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Disease and Development: The Role of Life Expectancy Reconsidered

Matteo Cervellati and Uwe Sunde

- This note estimates the causal effect of life expectancy on economic growth.
- The hypothesis of a non-monotonic effect is tested using finite mixture models.
- The evidence support the hypothesis of a non-monotonic effect of life expectancy.
- The results qualify earlier findings by Acemoglu and Johnson (2007).

# DISEASE AND DEVELOPMENT: THE ROLE OF LIFE EXPECTANCY RECONSIDERED\*

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## Abstract

This note estimates the causal effect of life expectancy on per capita income and tests the hypothesis of a non-monotonic effect using finite mixture models. The results confirm the hypothesis and qualify recent evidence for a negative effect by Acemoglu and Johnson (2007).

JEL-classification: J10, J13, N30, O10, O40, E10

Keywords: Life Expectancy, Demographic Transition, Epidemiological Revolution, Heterogeneous Treatment Effects, Finite Mixture Models

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## 1 Introduction

In their influential paper, Acemoglu and Johnson (2007) (AJ) investigate the effect of life expectancy on economic growth, exploiting within-country variation on the exogenous reduction in mortality that followed the epidemiological revolution of mid-20th Century. Contrary to previous evidence based on cross-country variation, see, e.g., Lorentzen, McMillan, and Wacziarg (2008), their results indicate that (instrumented) life expectancy had a positive effect on population growth but a negative effect on income per capita. The surprising conclusion is that better health does not have a positive effect on economic growth.

This note revisits the analysis in view of the non-monotonic relationship between life expectancy and population that is predicted from standard demographic transition theory. In light of the widely documented stylized facts, the standard representation of the “demographic transition” begins with an initial drop of mortality, DT, which is followed by a drop in fertility, FT (Chesnais, 1992 or Livi-Bacci, 1992). The time delay between DT and FT induces a hump-shaped population growth, which initially accelerates due to the lower mortality but eventually slows down due to reduced fertility. In the presence of Malthusian effects, GDP per capita may be affected negatively by life expectancy in response to the increase in population growth, but the effect should be positive in countries after the fertility transition.<sup>1</sup> The non-monotonic effect of life expectancy on population growth should therefore be associated with non-monotonic effects on GDP per capita, as illustrated in Figure 1.

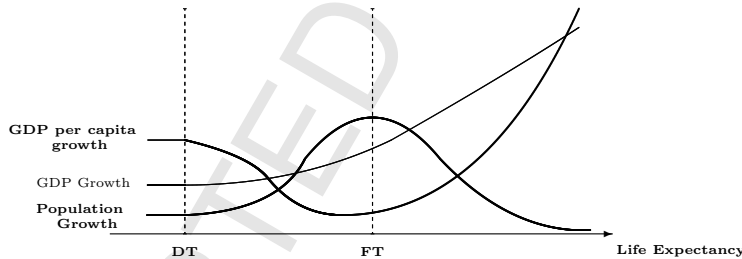


Figure 1: Life Expectancy, Population and Income Growth

This note replicates the analysis of AJ using their data and identification strategy, but relaxes the constraint that the effect should be the same in all countries since estimating the causal effect of life expectancy on income per capita growth without accounting for its inherent non-monotonicity may deliver misleading results. This is done using finite mixture models (FMM) that account for

<sup>1</sup>For theoretical studies predicting these dynamics see, e.g., Kalemli-Ozcan (2002), Soares (2005), Boucekkine, de la Croix and Peeters (2008), and Cervellati and Sunde (2007, 2011), among others.

possible non-monotonic causal effects of life expectancy on growth.

## 2 Empirical Framework, Data and Identification

The dependent variable is growth in log GDP per capita, the central explanatory variable is the change in life expectancy at birth.<sup>2</sup> The causal effect of changes in (instrumented) life expectancy,  $\Delta \widehat{\ln T}_i$ , in country  $i$  on growth in income per capita,  $\Delta \ln y_i$ , is estimated by AJ in a log-linear specification,

$$\Delta \ln y_i = C + \pi \Delta \widehat{\ln T}_i + u_i$$

using a long panel of 47 countries with two observations per country (1940 and 1980). The instrument for the change in life expectancy in a country is the drop in mortality from the 15 most important infectious diseases due to the epidemiological revolution. This reduction in mortality is exogenous since there were no effective treatments or vaccines for these diseases available by 1940. All of the diseases could be treated and even be prevented everywhere by 1980, independently of the level of economic development thanks to the advances in medical knowledge, drugs, prevention technologies (such as DDT for the eradication of malaria transmitting vectors) and through their world-wide dissemination by international organizations like WHO or UNICEF. Hence, the identifying assumption is that mortality from the respective diseases is exogenous in 1940 for lack of appropriate medical treatments, and unrelated to economic development in 1980 due to the world-wide dissemination of innovations in the medical sector after World War II.<sup>3</sup> As described in AJ, the predicted mortality change has a strong effect on changes in life expectancy, and countries with initially low life expectancy benefitted relatively more since mortality from the main killers was higher.

Demographers have used different criteria to characterize countries in terms of whether they passed the critical turning point of the demographic dynamics depicted in Figure 1. The conventional criteria are (Chesnais (1992, p. 19)):

1. *Life expectancy at birth exceeds 50;*
2. *Fertility or the crude birth rate has exhibited a sustained decline;*
3. *The crude birth rate has fallen below a given threshold (30/1000 or 25/1000).*

The application of each criterion allows to classify countries in two groups. In the sample of 47 countries studied by AJ there are 25, 28 and 31 countries that do not fulfil each of respective criterion by 1940. We call these countries pre-transitional, while the countries fulfilling the criteria

<sup>2</sup>The data sources are the *United Nations Demographic Yearbook* and Maddison (2003).

<sup>3</sup>See Acemoglu and Johnson (2007) for details.

are called post-transitional.<sup>4</sup> The simplest test of the hypothesis that the effect of life expectancy depends on the stage of the demographic transition is to exploit information on the pre-treatment status of countries in 1940 and to allow for a heterogeneous effect of life expectancy by splitting the sample. This strategy, which has been applied by Cervellati and Sunde (2011), has the advantage of closely reflecting the demographic transition theory, but has the disadvantage of relying on an exogenously imposed country classification.

An alternative, more flexible, way to account for the potential heterogeneous effect of the effect of life expectancy on growth countries is to estimate the effect of life expectancy and the probability of being in one of two distinct growth regimes jointly without imposing any ex-ante classification. This can be done by estimating the growth process as a finite mixture model with two latent components.<sup>5</sup> This approach has the advantage of being entirely data driven, and allows for a parametric estimation of the regime probabilities. In this case, the density function of observed growth rates conditional on the latent regime  $j = pre, post$  is given by

$$p(\Delta \ln y | \Delta \ln T; \pi, \mathbf{w}) = w^{pre}(X)p(\Delta \ln y_i | \Delta \ln T; \pi^{pre}) + w^{post}(X)p(\Delta \ln y_i | \Delta \ln T; \pi^{post}),$$

where  $\pi^j$  are the coefficients of interest that are supposed to differ across regimes, and  $w^j$  are weights that take values between 0 and 1. The weights are parameterized as a logit of the form

$$w^{pre}(X) = \frac{1}{1 + \exp(\gamma^{post} X)} \text{ and } w^{post}(X) = \frac{\exp(\gamma^{post} X)}{1 + \exp(\gamma^{post} X)},$$

with covariates  $X$  as determinants of regime membership, and  $\gamma^j$  being parameters to be estimated that capture the effect of the covariates  $X$  on the probability of being in either regime. The covariate  $X$  can be generically specified as a constant, or using variables that are potential determinants of the latent growth regime in 1940. We assume a normal distribution with standard deviation  $\sigma$  and estimate the parameters on the basis of  $N = 47$  observations in long differences by maximizing the log likelihood function

$$\max_{\pi^{pre}, \pi^{post}, w^{pre}, w^{post}} L = \prod_{i=1}^N (\ln (w^{pre}(X)p(\Delta \ln y_i | \Delta \ln T; \pi^{pre}) + w^{post}(X)p(\Delta \ln y_i | \Delta \ln T; \pi^{post}))),$$

where

$$p(\Delta \ln y_i | \Delta \ln T; \pi^j) = \frac{1}{\sqrt{2\pi(\sigma^j)^2}} \exp\left(-\frac{(\ln y_i - \ln T_i \pi^j)^2}{2(\sigma^j)^2}\right)$$

<sup>4</sup>The first criterion delivers the same classification as the third one for a threshold of 30/1000. The second criterion follows Reher (2004) by considering if a country has entered a falling trend of crude birth rates by the year 1935 using 5-year averages. The third criterion with a threshold of 25/1000 refers to advanced stages of the transition and is the most restrictive. See Cervellati and Sunde (2011) for a detailed discussion of the different classifications.

<sup>5</sup>See Frühwirth-Schnatter (2006) for a detailed account of finite mixture models, and Owen et al. (2009) for an application to growth regressions.

for  $j = pre, post$ .

The analysis below presents results for intention to treat (reduced form) models, using the predicted mortality instrument as regressor. This helps avoiding potential endogeneity problems associated with life expectancy and allows inference using standard tests.<sup>6</sup>

### 3 Results and Implications

Table 1 Panel (A) presents estimation results of GDP per capita regressed on predicted mortality changes. The dichotomous classification derived from the demographic criteria are applied using fully interacted models, that is by splitting the sample in pre- and post-transitional countries. To interpret the results recall that the predicted mortality change represents a reduction, which is negatively related to an increase in life expectancy. A negative coefficient therefore implies a positive effect of life expectancy on growth. The results show that, irrespective of the actual classification criterion, the effect of life expectancy on growth is consistently negative in the “Pre” regime (a positive coefficient of predicted mortality change) but consistently positive for countries in the “Post” regime (negative coefficient). Table 1 Panel (B) presents estimates of finite mixture models for growth in log GDP per capita as the dependent variable using the bi-variate classification of pre- and post-transitional countries as covariate  $X$  for predicting the membership to latent regimes. The results suggest the existence of two different regimes with opposite effects of life expectancy on income growth. Since the classification of countries obtained by the demographic criteria is a significant predictor of these regimes, we call them “Pre” and “Post”. The estimated probabilities of being in the “Post” regime are highly correlated with the classifications used in Panel (A), regardless of which variable is used as predictor of membership. The respective correlations are typically between 0.7 and 0.8 (detailed results are available upon request). The estimated coefficients are quantitatively comparable across the specifications and are similar to those obtained with fully interacted models in Panel (A).

Table 2 presents FMM results that do not rely on the classification of countries as pre- and post-transition to predict the two regimes. In columns (1) and (2) the weights are specified without any covariate. The distribution of growth rates is more dispersed in the pre-transitional regime, as is indicated by the larger estimate of  $\sigma$ . The remaining columns use life expectancy at birth, crude birth

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<sup>6</sup>From the discussion in AJ the relationship between predicted mortality reductions and increases in life expectancy is negative and approximately linear. Using the actual or the instrumented change in life expectancy delivers qualitatively similar results but in the second case standard confidence intervals cannot be used. Details are available upon request.

rate, natural population growth, or log income per capita, all in 1940, as predictors of the regime membership, respectively. The lowest values of the Akaike (AIC) and Bayesian (BIC) information criteria in columns (5)-(6) suggest that the models specifying the probability as function of crude birth rates and income per capita perform best and worst, respectively, among all models including the model without covariate. Overall, the findings support the hypothesis that life expectancy has a negative effect on growth in pre-transitional countries, but a positive effect in post-transitional ones. The estimates are quantitatively similar across specifications, indicating that the choice of regime predictors has only mild consequences compared to the main finding of non-monotonic effects of life expectancy on growth.

In line with theories of the demographic and economic transition, the results document that increases in life expectancy reduce GDP per capita growth in countries before their demographic transition. After the demographic transition the effects are reversed. Neglecting to account for the two different regimes may lead to misleading conclusions concerning the effect of life expectancy. These findings have relevant policy implications, provide a new interpretation of the estimates of the causal effect of life expectancy on economic growth in the literature, and substantially qualify the conclusions drawn by Acemoglu and Johnson (2007) that life expectancy has no significant positive impact on income growth.

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Table 1: Effect of Predicted Mortality on Log GDP Per Capita: Demographic Criteria

Panel (A): Split Sample Models Using Bi-Variate Classification							
Classification Criterion Sample	All	Criterion 1		Criterion 2		Criterion 3	
		Pre (1)	Post (2)	Pre (3)	Post (4)	Pre (5)	Post (6)
Predicted Mortality Change	0.59*** [0.15]	0.57*** [0.20]	-0.68** [0.26]	0.60*** [0.19]	-0.60** [0.25]	0.58*** [0.17]	-0.44** [0.17]
Number of countries	47	25	22	28	19	31	16
$R^2$	0.18	0.13	0.16	0.15	0.15	0.15	0.09

Panel (B): FMM using Bi-Variate Classification as Co-variate							
Dependent Variable Covariate for Probability	Growth in Ln GDP per Capita 1940-1980						
	Criterion 1		Criterion 2		Criterion 3		
	Pre (1)	Post (2)	Pre (3)	Post (4)	Pre (5)	Post (6)	
Predicted Mortality Change	0.465*** [0.134]	-0.621** [0.288]	0.497*** [0.142]	-0.606** [0.297]	0.533*** [0.148]	-0.588** [0.256]	
Probability of Post $\sigma$		0.314 0.319*** [0.045]	0.139*** [0.027]		0.295 0.322*** [0.044]	0.135*** [0.028]	0.313 0.315*** [0.045]
Coefficient of Covariate for component probability		5.187 [6.896]		4.258 [3.066]		3.244** [1.332]	
AIC		32.39		33.62		36.57	
BIC		47.19		48.42		51.37	
Number of Countries		47		47		47	

Regressions in long-difference specifications with two observations per country, for 1940 and 1980 for the base sample of Acemoglu and Johnson (2007). Dependent Variable is change in log GDP per capita 1940-1980,  $y$ . The regressor is the change in the predicted mortality instrument (see text).

Panel (A): OLS Regressions. See text for the classification criteria. Robust, small sample corrected standard errors in brackets.

Panel (B): Finite mixture models with two components. Co-variables used to model the probability of the latent regimes are dummies for the criteria of pre-/post-transitional countries in 1940. AIC and BIC are Akaike and Bayesian Information Criteria, respectively. Robust standard errors are in brackets.

\*\*\*, \*\*, \* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 2: Effect of Predicted Mortality Change on Log GDP Per Capita: Finite Mixture Models with Alternative Covariates

Dependent Variable Covariate for Probability	Growth in Ln GDP per Capita 1940-1980 - FMM using initial conditions as Co-variate											
	Life Exp.		CBR		Nat.Pop.Growth		Ln GDP p.c.		Life Exp./Ln GDP p.c.			
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Predicted Mortality Change	0.617*** [0.187]	-0.421 [0.289]	0.424 [0.260]	-0.519** [0.246]	0.461** [0.222]	-0.615*** [0.196]	0.495*** [0.140]	-0.602** [0.279]	0.552*** [0.139]	-0.514* [0.297]	0.404*** [0.153]	-0.484 [0.331]
Probability of Post	0.233		0.401		0.318		0.293		0.302		0.302	
$\sigma$	0.302*** [0.043]	0.154*** [0.045]	0.306*** [0.055]	0.158*** [0.050]	0.317*** [0.045]	0.137*** [0.029]	0.320*** [0.039]	0.138*** [0.022]	0.311*** [0.045]	0.146*** [0.035]	0.300*** [0.064]	0.158*** [0.047]
Coefficient of Covariate for component probability			0.119** [0.0498]		-0.211 [0.177]		-0.314 [0.209]		1.108 [0.700]		0.219** [0.109]	-1.851 [1.664]
AIC	43.13		36.97		33.63		42.87		37.10		53.75	
BIC	56.09		51.77		45.58		48.43		57.67		53.75	
Number of countries	47		47		47		47		47		47	

FMM with two components (see caption of Table 1 for details). The co-variables used to model the probability of the two components are life expectancy, crude birth rate (CBR), natural population growth rate (CBR-CDR), and ln income per capita, all measured as of 1940. Robust standard errors are in brackets. \*\*\*, \*\*, \* indicate significance at 1-, 5-, and 10-percent level, respectively.