"Disease and Development: The Effect of Life Expectancy on Economic Growth"

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Motivating Theory

- Aggregate production function for economy i:

$$Y_{it} = (A_{it} H_{it})^{\alpha} K_{it}^{\beta} L_{it}^{1-\alpha-\beta}$$

where $\alpha + \beta \leq 1$ and

$$\begin{aligned} K_{it} &= \text{capital} \\ L_{it} &= \text{land (normalization } L_{it} = 1) \\ H_{it} &= h_{it} N_{it} = \text{effective units of labour} \\ N_{it} &= \text{employment} \\ h_{it} &= \text{human capital per person} \end{aligned}$$

- Capital accumulation

$$K_{it+1} = s_i Y_{it} + (1 - \delta) K_{it}$$

Long Run

- Suppose $A_{it} = A_i$. If, in the long run, $h_{it} = h_i$ and $N_{it} = N_i$, then

$$K_i = \frac{s_i}{\delta} Y_i$$

↪ Substituting into the production function:

$$Y_i = (A_i h_i N_i)^{\alpha} \left(\frac{s_i}{\delta} Y_i \right)^{\beta}$$

↪ Re–arranging yields

$$\frac{Y_i}{N_i} = \frac{(A_i h_i)^{\frac{\alpha}{1-\beta}}}{N_i^{\frac{1-\alpha-\beta}{1-\beta}}} \left(\frac{s_i}{\delta} \right)^{\frac{\beta}{1-\beta}}$$

↪ Taking logs

$$y_i = \frac{\alpha}{1-\beta} \log A_i + \frac{\alpha}{1-\beta} \log h_i + \frac{\beta}{1-\beta} \log \frac{s_i}{\delta} - \left(\frac{1-\alpha-\beta}{1-\beta} \right) \log N_i$$

- Posited impacts of life expectancy, X_i:

$$N_i = \bar{N}_i X_i^{\lambda} \qquad A_i = \bar{A}_i X_i^{\gamma} \qquad h_i = \bar{h}_i X_i^{\eta}$$

where $\bar{N}_i$, $\bar{A}_i$ and $\bar{h}_i$ reflect components unrelated to life-expectancy and λ, γ and η are parameters

- Substituting yields

$$\begin{aligned} y_i &= \frac{\alpha}{1-\beta}\log \bar{A}_i + \frac{\alpha}{1-\beta}\log \bar{h}_i + \frac{\beta}{1-\beta}\log \frac{s_i}{\delta} - \left(\frac{1-\alpha-\beta}{1-\beta}\right)\log \bar{N} \\ &\quad + \left(\frac{1}{1-\beta}\right)\left(\alpha(\gamma+\eta) - (1-\alpha-\beta)\lambda\right) x_i \end{aligned}$$

where $x_i = \log X_i$

- Increased life expectancy raises per capita income when
  ↪ diminishing returns are limited: $1-\alpha-\beta$ is small
  ↪ impact on technology and human capital are large

Medium run

- Capital stock has not reach steady state level:

$$\frac{Y_i}{N_i} = \frac{\bar{K}_i^{\beta} (A_i h_i)^{\alpha}}{N_i^{1-\alpha}}$$

↪ taking logs

$$\begin{aligned} y_i &= \beta \log \bar{K}_i + \alpha \log A_i + \alpha \log h_i - (1-\alpha) \log \bar{N}_i \\ &\quad + (\alpha(\gamma+\eta) - (1-\alpha)\lambda)\, x_i \end{aligned}$$

↪ medium-run effect of increase in x_i is smaller or more negative than long-run effect

International Epidemiolgical Transition

- There was a dramatic improvement in life expectancy in LDCs after 1940 due to

(1) Wave of global drug innovations

↪ antibiotics: Penicillin, streptomycin (for TB)

↪ new vaccines: yellow fever, small pox, measles

(2) Discovery of DDT (dichlorodiphenyl trichloroethylene)

↪ eradication of malaria in many parts of the world

(3) Establishment of the WHO and UNICEF

↪ driving force behind expansion of public health in LDCs and immunization drives

(4) Change in international values

Coding of Diseases

- Collection of comparable data on 15 important infectious diseases word-wide including

↪ tuberculosis: largest single cause of death in 1940

↪ malaria: WHO decision to eradicate in 1955

↪ pneumonia: secondary infection that causes death (primary causes are TB, flu and AIDS)

- Global intervention dates — dates of significant events potentially reducing mortality from each disease

↪ streptomycin: introduced in 1940s

↪ DDT used extensively in 1940s, but WHO decision to eradicate in 1950s

↪ penicillin and vaccines introduced in 1940s

- Life Expectancy, Population and GDP Data

- Base Sample: 59 countries

↪ no Eastern European or Russia; no African countries

- Observations for 1940, 1950, 1960, 1970 and 1980

↪ post–1980 excluded from baseline due to effects of AIDS

- Initial observation (Figures 1 and 2)

↪ large convergence of in life expectancy

↪ no convergence of GDP per capita

Figure 1: Log life expectancy at birth for initially rich, middle-income and poor countries

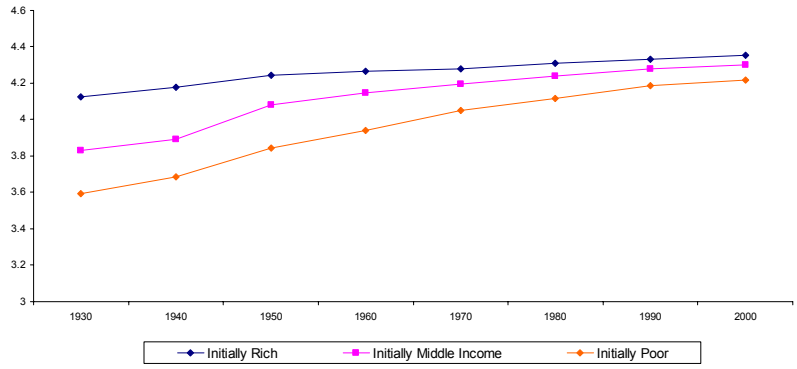
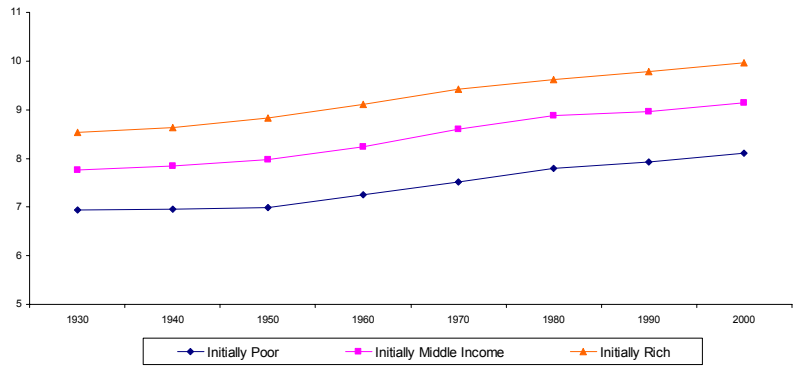


Figure 2: Log GDP per capita for initially rich, middle-income and poor countries



Estimation Framework

- Basic Regression:

$$y_{it+k} = \pi x_{it} + \zeta_i + \mu_t + \mathbf{Z}'_{it}\beta + \varepsilon_{it+k}$$

where

y_{it+k} = output per capita at time $t+k$ (also output and population
x_{it} = life expectancy at time t
ζ_i = country fixed effect (e.g. technology differences)
μ_t = common time-varying factors
$\mathbf{Z}_{it}$ = vector of other controls

OLS estimates

- Relationship between life expectancy and population (Table 2)

↪ elasticity exceeds 1

↪ results imply population grew because births did not decline enough to offset rise in life-expectancy

- Relationship between life expectancy and GDP (Table 3, Panels A-B)

↪ large, statistically significant impact

- Relationship between life expectancy and GDP per capita (Table 3, Panels C and D)

↪ suggest that positive effect on population size offsets or outweighs effect on GDP

Table 2
Life Expectancy, Population, and Births: OLS Estimates

Dependent variable indicated for each panel separately

	All Countries	*Base Sample*		*Low & Middle Income Countries Only*	*All Countries*		*Base Sample*			
	No leads	No leads	No leads	No leads	10 year lead	20 year lead	10 year lead	20 year lead	10 year lead	20 year lead
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
				Panel A: Dependent variable is log population						
	Panel, 1960-2000	Panel, 1960-2000	Panel, 1940-1980	Panel, 1940-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1940-1980	Panel, 1940-1980
Log Life Expectancy	1.46	1.69	1.21	1.24	1.72	1.61	1.34	0.97	1.33	1.26
	(0.29)	(0.43)	(0.20)	(0.28)	(0.26)	(0.34)	(0.46)	(0.46)	(0.22)	(0.21)
Number of observations	600	294	282	249	480	360	235	176	282	282
Number of countries	120	59	59	48	120	120	59	59	59	59
				Panel B: Dependent variable is log population						
	Just 1960 and 2000	Just 1960 and 2000	Just 1940 and 1980	Just 1940 and 1980	Just 1960 and 1990	Just 1960 and 1980	Just 1960 and 1990	Just 1960 and 1980	Just 1940 and 1980	Just 1940 and 1980
Log Life Expectancy	1.60	1.74	1.62	1.86	1.92	1.70	1.42	0.98	1.71	1.62
	(0.42)	(0.57)	(0.22)	(0.36)	(0.35)	(0.41)	(0.57)	(0.58)	(0.24)	(0.21)
Number of observations	240	118	94	72	240	240	118	118	94	94
Number of countries	120	59	47	36	120	120	59	59	47	47
				Panel C: Dependent variable is log number of births						
	Panel, 1960-1990	Panel, 1960-1990	Panel, 1940-1980	Panel, 1940-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1930-1970	Panel, 1930-1970
Log Life Expectancy	1.90	2.02	1.87	1.85	1.65	0.75	1.39	0.30	1.46	1.14
	(0.40)	(0.46)	(0.28)	(0.36)	(0.42)	(0.47)	(0.49)	(0.57)	(0.20)	(0.23)
Number of observations	460	188	233	198	345	230	141	94	234	187
Number of countries	115	47	47	36	115	115	47	47	47	47
				Panel D: Dependent variable is log number of births						
	Just 1960 and 1990	Just 1960 and 1990	Just 1940 and 1980	Just 1940 and 1980	Just 1960 and 1980	Just 1960 and 1970	Just 1960 and 1980	Just 1960 and 1970	Just 1940 and 1980	Just 1940 and 1970
Life Expectancy	2.09	2.00	1.88	1.97	1.72	0.75	1.37	0.30	1.55	1.30
	(0.53)	(0.42)	(0.41)	(0.47)	(0.50)	(0.47)	(0.59)	(0.57)	(0.25)	(0.31)
Number of observations	230	94	92	70	230	230	94	94	92	92
Number of countries	115	47	46	35	115	115	47	47	46	46

OLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses. Panels A and C are unbalanced panels with one observation per decade. Panels B and D are long-difference specifications with observations for only the beginning and end dates. Dependent variable is log population in Panels A and B and log total births in Panels C and D. Independent variable in all regressions is log life expectancy at birth. In columns 1-4, the dependent variable and independent variable are for the same time period; in columns 5-10, the dependent variable is for t+10 or t+20 as indicated, while the independent variable is for time t. "All countries" are those for which we have data on the dependent and independent variables. Base sample is countries for which we have disease data. Assignment of countries to low and middle income categories is based on 1940 income per capita; see text and Appendix A for details and definitions.

Table 3
Life Expectancy, GDP and GDP per capita: OLS Estimates

Dependent variable indicated for each panel separately

	All Countries	*Base Sample*		*Low & Middle Income Countries Only*	*All Countries*		*Base Sample*			
	No leads	No leads	No leads	No leads	10 year lead	20 year lead	10 year lead	20 year lead	10 year lead	20 year lead
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
				Panel A: Dependent variable is log GDP						
	Panel, 1960-2000	Panel, 1960-2000	Panel, 1940-1980	Panel, 1940-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1940-1980	Panel, 1940-1980
Log Life Expectancy	1.35	1.70	0.73	0.65	1.09	0.29	1.37	0.97	0.73	0.90
	(0.49)	(0.45)	(0.35)	(0.42)	(0.44)	(0.62)	(0.37)	(0.52)	(0.24)	(0.30)
Number of observations	600	294	283	228	480	360	235	176	283	283
Number of countries	120	59	59	48	120	120	59	59	59	59
				Panel B: Dependent variable is log GDP						
	Just 1960 and 2000	Just 1960 and 2000	Just 1940 and 1980	Just 1940 and 1980	Just 1960 and 1990	Just 1960 and 1980	Just 1960 and 1990	Just 1960 and 1980	Just 1940 and 1980	Just 1940 and 1980
Log Life Expectancy	1.17	1.55	0.78	0.65	1.07	0.39	1.61	1.11	0.75	0.92
	(0.80)	(0.49)	(0.58)	(0.73)	(0.59)	(0.76)	(0.48)	(1.02)	(0.39)	(0.47)
Number of observations	240	118	94	72	240	240	118	116	94	94
Number of countries	120	59	47	36	120	120	59	58	47	47
				Panel C: Dependent variable is log GDP per capita						
	Panel, 1960-1990	Panel, 1960-1990	Panel, 1940-1980	Panel, 1940-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1960-1990	Panel, 1960-1980	Panel, 1940-1980	Panel, 1940-1980
Log Life Expectancy	-0.10	0.003	-0.44	-0.44	-0.63	-1.31	0.03	-0.001	-0.57	-0.33
	(0.48)	(0.46)	(0.30)	(0.23)	(0.51)	(0.69)	(0.50)	(0.75)	(0.28)	(0.39)
Number of observations	600	294	283	228	480	360	235	176	283	283
Number of countries	120	59	59	48	120	120	59	59	59	59
				Panel D: Dependent variable is log GDP per capita						
	Just 1960 and 2000	Just 1960 and 2000	Just 1940 and 1980	Just 1940 and 1980	Just 1960 and 1990	Just 1960 and 1980	Just 1960 and 1990	Just 1960 and 1980	Just 1940 and 1980	Just 1940 and 1980
Log Life Expectancy	-0.42	-0.19	-0.81	-0.13	-0.84	-1.31	0.18	-0.48	-0.96	-0.70
	(0.82)	(0.76)	(0.42)	(0.69)	(0.70)	(0.85)	(0.82)	(1.18)	(0.43)	(0.50)
Number of observations	240	118	94	54	240	240	118	116	94	94
Number of countries	120	59	47	27	120	120	59	58	47	47

OLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses. Panels A and C are unbalanced panels with one observation per decade. Panels B and D are long-difference specifications with observations for only the beginning and end dates. Dependent variable is log total GDP in Panels A and B and log GDP per capita in Panels C and D. Independent variable in all regressions is log life expectancy at birth. In columns 1-4, the dependent variable and independent variable are for the same time period; in columns 5-10, the dependent variable is for t+10 or t+20 as indicated, while the independent variable is for time t. "All countries" are those for which we have data on the dependent and independent variables. Base sample is countries for which we have disease data. Assignment of countries to low and middle income categories is based on 1940 income per capita; see text and Appendix A for details and definitions.

Instrumental Variables Approach: Predicted Mortality

- **Problem:** OLS estimates need not reflect **causal** effect of health

↪ health is almost certainly endogenous to income

↪ empirical strategy taken here: exploit exogenous source of variation in life expectancy due to global intervention

- First-stage relationship:

$$x_{it} = \psi M_{it}^{I} + \tilde{\zeta}_i + \tilde{\mu}_t + \mathbf{Z}_{it}' \tilde{\beta} + u_{it}$$

where

$$M_{it}^{I} = \text{ predicted mortality}$$

- Predicted mortality is constructed as

$$M_{it}^{I} = \sum_{d \in D} \left[(1 - \Delta_{dt}) M_{di40} + \Delta_{dt} M_{dFt} \right]$$

where

M_{dit}	=	mortality in country i from disease d at time t
Δ_{dt}	=	dummy for past intervention for disease d at time t
D	=	set of all 15 diseases
M_{di40}	=	pre-intervention mortality from disease d
M_{dFt}	=	mortality rate from disease d at world health frontier

- M_{it}^{I} uses pre-intervention mortality rates until intervention, then uses frontier rate after intervention (=0 in baseline)

First Stage Estimates

- Strong negative relationship between changes in predicted mortality and changes in life expectancy (Figures 3 and 4)

- Baseline specification (Table 5, first column)

↪ improvement in predicted mortality of 0.43 per hundred leads to a 13% in life expectance (6.5 years)

↪ remaining columns verify robustness of estimated effect

Figure 3: Change in log life expectancy and change in predicted mortality, 1940-80, base sample

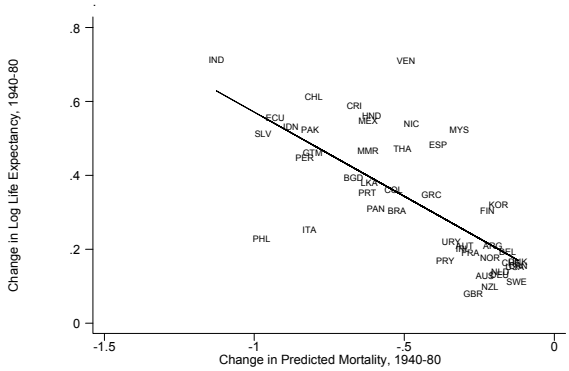


Figure 4: Change in log life expectancy and change in predicted mortality, 1940-80, low and middle-income countries

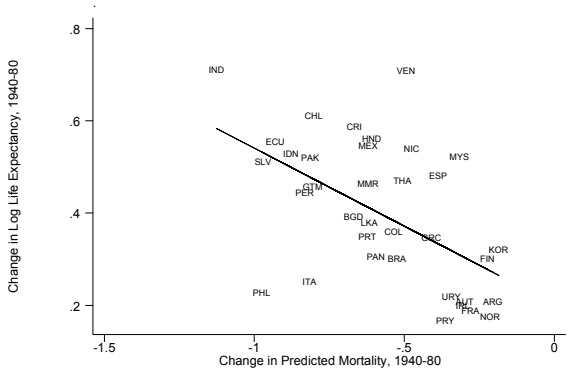


Table 5

First Stage Estimates: Predicted Mortality and Life Expectancy

Dependent Variable is log life expectancy

	Baseline predicted mortality								Using global mortality rate		Alternative timing	TB, malaria, and pneumonia mortality only
	Base Sample		*Including Eastern Europe*	*Low and Middle Income Countries Only*	*Balanced Panel Sample*	*Base Sample, Interaction with Institutions*	*Base Sample, Interaction with Initial (1930) log GDP p.c.*	*Base Sample, Interaction with Continent Dummies*	*Base Sample*	*Low and Middle Income Countries Only*	*Base Sample*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A	Panel, 1940-1980	Panel, 1930-1980	Panel, 1940-1980	Panel, 1940-1980	Balanced Panel, 1940-1980	Panel, 1940-1980	Panel, 1940-1980	Panel, 1940-1980	Panel, 1940-1980	Panel, 1940-1960	Panel, 1940-1980	Panel, 1940-1980
Predicted Mortality	-0.33	-0.36	-0.34	-0.23	-0.32	-0.27	-0.24	-0.25	-0.41	-0.26	-0.33	-0.35
	(0.06)	(0.06)	(0.06)	(0.08)	(0.06)	(0.07)	(0.10)	(0.07)	(0.08)	(0.10)	(0.06)	(0.08)
R-squared	0.93	0.93	0.92	0.93	0.94	0.94	0.95	0.95	0.93	0.93	0.93	0.93
Number of observations	283	316	312	228	230	271	243	283	263	208	283	283
Number of countries	59	59	65	48	46	56	49	59	59	48	59	59
Panel B	Just 1940 and 1980	Just 1930 and 1980	Just 1940 and 1980	Just 1940 and 1980	Just 1940 and 1980	Just 1940 and 1980	Just 1940 and 1980	Just 1940 and 1980	Just 1940 and 1960	Just 1940 and 1960	Just 1940 and 1980	Just 1940 and 1980
Predicted Mortality	-0.44	-0.53	-0.46	-0.31	-0.45	-0.35	-0.25	-0.30	-0.40	-0.29	-0.45	-0.49
	(0.09)	(0.11)	(0.06)	(0.12)	(0.09)	(0.10)	(0.13)	(0.11)	(0.12)	(0.17)	(0.09)	(0.11)
R-squared	0.95	0.95	0.95	0.95	0.95	0.95	0.96	0.96	0.95	0.94	0.95	0.95
Number of observations	94	66	106	72	92	94	94	94	94	72	94	94
Number of countries	47	33	53	36	46	47	47	47	47	36	47	47

OLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses. Panel A is unbalanced panel with one observation per decade. Panel B is long-difference specifications with observations for only the beginning and end dates. Dependent variable in both panels is log life expectancy at birth. Independent variable in columns 1-8 is baseline predicted mortality; in columns 9-10, global mortality; in column 11, predicted mortality has alternative timing, and in column 12 predicted mortality is constructed from tuberculosis, pneumonia, and malaria deaths only. See text and Appendix A for the construction of the predicted mortality instrument, definitions and data sources. Eastern Europe is countries that became part of the Soviet bloc after 1945. Assignment of countries to low and middle income categories is based on 1940 income per capita.

Balanced panel is countries with no missing data between 1940 and 1980. In columns 6-8 we include time dummies interacted with: in column 6, institutions, measured as constraint on the executive in 1950, 1960, and 1970, from Polity IV; in column 7, log GDP per capita in 1930; and in column 8, a full set of continent dummies (Africa, Asia, Americas, Europe; Oceania is the omitted category).

Main Results of IV Approach

- **Population**

(1) Strong negative reduced–form relationship between population growth (1940-80) and change in predicted mortality (Figure 9)

(2) Elasticity of population with respect to life expectancy is 1.31 ($s.e. = 0.37$) using IV estimator (Table 8)
↪ robust to various specifications

- **GDP**

(1) Slight negative reduced–form relationship between GDP growth and change in predicted mortality (Figure 10)

(2) Elasticity of GDP with respect to life expectancy is close to zero, but large standard errors, using IV estimator (Table 10)
↪ more positive effects over longer horizons (Columns 8-11)

Figure 9: Change in log population and change in predicted mortality, 1940-80, base sample

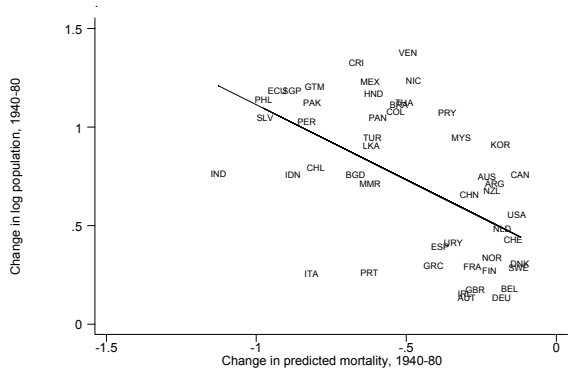


Figure 10: Change in log total GDP and change in predicted mortality, 1940-80, base sample

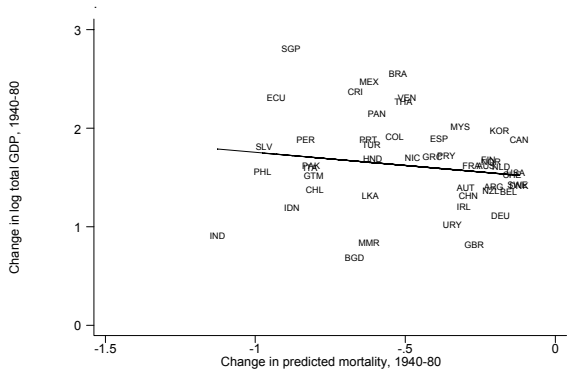


Table 8

The Effect of Life Expectancy on Log Population: 2SLS Estimates

	Dependent variable is log population										
	Baseline instrument						Global mortality instrument	Baseline instrument			
	Base Sample		*Including Eastern Europe*	*Low and Middle Income Countries Only*	*Base Sample, Interaction with Institutions*	*Base Sample, Interaction with Initial (1930) Log Population*	*Base Sample*				
	No leads Panel, 1940-1980	No leads Panel, 1930-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	10 year lead Panel, 1940-1980	20 year lead Panel, 1940-1980	30 year lead Panel, 1940-1970	40 year lead Panel, 1940-1960
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A											
Log Life Expectancy	1.31	1.35	1.48	1.58	1.22	1.33	1.65	1.50	1.58	1.49	1.17
	(0.37)	(0.36)	(0.39)	(0.76)	(0.50)	(0.35)	(0.40)	(0.37)	(0.35)	(0.37)	(0.39)
p-value for Year Dummies x Institutions or initial log population					[0.02]	[0.003]					
Number of observations	283	316	312	228	272	244	263	284	284	226	167
Number of countries	59	59	63	46	56	49	59	59	59	59	59
	No leads Just 1940 and 1980	No leads Just 1930 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	10 year lead Just 1940 and 1980	20 year lead Just 1940 and 1980	30 year lead Just 1940 and 1980	40 year lead Just 1940 and 1980
Panel B											
Log Life Expectancy	1.67	1.62	1.79	2.40	1.63	1.68	1.70	1.79	1.75	1.63	1.48
	(0.50)	(0.56)	(0.50)	(1.01)	(0.73)	(0.44)	(0.48)	(0.47)	(0.42)	(0.47)	(0.45)
Post year dummy x Institutions or initial log population					-0.01	-0.06					
					(0.05)	(0.03)					
Number of observations	94	66	106	72	94	94	94	94	94	80	80
Number of countries	47	33	53	36	47	47	47	47	47	40	40

2SLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses. Panel A is unbalanced panel with one observation per decade. Panel B is long-difference specification with observations for only the beginning and end dates. Dependent variable in both panels is log total population. Independent variable in both panels is log life expectancy at birth. In columns 1-6 and 8-11, log life expectancy is instrumented by predicted mortality (baseline instrument), and in column 7 it is instrumented by global mortality. First stages are in Table 5. In columns 1-7, the dependent and independent variables are for the same time period; in columns 8-11, the dependent variable is t+10, t+20 etc., as indicated, while the independent variable is at time t. Columns 5 and 6 include year dummies interacted with: institutions, in column 5, as average of constraint on executive in 1950, 1960, and 1970 from Polity IV, where scores range from 1 to 7 and non-independent countries are assigned score of 1; and initial log population, in column 6, is for 1930. See text and Appendix A for construction of the mortality instruments, definitions, and data sources.

Table 10
The Effect of Life Expectancy on Log GDP: 2SLS Estimates

	Dependent variable is log GDP										
	Baseline instrument						Global mortality instrument	Baseline instrument			
	Base Sample		*Including Eastern Europe*	*Low and Middle Income Countries Only*	*Base Sample, Interaction with Institutions*	*Base Sample, Interaction with Initial (1930) log GDP*	*Base Sample*				
	No leads Panel, 1940-1980	No leads Panel, 1930-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	10 year lead Panel, 1940-1980	20 year lead Panel, 1940-1980	30 year lead Panel, 1940-1980	40 year lead Panel, 1940-1980
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A											
Log Life Expectancy	-0.03	-0.13	0.11	-0.28	-0.35	-0.49	0.45	0.52	0.53	0.61	0.14
	(0.67)	(0.62)	(0.66)	(1.19)	(0.82)	(0.58)	(0.59)	(0.48)	(0.44)	(0.60)	(0.85)
p-value for Year Dummies x Institutions or initial GDP					[0.005]	[0.01]					
Number of observations	283	316	312	228	271	243	263	283	283	224	165
Number of countries	59	59	65	48	56	49	59	59	59	59	59
	No leads Just 1940 and 1980	No leads Just 1930 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	10 year lead Just 1940 and 1980	20 year lead Just 1940 and 1980	30 year lead Just 1940 and 1970	40 year lead Just 1940 and 1960
Panel B											
Log Life Expectancy	0.32	0.06	0.43	-0.39	-0.11	-0.07	0.51	0.55	0.64	0.64	0.33
	(0.84)	(0.95)	(0.82)	(1.44)	(0.98)	(0.73)	(0.71)	(0.63)	(0.66)	(0.76)	(0.94)
Post year dummy x Institutions or initial GDP					-0.06	-0.11					
					(0.06)	(0.06)					
Number of observations	94	94	106	72	94	94	94	94	94	94	94
Number of countries	47	47	53	36	47	47	47	47	47	47	47

2SLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses. Panel A is unbalanced panel with one observation per decade. Panel B is long-difference specification with observations for only the beginning and end dates. Dependent variable in both panels is log GDP. Independent variable in both panels is log life expectancy at birth. In columns 1-6 and 8-11, log life expectancy is instrumented by predicted mortality (baseline instrument), and in column 7 it is instrumented by global mortality. First stages are in Table 5. In columns 1-7, the dependent and independent variables are for the same time period; in columns 8-11, the dependent variable is t+10, t+20 etc., as indicated, while the independent variable is at time t. Columns 5 and 6 include year dummies interacted with: institutions, in column 5, as average of constraint on executive in 1950, 1960, and 1970 from Polity IV, where scores range from 1 to 7 and non-independent countries are assigned score of 1; and initial GDP, in column 6, is for 1930. See text and Appendix A for construction of the mortality instruments, definitions, and data sources.

- **GDP per Capita**

(1) Strong positive reduced–form relationship between per capita GDP growth and change in predicted mortality (Figure 11)

(2) Elasticity of GDP per capita with respect to life expectancy is -1.30 (s.e.$= 0.5$) using IV estimator (Table 11)

$\hookrightarrow$ smaller estimate under some specifications (columns 3-6)

Table 11

The Effect of Life Expectancy on Log GDP per capita: 2SLS Estimates

	Dependent variable is log GDP per capita										
	Baseline instrument						Global mortality instrument	Baseline instrument			
	Base Sample		*Including Eastern Europe*	*Low and Middle Income Countries Only*	*Base Sample, Interaction with Institutions*	*Base Sample, Interaction with Initial (1930) log GDP p.c.*	*Base Sample*				
	No leads Panel, 1940-1980	No leads Panel, 1930-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	No leads Panel, 1940-1980	10 year lead Panel, 1940-1980	20 year lead Panel, 1940-1980	30 year lead Panel, 1940-1980	40 year lead Panel, 1940-1980
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A											
Log Life Expectancy	-1.30	-1.39	-1.32	-1.76	-1.45	-0.46	-1.17	-0.98	-1.04	-0.87	-1.04
	(0.53)	(0.46)	(0.53)	(1.13)	(0.74)	(0.85)	(0.45)	(0.39)	(0.45)	(0.55)	(0.90)
p-value for Year Dummies x Institutions or initial GDP pc					[0.02]	[0.03]					
Number of observations	283	316	312	228	271	243	263	283	283	224	165
Number of countries	59	59	65	48	56	49	59	59	59	59	59
	No leads Just 1940 and 1980	No leads Just 1930 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	No leads Just 1940 and 1980	10 year lead Just 1940 and 1980	20 year lead Just 1940 and 1980	30 year lead Just 1940 and 1970	40 year lead Just 1940 and 1960
Panel B											
Log Life Expectancy	-1.32	-1.44	-1.33	-2.35	-1.64	-1.59	-1.17	-1.24	-1.12	-0.92	-0.89
	(0.56)	(0.61)	(0.54)	(1.13)	(0.77)	(1.22)	(0.51)	(0.66)	(0.78)	(0.81)	(1.01)
Post year dummy x Institutions or initial GDP pc					-0.05	0.07					
					(0.06)	(0.28)					
Number of observations	94	94	106	72	94	94	94	94	94	94	94
Number of countries	47	47	53	36	47	47	47	47	47	47	47

2SLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses. Panel A is unbalanced panel with one observation per decade. Panel B is long-difference specification with observations for only the beginning and end dates. Dependent variable in both panels is log GDP per capita. Independent variable in both panels is log life expectancy at birth. In columns 1-6 and 8-11, log life expectancy is instrumented by predicted mortality (baseline instrument), and in column 7 it is instrumented global mortality. First stages are in Table 5. In columns 1-7, the dependent and independent variables are for the same time period; in columns 8-11, the dependent variable is t+10, t+20 etc., as indicated, while the independent variable is at time t. Columns 5 and 6 include year dummies interacted with: institutions, in column 5, as average of constraint on executive in 1950, 1960, and 1970 from Polity IV, where scores range from 1 to 7 and non-independent countries are assigned score of 1; and initial GDP per capita, in column 6, is for 1930. See text and Appendix A for construction of the mortality instruments, definitions, and data sources.

Interpretation using neoclassical model

- Medium run

$$\pi = \alpha(\gamma + \eta) - (1 - \alpha)\lambda$$

↪ from estimates: $\lambda \simeq 1.5$

↪ if labour share $\alpha \simeq \frac{1}{3}$ and land share $1 - \alpha - \beta \simeq \frac{1}{3}$, then $\beta \simeq \frac{1}{3}$

↪ given that

$$\begin{aligned} \hat{\pi} &= \frac{1}{3}(\gamma + \eta) - \frac{2}{3}(1.5) = -1.3 \\ &\Rightarrow \quad \gamma + \eta < 0 \end{aligned}$$

- Long run

$$\begin{aligned} \hat{\pi} &= \frac{\alpha}{1 - \beta}(\gamma + \eta) - (\frac{1 - \alpha - \beta}{1 - \beta})\lambda = -0.75 \\ &= \frac{1}{2}(\gamma + \eta) - \frac{1}{2}(1.5) = -0.75 \\ &\Rightarrow \quad \gamma + \eta = 0 \end{aligned}$$

Life Expectancy and Years of Schooling

- Uses years of schooling as a direct measure of human capital to estimate η

- Both OLS and IV estimates imply insignificant impact of life expectancy on investment in human capital (Table 12)

$\hookrightarrow$ consistent with other results

Table 12

The Effect of Life Expectancy on Years of Schooling: 2SLS Estimates

Dependent variable is years of schooling

	OLS	Baseline instrument	Baseline instrument	OLS	Baseline instrument	Baseline instrument	OLS	Baseline instrument	Baseline instrument
	Base Sample		*Low and Middle Income Countries Only*	*Base Sample*		*Low and Middle Income Countries Only*	*Base Sample*		*Low and Middle Income Countries Only*
	10 year lead	10 year lead	10 year lead	20 year lead	20 year lead	20 year lead	30 year lead	30 year lead	30 year lead
	Panel, 1950-1980	Panel, 1950-1980	Panel, 1950-1980	Panel, 1950-1970	Panel, 1950-1970	Panel, 1950-1970	Panel, 1950-1960	Panel, 1950-1960	Panel, 1950-1960
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Life Expectancy	-0.50	-0.42	-0.73	-0.14	0.07	1.10	5.01	1.40	-1.40
	(1.45)	(4.15)	(5.92)	(1.63)	(4.51)	(6.52)	(1.65)	(3.67)	(5.17)
Number of observations	212	212	168	159	159	126	106	106	84
Number of countries	53	53	40	53	53	42	53	53	42

OLS and 2SLS regressions with a full set of year and country fixed effects. Robust standard errors, adjusted for clustering by country, in parentheses.Unbalanced panel with one observation per decade. Dependent variable is years of schooling. Independent variable is log life expectancy at birth. In columns 2, 3, 5, 6, 8 and 9, log life expectancy is instrumented by predicted mortality (baseline instrument). First stages are in Table 5. In columns 1-3, the dependent and independent variables are for the same time period; in columns 4-9, the dependent variable is t+10, t+20, and t+30 as indicated, while the independent variable is at time t. See text and Appendix A for construction of the predicted mortality instrument, definitions and data sources.

Conclusions

- Increase in life expectancy due to the international epidemiological transition led to

↪ large impact on population due to fall in death rates with no offsetting decline in birth rates

↪ small initial impact on GDP which grew over next 40 years, but not enough to offset effect on population

↪ negative initial impact on per capita GDP, slowly wearing off over next 40 years

- "This evidence sheds considerable doubt on the view that health has a first–order impact on economic growth."

- Caveat: results need not imply to current diseases

↪ HIV/AIDS affects individuals at the peak of their productivity ⇒ larger impact on growth