Life Expectancy and Human Capital Investments: Evidence from Maternal Mortality Declines

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Health → Life expectancy → Education

- Longer time horizon increases the value of investments that pay out over time

- Improvements in life expectancy increase the incentive to invest in education

- Cross-country evidence is mixed
  - No effect: Acemoglu and Johnson (2006)
Contribution

• Question:
  What is the effect of life expectancy on educational investment?

• Obtain estimates that isolate life expectancy channel
  – Use declines in maternal mortality
  – Study Sri Lanka between 1946 and 1953

• Difference-in-difference-in-differences
  – Gender
  – Time
  – District
Motivation

• Interested in apportioning the benefits of health improvements into various channels

• Cost-benefit analysis of health interventions, e.g., targeting young versus old

• Test general hypothesis that people update subjective expectations
Why maternal mortality?

- Adult mortality
  - *Future* mortality risk at time of human capital investment
  - Early in adulthood, so averted death $\rightarrow$ large gain in life expectancy

- Does not affect school-age morbidity (Miguel and Kremer (2004), Bleakley (2007))

- Salient (easily observed) cause of death

- Males serve as comparison group
Why Sri Lanka?

- Rapid decline in maternal mortality ratio (maternal deaths per 100 live births), or MMR
  - MMR in 1946 was 1.8%
  - MMR by 1953 had fallen to 0.5%
- Represents a large mortality improvement
  - Total fertility rate (lifetime births) was ~5, so lifetime mortality risk of ~9%
- Geographic variation within Sri Lanka in MMR decline
- Good data
Preview of results

- MMR declines led to a 1.5 year increase in female life expectancy

- MMR declines increased female literacy by 2.5%
  - 1 percentage point (ppt) from a base of 44 ppt

- MMR declines increased female education by 4.1%
  - 1 extra year of life $\Rightarrow$ 0.12 to 0.15 more years of schooling

- Elasticity of human capital with respect to life expectancy: 0.6 to 1.0
Outline

1. Conceptual framework

2. Background on MMR declines + data

3. Empirical results: Effect of MMR on
   - Life expectancy
   - Literacy and completed education
   - (Fertility)
Conceptual framework

- Goal: how do reductions in maternal mortality risk affect investment in education?

- Household maximizes expected income and makes 2 decisions
  - Whether to have a child \((C_w)\)
  - Schooling of child \((s_g, s_b\) for girl, boy)

- Probability of dying during childbirth, \(\mu\) (at time \(\tau\); otherwise live until \(T\))
  - Applies to mother + applies to daughter

- Return to schooling that accrue over time \((\gamma)\)

- Assume no spillover effects on boys
Maximization problem

$$\max_{s_g, s_b, C_w} \left[ Y_w(C_w) + Y_h + \frac{C_w}{2} (Y_b(s_b) + Y_g(s_g)) \right]$$

where

$$Y_w = (1 - C_w \mu) \int_{\tau}^{T_w} e^{-\delta(t-\tau)} ye^{\gamma s_w} dt$$

$$Y_g = \int_{s_g}^{\tau} e^{-\delta t} ye^{\gamma s_g} dt + (1 - C_g \mu) \int_{\tau}^{T_g} e^{-\delta t} ye^{\gamma s_g} dt$$

$$Y_h = \int_{\tau}^{T_h} e^{-\delta(t-\tau)} ye^{\gamma s_h} dt, \quad Y_b = \int_{s_b}^{T_b} e^{-\delta t} ye^{\gamma s_b} dt$$

- High $\mu$ raises cost and lowers benefit of mother’s childbearing
- High $\mu$ lowers benefit of daughter’s schooling
Predicted effects of maternal mortality risk

- Reduces the benefit of girls’ schooling since shorter time horizon over which to earn returns
  - MMR declines $\rightarrow$ Increase in girls’ education for young cohorts

- Raises cost of childbearing (chance of mother dying) and lowers benefit (daughter will have shorter life)
  - MMR declines $\rightarrow$ Increase in fertility
Background on MMR declines

• Expansion of health care services, with focus on maternal and child health
  – Ambulances
  – Hospitals and health centers
  – Birth attendants

• New technologies (sulfa drugs, penicillin)

• Malaria eradication
Figure 3b: Maternal mortality for Sri Lanka, 1939-1955

Trend break in 1947 (with or without malaria years)
Figure 2: Declines in maternal mortality across districts
Other background information

- Returns to education for women
  - Labor mkt returns \(~7\%\) (Psacharapoulos 1994)
  - Other returns: better husband, better children, control over fertility, etc.

- Other national changes occurred, e.g., independence, end of school fees
  - Identifying assumption is no gender-district-level effects correlated with MMR declines

- Malaria control and nutrition programs affect schooling
  - Affect both genders
  - Will control for these as robustness check
Data

• Vital statistics
  – Mortality by gender, 5-year age group, district, year
  – Maternal mortality ratio (not by age)

• Census of 1946 and 1953
  – Population
  – % Literate by age
  – School enrollment

• Census of 1971
  – Literacy
  – Completed education
  – District of birth
Limitations of data

• No data on completed schooling in 1946 and 1953 census

• No district-level data on education or health infrastructure or utilization
Life expectancy measures

- Use mortality tables to calculate life expectancy

- Notation:

  \[ e(15-65) \] is life expectancy, conditional on survival to 15 and censored at 65

- Use ages 15 to 65 as period over which returns to education mainly earned
Female $e(15-65)$ rose by 7.4 years & male $e(15-65)$ by 6.6 years
Changes in female-male life expectancy versus MMR

Figure 5: Changes in female-male life expectancy & MMR

1946 to 1953 change in female-male e(15-65) gap
Maternal mortality ratio in 1946
Life expectancy gains from MMR declines

- By how much did declines in MMR increase \( e(15-65) \) for females?

- Method 1: Calculate counterfactual life expectancy
  - In 1946, MMR was 26% of deaths for ages 15-45
  - Reduce this risk by 70% \( \rightarrow \) 1.4 year gain in female \( e(15-65) \)

- Method 2: Regression
  - Fewer assumptions (about MMR by age, competing risks)
  - Probe omitted variable bias using other life expectancy measures
Empirical strategy: DDD

- Time, gender, district

\[ e_{dgt} = \beta_1 \cdot MMR_{dt} \times female + \mu_{dg} + \gamma_{dt} + \nu_{gt} + \varepsilon_{dgt} \]

\( N = 76 \) (19 districts \( \times \) 2 genders \( \times \) 2 years)

- Use 3-year running average for MMR (and other annual data) to reduce measurement error

- Control for gender-specific death rates for malaria & nutritional diseases (anemia, helminths, diarrhea, vitamin deficiencies)
  - Concern is school-age morbidity rates
  - Could be over-controlling
## Effect of MMR on life expectancy

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Basic</th>
<th>Add malaria death rates</th>
<th>Add nutritional diseases</th>
<th>Add nutritional diseases and malaria death rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta e(15-65)$</td>
<td>-1.204***</td>
<td>-1.302***</td>
<td>-1.135***</td>
<td>-1.369***</td>
</tr>
<tr>
<td>$\Delta$MMR*female</td>
<td>[0.198]</td>
<td>[0.307]</td>
<td>[0.181]</td>
<td>[0.444]</td>
</tr>
<tr>
<td>$\Delta e(45-65)$</td>
<td>0.054</td>
<td>-0.033</td>
<td>0.115</td>
<td>-0.041</td>
</tr>
<tr>
<td>$\Delta$MMR*female</td>
<td>[0.089]</td>
<td>[0.120]</td>
<td>[0.090]</td>
<td>[0.204]</td>
</tr>
<tr>
<td>$\Delta e(0-15)$</td>
<td>-0.088*</td>
<td>-0.081</td>
<td>-0.072**</td>
<td>-0.022</td>
</tr>
<tr>
<td>$\Delta$MMR*female</td>
<td>[0.050]</td>
<td>[0.065]</td>
<td>[0.031]</td>
<td>[0.050]</td>
</tr>
<tr>
<td>$\Delta IMR$</td>
<td>0.133</td>
<td>0.081</td>
<td>0.306*</td>
<td>0.222</td>
</tr>
<tr>
<td>$\Delta$MMR*female</td>
<td>[0.164]</td>
<td>[0.192]</td>
<td>[0.159]</td>
<td>[0.247]</td>
</tr>
</tbody>
</table>
Up to what age do people become literate?

Female literacy by age cohort

Age effects: literacy ↑ across age cohorts
Birth cohort effects: literacy ↓ across age cohorts
Literacy as outcome

- Use age 5-19 years as treated group

- If age 19 when outcomes observed in 1953, you were age 13 when MMR decline began in 1947

- Almost no childbearing among those age 15-19 in 1953 (age 8-12 in 1946)
Female literacy rose by 14.5 ppts & male lit. rose by 11.2 ppts
Estimating equation for literacy

- Behavior unlikely to respond instantly; use 3-year lagged MMR

\[ \text{lit}_{adgt} = \beta_1 \cdot \text{Lagged}M\text{MR}_{dt} \times \text{female}_g + \mu_dg + \gamma_{dt} + \nu_{gt} + \varepsilon_{adgt} \]

- \( a \) is 5-year age group; also include dummies for age interacted with district, gender, and time

- Obsns in regression are for treated ages, eg, 5-9, 10-14, 15-19, so \( N = 19 \text{ districts} \times 2 \text{ genders} \times 2 \text{ years} \times 3 \text{ age groups} \)

- Cluster on district-gender

- As placebo test, will repeat using older cohorts whose literacy was predetermined
Changes in female-male literacy versus MMR

Figure 7: Changes in female-male literacy versus MMR
## Effect of MMR on literacy

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Add nutritional diseases &amp; malaria death rates</th>
<th>1946 level as IV for 1946-53 drop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ages 5-19 (treated group)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lagged MMR*female</td>
<td>-0.879*</td>
<td>-1.652**</td>
<td>-1.008**</td>
</tr>
<tr>
<td></td>
<td>[0.453]</td>
<td>[0.656]</td>
<td>[0.470]</td>
</tr>
<tr>
<td><strong>Placebo test: Ages 25-44</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lagged MMR*female</td>
<td>-0.151</td>
<td>0.273</td>
<td>-0.149</td>
</tr>
<tr>
<td></td>
<td>[0.469]</td>
<td>[0.450]</td>
<td>[0.476]</td>
</tr>
</tbody>
</table>
Magnitudes

- MMR declined by 1.3 points during 1946-53
- Increased female literacy by 1.1 percentage point, or 2.5%
- 1/3 of relative gains in literacy for females over period
- Elasticity of literacy with respect to $e(15-65) = 0.6$
  - MMR led to 1.5 year increase in female $e(15-65)$, or 4.1%
## School enrollment

<table>
<thead>
<tr>
<th>% in school (ages 5 to 24)</th>
<th>Basic</th>
<th>Add nutritional diseases &amp; malaria death rates</th>
<th>1946 level as IV for 1946-53 drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>lagged MMR*female</td>
<td>-0.904*</td>
<td>-0.686</td>
<td>-0.979**</td>
</tr>
<tr>
<td></td>
<td>[0.458]</td>
<td>[0.995]</td>
<td>[0.460]</td>
</tr>
</tbody>
</table>

0.9 % increase in probability of attending school $\times 20$ years $= 0.18$ years of schooling, corresponding to 1.2 extra years of life
Threats to validity

• Labor demand effect, e.g., demand for midwives
  – Estimated effect is that 16,500 extra girls became literate
  – Increase from 400 to about 900 midwives

• Less developed districts just catching up on all fronts
  – Placebo test on older cohorts: there were no pre-trends
  – 1946 MMR not correlated with 1946 gender gap in literacy
Threats to validity (continued)

• Effect of MMR on girls’ literacy due to fewer orphan girls
  – Take extreme case: every orphaned girl is illiterate, and no effect of maternal death on boys
  – Much smaller effect size than estimated effect

• Girls freed up from home production when family members are healthier
Estimates with 1971 Census

• Advantages
  – Completed years of schooling
  – District of birth

• Disadvantages
  – Attrition
  – Missing schooling data (correlated with MMR)
  – No before-after data; use older cohorts as comparison group

• Assign older cohorts the 1953 level of MMR in their birth district and young cohorts (5-19 in 1953) the 1953 level

\[ educ_{adg} = \beta \cdot MMR_{da} \times female_g + \lambda_{ad} + \theta_{ag} + \gamma_{dg} + \varepsilon_{adg} \]
# Attrition and missing data in 1971 Census

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Survival rate (cell size in 1971/ cell size in 1953)</th>
<th>Education missing in 1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>lagged MMR*female</td>
<td>0.0106 [0.0137]</td>
<td>0.0246** [0.0076]</td>
</tr>
<tr>
<td></td>
<td>0.0127 [0.0131]</td>
<td>0.0195** [0.0078]</td>
</tr>
<tr>
<td>Literacy in 1953</td>
<td>0.0007 [0.0015]</td>
<td>-0.0019** [0.0007]</td>
</tr>
</tbody>
</table>
# Education results with 1971 Census

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Literate</th>
<th>Years of education</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>OLS</td>
<td>OLS</td>
</tr>
<tr>
<td>lagged MMR * female</td>
<td>-2.711**</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>[0.8437]</td>
<td>-0.133**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.132**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.028] [0.057] [0.057]</td>
</tr>
<tr>
<td>Excluded variables</td>
<td>n/a</td>
<td>n/a District of 1971 residence dummies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>District of residence missing, ethnicity missing &amp; religion missing</td>
</tr>
</tbody>
</table>
Magnitudes

• MMR declined by 1.3 points during 1946-53

• Increased female education by 0.17 years, or 4.1%

• Elasticity of education with respect to e(15-65) = 1.0
Effects on birth rate

- No third difference of gender

\[ birthrate_{dt} = \beta_0 + \beta_1 \cdot \text{LaggedMMR}_{dt} + \gamma_t + \delta_d + \nu_{dt} \]

- Control for changes in male e(0-65)

- Same programs that reduced MMR also affected infant mortality
## Effect of MMR on birth rate

<table>
<thead>
<tr>
<th></th>
<th>DD with male e(0-65) as control</th>
<th>+ malaria &amp; nutritional death rates</th>
<th>+ lagged IMR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable:</strong></td>
<td><strong>Birth rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lagged MMR</td>
<td>-5.15*</td>
<td>-4.43*</td>
<td>-4.34</td>
</tr>
<tr>
<td></td>
<td>[2.55]</td>
<td>[2.45]</td>
<td>[2.67]</td>
</tr>
</tbody>
</table>

Avg birth rate in 1946: 179 births per 1000 women ages 15-45

MMR decline over 1946-53 led to 4% increase in birth rate (explains 1/3 of increase in fertility over period)
Conclusions

• Human capital is responsive to longevity
  – Elasticity of literacy with respect to life expectancy is 0.6
  – 1 extra year of life $\Rightarrow$ 0.12 to 0.15 more years of schooling

• For cost-benefit analysis of policies to improve health, incentive effects on investment are an important component

• Recent longevity declines in many countries (HIV, war) have an added deleterious effect of dampening incentive to invest
Implications for HIV/AIDS in Africa

- How much does mortality risk from HIV/AIDS depress educational attainment?

- S. Africa today: 40% of deaths ages 15-49 are AIDS related

- Implies that AIDS has reduced e(15-65) by 3 years or 10%

- Elasticity of human capital w.r.t. e(15-65) of 0.6 to 1.0 ⇒ 6% to 10% decline in education, or 0.3 to 0.5 yrs

- If return to education is 5% ⇒ 1.5% to 2.5% reduction in income
Extra slides
Figure 8: Relationship between maternal mortality and literacy gender gaps in 1946.
Figure 6: Birth rate and excess female mortality by age

<table>
<thead>
<tr>
<th>Low MMR districts</th>
<th>High MMR districts</th>
</tr>
</thead>
</table>

- **Female/male mortality ratio**
- **Birth rate**

- Age range: 0 to 60 years
Figure 1: Expansion of health services in Sri Lanka

- **Number of ambulances**
  - 1930: 500
  - 1940: 600
  - 1950: 800

- **Number of health centers**
  - 1930: 3
  - 1940: 5
  - 1950: 7

- **Government midwives per 1000 births**
  - 1930: 10
  - 1940: 15
  - 1950: 20

- **Hospital beds (000's)**
  - 1930: 3
  - 1940: 5
  - 1950: 7
Figure 3a: Maternal mortality by district, 1925-1955

Graphs by district