0.427	0.898	0.903	0.901
	101.021	25.791	35.514	1371.380	312.059	355.925

Note: Standard errors in brackets. Significance levels: * p<0.05, ** p<0.01, *** p<0.001. Although not reported here, life expectancy at age 15 results in similar estimate for both of schooling and earnings as those of life expectancy at age 5 or 10.