Elasticity of economic development and child mortality, 1950–2011

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150-word abstract

We construct "Preston curves" depicting the relationship between child mortality (${}_5q_0$) and economic development, using all available years (1950–2011) of data from the UN Inter-agency Group for Child Mortality Estimation and the Penn World Table, for real Gross Domestic Product (GDP) per capita. Unlike the classical curves for life expectancy, we use log-log scale, which gives a better (and linear) fit. This has the advantage that the slope coefficient is directly interpretable as an elasticity, viz., the percentage change (decline) in child mortality for a one-percent increase in per capita GDP. This elasticity has been reasonably stable during the 62-year time span. If we think of income as "buying" lower child mortality, then we must realize that relative improvements in ${}_5q_0$ (elasticities) have not become more favorable in the long run. This has implications for full achievement of Millennium Development Goal 4 — however, under 5 mortality rates continue to decline, even at the lowest levels of per-capita income.

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Overview

In this paper, we extend the concept of Preston curves — changing relationships between life expectancy and national income — to under-five mortality.

We use data on ${}_5q_0$ (median series), 1950–2011, from the UN Interagency Group for Child Mortality Estimation (2014). We match these to data on constant-dollar Gross Domestic Product (GDP) per capita, from the Penn World Table (2013).

We present child mortality Preston curves on log-log scale; we are the first to do so, to the best of our knowledge. This results in a good fit of a straight line to the data, and has the felicitous side effect that the slope of the cross-sectional regression line may be interpreted as an elasticity — viz., the percent change in ${}_5q_0$ for a one-percent change in GDP per capita. This elasticity has been relatively constant over the last 62 years. Proportional changes in real income per capita give comparable proportional changes in child mortality in 1950 as in 2011. Since 1950, ${}_5q_0$ has fallen worldwide, in both rich and poor countries, so the robustness of the elasticity is not a sign of lack of progress, per se.

Background

This is a placeholder for what will be a comprehensive literature review.

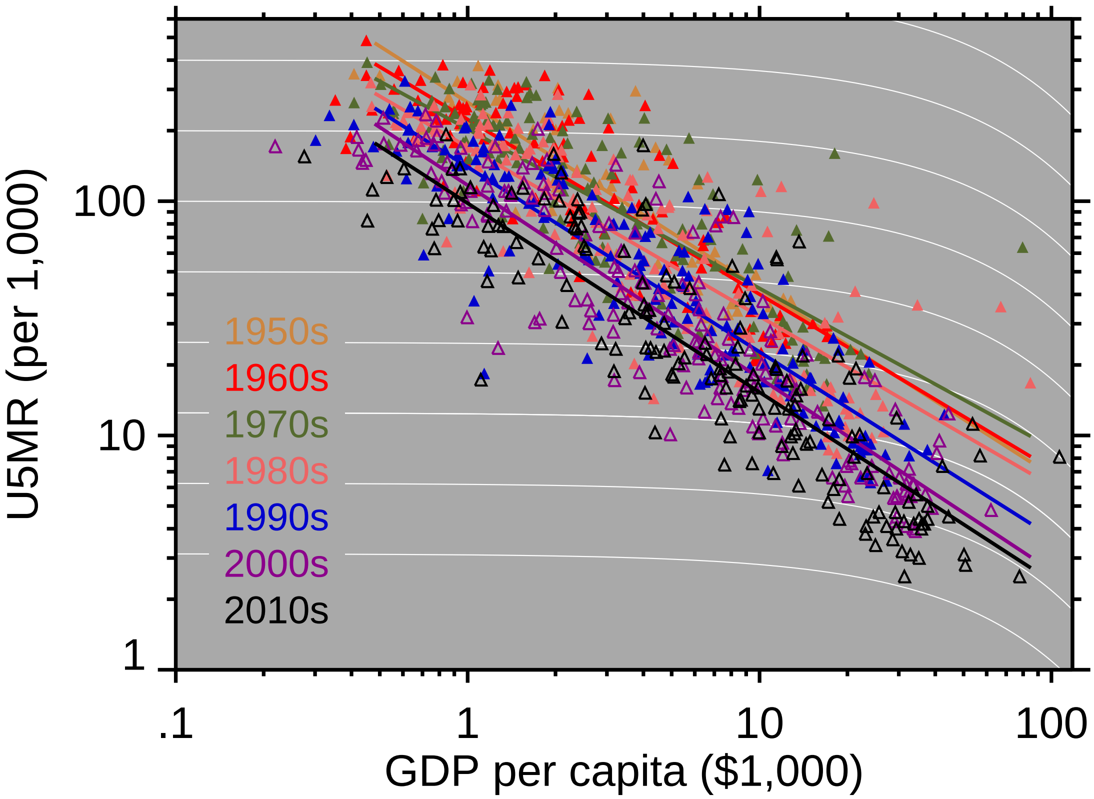

Figure 1: Log-log Preston curves for under-five mortality, for six decades (1950s–2010s). White gridlines show constant 10% reduction in mortality for each $10,000 increase in GDP per capita.

Results

Figure 1 depicts ${}_5q_0$ Preston curves for seven decades, 1950s–2010s.[1] The graph is in log-log scale, and decades are color-coded. In each decade, we use the first observation for any given country. For example, for the 1970s, most of the data are from 1970, but some countries enter the dataset later, such as Djibouti in 1976. We chose this approach so that, to the greatest extent possible, all the data in figure 1 would be spaced 10 years apart. Thus, data from the 2010 decade (year 2010 for all points) are exactly 10 years apart from data from the 2000 decade (year 2000 for all points). The white gridlines depict a constant 10% reduction in mortality for each $10,000 increase in per capita GDP. The gridlines are, therefore, close to parallel on log-log scale, but are not straight horizontal lines. The color-coded diagonal lines are decade-specific OLS regression lines of $\log({}_5q_0)$ on log(GDP p.c.).

Figure 2 shows the absolute values of slopes of the regression lines for all 62 years; to reduce crowding, figure 1 depicts only six decades. These slopes, because they come from a log-log plot, represent elasticities, in other words the percentage change in ${}_5q_0$ for a given percentage change in GDP per capita. For example, a slope of -1.0 indicates that a 50% increase in GDP p.c. would result in an average decrease in ${}_5q_0$ of 50%.

Predicted ${}_5q_0$ values for three levels of GDP per capita, based on the models estimated from annual log-log Preston curves, are presented in figure 3,

[1] The findings (i.e., graphs) presented here are from an unbalanced panel of countries. Because of lack of raw data from which to produce estimates, and because of waves of decolonization, not all 163 countries have estimates going back to 1950. In figure 1, there are 163 points for 1990–2010, 139 for 1980, 132 for 1970, 100 for 1960, and 58 for 1950. We intend to replicate the analysis with balanced panels to check for robustness.

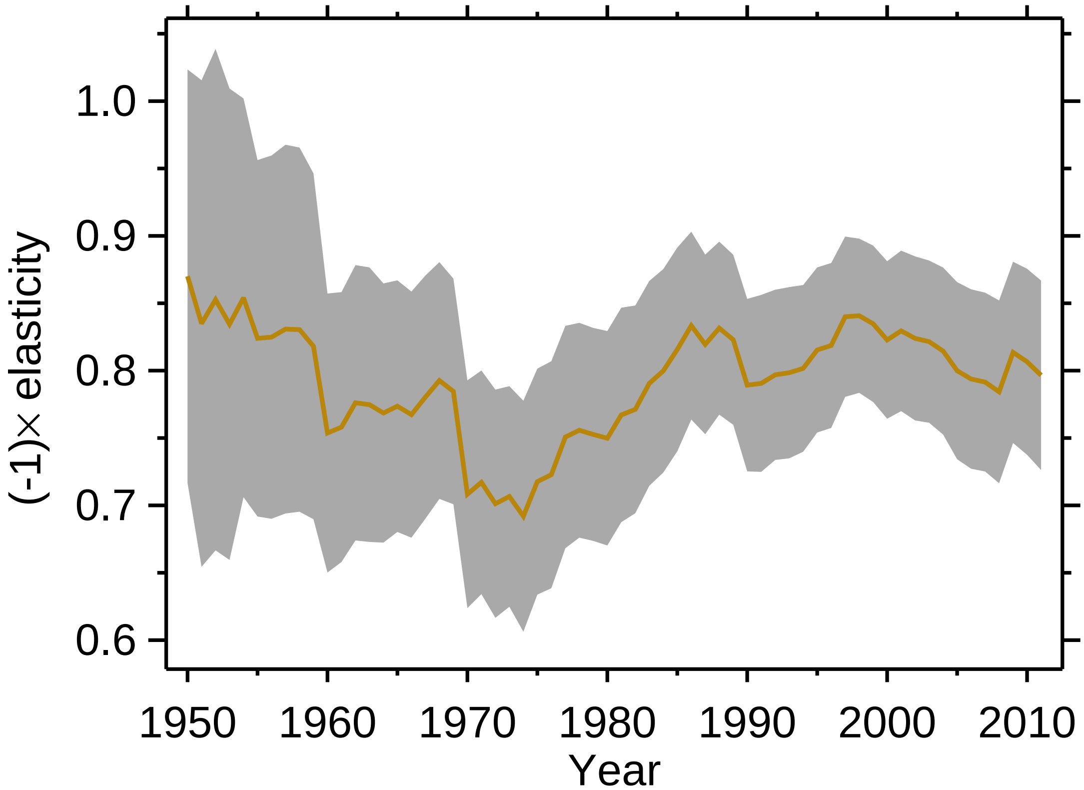

Figure 2: Elasticities (with 95% confidence bounds) over time. These values are the slopes of the lines in figure 1 (for every year, not for every decade). Mortality *declines* with increasing income, thus, these slopes are negative (cf. figure 1), but for ease of presentation, this graph presents the elasticities as absolute values. Higher (absolute value) elasticities are "better" in the sense that they represent a larger percentage decline in ${}_5q_0$ for a given percentage increase in GDP per capita.

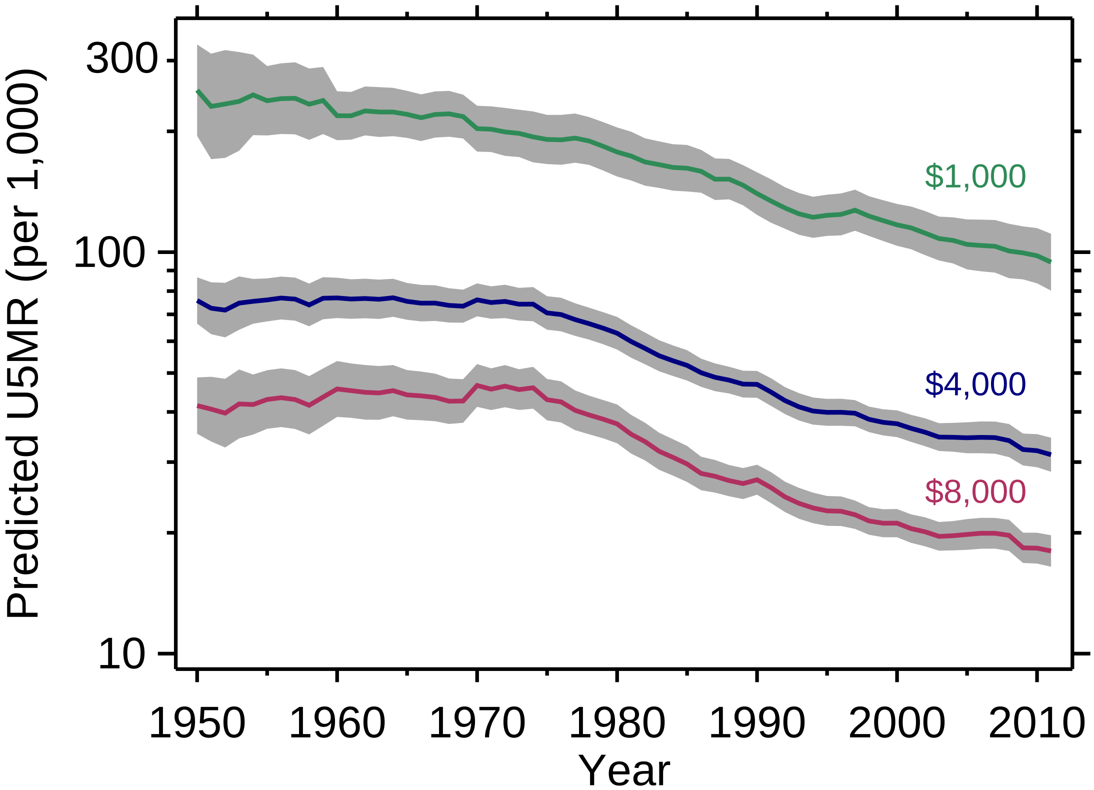

Figure 3: Predicted values (with 95% confidence bounds) of ${}_5q_0$, over time, at three different levels of GDP per capita. Predictions based on the linear fits like those in fig 1. The declines over time are (very) roughly linear, but note that the vertical axis is logarithmic (in keeping with figure 1). Thus, the $1,000 curve declines from ${}_5q_0$ =253‰ to 94‰; the $4,000 curve declines from ${}_5q_0$ =76‰ to 31‰; the $8,000 curve declines from ${}_5q_0$ =41‰ to 18‰.

along with 95% confidence intervals of the predictions. These are calculated from:

$$(\text{predicted } {}_5q_0)_i = \exp\left[\alpha_i + \beta_i \log(X)\right]$$

where the subscript i denotes the year, α_i and β_i are estimated from the year-specific log-log regression, and $X = \{\$1000, \$4000, \$8000\}$ GDP per person in constant dollars. Note that figure 3 has log scale on the y-axis but the equation above is for predicted ${}_5q_0$ on direct scale. Examining figure 3, the predicted ${}_5q_0$ for a country with $1,000 GDP per capita in 1950 was 253 per 1,000, falling to 94 per 1,000 in 2011; the most-recent value is 37% of the 1950 value, at the same income level in constant dollars (an absolute decline of 159 per thousand). This is an example of the powerful impact of inexpensive child health innovations such as vaccines (including the eradication of smallpox in 1979) and oral rehydration therapy, both of which are available in 2011 (to some extent) even in the poorest places, but were hardly available in 1950.[2] Even a country "treading water" at a low level of per capita income will see tremendous declines in ${}_5q_0$.

Figure 4 shows the proportional decline in (model-fitted) child mortality, from 1950 to 2011: $({}_5q_0^{1950} - {}_5q_0^{2011})/{}_5q_0^{1950}$, for a wide range of GDP per capita values. The greater the starting value of ${}_5q_0$ (i.e., lower GDP p.c.), the greater the proportional change over the 62-year period. Intuitively this makes sense, since moving from ${}_5q_0 = 200/1,000$ to $100/1,000$ has been witnessed any number of times as countries develop, but going from ${}_5q_0 =$

[2]Many vaccines, such those against as measles and poliomyelitis, were not licensed in 1950, and thus were not available anywhere. Oral rehydration therapy for diarrhea was not developed until the mid-1960s (Hirschhorn et al., 1966) and not implemented until the late-1960s (Nalin et al., 1968).

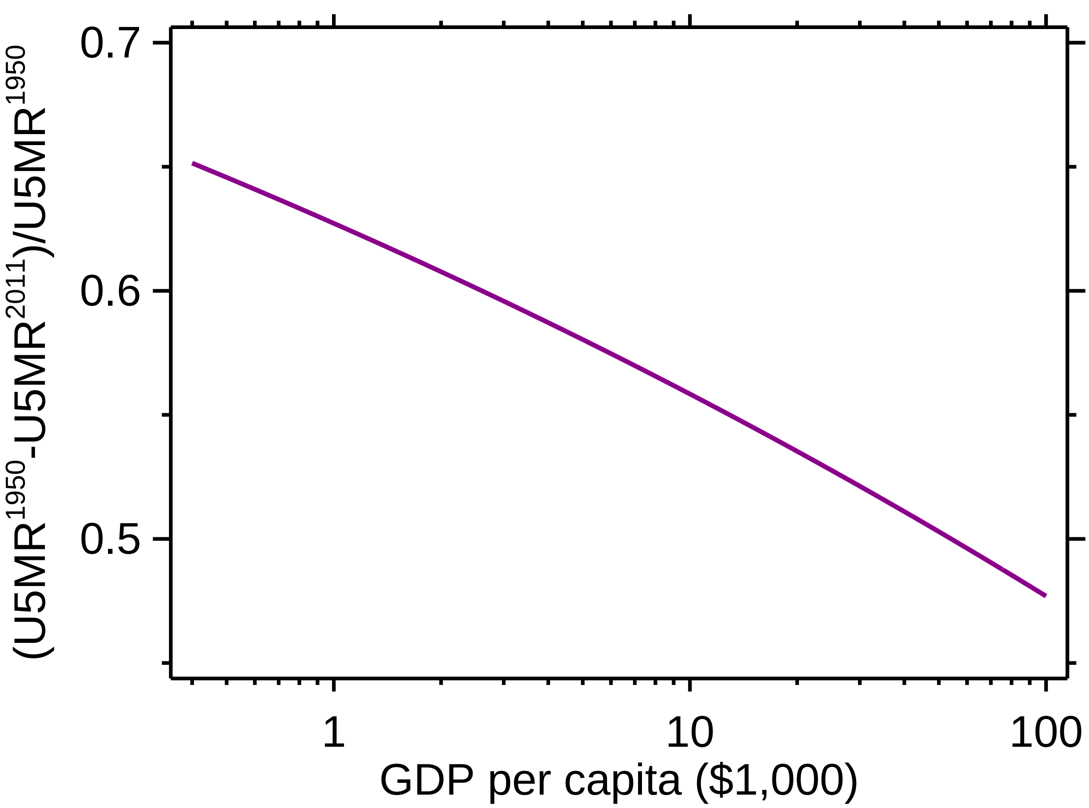

Figure 4: Model-predicted $({}_5q_0^{1950} - {}_5q_0^{2011})/{}_5q_0^{1950}$. The proportional change in ${}_5q_0$ between 1950 and 2011 is smaller, the greater the starting value of ${}_5q_0$.

$2/1,000$ to $1/1,000$ is much harder, because it seems that zero is *not* the natural floor for ${}_5q_0$.

The relationship between $\log({}_5q_0)$ and $\log(\text{constant-dollar GDP per capita})$ is nearly perfectly linear. The goodness of fit as measured by the R^2 varies between .68 and .88, and is only below .70 in three years (figure 5). Even by the standards of country-level data analysis, where goodness of fit tends to be much higher than when using microdata, these are great fitting models.

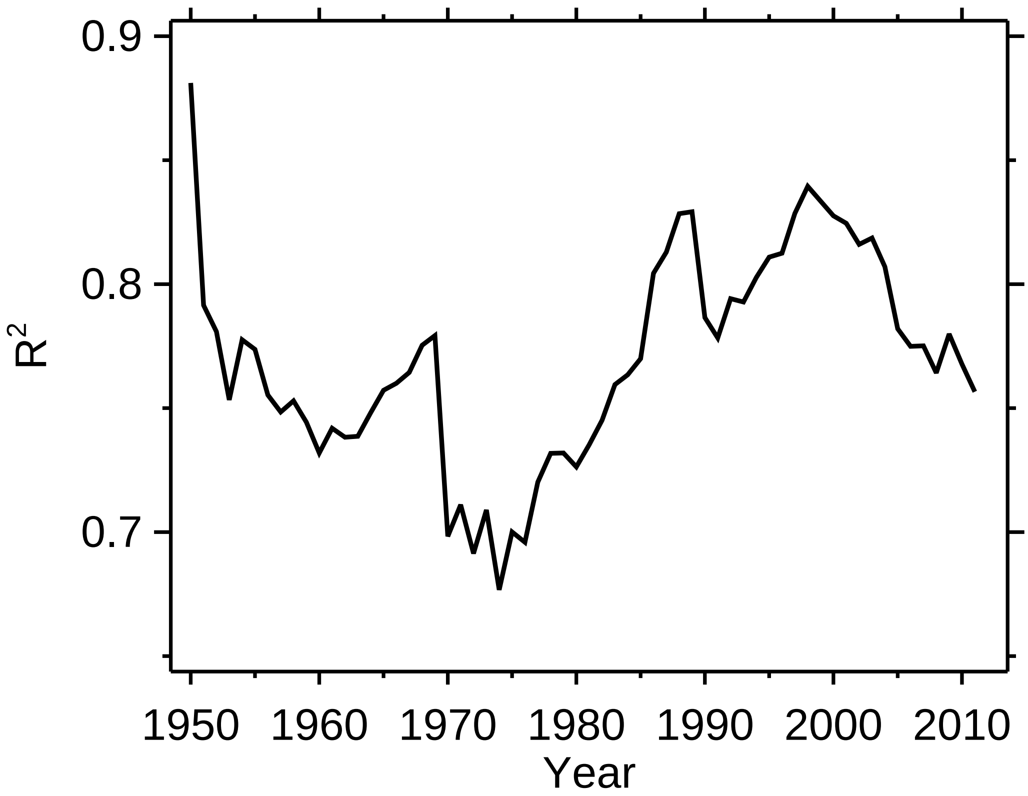

Figure 5: R^2, from models in fig 3. Over time, the models vary between a very good and an excellent fit to the data.

Discussion and Conclusions

This section will be greatly elaborated, obviously.

Returning to figure 1, and as a purely empirical matter (as opposed to the actual mechanisms of child survival "on the ground"), there are two ways in which countries can lower ${}_5q_0$. One is to wait. Thanks to the Expanded Program of Immunization (EPI), vaccination is widespread today, even in poor countries. Many of today's vaccines were not licensed in 1950, and no developing country had widespread vaccination in 1950. Oral rehydration therapy is widely used today — again, even in poor countries. This technology is simple and inexpensive (by any standard), but did not exist until the late 1960s. So, poor countries can wait until public health innovations become affordable even at any level of national income (net of international aid programs, like the EPI).

Another way for countries to lower ${}_5q_0$ is economic development, operationalized here as GDP per capita. A novel contribution of this paper is to re-cast the classic Preston (1975) curve both for ${}_5q_0$ (as opposed to life expectancy at birth) and in log-log form, thus interpreting the slopes as elasticities. We find that the elasticity — the percent change in ${}_5q_0$ for a percent change in GDP per capita — has been remarkably stable over the last six decades. Thus, the changes that accrue by "waiting" are in the intercept, only (or how the lines tend to sink in figure 1). Technological innovation has helped the intercept change over time, but, somewhat surprisingly, has not affected the elasticity.

Of course, any country that increases GDP per capita, over time, will "vector", so to speak — $_5q_0$ changes both because of increasing GDP per capita, and due to the changes that lower $_5q_0$ happen over time.

Works Cited

Hirschhorn, Norbert, John Lindenbaum, William B. Greenough III, and S. Mahmood Alam. 1966. "Hypoglycæmia in children with acute diarrhœa." *Lancet* 288(7455):128–133.

Nalin, David R., Richard A. Cash, Rafiqul Islam, Majid Molla, and Robert A. Phillips. 1968. "Oral maintenance therapy for cholera in adults." *Lancet* 292(7564):370–372.

Penn World Table, version 8.0. 2013. `http://www.rug.nl/research/ggdc/data/penn-world-table`. DOI: 10.15141/S5159X.

Preston, Samuel H. 1975. "The changing relation between mortality and level of economic development." *Population Studies* 29(2):231–248.

UN Inter-agency Group for Child Mortality Estimation. 2014. `http://childmortality.org/files_v17/download/U5MR.xlsx`.