Annex 30D. Incorporating Education's Effect on Mortality into IRRs

Supplemental material for: E. Pradhan, S. Martinez, M. Schaferhoff, and D.T. Jamison. 2017. "The Effects of Education Quantity and Quality on Child and Adult Mortality: Their Magnitude and Their Value." In *Disease Control Priorities* (third edition), Volume 8, *Child and Adolescent Health and Development*, edited by D.A.P Bundy, N. de Silva, S. Horton, D.T. Jamison, and G.C Patton. Washington DC: World Bank.

Introduction

This annex deals with the addition of the estimated coefficients generated by empirical work (as well as estimates on the value of changes in mortality) into the Internal Rate of Return of education analysis. Pradhan and others (2016) estimated the effect of one additional year of education on under-5 mortality (C_5), on the adult female mortality (C_F), and on adult male mortality (C_M). The techniques most appropriate differ between under-five and adult mortality, but in both cases they involve assigning to different women's ages four separate numbers with having one additional year of education: value of changed earnings, value of changed under-five mortality rates, value of change adult female and male mortality rates. This section describes our approach to valuation of changes in mortality rates.

I. Example of health valuation of an additional year of schooling

Value of Changes in the Under-5 Mortality Rate

Here we consider a cohort of 1000 females receiving one additional year of schooling in a country (province) where the income per capita is y, the TFR is f and the under-5 mortality is q_5. We also need the value of an under-five death averted.

Following the (current) methods used by the Lancet Commission on investing in health, we value an under-five death averted at 50% of an adult death averted and we value adult deaths averted (the so called VSL) as $80y\ to\ 180y\ as\ a\ range$.

Over the lifetime of these 1,000 women if current fertility rates prevail, they will have $1000f$ children, out of whom $1000 \cdot f \cdot q_5$ will die before their 5th birthday. As an example, if $f = 3$ and $q_5 = 0.05$ (50 in a thousand), there will be 3000 children born of whom 150 will die. The reduction in the number of under-5 deaths would be, if all the women had 1 additional year of education, $1000 \cdot f \cdot q_5 \ = 150c_5$. If in turn $c_5 = 0.04$, then the reduction in number of deaths will be 6. The value of this reduction will be: $0.5 \cdot \ VSL \cdot 6$.

Continuing with the example, if the country is lower middle income, with a GDP_{pc} of \$2,000 per year, the $VSL, using\ VSL\ multiplier\ of\ 100$, is \$200,000, and the VSL_{Child} =\$100,000. The value of averting the 6 child deaths is \$600,000, or \$600 per woman. It is reasonable (if somewhat arbitrary) to divide this evenly across the 20 years following the completion of the year of schooling, say at the age of 15. Let the value of changed under-five mortality rates at the woman's age a denoted by $VCCM(a)$. In this example:

$$VCCM(a) = \begin{cases} 30 \text{ for } 15 < a \leq 35 \\ 0 \text{ for } a > 35 \end{cases}$$

Value of Changes in the Adult Mortality Rate

The coefficients C_F and C_M of female education on adult female and adult male mortality rates differ from each but the methods for calculating value is the same. This annex therefore discusses only changes in adult mortality rates. By 'Adult Mortality Rate' we mean ${}_{45}q_{15}$, i.e., the probability that a person age 15 will die in the 45 years after their 15th birthday, i.e. when they are 60. We also use the notation AFM for ${}_{45}q_{15}$ for females and AMM for males.

$AFM \cdot C_f$ will be the reduction in the number of deaths associated with one year of education. Again, if AFM starts at 100 per thousand and if $C_F = 0.02$ the there would be a reduction of 2 in the number of deaths in the cohort over 45 years. Analogously to how we assessed the value of reduction in under-five mortality rates we could first value that reduction (using the same country context as before):

$$Value\ of\ 2\ deaths\ averted\ =\ 2 \cdot \$200{,}000$$

$$=\ \$400{,}000 \Rightarrow \frac{\$400}{women}$$

Spreading this uniformly over 45 years gives \$9 per woman per year. This is

$$VCAFM(a) = \$9, 15 < a \leq 60$$

This procedure, however, would bias the estimated IRR upward since most of the reduction in mortality rates will occur in older years where the absolute levels of mortality are higher. We can use either an approximate or an exact mechanism to adjust.

The more exact approach requires changing the death rates at each age based on the country's life table and initial value of AFM. Let $m(a)$ be the age specific mortality rate at age in the country life table. $s(a)$, the survival rate, is defined as s(a)=1-m(a) ($m(a) = {}_{1}q_{a}$).

Now if we start with 100 people age 15, there will be $1000 \cdot\ s(15)$ at age 16, and $1000 \cdot\ s(15) \cdot s(16)$ left at age 17, etc. The number of surviving at age 60 will be $S = 1000 \cdot \prod_{a=15}^{59} s(a)$. In this sense, $1000 - S$ is the number who died which equals AFM expressed per 1000. Let $\Delta\ AFM$ equal the change in AFM from a year of female education. This is, $\Delta\ AFM\ =\ C_f\ AFM$. Then, $\Delta\ S\ =\ -\Delta\ AFM$. Assume we reduce mortality rates at all ages by multiplying by α, $0 < \alpha < 1$. This will give us a new value of S, $S(\alpha)$, where $S(\alpha) > S$.

$$S(\alpha) = \prod_{i=15}^{59} 1 - \alpha \cdot m(i)$$

Now we have to choose α^* such that

$$S(\alpha^*) - S = -\Delta\ AFM$$

We now have values for $\Delta\ m(a)$

$$\Delta\ m(a)\ =\ m(a) - \alpha\ m(a)$$

$$=\ m(a)(1 - \alpha)$$

Where α is probably on the order of 10^{-3}

Then, instead of equation (3) we have

$$VCAFM(a) = m(a)(1-\alpha)VSL$$

for when $15 < a \leq 60$.

For example, let $m(a) \approx 10^{-2}$, then

$$VCAFM(a) \approx 10^{-2} \cdot 10^{-3} \cdot 2 \cdot 10^{5} \approx 2$$

Mechanical Solution for $\boldsymbol{\alpha}^*$

To solve mechanically for α^* we proceed to use a simple maximization tool. Following the formula above, we choose a value for α close to the value of α^* and then minimize the difference between the two sides of the equation. On one side, we use data from the World Population Prospects, 2015, to determine the probability to die at age t, ${}_5q_t$, for $t = 15, 20, 25, 30, 35, 40, 45, 50, 55$). We then multiply for this value by our target $(1-\alpha)$ and subtract that from 1. The product of all these values across t is the right hand side of the solution.

The left hand side is $1-(1-\beta)\cdot M$, where β is the estimated coefficient from the empirical research, and M is the probability of a 15-year-old surviving up to age 60 conditional on survival until age 15.

II. Calculating Health-inclusive Internal Rate of Return and Benefit Cost Ratio

The following section lays out the exact method used for calculating health-inclusive internal rate of return and Benefit Cost Ratio. We first consider the health benefits, followed by the earnings benefits, then the direct and opportunity costs of schooling. The health-inclusive social rate of return and benefit cost ratio consider all these benefit and cost streams whereas the standard social rate of return / earnings-only benefit cost ratio consider both direct and opportunity costs of schooling but only the earnings benefits.

Under-five Mortality Benefit

$$b_2(a) = Benefit\ of\ increased\ schooling\ on\ under\ five\ mortality\ at\ age\ (a)$$
$$b_2(a) = \frac{gr * TFR * U5MR * \beta_{U5MR} * VSLm * GDP\ per\ capita}{2*(40-20+1)*1000}$$

Where,

$gr = Ratio\ of\ girls\ to\ boys\ attending\ one\ more\ year\ of\ school$

$TFR = Total\ Fertility\ Rate\ at\ base\ year$

$U5MR = Under\ five\ mortality\ rate\ at\ base\ year$

$\beta_{U5MR} = \text{Proportion reduction in U5MR because of one additional year of female schooling}$

$\text{VSLm} = \text{VSL multiplier} = [80{,}180]$

$$b_2 = \sum_{a=20}^{40} b_2(a)$$

Our methodology above approximates the benefit from reduction in under-five mortality by uniformly distributing the benefit given total fertility over the reproductive rage of 20-40 years of age. A next step in analysis would incorporate age specific fertility patterns rather than the uniform approximation applied here.

Adult Male Mortality Benefit

$$b_3(a) = benefit\ of\ increaed\ schooling\ on\ adult\ male\ (m)\ mortality\ at\ age\ (a)$$

$$b_3(a) = \frac{gr * \ {}_5q_{a,m} * \beta_m * VSLm * GDP\ per\ capita}{5 * 1000}$$

Where,

$$gr = Ratio\ of\ girls\ to\ boys\ attending\ one\ more\ year\ of\ school$$

$${}_5q_{a,m} = Male\ age - specific\ adult\ mortlality\ between\ age\ (a, a + 5)$$

$$\beta_m = Proportion\ reduction\ in\ {}_5q_{a,m}\ because\ of\ one\ additional\ year\ of\ female\ schooling$$

$$\mathrm{VSLm} = \mathrm{VSL\ multiplier} = [80{,}180]$$

$$b_3 = \sum_{a=15}^{60} b_3(a)$$

Adult Female Mortality Benefit

$$b_4(a) = social\ benefit\ of\ increaed\ schooling\ on\ adult\ female\ \ (f)\ mortality\ at\ age\ (a)$$

$$b_4(a) = \frac{gr * {}_5q_{a,f} * \beta_f * VSLm * GDP\ per\ capita}{5 * 1000}$$

Where,

$$gr = Ratio\ of\ girls\ to\ boys\ attending\ one\ more\ year\ of\ school$$

$${}_5q_{a,f} = Female\ age - specific\ adult\ mortlality\ between\ age\ (a, a + 5)$$

$$\beta_f = Proportion\ reduction\ in\ {}_5q_{a,f}\ because\ of\ one\ additional\ year\ of\ female\ schooling$$

$$\mathrm{VSLm} = \mathrm{VSL\ multiplier} = [80{,}180]$$

$$b_4 = \sum_{a=15}^{60} b_4(a)$$

Earnings Benefit

$$\boldsymbol{b_5 = earnings\ benefit\ of\ increased\ schooling\ at\ age\ (a)}$$

$$\boldsymbol{b_5(a) = \frac{ws(a) - wp(a)}{\#\ of\ years\ of\ secondary\ schooling}}$$

$$where,$$
$$ws(a) = Earnings\ of\ a\ secondary\ school\ graduate\ at\ age\ (a)$$

$$wp(a) = Earnings\ of\ a\ primary\ school\ graduate\ at\ age\ (a)$$

Direct Cost

$$c_1 = Direct\ cost\ of\ one\ year\ of\ schooling$$

$$if\ a_p = Theoretical\ age\ of\ start\ of\ primary\ schooling, and\ s = Mean\ years\ of\ schooling\ at\ base\ year,$$
$$A = Age\ of\ attending\ one\ additional\ year\ of\ school = s + a_p + 1$$

$$c_1(a) = \begin{matrix} c_1 & if\ a = A \\ 0 & lsewhere \end{matrix}$$

Opportunity Cost

$$c_2 = Opportunity\ cost\ of\ attending\ one\ additional\ year\ of\ schooling.$$

$$if\ a_p = Theoretical\ age\ of\ start\ of\ primary\ schooling, and\ s = Mean\ years\ of\ schooling\ at\ base\ year,$$
$$A = Age\ of\ attending\ one\ additional\ year\ of\ school = s + a_p + 1$$

$$c_2(a) = \begin{matrix} c_2 & if\ a = A \\ 0 & elsewhere \end{matrix}$$

INTERNAL RATE OF RETURN (r):

The health-inclusive RoR (r_h), hRoR is simply that value of r_h such that $hPVNR(r_h)$= 0.

$$hPVNR(r_h) = \sum_{a=A}^{65} \frac{wv(a) + hv(a) - c_1(a) - c_2(a)}{(1 + r_h)^{a-A}}$$
$$Here, hv(a) = b_2(a) + b_3(a) + b_4(a),$$
$$wv(a) = b_5(a)$$

Hence, the health-inclusive rate of return is the value of r_h such that equation below holds true.

$$0 = \sum_{a=A}^{65} \left(\sum_{i=1}^{5} b_i(a) - \sum_{j=1}^{2} c_j(a) \right) * (1 + r_h)^{-a}$$

BENEFIT COST RATIO:

The health-inclusive benefit cost ratio is the ratio of costs and benefits discounted at an annual discount rate r. Hence, for each r (which in our estimation ranges from 1% to 5%), $\mathrm{BCR}_{\mathrm{he}}(\mathrm{r})$ is estimated as follows:

$$\mathrm{BCR_{he}(r)} \; = \frac{\sum_{j=2}^{5} \sum_{i=A}^{64} b_j(i) * (1 - r)^{i-A}}{\sum_{j=1}^{2} \sum_{i=A}^{64} c_j(i) * (1 - r)^{i-A}}$$

And, the earnings only BCR is simply:

$$\mathrm{BCR_{e}(r)} \; = \frac{\sum_{i=A}^{64} b_5(i) * (1 - r)^{i-A}}{\sum_{j=1}^{2} \sum_{i=A}^{64} c_j(i) * (1 - r)^{i-A}}$$