Annex 30C. Technical Annex: Hierarchical Linear Model

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.

Hierarchical Linear Model

We developed hierarchical linear models (HLMs) to understand the impact of schooling on mortality and fertility (Equation 30C.1). Our HLMs assume that the data are grouped by hierarchical levels and that variance is shared in the levels of aggregation of the data. Because of this assumption, HLMs allow for the simultaneous study of the relationship that observations have within a same level, as well as across levels. When compared to fixed-effects models, hierarchical models allow for an additional level of analysis because of the random coefficients specific to each unit of observation and to every level to which they belong. This is analogous to estimating different regression lines for every level, as well as for the set of observations overall. In our model, we allow for errors and intercepts to change by each country, and allow for heterogeneity of the impact of any technological progress and uptake across countries.

Equation 30C.1. Hierarchical Linear Model

$$y_{it} = \beta_0 + \beta_1 educ_{it} + \sum_{a=1}^{t} \beta_{2a} time_t + \beta_3 Log(GDP_{PC}) + \beta_{2i} time_t + u_i + \epsilon_{it} \quad \text{--- (1)}$$

Estimating the Impact of Education Gains in the MDG Period

Table 30C.1 below shows the under-five, adult male and female deaths in 2010-2015. In this exercise, we want to estimate the counterfactual deaths for 2010-2015 where we assume that education levels had stagnated in 1990.

On average, female schooling increased from 1.2 years to 2.7 years in LICs, and 4.6 years to 7.1 years in MICs during the MDG period of 1990-2015. From our regression results in Table 30C.2, we have coefficient of female education on under-five, adult male and adult female mortality.

Table 30C.1: Deaths Between 2010-2015 in LICs and MICs

	Deaths (in millions) 2010-2015			
	Under-Five	**Adult Male (15-59)**	**Adult Female (15-59)**	**TOTAL**
Middle-income countries	24.4	31.4	20.5	76.4
Low-income countries	9.9	4.6	4.0	18.4
Low and Middle Income Countries	34.3	36.0	24.5	94.8

If d_a is the actual deaths between 2010-2015, and d_c is the counterfactual deaths in the scenario where education had stayed at the 1990 levels, we know the following:

$$\frac{d_c}{d_a} = \frac{mr_c}{mr_a}$$

where mr_c is the mortality rate in the counterfactual and mr_a is the actual mortality rate in the period 2010-2015. We derive this estimate assuming that the population at risk, p, is constant across these two scenarios, or

$$d_a = p * mr_a, and\ d_c = p * mr_c$$

From the ln linear model in Table 30.2, for each of the mortality rates (under-five, adult male and adult female) we have,

$$LN[mr] = \alpha + \beta * educ + \cdots$$

Exponentiating above, we get:

$$mr = e^{\alpha+\beta*educ+\cdots} = e^{\alpha} * e^{\beta*educ} * e^{\cdots}$$

We have, for the actual education increases in the MDG period, $educ_a$, and mortality rate mr_a,

$$mr_a = e^{\alpha} * e^{\beta*educ_a},$$

and similarly, for the counterfactual scenario of $educ_c$, and counterfactual mortality rate mr_c,

$$mr_c = e^{\alpha} * e^{\beta*educ_a} * e^{\beta*\Delta educ}$$

$$since\ e^{\beta*(educ_a+\Delta educ)} = e^{\beta*educ_a} * e^{\beta*\Delta educ}\ and\ educ_c = educ_a + \Delta ed$$

From before, we have,

$$\frac{d_c}{d_a} = \frac{mr_c}{mr_a}$$

Or,

$$d_c = \frac{mr_c}{mr_a} * d_a = d_a * \frac{e^{\alpha} * e^{\beta * educ_a} * e^{\beta * \Delta educ}}{e^{\alpha} * e^{\beta * educ_a}} = d_a * e^{\beta * \Delta educ}$$

Hence, for each population of under-five, adult male and adult female, we have, counterfactual deaths (d_c) as follows:

$$d_c = d_a * e^{\beta * \Delta educ}$$

Where d_a is the number of actual deaths, β is the coefficient of female education on mortality, and $\Delta educ$ is the difference in years of schooling between 1990 and 2015.

The approach above gives us counterfactual deaths and overall deaths averted as shown in Table 30C.2 and 30C.3 below.

Table 30C.2: Counterfactual Number of Deaths Between 2010-2015 in LICs and MICs

	Deaths (in millions) 2010 - 2015			
	Under-Five	**Adult Male (15-59)**	**Adult Female (15-59)**	**TOTAL**
Middle-income countries	27.1	33.2	22.5	82.7
Low-income countries	10.5	4.7	4.2	19.4
Low and Middle Income Countries	37.6	37.9	26.6	102.1

Table 30C.3: Deaths Averted in 2010-2015 in LICs and MICs because of Increases in Educational Attainment During the MDG Period

	Deaths Averted (in millions) 2010-2015			
	Under-Five	**Adult Male (15-59)**	**Adult Female (15-59)**	**TOTAL**
Middle-income countries	2.6	1.8	1.9	6.3
Low-income countries	0.6	0.2	0.2	1.0
Low and Middle Income Countries	3.2	1.9	2.2	7.3