Life Expectancy and Economic Growth: The Role of the Demographic Transition*

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Abstract

In this paper we investigate the causal effect of life expectancy for economic growth by explicitly accounting for the role of the demographic transition. Rather than focusing on issues of empirical identification, this paper concentrates attention on the econometric specification. We present a simple theory of the economic and demographic transition where investments in human capital are associated to reductions in fertility. The theory predicts that lower mortality leads to increases in population growth in pre-transitional economies where fertility stays large. Mortality reductions lead, however, to lower population growth and larger human capital after onset of the demographic transition. The effect of life expectancy on income per capita is therefore ambiguous until the onset of the demographic transition but positive afterwards. Life expectancy is also likely to trigger the transition to sustained income growth. We provide evidence for supporting these predictions using the data on predicted mortality reductions following the epidemiological revolution.

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

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1 Introduction

Virtually all around the world, sound economic performance goes hand in hand with good health and low mortality. The question about the direction of causality in this relationship – whether improving health and life expectancy leads to better economic performance and an acceleration of economic growth or the other way around – is of obvious relevance. In theory, increasing life expectancy may have positive or negative effects on per capita income. On the one hand lower mortality may increase income per capita by increasing the productivity of available resources (most notably human capital). On the other hand, for given fertility, lower mortality leads to an increase in population size. In the presence of fix factors of production a larger population tends to reduce income per capita. Recent empirical investigations come to opposite conclusions about the causal impact of health and life expectancy on growth. Lorentzen, McMillan and Wacziarg (2008) use cross-country (longitudinal) data and find evidence for higher life expectancy leading to lower fertility and faster economic growth.[1] Acemoglu and Johnson (2007), on the other hand, find no evidence for a causal effect of life expectancy based on the major improvement in health and life expectancy in the context of the epidemiological transition after World War II. Their findings suggest that health improvements imply some growth in aggregate incomes, but mainly trigger faster population growth, such that as consequence growth in income per capita actually slows down.[2] This paper argues that the assessment of the causal effect of changes in life expectancy requires considering the endogenous change in fertility behavior and investments in human capital. Explicitly accounting for the, so called, demographic transition and the intertwined economic transition also allows to reconciled the seemingly contradictory empirical findings.

The demographic transition represents a marked change in population dynamics, reflected by a pronounced drop in fertility following a reduction in mortality. The typical dynamics of the demographic transition are depicted in Figure 1 (which reproduces Fig. 1.1 from Chesnais, 1992). Initially both fertility and mortality rates are high and population growth is low. At some point in time, A, mortality begins to fall, while fertility still remains high. The consequence is an increase in the natural rate of population growth.[3] Fertility begins to fall only with some delay, at time B, thereby leading to a reduction in birth rates. The reduction in fertility eventually leads to a reduction in the rate of population growth. In the usual terminology, a country experiences a demographic transition when the natural rate of population growth begins decreasing in response to reductions in mortality and fertility. In other words, the demographic transition is observed when the reduction in fertility is sufficiently pronounced to compensate for

[1] Similar findings based on cross-country regressions are reported by, e.g., Bloom and Sachs (1998), Gallup, Sachs, and Mellinger (1999), Gallup and Sachs (2001), and Bloom and Canning (2005).

[2] Using simulations based on microeconomic estimates to infer the role of health improvements for income per capita for a constant population Weil (2007) also finds positive, but fairly small effects on aggregate income.

[3] Notice that the picture plots crude birth and death rates, that is, the total number of birth and death over total population alive at each point in time. In the initial phase the birth rates tend to decline slightly as consequence of the increase in population size although total fertility is unchanged.

the mechanical increase in population due to the lower mortality.

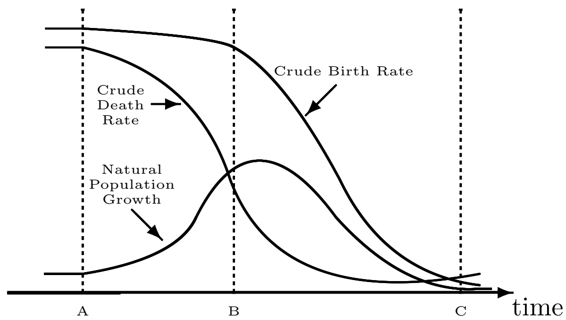

Figure 1: The Stages of the Demographic Transition

The mechanism investigated in this paper can be illustrated by looking again at Figure 1. Consider an exogenous reduction in mortality in a country during phase $[A, B]$. As fertility rates remains high, the lower mortality leads to an acceleration in population growth. The opposite is true for a country that has already undergone the fertility transition. An exogenous increase in life expectancy during phase $[B, C]$ triggers an even larger drop in fertility thereby reducing population growth further. This mechanism is complemented by the existence of a negative correlation between investments in human capital and fertility. Hence, the productivity effect becomes stronger precisely when fertility drops (see Galor and Weil, 2000, Galor, 2005, Soares, 2005 and Cervellati and Sunde, 2005 and 2007). Intuitively, a Malthusian "population effect" is at work before the demographic transition, while it reverses afterwards. Taken together these demographic and economic mechanisms imply that the population effect may dominate until the onset of the transition while mortality reductions are unambiguously positive for per capita income after the fertility drop. Additionally, reductions in mortality increase the probability of triggering the transition if they suffice to bring a country out of the "high fertility - low education" trap that characterizes pre-transitional economies.

Previous empirical investigations of the role of mortality have mainly concentrated on the problem of the econometric *identification* of a causal effect of health or life expectancy, searching for appropriate exogenous variation in life expectancy.[4] In this paper we complement this literature by focussing on the issue of the appropriate *specification* of the empirical analysis. We provide a simple theory to illustrate the prediction of different causal effects of life expectancy at different stages of (demographic) development. To account for the causal effects of life expectancy we use the data by Acemoglu and Johnson (2007) on predicted mortality reductions following the epidemiological transition after World War II. In our empirical specification we allow for different estimates of the causal effect of life expectancy on per

[4]Different strategies have been proposed in the literature. Lorentzen, McMillan and Wacziarg (2008) exploit permanent differences in the mortality environment related to geography, climate and the potential exposure to diseases like malaria. Acemoglu and Johnson (2007) exploit shocks to mortality related to the introduction of better treatments like penicillin (see more details below).

capita income, population growth and education, depending on whether a country is pre-transitional or post-transitional before the treatment. The identification of the stages of the transition follows the classification criteria used in the demographics literature.

We find that the effects of life expectancy improvements differ drastically depending on whether one looks at pre-transitional or post-transitional countries. Prior to the demographic transition, the main effect of reductions in mortality is to breed larger population growth, which tends to reduce per capita income and does not significantly affect education. After the onset of the transition, however, reductions in mortality reduce population growth, accelerates human capital formation and increase income per capita. Over the period 1940-1980 we find a positive and significant effect of life expectancy on the share of educated individuals only in post-transitional countries. Most countries that are pre-transitional in 1940 experience reductions in fertility around 1970. By 2000 the effect of life expectancy on education is positive and significant for all countries. This is in line with the prediction of a positive response of human capital in association with reduced fertility. Finally we find that improvements in life expectancy increase the probability of a country undergoing the demographic transition. Taken together the evidence strongly support the predictions.

The analysis has several implications. The results allow to re-interpret the existing evidence on the role of life expectancy for development. The previous findings in the literature are reconciled by explicitly considering the effect of mortality on fertility and education. The findings also suggest that the estimated average treatment effect depends on the composition of the sample in terms of pre-transitional and post-transitional countries. This implies that in general the economic interpretation of average treatment effects on income per capita is difficult, and potentially misleading, since reductions in mortality influence the population and human capital dynamics non-linearly. Finally, the results may be relevant for policy implications also in view of the fact that most developing countries have recently experienced the onset of the demographic transition.

The paper is structured as follows. Section 2 presents a simple theoretical framework that helps illustrating our main idea. Based on this theory we develop an estimation framework and discuss its empirical implementation in Section 3. Section 4 presents our main results, and Section 5 concludes. All proofs are collected in the appendix.

2 Human, Fertility and Mortality

This section presents a simple micro-founded growth model which is used to frame the empirical analysis in the following section. The theory illustrates the predictions of different effects of mortality on (per capita) income in the different phases of (demographic) development and the prediction that sufficiently large reductions in mortality are needed to trigger the economic and demographic transition.

2.1 Set-up

Consider the closed-economy neoclassical growth model in continuous time tA unique consumption good is produced with a constant returns to scale aggregate production function

$$Y_t = (A_t H_t)^{\alpha} K_t^{\beta} L_t^{1-\alpha-\beta} \tag{1}$$

where $\alpha + \beta \leq 1$ and K_t denotes aggregate capital and $L_t \equiv L$ denotes land which is taken to be in fix supply. The aggregate human capital (or the aggregate amount of effective units of labor) is supplied inelastically and given by,

$$H_t = h_t N_t \tag{2}$$

where h_t denotes the individual level of human capital and N_t is the size of population. Technology (or total factor productivity) is captured by A_t.

In the short and medium run, improvements in health or life expectancy may influence total production by affecting technology, human capital and the size of population.[5] Denote by T_t the level of life expectancy. Following Acemoglu and Johnson (2007), the role of life expectancy for total factor productivity and human capital in reduced form is assumed to be iso-elastic

$$A_t = \overline{A} T^{\theta} \tag{3}$$

with $\theta \geq 0$ and

$$h_t = \overline{h} T_t^{\eta} \tag{4}$$

with $\eta \geq 0$. Reductions in mortality mechanically affect population size directly, since more people survive at each point in time, and indirectly if the likelihood of successfully reaching childbearing increases. Both effects imply that reduced mortality increases population size.[6] Restricting attention to iso-elastic specifications, these mechanical effects of mortality on population can be captured as

$$N_t = \overline{N} T_t^{\lambda} \tag{5}$$

or, in logs, $\ln N_t = \ln \overline{N} + \lambda \ln T_t$, with $\lambda > 0$. The level of log per capita income is then given by

$$\ln y_t = \alpha \ln A_t + \alpha \ln h_t - (1-\alpha) \ln N_t + B_t \tag{6}$$

where $B_t = \beta \ln K_t + (1-\alpha-\beta) \ln L_t$. Consider for the moment B_t as being independent from life expectancy which is a reasonable assumption in the short and medium run.[7] Using (3), (4) and (5) we

[5] Adjustments of physical capital are considered only over the long run, see the discussion below.

[6] Notice that both direct and indirect effects are at work in the short and medium run. The direct effect is only temporary, however, since it affects the level of population but not its rate of growth in the long run. Only the effect on the probability of childbearing is persistent (see discussion below).

[7] Restricting attention to the medium run without adjustment of physical capital is without loss of generality for our argument. Appendix C shows that considering full adjustment of the capital stock does not change the main results.

have

$$\ln y_t = \pi \ln T_t + C_t$$

where $C_t = B_t + \alpha \left(\ln \overline{A} + \ln \overline{h}\right) - (1-\alpha) \ln \overline{N}$ and

$$\pi = \alpha(\theta + \eta) - (1-\alpha)\lambda \gtreqless 0 \tag{7}$$

where π is the parameter linking life expectancy to per capita income. Equation (7) illustrates the main source of ambiguity concerning the role of life expectancy for income per capita. If life expectancy increases population size, then income per capita is reduced in the presence of fixed factors of production and decreasing marginal productivity of N. This is a negative Malthusian "population effect": $-(1-\alpha)\lambda < 0$. Life expectancy, however, may have a positive "human capital" effect which tends to increase income per capita: $\alpha(\theta + \eta) > 0$.

2.2 Fertility and Population Size

The theoretical prediction of an ambiguous effect of life expectancy on per capita income, reflected by (7), is derived under the assumption that fertility is constant, or at least unrelated to mortality. The evolution of population depends on the net rate of reproduction, NRR, which is defined as [8]

$$NRR = np(\varphi) \tag{8}$$

The variable n denotes the total fertility rate, TFR, which measures the number of children that would be born to an individual over her lifetime if that individual were to survive until the end of reproductive life. The variable φ denotes the mean age of reproduction which is also referred to as the mean length of a generation. The probability of surviving until the (mean) age of reproduction φ is denoted by $p(\varphi)$ and depends on the death rates in infant, child and young ages. Equation (8) states that the natural rate of reproduction depends on planned fertility n net of mortality up to fertile age, $1 - p(\varphi)$. Alternatively the NRR can be interpreted with reference to the whole population as the expected total number of children that the representative individual has during his fertile life. Consider an initial period $t_0 = 0$ characterized by population size N_0. Population in period $t \geq t_0$ can be expressed as,[9]

$$N_t = N_0 \left[NRR \frac{\Delta t}{\varphi} \right] \tag{9}$$

[8] The net reproduction rate, NRR, is the average number of daughters that would be born to a woman if she passed through her lifetime conforming to the age-specific fertility and mortality rates. For simplicity, we restrict to a model of asexual reproduction, and therefore treat the net reproduction rate as the number of offspring born to a representative individual of a cohort.

[9] Equivalently the evolution of population size could be expressed in terms of r which is the implicit rate of population growth that it is necessary to increase population size by an amount NRR in a period of time φ. In fact, equation (9), is the linear approximation the relationship between r and NRR initially formalized by Lotka (see Preston et al., 2001, p. 152).

which implies that popolation grows overtime proportionally to NRR and that in a spell of time of one generation, i.e. when $\Delta t = \varphi$, population grows exactly by a factor NRR. Making use of (8) and taking logs this implies,

$$\ln N_t = \ln N_0 + \ln(\Delta t/\varphi) + \ln n + \ln p(\varphi) \tag{10}$$

Mortality may affect the size of population by inducing changes in fertility, n, and by (mechanically) increasing the probability of surviving to mean age of childbearing, $p(\varphi)$. For simplicity, we keep assuming that the mechanical effects of population on life expectancy are reflected by an iso-elastic reduced form dependence, so that we can rewrite (10) as,

$$\ln N_t = [\ln N_0 + \ln(\Delta t/\varphi) + \ln n_t] + \lambda \ln T_t \tag{11}$$

where $\lambda \geq 0$ captures the joint mechanical effects of mortality on fertility $p(\varphi)$. Notice that if the total fertility rate n is constant, or independent from life expectancy, then equation (11) is qualitatively equivalent to the formulation (5), so that reductions in mortality lead to a larger rate of population growth. If this is the only effect at work then $\partial \ln N/\partial \ln T = \lambda > 0$.[10] In general, however, the total "population" effect implied by equation (11) depends on how the total fertility rate n is affected by life expectancy T, however. In fact, recalling the discussion of Figure 1, the response of fertility to mortality differs before and after the demographic transition. By its very definition, the demographic transition is identified by the reduction in net fertility rates r, which is closely linked to the (preceding) reduction in mortality rates. In the notation of our model, a demographic transition takes place only when population growth falls in response to a reduction of mortality (or an increase in life expectancy), $\partial \ln N/\partial \ln T < 0$. This is the case only when the reduction in fertility, $\ln n$, is larger than the mechanical effect on population size, $\lambda \ln T$. Once an economy enters the demographic transition, the reduction in fertility rates more than compensate the mechanical increase in population so that increases in life expectancy lead to lower rate of population growth. This implies that after the onset of the demographic transition the predicted effect of mortality reductions on per capita income is unambiguously positive. To obtain a more thorough understanding of the determinants of the net reproduction rate in general, and of n in particular, we now move on to study endogenous education and fertility choices.

2.3 A Simple Model of the Economic and Demographic Transition

Three main mechanisms that link changes in mortality to changes in fertility have been investigated in the literature. The first involves a precautionary demand for children by parents that care for the number of children that survive to adulthood in the presence of stochastic fertility and mortality, see Kalemli-Ozcan

[10] Notice that the effect of mortality on $p(\varphi)$ is mechanical and unrelated to fertility. Similarly one could explicit model the direct mechanical effect on the number of people surviving at each age. Notice, however, the direct effect only influences the level of population size but not its net growth rate (see Preston, Heuveline, and Guillot (2001).

(2003). This precautionary effect is likely to be stronger in the context of mortality affecting young adults than for child and infant mortality, because replacing children is easier than replacing adult offsprings.[11] The second mechanism works through a shift from the quantity of children to their quality in response to their increasing longevity, see, Soares (2005). The third mechanism links life expectancy to fertility through individuals' acquisition of their own human capital, coupled with differential fertility. Reductions in mortality increase the returns to investments in (own) education, as well as the (opportunity) cost of raising children. This creates a differential fertility effect which materializes in a negative relationship between parents education and their fertility, see Cervellati and Sunde (2005, 2007).

These channels are likely to be jointly at work, and to complement each other, in explaining the reduction in fertility following reductions in mortality during to the demographic transition. We next illustrate the argument by restricting attention to the differential fertility effect. We do this for two main reasons. First, this channel predicts a direct link between the observation of the demographic transition (reduction in mortality and fertility) and the economic transition (the acquisition of human capital).[12] Second, a unique prediction of this channel is that the reduction in fertility may take place with some delay after the reduction in mortality, since fertility reductions are observed only when the parent generation has completed their education and fertility. In fact, the consideration of a possible temporal mismatch between mortality reductions and fertility reductions may be important in interpreting empirical evidence over a time horizon of few generations.

Consider the following simple theory of the economic and demographic transition. At each point in time t there is a continuum of individuals alive with total mass N_t, which includes individuals of different. We identify cohort j by its date of birth. Members of a given age cohort j are homogeneous. To highlight the main point in the simplest way we restrict attention to a stable population model in which age specific implicit birth and death rates are constant overtime.[13] In a stable population model the growth rate of population can be non-zero in the long run and is independent of the age structure. A useful implication of this framework is that for any given distribution of age specific mortality rates we have $n_t = n_j$ and $T_t = T_j$.[14] We can therefore focus attention to the study of optimal total fertility rate n_j in a representative cohort j.

Individuals of cohort j derive utility from their (lifetime) consumption, c_j, and the number of their

[11] Modelling this effect requires considering that parents derive utility only from children surviving to adulthood (which depends on $p(\varphi)$) within a non-homothetic formulation of preferences.

[12] Furthermore this channel can be easily tested.

[13] Constant age-specific fertility and death rates are necessary conditions for a stable population in which the age structure is constant over time, as was formalized by Lotka in 1939, see Preston et al. (2001).

[14] This is convenient since it allows to directly map variables relating to cohorts j into variables relating to periods t. Notice that the age structure of the population is irrelevant for the main prediction that the population effect and human capital effect of mortality change after the demographic transition. Restricting to a stable population model is therefore without any loss of generality for the argument.

children n_j,[15]

$$U_j = c_j^{\gamma} n_j^{1-\gamma} \tag{12}$$

The main trade-off individuals face is about the use of available lifetime. They can invest their time in acquiring human capital, raising children, and producing income. Each agent is endowed with an amount of effective labor $\overline{h}$ which is available in the absence of any investment. Denote by $e \in [0, T_j]$ the time that agents spend in acquiring human capital, i.e. to increase their effective labor. We follow Cervellati and Sunde (2005) and assume that individuals are endowed with a basic level of human capital, $\overline{h}$ to which formal education adds in terms of effective human capital.[16] If no time is invested in education, then the level of effective labor is not increased. This is modelled as

$$h_j = \overline{h} e_j^{\eta} \text{ if } e_j > 0 \tag{13}$$

while $h_j = \overline{h}$ if $e_j = 0$ with $\eta \in (0, 1)$.

Denote by $k(T_j)$ the total lifetime cost of raising a child,

$$k(T_j) = k T_j^{x(e)} \,. \tag{14}$$

If $x(e) = 1$ then equation (14) simply means that raising a child has an opportunity cost equal to a share k of lifetime T_j. In order to capture the differential fertility associated to own education we assume that the lifetime (opportunity) cost of raising children increases for educated educated parents so that and $x(e) = 1$ if $e = 0$ while $x(e) = 1 + x$ if $e > 0$ with $x \in (0, 1)$. This simple modelling strategy implies that educated parents face a larger opportunity cost of fertility.[17] Taken together (13) and (14) imply that the relative costs associated with education and raising children is decreasing with life expectancy, i.e., greater life expectancy induces the acquisition of more education and leads to lower total fertility rates n_j.

Denote by $w_j(T_j)$ the average wage paid to each unit of effective human capital during the life of cohort j.[18] The lifetime budget constraint is,

$$c_j \leq w_j(T_j) h(e_j) [T_j - k(T_j) n_j - e_j] \tag{15}$$

[15]Utility formulation essentially follows Galor and Weil (2000), where the second component generates a link between generations that can be interpreted as a warm glow type of altruistic preferences. Individuals can perfectly smooth consumption as well as the utility from children over their life. But, crucially, they cannot perfectly substitute utility from their own consumption with utility derived from their offspring.

[16]This is formally equivalent to assuming that the production of human capital is characterized by a fix cost in terms of time, $\underline{e} \geq 1$, which has to be covered for education to be effective.

[17]Also notice that the acquisition of own education reinforces the switch from quantity to quality of children studied in Soares (2005) if educated parents face a lower cost producing educated children.

[18]This is given by

$$w(T) = \frac{\int_0^{\infty} w(a) p(a) \, da}{\int_0^{\infty} a p(a) \, da}$$

where $p(a)$ represents the probability of surviving until age a and life expectancy is given by $T = \int_0^{\infty} a p(a) \, da$.

where $w_j(T_j)\,h(e_j)T_j$ is the total potential lifetime income that would be earned by $h(e_j)$ units of effective labor for a lifetime T_j. The choice problem of agents in cohort j is given by,

$$\begin{aligned} \{n_j^*, e_j^*\} &= \arg\max_{n\geq 0, e\geq 0} c_j^{\gamma} n_j^{1-\gamma} \\ & \quad s.t.\ (13) \text{ and the budget constraint } (15) \end{aligned}$$

We next characterize the optimal total fertility rate and the optimal investments in human capital, and then derive the implications of reducing mortality for the patterns of the economic and demographic transition.

Lemma 1. *There is exists a unique level of life expectancy* $\underline{T} = \left[\frac{(\eta\gamma)^{\eta\gamma}}{(1+\eta\gamma)^{(1+\eta\gamma)}}\right]^{\frac{1}{2x(1-\gamma)-\eta\gamma}}$. *The equilibrium human capital and fertility are:*

$$h_j^* = \overline{h} \text{ and } n_j^* = \frac{1-\gamma}{k};\ \text{if } T_j \leq \underline{T}.$$

and

$$h_j^* = \overline{h}\left(\frac{\gamma\eta}{1+\gamma\eta}\right)^{\eta} T_j^{\eta} \text{ and } n_j^* = \frac{1-\gamma}{(1+\gamma\eta)\,k} T_j^{-x};\ \text{if } T_j > \underline{T}$$

Proof. See Appendix. □

The Lemma points out four implications of the model 1) life expectancy must be large enough to induce investments in human capital and reduction in total fertility rates; 2) the total fertility rate is, *ceteris paribus*, lower in absolute terms whenever the individual invests in education;[19] 3) education does not increase with T if $T_j \leq \underline{T}$, but education is increasing in T if $T_j > \underline{T}$; 4) life expectancy does not affect total fertility rates as long as $T_j \leq \underline{T}$, while total fertility decreases in life expectancy if $T_j > \underline{T}$.

Hence, the optimal choice of education and fertility depends on the whether the economy is characterized by a pre-transitional or post-transitional demographic regime. If mortality is too high and life expectancy too low individuals do not find it profitable to invest in education. In this case, their low life expectancy constrains individuals in their education choices.[20] If life expectancy is sufficiently high, optimal investments in education are positive. An increase in life expectancy leads to an increase in education investments and decreased fertility. Intuitively, improvements in life expectancy make investments in education relatively cheaper when mortality is sufficiently low, and lead to a substitution from fertility towards education.

Recall that with time invariant age specific death rates we have $r_t = r_j$ and $T_t = T_j$. The aggregate level of human capital can therefore still be expressed as in (2), $H_t = h_t N_t$ for any t. Using the equilibrium level of human capital from Lemma 1 we have,

$$H_t = \begin{cases} \overline{h} N_t & \text{if } \ T_t \leq \underline{T} \\ \overline{h}\left(\frac{\gamma\eta}{1+\gamma\eta}\right)^{\eta} T_j^{\eta} N_t & \text{if } \ T_t > \underline{T} \end{cases}$$

[19]In light of the literature, this is consistent with differential fertility across different education groups

[20]This mechanism would be at work in a pre-transitional phase also if subsistence levels in consumption are considered, see, e.g., Galor and Weil (2000) or de la Croix and Licandro (2007).

An economy experiences a demographic transition when the natural population growth rate, r, falls in response to reductions in mortality. From Lemma 1 and considering the expression for population size (11) we have,

Lemma 2. *A country undergoes the demographic transition when $\partial r/\partial T < 0$. Hence, a demographic transition takes place if $T_t > \underline{T}$, and if*

$$x > \lambda \,. \tag{16}$$

The previous Lemma states that a necessary condition for observing a demographic transition is that life expectancy is large enough. Condition (16) implies that, in order for a demographic transition to be observed, the reduction in total fertility rates, n, must be larger than the mechanical increase in population size, λ, as consequence of a reduction in mortality. To illustrate the role of the demographic transition we assume that condition (16) holds.[21]

2.4 Effects of Life Expectancy on Population, Human Capital and Income

Recall the expression for log per capita income, (6),

$$\ln y_t = \alpha \ln A_t + \alpha \ln h_t - (1-\alpha) \ln N_t + B_t$$

where $B_t = [\beta \ln K_t + (1-\alpha-\beta) L_t]$. Substituting for expression for population size at t, (11), we have

$$\begin{aligned} \ln y_t &= \alpha \ln \overline{A} + \alpha\theta \ln T_t + \alpha \ln h_t - (1-\alpha)(\ln n + \lambda \ln T_t) \\ &\quad -(1-\alpha)(\ln N_0 + \ln(\Delta t/\varphi)) + B_t \end{aligned}$$

From Lemma 1 it follows that the effect of T on $\ln n$ and $\ln h$ depends on whether the country is pre-transitional or post-transitional. Using condition (3), we have that in pre-transitional countries, i.e. with $T \leq \underline{T}$,

$$\begin{aligned} \ln y_t^{pre} &= \alpha \ln \overline{A} + \alpha\theta \ln T_t + \alpha \ln \overline{h} - (1-\alpha)[\lambda] \ln T_t \\ &\quad -(1-\alpha)[\ln N_0 + \ln(\Delta t/\varphi) + \ln(1-\gamma) - \ln k] + B_t \\ &= \zeta + \pi^{pre} \ln T_t - (1-\alpha)[\ln(\Delta t/\varphi)] \end{aligned} \tag{17}$$

where $\zeta = \alpha \left[\ln \overline{A} + \ln \overline{h}\right] - (1-\alpha)[\ln N_0 + \ln(1-\gamma) - \ln k] + B_t$ and

$$\pi^{pre} = \alpha\theta - (1-\alpha)\lambda < (>)\, 0 \,. \tag{18}$$

Hence, in pre-transitional countries the main effect of mortality is to increase population. The coefficient π^{pre} can be positive only if the externality of life expectancy on *TFP* is sufficiently large to more than compensate the negative population effect.

[21] Cervellati and Sunde (2007) present a more general theory in which lower mortality induces parents to spend more time on their own education, thereby devoting less lifetime to work with reduced fertility. They also study the conditions under which a demographic transition can take place and present evidence on the role of differential fertility and mortality.

Repeating the same reasoning for post-transitional countries with $T > \underline{T}_i$, we have

$$\begin{aligned} \ln y_t^{post} &= \alpha \ln \overline{A} + \alpha\theta \ln T + \alpha \ln \overline{h} + \alpha\eta \ln T_t + \alpha\eta \ln\left[\gamma\eta/\left(1+\gamma\eta\right)\right] \\ &\quad + (1-\alpha)\left[x-\lambda\right]\ln T_t - (1-\alpha)\left[\ln N_0 + \ln\left(\Delta t/\varphi\right) + \ln\left(1-\gamma\right) - \ln\left[\left(1+\gamma\eta\right)k\right]\right] + B_\tau \\ &= \zeta + \pi^{post}\ln T_t - (1-\alpha)\ln\left(\Delta t/\varphi\right) + \sigma \end{aligned} \tag{19}$$

where $\sigma = \alpha\eta \ln\left[\gamma\eta/\left(1+\gamma\eta\right)\right] + (1-\alpha)\ln\left[\left(1+\gamma\eta\right)\right]$. Consequently, the parameter of interest is given by

$$\pi^{post} = \alpha\left(\theta+\eta\right) + (1-\alpha)\left[x-\lambda\right] > 0 \tag{20}$$

where we assume that condition (16) holds. From condition (8) this implies that the net replacement rate decreases following the reduction in mortality, that is, the country enters the demographic transition. Notice that a drop in net fertility is only a sufficient but not a necessary condition for an increase in per capita income, however. In fact, π^{post} can be positive even if net fertility has not dropped yet due to the existence of a positive human capital effect $\alpha\left(\theta+\eta\right) > 0$.

We summarize the results in

Proposition 1. *An increase in life expectancy* T

- *has a negative/ambigous effect on log per-capita income,* $\partial \ln y/\partial \ln T < (>) 0$ *and a positive effect on the rate of population growth* $\partial r/\partial \ln T > 0$ *if* $T \leq \underline{T}$*;*
- *has positive effect on per-capita income,* $\partial \ln y/\partial \ln T > 0$ *and a negative effect on the rate of population growth* $\partial r/\partial \ln T < 0$ *if* $T_i > \underline{T}$*.*

Proof. Follows directly from Lemma 1, (18) and (20). □

Hence, the effect of longevity on per capita income goes in opposite directions in pre-transitional and post-transitional countries. In pre-transitional countries, the main effect of an increase in life expectancy is to increase population size rather than investments in human capital. The effect of lower mortality on population size can be expected to dominate the effect on human capital investments, and income per capita drops. In post-transitional countries, on the other hand, improvements in life expectancy lead to lower fertility and larger investments in human capital. As a result, per-capita income increases.

Finally notice that reductions in mortality are necessary, but not sufficient, conditions to induce a demographic transition. In fact, the larger the increase in T and the closer the initial level of life expectancy to $\underline{T}$ the more likely is that reductions in mortality trigger a transition and, consequently, an increase in per capita income. This last prediction is summarized in,

Proposition 2. *An increase in life expectancy increases the probability of observing an economic and demographic transition.*

Proof. Follows directly from Lemma 1. □

This simple model captures three features that are central to the recent literature on the economic and demographic transition. First, in pre-transitional economies reductions in mortality increase the rate of population growth but may affect investments in human capital little. Second, in post-transitional economies, in which investments in education are already positive, improvements in longevity lead to a reduction in fertility and to an increase in education investments. Third, increasing life expectancy may lead to a demographic transition, inducing positive (and increasing) investments in education and reversing fertility behavior. This is likely to happen only once life expectancy is large enough.

3 Estimation Framework and Empirical Implementation

The main testable predictions of the model are summarized in Propositions 1 and 2. Reductions in mortality have a positive effect on aggregate income but possibly an overall negative effect on per capita income and a positive effect on population growth in pre-transitional countries. In post transitional countries the effect on per capita income is positive while the rate of population growth is reduced. Finally, reductions in mortality increase the likelihood of observing a transition.

3.1 Estimation Framework

The estimation framework directly follows from the previous derivation. We restrict attention to investigating the medium-run effects of a change in life expectancy. That is we follow Acemoglu and Johnson (2007) in assuming that the total capital stock K remains fixed at its initial level, while life expectancy and all associated demographic variables change. Taking into account endogenous adjustments in capital stock leaves the main predictions unaffected.[22]

Denoting a country by subscript i, rewriting conditions (17) and (19) and adding an error term, we obtain

$$\ln y_{it} = \pi^{pre} \ln T_{it} + \zeta_i^{pre} + \mu_t^{pre} - (1-\alpha) \ln (\Delta t/\varphi) + \epsilon_{it}^{pre}$$

as expression for log per capita income in pre-transitional countries, that is with $T < \underline{T}_i$.[23] For post transitional countries $T > \underline{T}_i$ log income is given by

$$\ln y_{it} = \pi^{post} \ln T_{it} + \zeta_i^{post} + \mu_t^{post} - (1-\alpha) \ln (\Delta t/\varphi) + \sigma_i + \epsilon_{it}^{post}$$

The time invariant, but potentially country-specific, components of the expressions that are functions

[22]Allowing for full adjustment of aggregate capital to demographic changes by assuming e.g. a fixed proportion of consumed income being saved and bequeathed to the next generation, makes the effect of life expectancy greater ("more positive") as in Acemoglu and Johnson (2007). More importantly for our purposes, however, these extensions leave the opposite effects of life expectancy on per capita income for pre-transitional and post-transitional countries unchanged. See the Appendix.

[23]Notice that the threshold $\underline{T}$ depends on the fix costs of education $\underline{e}$ as well as the productivity parameter η.

of parameters are collected in country fixed effects ζ, while time varying factors common to all pre-transitional or post-transitional countries are collected in the μ^{pre} and μ^{post}. The coefficients $\pi^{pre}$and π^{post} are the respective parameters of interest.

From (17) we can express the change in log per capita income over the time horizon $\Delta t = t_2 - t_1$ in pre-transitional

$$\Delta \ln y^{pre} \equiv \ln y^{pre}_{t_2} - \ln y^{pre}_{t_1} = \pi^{pre} \Delta \ln T - (1-\alpha)\left[\ln(\Delta t_2) - \ln(\Delta t_1)\right] \tag{21}$$

and post-transitional countries,

$$\Delta \ln y^{post} \equiv \ln y^{post}_{t_2} - \ln y^{post}_{t_1} = \pi^{post} \Delta \ln T - (1-\alpha)\left[\ln(\Delta t_2) - \ln(\Delta t_1)\right] \tag{22}$$

where $\Delta \ln T \equiv \ln T_2 - \ln T_1$, $\Delta t_2 \equiv t_2 - t_0$ and $\Delta t_1 \equiv t_1 - t_0$.

The empirical specifications in terms of differences in log per capita income in pre-transitional and post-transitional countries in a time horizon Δt :

$$\Delta \ln y^{pre}_i = C + \pi^{pre} \Delta \ln T_i + \Delta \mu^{pre}_t + u^{pre}_{it} \tag{23}$$

$$\Delta \ln y^{post}_i = C + \pi^{post} \Delta \ln T_i + \Delta \mu^{post}_t + u^{post}_{it} \tag{24}$$

where the constant C also depends on the time spell and it is common to pre and post transitional countries (i.e. the term $-(1-\alpha)\left[\ln(\Delta t_2) - \ln(\Delta t_1)\right]$). Notice that possible changes overtime of σ_i are captured in the difference between $\Delta\mu^{post}_t$ and $\Delta\mu^{pre}_t$.

Recall that from our theory we would expect $\pi^{pre} \gtreqless 0$ and $\pi^{post} > 0$ and that the difference between the two essentially depends on the different human capital and fertility levels. In fact notice that if h is assumed to be generically iso-elastic in T as in (4) and n is taken to be unrelated to mortality, then (18) and (20) collapse to equation (7),

$$\pi^{pre} = \pi^{post} = \pi = \alpha(\theta + \eta) - (1-\alpha)\lambda \gtreqless 0\,.$$

This coincides with the coefficient of interest estimated using the estimation strategy of Acemoglu and Johnson (2007).

3.2 Data and Empirical Implementation

The main outcome variables of interest for the empirical investigation are life expectancy at birth, GDP, GDP per capita and population size.[24] The estimation of the causal effects of life expectancy uses the predicted mortality instrument proposed by Acemoglu and Johnson (2007). This instrument uses information on the reduction in mortality due to the epidemiological transition in the 1940s to predict the mortality decline. Three components of the epidemiological transition motivate this instrument: the wave

[24] The essential data sources are the UN Demographic Yearbook, and Maddison (2003), see Acemoglu and Johnson (2007) for details.

of drug and chemical innovations that lead to effective vaccines and medicines for major diseases (like vaccines for yellow fever, antibiotics, or chemicals like DDT); the establishment of international institutions like the WHO or UNICEF that facilitated the distribution of medical and public health technology; and, finally, the change in international values leading to a fast dissemination of medical knowledge. Importantly, as consequence of the global character of these innovations, the exclusion restriction that the instrument is exogenous to a particular country's level of development and does not affect income or population through other channels than life expectancy appears satisfied. The base sample consists of 47 countries for which all relevant data on the predicted mortality instrument, life expectancy, and outcome variables on the second stage are available for 1940 and 1980 (or 2000). In further investigations of the human capital channel we also use data on the population share without schooling and on the average years of schooling in the population of working age constructed by Soto and Cohen (2007).

Following Acemoglu and Johnson (2007), we estimate the models (23) and (24) in long differences, i.e., using panel data with only two observations per country, (1940 and 1980, or 1940 and 2000). The choice of a forty years horizon is justified by the fact that changes in fertility behavior and investments in human capital are likely to take place in the course of generations and, therefore, need a sufficiently long observation period to take place and to be detected. Changes in life expectancy at some point in time after 1940 are expected to affect fertility and education decisions in the following decades and should be captured by 1980 or 2000, but possibly not before.

According to Proposition 1, one should explicitly discriminate between countries which are pre-transitional and post-transitional in order to identify the effect of improvements in life expectancy. Ideally, one would consider if the reduced mortality treatment is applied to a pre or post transitional country during the observation period. In fact, the available data on fertility and realized mortality in principle does allow for an identification of the onset of the demographic transition without many ambiguities within a range of about ten years (see the discussion below). However, the data on the predicted mortality only contain country-specific instruments for the predicted change in mortality over the full period 1940-1980. We therefore lack information on the year (or decade) in which the instrument became effective, for example as specific drugs were implemented in a particular country and started having effects on mortality, however. This prevents us from fine-tuning the empirical analysis of the treatment on countries in the pre-transitional and post-transitional phases within the observation period.

Countries can be classified as pre-transitional or post-transitional according to several alternative criteria. As discussed above, the main distinctive feature of the demographic transition is the non-monotonic response of fertility to changes in life expectancy. In the demography literature, three main criteria are to identify the demographic transition, see, e.g., Chesnais (1992, p. 19). First, the onset of the demographic can be identified by the drop in fertility. This criterion identifies the initial period after which fertility, or the crude birth, rate exhibits a sustained decline. Second, a country is considered post transitional when mortality is sufficiently low. The usual threshold for life expectancy at birth is taken to be fifty years. Third, a country is post-transitional if the crude birth rates is sufficiently low. The typical threshold taken to be at 30 births per 1000 inhabitants. According to these criteria, we consider a country to be post-transitional if, by the onset of the epidemiological revolution in 1940, the following criteria are satisfied:

1. life expectancy at birth exceeds 50;
2. fertility or the crude birth rate has already exhibited a sustained decline;
3. the crude birth rate has fallen below the threshold of 30/1000.[25]

The first requirement is expected to be, on average, the least restrictive one in defining post-transitional countries because the drop in mortality generally precedes the drop in fertility (often substantially). The second requirement, in turn, is less restrictive than the third criterion since it classifies a country as post-transitional when the sustained fertility reduction has started although the process may not be complete (so that the crude birth rate may be still above 30/1000).

In the following we classify a country to be already post-transitional in 1940 by considering each one of the three requirements. To verify the second requirement we follow Reher (2004) and consider a country to be post transitional if it has entered the falling trend in terms of the 5-year averages of crude birth rates by the year 1935. It turns out that, in the sample of countries considered by Acemoglu and Johnson (2007), the application of each of the three different criteria leads to the same classification of countries. This classification delivers 25 pre-transitional and 22 post-transitional countries in 1940, i.e. before the onset of the epidemiological revolution. This classification also coincides with the one proposed by Reher (2004) using the second requirement only. The only difference concerns Greece, Ireland and New Zealand which are not classified in Reher (2004).[26] In our baseline classification we consider these three countries as post-transitional in 1940 since they clearly satisfy requirements 1 and 3. Nonetheless, for robustness we also use the alternative classification and consider them as pre-transitional (Criterion 2a). As a second robustness check we consider a more restrictive requirement and classify the countries as post transitional only if, together with requirements 1 and 2, the crude birth rate in 1940 is below 25/1000 (Criterion 3a). This is the most restrictive criterion and delivers 31 pre-transitional countries and only 16 post-transitional countries. In this case Argentina, Canada, Finland, the Netherland, New Zealand and Portugal are also classified as pre-transitional in 1940. For a graphical illustration of the demographic dynamics underlying these criteria, Figure 2 in the Appendix depicts the crude birth rates of all 47 countries in our sample over the time horizon 1940-2000.

Finally, for comparability we also use the classification of Acemoglu and Johnson (2007) for initial

[25] As discussed below, for robustness we also consider the threshold of 25/1000 which, however, is more restrictive and fragile to short term fluctuations in birth rates like, e.g., the baby boom.

[26] In the case of Greece the problem is the lack of reliable data before 1950. Ireland and New Zealand display a very flat profile of crude birth rates around 30/1000 after 1940 and a clear drop only in 1980 and 1960 respectively.

income groups in 1940 (rich and non-rich). This may also be justified in view of the fact that the economic and demographic transitions tend to be closely related. It is important to notice, however, that this classification does not directly relate to the theoretical argument presented above since the level of income does not perfectly coincide with the stages of the demographic transition. This implies that the classification in terms of rich and non rich countries cannot, strictly speaking, be interpreted in line of the theory presented above.[27] The classification of countries according to all these criteria is listed in Table 11 in the appendix.

We also apply the three classification criteria in 1980 (and 2000). This allows us to distinguish countries that entered the demographic transition (the fertility decline) during the observation window 1940-1980 (and 1940-2000), from countries that remained fully pre-transitional throughout the observation window. As expected all post-transitional countries in 1940 remain post transitional during the entire observation window, while some countries undergo the demographic transition (see below for more details on this classification). This information allows to investigate the prediction stated in Proposition 2 that reductions in mortality should facilitate the demographic transition in the countries that are still pre-transitional in 1940. Table 12 reports the baseline classification of the countries into post-transitional, intermediate (undergoing the transition between 1940 and 1980), and pre-transitional throughout 1940-1980, together with the two robustness classifications and the classification in rich and non rich countries.

4 Estimation Results

4.1 The Effect of Life Expectancy in Pre and Post transitional countries

From Proposition 1, improvements in life expectancy are expected to have different effects on GDP per capita in pre-transitional and in post-transitional countries. In post-transitional countries an increase in life expectancy leads to a reduction in both birth rates and net rates of population growth, and to an increase in education and income per capita. In pre-transitional countries, the birth rate is expected to be only weakly affected by increases in life expectancy, while the net rate of population growth should increase. As a result, the effect on GDP per capita is ambiguous or negative before the onset of the demographic transition.

Preliminary Analysis. Consider the dynamic evolution of the average crude death rates, crude birth rates and natural rate of population growth for post and pre transitional countries. Figure 3(a) depicts these variables for the countries which are already post transitional by 1940.[28] In these countries the death rates are about 12/1000 in 1940, decline by about 25 percent until 1960, and stabilize afterwards.[29]

[27] For example in 1940 several European countries are classified as non rich although they are clearly post-transitional.

[28] The lines reflect the average of the respective variables for countries classified as post-transitional according to the first column of Table 11. The shaded area represents 95 percent confidence intervals.

[29] In fact, life expectancy at birth keeps increasing although the crude death rate stabilizes due to the increase in the share of elderly in these countries. While the average life expectancy at birth in the entire sample is 49.3 years in 1940, average

The crude birth rate and the net rate of population growth decline by about 50 percent by 1980 and keep decreasing until year 2000.

Figure 3(b) plots the respective series for countries which are still pre-transitional in 1940. As expected, for this group of countries both death and birth rates are larger in 1940. The average crude death rate in 1940 is almost 20/1000 and displays a clear negative trend. Death rates are reduced by about 50 percent in 1970 when they reach 10/1000, which is about the average death rate of post transitional countries in 1940. After 1970, death rates drop by about 20 percent in the next twenty years and eventually tend to stabilize.[30] The crude birth rate is essentially unchanged until 1960 and displays a sizable decline only after 1970. Accordingly, the natural rate of population growth is initially increasing and starts declining during the 1960s. By 1990, the natural rate of reproduction is essentially the same as in 1940.

Figure 3 illustrates the different phases of the demographic transition. Reductions in mortality breed larger population growth until the onset of the demographic transition, but this trend is reversed afterwards turns negative for post-transitional countries. It is noteworthy that after 1970 the time series of pre-transitional countries resemble the those of countries which are already post-transitional in 1940.

To gain some visual impression of the time series patterns of the variables of interest, Figure 4 depicts the time series of average log income per capita and log population in post-transitional and pre-transitional countries, respectively. The figure illustrates the smaller increase in population size in post-transitional countries compared to pre-transitional countries. At the same time, the increase in log income per capita is less pronounced in pre-transitional countries. The difference in the slopes of the series of income and population for the two groups appears larger before 1980.

Figure ?? (a) plots the shares of population without any formal schooling in the two groups of countries. Panel (b) depicts the evolution of average years of schooling in the working age population, that is restricting attention to individuals aged from 15 to 64. Education improves in all countries both at the extensive margin (the share of people with some schooling) and at the intensive margin (reflected by average years of education). The data display a clear convergence between pre-transitional and post-transitional countries at the extensive margin (panel (a)). The average difference in terms of share of individuals with no schooling drops from above 30 percent to less than 10 percent with Improvements are sizable also in terms of average years of schooling although there is some convergence in years of schooling only after 1980. In fact while average years of schooling significantly increase from around 2 to above 6 in pre-transitional countries, it also increases from about 8 to 13 in post-transitional ones. This suggest a clear convergence at the extensive margin but that the gap at the intensive margin is still sizable in 2000.[31]

life expectancy in post-transitional countries equals 61.2 years. By 1980, overall average life expectancy has increased to 67.6 years, while in post-transitional countries, life expectancy is 73.7.

[30] Average life expectancy at birth in pre-transitional countries equals 38.8 years in 1940, and 62.3 years in 1980.

[31] The fact that the demographic transition is typically associated to the change in the composition of the population

It is noteworthy that the dynamic evolution of average years of schooling in the two groups of countries is similar to the one of GDP per capita in Figure ??. Notice that the lack of convergence in years of schooling and GDP per capita despite the change in the education composition of the population is associated to the larger population growth in pre-transitional countries, see Figure 3 panel (b).

Figure ?? reports the scatterplot of the relationship between predicted mortality reductions and changes in life expectancy, log population and GDP per capita from 1940 to 1980. Notice that predicted mortality is a negative variable. Panel (a) graphically illustrates the fact that larger predicted mortality reductions are indeed positively correlated to changes in life expectancy in both pre and post transitional countries. Panel (b) shows that log population is low and decreasing with predicted mortality reductions in post transitional countries while it is remains large in pre-transitional countries. Panel (c) shows that the changes in GDP per capita are large and increasing in predicted mortality in post transitional countries while are lower and decreasing in predicted mortality in pre-transitional countries.

As a first empirical investigation of the effect of life expectancy we present OLS results for log GDP per capita as dependent variable in Table 1. Panel (A) collects the results for the long panel 1940-1980, while Panel (B) shows results over the longer horizon 1940-2000. The overall coefficient of life expectancy obtained for the entire sample is negative, irrespective of the time horizon, as is shown in column (1). However, when splitting the sample into pre-transitional and post-transitional countries, the effect is generally negative and fairly weak for pre-transitional countries, but positive and highly significant for post-transitional countries. This pattern emerges for the different classification criteria, and over both time horizons. The pattern is opposite when considering log population as dependent variable, see Table 2, since life expectancy is positively associated to population growth in pre-transitional countries. The correlation is negative (and non significantly) in post-transitional countries. These correlations provide a first indication of the predicted different effects depending on the onset of the demographic transition. Of course, these findings have to be interpreted with caution for endogeneity problems. In order to circumvent this problem, we adopt the identification strategy based on the predicted mortality change thanks to the epidemiological transition as instrument, suggested by Acemoglu and Johnson (2007). Reduced form estimates using this instrument rather than log life expectancy as primary regressor of interest reveal that the pattern of the OLS results is likely to translate into causal effects.[32]

Causal Effect of Life Expectancy on Income and Population. Table 3 presents the main results concerning the causal effect of life expectancy for GDP per capita as dependent variable using the predicted mortality change instrument. Again, panel (A) contains results for the base sample with observations in 1940 and 1980, while Panel (B) contains results for the period 1940 to 2000. Column

rather than the average years of schooling has bees studied in more details in Cervellati and Sunde (2007).

[32]See Tables 13 and 14 in the Appendix for the corresponding reduced form estimates. When interpreting the estimates, it should be noted that the predicted mortality change is negative, because the epidemiological revolution reduced mortality. Larger negative changes in predicted mortality therefore correspond to larger increases in life expectancy.

(1) replicates the analysis by Acemoglu and Johnson (2007). The average effect of an increase in life expectancy, instrumented by predicted mortality reductions, on income per capita is negative. The reason for this finding can be seen in column (1) of the respective panels of Tables 4 and 5: An increase in life expectancy overall significantly increases the population, but only has a weak and insignificant effect on aggregate GDP.

Columns (2) and (3) show the results for the sub-samples of countries that are pre-transitional and post-transitional in 1940. We find a significant positive effect of life expectancy on GDP per capita for the post-transitional countries. This effect is almost twice as large, but of the opposite sign, compared to the average treatment effect. For pre-transitional countries, the effect of an increase in life expectancy on GDP per capita is negative. This effect is larger than the average treatment effect obtained with the pooled sample, but it is insignificant. Notice, however, that the standard errors of the coefficient estimates for this group of countries is quite large.

Columns (4) and (5) report the results using the alternative classification criterion 2a according to which Greece, Ireland and New Zealand are classified as pre-transitional in 1940. The same pattern emerges and this classification leaves the results for post-transitional countries unchanged. The negative effect on pre-transitional countries is now significant at the 10 percent level.

Columns (6) and (7) report the results for the sample with the most restrictive classification based on birth rates below 25/1000. The results are qualitatively identical. The effect of an increase in life expectancy is significantly negative only for pre-transitional countries, while it is significantly positive for post-transitional countries. Interestingly, the effects become quantitatively smaller the more restrictive the criterion for selecting post-transitional countries. The point estimate tend to converge towards the average treatment of -1.32. This is consistent with the fact that some of pre-transitional enter the fertility decline soon after 1940, with the consequence of a slow-down of population growth and a positive effect on income per capita.

Finally, when countries are classified in terms of their initial income levels, see columns (8) and (9), the results are qualitatively similar. As shown by Acemoglu and Johnson (2007), the effect of life expectancy on income per capita is significantly negative for the poor and middle income countries. For completeness we include also the treatment effect for rich countries which is positive. It should be noted, however, that strictly speaking these results cannot be directly interpreted in light of the theoretical argument on the role of the demographic transition. Nonetheless they provide another indication for the heterogenous effect of reduced mortality.

Panel B of Table 3 displays the results for the longer observation period 1940-2000. The results are essentially identical to those in panel A, but the coefficient estimates are generally larger. This implies that the results on the different effects of life expectancy on per capita GDP in pre-transitional and post-transitional countries is not driven by a too short observation period. Moreover, when estimating the treatment effects for pre-transitional and post-transitional countries in a nested model, one can perform an Chow-test of equality of the coefficient of life expectancy across the two sub-samples. The F-statistics of this test are depicted in the lower parts of the two panels of Table 3. They indicate that, with one exception where the estimate for the pre-transitional countries is very imprecise, the null of equal coefficients can be rejected at conventional levels.

Table 4 shows the effect of life expectancy on population. The effect appears to be overall negative in post-transitional countries and positive in pre-transitional countries, regardless of the classification criterion. The effects are also more significant over the longer period 1940-2000 (panel B). Finally, Table 5 shows that the effect of total GDP tends to be positive in post transitional countries and negative in pre-transitional countries, but the effect is usually not statistically significant.[33]

Compared to the OLS estimates the IV estimates display coefficient of the same sign which are slightly larger in absolute size and more significant.[34]

Causal effect of Life Expectancy on Education. In theory we expect a different effect of life expectancy on income per capita due to the correlation between investments in education and fertility. From Proposition 1, life expectancy leads to increasing education and lower fertility after the onset of the transition. Life expectancy is expected to have little causal effect on education until the onset of the transition. In other words life expectancy have stronger effects on education only when it successfully leads to reductions in fertility. The effect of life expectancy on education should be positive in countries which are post transition in 1940 but lower effects on education in countries which are pre-transitional in 1940. The effect should be stronger in these countries after the transition.

As preliminary investigation we run OLS estimates of the effect of life expectancy on education. Data for education are available from 1960. Table 6 reports the estimates of the effect of life expectancy on the share of population of more than 15 years of age without any formal schooling. Panel (A) reports the effect of changes in life expectancy in 1940-1980 on the change in the share of population without schooling in 1960-1980. The effect is negative and significant for all countries. The effect is stronger over the time horizon 1960-2000 as shown in panels (B) and (C) (which measures the change life expectancy in 1940-2000).

The respective IV estimates are reported in Table 7. The average effect is negative and significant over all time horizons. Panel (A) shows that by 1980 the effect is strong and significant only in post-transitional countries. In Panel (B) the effect turns positive by 2000 although it is slightly lower in pre-transitional than in post transitional countries.[35] Panel C reports the overall effect considering also

[33]In fact, when restricting attention to later observation periods, such as 1970-2005, the causal effect of life expectancy on GDP per capita becomes insignificant and the coefficient becomes very small for pre-transitional countries. This suggests that even countries that had not entered the demographic transition by 1940 but potentially later might eventually benefit from improvements in life expectancy in economic terms.

[34]The fact that the IV estimates are larger is a typical finding in the literature and is generally interpreted as suggesting a reduced incidence of attenuation bias due to measurement errors under IV (see p. 103.

[35]The only exception is column (7) which considers only the set of countries which are post transitional in 1940 according

the change in life expectancy until 2000. In this case the average effect is very similar for all countries. In line with the predictions, the findings suggest a delayed response of education to reductions in mortality in pre-transitional countries which is sizable only in the longer horizon.[36]

Overall, the findings of the effect of changes in life expectancy on GDP per capita, population and education, suggest that the cumulative effect of larger population growth over the period 1940-2000 dominates the possible positive effects associated to large education. This effect appears to be related to fact that on average these countries undergo the demographic transition shortly before 1980.

4.2 Life Expectancy and the Demographic Transition

According to Proposition 2, reductions in mortality may trigger a demographic transition if they lead to a sufficiently large level of life expectancy. The fact that some pre-transitional countries undergo a demographic transition during the observation period is suggested also by Figure 4(b).

Table 8 presents results for GDP per capita separately for the countries that are already post-transitional in 1940 (which are the same post-transitional countries as before), for countries undergoing the transition between 1940 and 1980, and for countries which remain pre-transitional until 1980. This is done to further investigate the role of the demographic transition and as a robustness exercise. Differently from the classification which is obtained by applying the criteria in 1940, however, the consideration of intermediate countries that undergo the transition between 1940 and 1980 differs depending on the different requirement stated above.[37] Correspondingly, we have three different classifications of intermediate and pre-transitional countries over the horizon 1940-1980 (or 1940-2000, respectively). We report the results for the classifications obtained applying each of the three criteria separately. Countries can be classified as intermediate or pre-transitional if they displays a life expectancy below 50 years in 1940, but above 50 years (or still below 50 years) in 1980 or 2000 (columns (1), (2) and (3)). Alternatively, we consider the observation of a sustained fertility decline (columns (4), (5) and (6)).[38] We consider crude birth rates below 30/1000 in columns (7), (8) and (9). Finally, for robustness, columns (10)-(12) display

to most restrictive criteria. The effect on the share of non educated individuals is low since this share is already very low in 1940 in these countries.

[36]Similar findings emerge when looking at the changes in the share of population with no schooling aged 25 and above. The results are reported in the Appendix in Table 16. The main difference is that the effect on pre-transitional countries is less significant even by 2000. This is expected since this estimate excludes all individuals aged 15 to 25 by 2000 which are the cohorts most likely affected by the reduction in fertility of the late seventies. Table 17 presents similar findings for average years of schooling in the population of working age (15-64).

[37]This is expected since as discussed above, the different criteria tend to capture different phases of the demographic transition. The criteria lead to same classification for 1940 since most of post transitional countries in 1940 did undergo the transition in the late nineteenth and early twentieth century.

[38]The requirement of sustained fertility decline is in line with to refined classification of Reher which classifies countries that entered the fertility decline between 1950 and 1964 as "followers", and countries that entered the fertility decline between 1965 and 1979 as "trailers". Countries for which the fertility decline only began after 1980 are classified as "latecomers".

the results for the alternative criterion 2a.

Panel A of Table 8 reports the results for GDP per capita in the period 1940-1980. Panel B extends the estimation until 2000. Finally, Panel C considers the effects on growth of GDP per capita in 1940-2000, classifying the demographic transitions which take place from 1940 to 2000. Table 9 reports the corresponding results for population as dependent variable. The findings are consistent with the previous results: post-transitional countries benefit most, in terms of GDP per capita, from an increase in life expectancy. The effect on GDP per capita for countries undergoing the transition in the period of observation is typically insignificant although it tends to be negative and larger in absolute size than the average effect for the full set of pre-transitional countries (as reported in Table 3). In fact, recall that at the onset of the transition fertility remains large. As illustrated in Figure 1 the natural population growth rate is largest for countries around the transition than for countries that are still fully pre-transitional. Therefore it is to expected that largest cumulative increase in population is displayed by countries undergoing the transition in the observation period. Table 9 shows that, irrespective of the classification, the increase in population growth is largest for countries undergoing the transition. This translates in the largest negative population effect on income per capita.

Finally, we investigate the prediction of Proposition 2 that increases in life expectancy might be causal for triggering the demographic and economic transition. We estimate linear probability models with the binary variable whether or not a country has undergone the demographic transition, using the same identification strategy based on the predicted mortality instrument as before. The dependent variable now takes value 1 if a country passes from being pre-transitional to being post transitional in 1980 (or 2000) and it takes value 0 otherwise. Note that the instrumentation strategy should still be valid in this context, as the exclusion restriction that the instrument (the predicted drop in mortality due to the epidemiological revolution) is exogenous to the outcome of interest (the probability to undergo the demographic transition) and affects the outcome through no other channel than through its effect on life expectancy, still appears satisfied.

The results are displayed in Table 10. Again, panel A contains results for undergoing the transition during the observation period 1940-1980, while panel B shows results for the period 1940-2000. Column (1) shows that an increase in life expectancy significantly increases the probability of a country that has life expectancy at birth below 50 years in 1940 makes a transition to life expectancy above 50 by 1980 (panel A) or by 2000 (panel B). Similar results obtain for a transition in terms of entering a phase of a sustained fertility drop, see column (2). Concerning a transition in crude birth rates, the effect is positive but insignificant over the shorter horizon, but positive and significant over the longer horizon. This might have to do with the fact that according to this criterion only 8 countries undergo the transition between 1940 and 1980, but 20 countries undergo the transition by 2000. Column (4) presents a robustness check based on the criterion of a country coded as pre-transitional by criteria 1, 2, and 3 making a transition of crude birth rates falling below $\frac{25}{1000}$. The coefficients are insignificant, however, most likely due to the small number of countries making the transition according to this fairly restrictive criterion. Finally, column (5) presents the results for the alternative criterion of a sustained fertility drop, 2a. Overall, the increase in life expectancy appears to significantly increase the probability that a country undergoes the demographic transition. This is especially true for the less restrictive criteria of reaching life expectancy above 50 and displaying a sustained fertility decline by 1980 or 2000. Fewer countries reach birth rates below 30/1000 in the respective observations period and according to this requirement the effect of increasing life expectancy on the probability of observing a transition is positive but insignificant.

5 Concluding Remarks

This paper has argued that the causal effect of life expectancy on income per capita is likely to differ systematically between countries that have undergone the demographic transition, and countries that are still pre-transitional. This implies that average treatment effects heavily depend on the sample composition − the shares of pre-transitional and post-transitional countries in the estimation sample. When replicating previous estimations separately for pre-transitional and post-transitional countries, we find, consistent with the theoretical predictions, that increases in life expectancy reduce income per capita in pre-transitional countries, but increase income per capita in post-transitional countries. Moreover, we find evidence supporting the second theoretical prediction, that larger life expectancy increases the likelihood of a country undergoing the demographic transition. The findings appear to be robust to applying alternative criteria for distinguishing pre-transitional and post-transitional countries, and over different time horizons.

The results have important implication for the interpretation of earlier findings in the literature. In particular, results that life expectancy has weak or even negative average treatment effects on income per capita might be driven by looking at samples with predominantly countries that are pre-transitional or about to undergo the demographic transition. Our estimates suggest that the effect of life expectancy was significant and positive for post-transitional countries in the period 1940-2000. Given that most countries by now have made progress towards a demographic transition, the average treatment effect of improvements in life expectancy on per capita income is likely to be positive for health innovations and mortality reductions applied nowadays. Moreover, the causal effect of life expectancy actually triggering the transition should be taken into consideration when analyzing the economic returns of health improvements.

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A Tables

Table 1: Effect of Life Expectancy on Log GDP Per Capita

Observation Period	**Panel (A): 1940-1980**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	-0.81***	-0.29	2.03***	-0.48	1.79***	-0.70*	1.73***	-1.17***	4.34***
	[0.26]	[0.65]	[0.44]	[0.44]	[0.52]	[0.38]	[0.46]	[0.38]	[0.92]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.14	0.01	0.35	0.03	0.27	0.07	0.29	0.16	0.40

Observation Period	**Panel (B): 1940-2000**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	-1.14***	-1.95	2.15***	-1.56**	1.92**	-1.23**	1.69**	-1.82***	1.72
	[0.29]	[1.14]	[0.67]	[0.75]	[0.82]	[0.50]	[0.69]	[0.44]	[2.41]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.18	0.17	0.23	0.18	0.19	0.14	0.18	0.27	0.07

Results from OLS regressions, the dependent variable is log GDP per capita, $\ln y$. Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007). Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 9B(3) and 9B(4), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 2: Effect of Life Expectancy on Log Population

Observation Period	**Panel (A): 1940-1980**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	1.62***	0.50	-0.53	1.13***	-0.28	1.05***	-0.12	1.86***	-3.00
	[0.18]	[0.38]	[0.42]	[0.38]	[0.42]	[0.23]	[0.49]	[0.24]	[2.00]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.54	0.07	0.05	0.30	0.01	0.33	0.003	0.52	0.12

Observation Period	**Panel (B): 1940-2000**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	1.97***	0.33	-0.79	1.31**	-0.55	1.28***	-0.36	2.21***	-2.70
	[0.22]	[0.50]	[0.50]	[0.48]	[0.52]	[0.30]	[0.60]	[0.30]	[2.87]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.55	0.02	0.06	0.28	0.03	0.32	0.02	0.51	0.06

Results from OLS regressions, the dependent variable is log population, $\ln N$. Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007). Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 9B(3) and 9B(4), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 3: Causal Effect of Life Expectancy on Log GDP Per Capita

Observation Period	**Panel (A): 1940-1980**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	-1.32***	-5.45	2.28***	-2.35*	2.23***	-1.72**	1.79*	-2.35**	11.21*
	[0.36]	[5.48]	[0.67]	[1.35]	[0.74]	[0.69]	[0.94]	[0.79]	[5.79]
Number of countries	47	25	22	28	19	31	16	36	11
Shea Partial R^2	0.50	0.05	0.37	0.20	0.35	0.35	0.28	0.28	0.27
First Stage F-Stat.	47.3	1.2	5.5	5.4	4.8	14.3	3.4	13.8	3.7
F-Test: Equality of π		$p< 0.17$		$p< 0.01$		$p< 0.01$		$p< 0.02$	
Joint First Stage F-Stat.		1.95		8.81		9.33		6.00	

Observation Period	**Panel (B): 1940-2000**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	-1.51***	-5.28	2.74***	-3.14*	2.64***	-2.02**	1.83***	-2.68***	14.25
	[0.41]	[3.22]	[0.75]	[1.62]	[0.87]	[0.92]	[0.79]	[0.96]	[9.99]
Number of countries	47	25	22	28	19	31	16	36	11
Shea Partial R^2	0.61	0.22	0.41	0.37	0.39	0.49	0.33	0.41	0.11
First Stage F-Stat.	60.2	5.7	6.5	10.9	5.8	23.0	4.2	21.8	2.0
F-Test: Equality of π		$p< 0.02$		$p< 0.01$		$p< 0.01$		$p< 0.09$	
Joint First Stage F-Stat.		5.95		9.88		10.15		3.11	

Results from 2SLS regressions, the dependent variable is log GDP per capita, $\ln y$, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007), the results replicate their results in Table 9B(1) and Table 9B(2), respectively. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 9B(3) and 9B(4), respectively. F-Tests of the null of equality of π are Chow tests of equality of coefficients in the two sub-samples, conducted in a nested specification, joint F-statistics for the first stage of these specifications are also reported. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 4: Causal Effect of Life Expectancy on Log Population

Observation Period	Panel (A): 1940-1980								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	1.67***	-0.06	-1.14*	1.31	-1.09	1.07**	-0.52	2.04***	0.52
	[0.34]	[1.73]	[0.57]	[0.88]	[0.63]	[0.48]	[0.56]	[0.67]	[6.33]
Number of countries	47	25	22	28	19	31	16	36	11
Shea Partial R^2	0.50	0.05	0.37	0.20	0.35	0.35	0.28	0.28	0.27
First Stage F-Stat.	47.3	1.2	5.5	5.4	4.8	14.3	3.4	13.8	3.7

Observation Period	Panel (B): 1940-2000								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	1.96***	0.54	-1.61**	1.51*	-1.58*	1.34***	-0.85	2.19***	0.22
	[0.36]	[1.12]	[0.75]	[0.76]	[0.81]	[0.48]	[0.78]	[0.62]	[12.3]
Number of countries	47	25	22	28	19	31	16	36	11
Shea Partial R^2	0.61	0.22	0.41	0.37	0.39	0.49	0.33	0.41	0.11
First Stage F-Stat.	60.2	5.7	6.5	10.9	5.8	23.0	4.2	21.8	2.0

Results from 2SLS regressions, the dependent variable is log population, $\ln N$, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007), the results replicate their results in Table 9B(1) and Table 9B(2), respectively. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 8A(3) and 8A(4), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 5: Causal Effect of Life Expectancy on Log GDP

Observation Period	Panel (A): 1940-1980								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	0.31	-5.89	1.14	-1.17	1.15	-0.72	1.26	-0.39	11.73
	[0.50]	[6.47]	[0.71]	[1.58]	[0.78]	[0.87]	[0.84]	[0.93]	[10.8]
Number of countries	47	25	22	28	19	31	16	36	11
Shea Partial R^2	0.50	0.20	0.35	0.35	0.28	0.05	0.37	0.28	0.27
First Stage F-Stat.	47.3	1.2	5.5	5.4	4.8	14.3	3.4	13.8	3.7

Observation Period	Panel (B): 1940-2000								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log life expectancy	0.42	-4.91*	1.13	-1.71	1.06	-0.74	0.99	-0.55	14.47
	[0.37]	[2.55]	[0.89]	[1.35]	[1.04]	[0.78]	[0.83]	[0.78]	[16.9]
Number of countries	47	25	22	28	19	31	16	36	11
Shea Partial R^2	0.61	0.41	0.41	0.37	0.39	0.49	0.33	0.22	0.11
First Stage F-Stat.	60.2	6.5	21.8	10.9	5.8	23.0	4.2	5.7	2.0

Results from 2SLS regressions, the dependent variable is log GDP, $\ln Y$, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007), the results replicate their results in Table 9B(1) and Table 9B(2), respectively. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 9A(3) and 9A(4), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 6: Effect of Life Expectancy on Population Share Without Schooling

Observation Period	Panel (A): Schooling 1960-1980, Life Expectancy 1940-1980						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.43***	-0.05	-0.46***	-0.26**	-0.47***	-0.34***	-0.37***
	[0.06]	[0.14]	[0.12]	[0.11]	[0.15]	[0.08]	[0.07]
Number of countries	45	23	22	26	19	29	16
R^2	0.53	0.004	0.63	0.17	0.60	0.29	0.67

Observation Period	Panel (B): Schooling 1960-2000, Life Expectancy 1940-1980						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.81***	-0.27	-0.70***	-0.58***	-0.71**	-0.69***	-0.51***
	[0.08]	[0.22]	[0.24]	[0.16]	[0.29]	[0.12]	[0.13]
Number of countries	45	23	22	26	19	29	16
R^2	0.63	0.05	0.56	0.29	0.53	0.42	0.58

Observation Period	Panel (C): Schooling 1960-2000, Life Expectancy 1940-2000						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.73***	-0.46***	-0.69***	-0.62***	-0.68**	-0.67***	-0.50***
	[0.06]	[0.16]	[0.22]	[0.09]	[0.26]	[0.08]	[0.11]
Number of countries	45	23	22	26	19	29	16
R^2	0.72	0.19	0.57	0.45	0.54	0.55	0.59

Results from OLS regressions, the dependent variable is the percentage of the population aged 15 or over without schooling. Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country. Panel (A) displays results for changes in the share without schooling 1960-1980 on changes in life expectancy 1940-1980; panel (B) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-1980; Panel (C) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-2000. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 7: Causal Effect of Life Expectancy on Population Share Without Schooling

Observation Period	**Panel (A): Schooling 1960-1980, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.46***	0.63	-0.65***	-0.17	-0.68***	-0.36*	-0.49***
	[0.11]	[1.04]	[0.13]	[0.33]	[0.14]	[0.21]	[0.09]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.48	0.04	0.47	0.19	0.28	0.32	0.37
First Stage F-Stat.	43.5	0.8	5.5	5.8	4.8	13.2	3.4

Observation Period	**Panel (B): Schooling 1960-2000, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.95***	-0.46	-1.03***	-0.80**	-1.07***	-0.92***	-0.70***
	[0.13]	[1.01]	[0.25]	[0.35]	[0.28]	[0.22]	[0.15]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.48	0.04	0.47	0.19	0.28	0.32	0.37
First Stage F-Stat.	43.5	0.8	5.5	5.8	4.8	13.2	3.4

Observation Period	**Panel (C): Schooling 1960-2000, Life Expectancy 1940-2000**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.75***	-0.22	-0.94***	-0.54**	-0.97***	-0.68***	-0.63***
	[0.085]	[0.46]	[0.24]	[0.22]	[0.27]	[0.15]	[0.11]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.56	0.14	0.41	0.30	0.39	0.43	0.33
First Stage F-Stat.	54.1	3.4	6.5	8.8	5.8	19.8	4.3

Results from 2SLS regressions, the dependent variable is the percentage of the population aged 15 or over without schooling, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country. Panel (A) displays results for changes in the share without schooling 1960-1980 on changes in life expectancy 1940-1980; panel (B) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-1980; Panel (C) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-2000. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 8: Causal Effect of Life Expectancy on Log GDP Per Capita: Intermediate Countries

Panel (A): Observations 1940-1980, Criteria 1940-1980

Criterion	1: LEB > 50			2: Sustained Fert. Drop			3: CBR<30/1000			2a: Sustained Fert. Drop		
Sample	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log life expectancy	2.285***	-5.342		2.285***	-7.897	-2.020	2.285***	-1.685	-20.51	2.234***	-2.489	-2.02
	[0.665]	[5.460]		[0.665]	[10.73]	[1.304]	[0.665]	[0.887]	[84.65]	[0.736]	[1.632]	[1.304]
Number of countries	22	24		22	20	5	22	8	17	19	23	5
Shea Partial R^2	0.37	0.05		0.37	0.03	0.60	0.37	0.32	0.004	0.35	0.21	0.60
First Stage F-Stat.	5.49	1.14		5.49	0.63	8.69	5.49	3.84	0.06	4.85	4.75	8.69

Panel (B): Observations 1940-2000, Criteria 1940-1980

Criterion	1: LEB > 50			2: Sustained Fert. Drop			3: CBR<30/1000			2a: Sustained Fert. Drop		
Sample	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log life expectancy	2.742***	-5.273		2.742***	-7.415*	-0.484	2.742***	-7.958*	-3.461	2.642***	-3.670*	-0.484
	[0.747]	[3.247]		[0.747]	[4.100]	[0.502]	[0.747]	[3.706]	[4.401]	[0.866]	[1.929]	[0.502]
Number of countries	22	24		22	20	5	22	8	17	19	23	5
Shea Partial R^2	0.41	0.21		0.41	0.25	0.70	0.41	0.35	0.13	0.39	0.43	0.70
First Stage F-Stat.	6.48	5.64		6.48	5.19	6.54	6.48	5.96	1.93	5.82	10.17	6.54

Panel (C): Observations 1940-2000, Criteria 1940-2000

Criterion	1: LEB > 50			2: Sustained Fert. Drop			3: CBR<30/1000			2a: Sustained Fert. Drop		
Sample	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log life expectancy	2.742***	-5.276		2.742***	-5.276		2.742***	-5.149***	2.837	2.642***	-3.139*	
	[0.747]	[3.192]		[0.747]	[3.192]		[0.747]	[1.581]	[47.93]	[0.866]	[1.622]	
Number of countries	22	25		22	25		22	20	5	19	28	
Shea Partial R^2	0.41	0.20		0.41	0.20		0.41	0.49	0.002	0.39	0.37	
First Stage F-Stat.	6.48	5.66		6.48	5.66		6.48	34.43	0.01	5.82	10.90	

Results from 2SLS regressions, the dependent variable is log GDP per capita, $\ln y$, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panels (B) and (C), respectively. All specifications include a full set of year and country fixed effects. Classification criteria are applied in 1940 and 1980 for panels (A) and (B), and in 1940 and 2000 in panel (C). Classification of Post-Transitional in 1940 in columns (1) to (9) is according to criteria 1, 2, and 3 (life expectancy at birth above 50, sustained fertility drop, crude birth rate below 30/1000) as discussed in the text. Intermediate countries are defined as passing the respective criterion (criterion 1, life expectancy at birth above 50 in column (2), criterion 2, sustained fertility drop in column (4), and criterion 3, crude birth rate below 30/1000 in column (6)) by 1980 (panels A and B) or 2000 (panel C). Columns (10)-(12) include comparable results for re-coding three countries concerning the sustained fertility drop (criterion 2a). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 9: Causal Effect of Life Expectancy on Log Population: Intermediate Countries

Observation Period	Panel (A): Observations 1940-1980, Criteria 1940-1980											
Criterion	1: LEB > 50			2: Sustained Fert. Drop			3: CBR<30/1000			2a: Sustained Fert. Drop		
Sample	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log life expectancy	-1.143*	-0.025		-1.143*	0.276	-0.197	-1.143*	1.606	-6.868	-1.088	1.556	-0.197
	[0.569]	[1.775]		[0.569]	[2.368]	[1.019]	[0.569]	[1.490]	[27.55]	[0.629]	[1.036]	[1.019]
Number of countries	22	24		22	20	5	22	8	17	19	23	5
Shea Partial R^2	0.37	0.05		0.37	0.03	0.60	0.37	0.32	0.004	0.35	0.21	0.60
First Stage F-Stat.	5.49	1.14		5.49	0.63	8.69	5.49	3.84	0.06	4.85	4.75	8.69

Observation Period	Panel (B): Observations 1940-2000, Criteria 1940-1980											
Criterion	1: LEB > 50			2: Sustained Fert. Drop			3: CBR<30/1000			2a: Sustained Fert. Drop		
Sample	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log life expectancy	-1.615**	0.553		-1.615**	1.095	-0.247	-1.615**	2.854	-1.105	-1.583*	1.822**	-0.247
	[0.747]	[1.151]		[0.747]	[1.293]	[0.934]	[0.747]	[1.653]	[1.154]	[0.814]	[0.848]	[0.934]
Number of countries	22	24		22	20	5	22	8	17	19	23	5
Shea Partial R^2	0.41	0.21		0.41	0.25	0.70	0.41	0.35	0.13	0.39	0.43	0.70
First Stage F-Stat.	6.48	5.64		6.48	5.19	6.54	6.48	5.96	1.93	5.82	10.17	6.54

Observation Period	Panel (C): Observations 1940-2000, Criteria 1940-2000											
Criterion	1: LEB > 50			2: Sustained Fert. Drop			3: CBR<30/1000			2a: Sustained Fert. Drop		
Sample	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log life expectancy	-1.615**	0.539		-1.615**	0.539		-1.615**	0.634	2.008	-1.583*	1.511*	
	[0.747]	[1.121]		[0.747]	[1.121]		[0.747]	[0.824]	[22.08]	[0.814]	[0.761]	
Number of countries	22	25		22	25		22	20	5	19	28	
Shea Partial R^2	0.41	0.20		0.41	0.20		0.41	0.49	0.002	0.39	0.37	
First Stage F-Stat.	6.48	5.66		6.48	5.66		6.48	34.43	0.01	5.82	10.90	

Results from 2SLS regressions, the dependent variable is log population, $\ln N$, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panels (B) and (C), respectively. All specifications include a full set of year and country fixed effects. Classification criteria are applied in 1940 and 1980 for panels (A) and (B), and in 1940 and 2000 in panel (C). Classification of Post-Transitional in 1940 in columns (1) to (9) is according to criteria 1, 2, and 3 (life expectancy at birth above 50, sustained fertility drop, crude birth rate below 30/1000) as discussed in the text. Intermediate countries are defined as passing the respective criterion (criterion 1, life expectancy at birth above 50 in column (2), criterion 2, sustained fertility drop in column (4), and criterion 3, crude birth rate below 30/1000 in column (6)) by 1980 (panels A and B) or 2000 (panel C). Columns (10)-(12) include comparable results for re-coding three countries concerning the sustained fertility drop (criterion 2a). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 10: Effect of Life Expectancy on the Probability of Entering the Demographic Transition

Observation Period	Panel (A): 1940-1980				
Criterion	LEB > 50 (1)	Fert. Drop (2)	CBR< $\frac{30}{1000}$ (3)	CBR< $\frac{25}{1000}$ (4)	Sust.Fert.Drop (5)
Log life expectancy	2.637***	2.409***	0.602	-0.086	2.103***
	[0.345]	[0.447]	[0.421]	[0.295]	[0.466]
Number of countries	47	47	47	47	47
Number of transitions 0/1	24	20	8	3	23

Observation Period	Panel (B): 1940-2000				
Criterion	LEB > 50 (1)	Fert. Drop (2)	CBR< $\frac{30}{1000}$ (3)	CBR< $\frac{25}{1000}$ (4)	Sust.Fert.Drop (5)
Log life expectancy	2.204***	2.204***	1.768***	0.41	1.960***
	[0.241]	[0.241]	[0.285]	[0.335]	[0.279]
Number of countries	47	47	47	47	47
Number of transitions 0/1	25	25	20	10	28

Results from 2SLS regressions, the dependent variable is 1 if a country is satisfies the classification for a post-transitional country and 0 if it does not satisfy the criterion; the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. Classification of Pre-Transitional and Post-Transitional countries in columns (1), (2), (3) and (4) is as explained in notes to Table 3; classification of transitions in column (5) involve transitions using the alternative sustained fertility drop criterion. Shea Partial R^2 is 0.50 (0.60), and the First Stage F-Statistic is 47.32 (60.24) in Panel A (B), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

B Proofs

Proof of Lemma 1. Recall that agents face the following maximization problem:

$$\max_{e\geq 0, n\geq 0} \left[w_j h_{jt}\left(T_{jt} - k\left(T_{jt}\right)n_{jt} - e_{jt}\right)\right]^{\gamma} \cdot \left[n_{jt}\right]^{(1-\gamma)}$$

where $h_{jt} = \overline{h}e_{jt}^{\eta}$ if $e_{jt} > 0$ and $h_{jt} = \overline{h}$ if $e_{jt} = 0$. We first investigate the optimal education and fertility decisions in an interior optimum. To proceed let us therefore assume for the moment that $e_{jt}^* > \underline{e}$ so that $h_{jt} = \overline{h}e_{jt}^{\eta}$. From the first order condition for education we have that

$$e_{jt} = \frac{\eta}{1+\eta}\left(T_{jt} - k(T_{jt})n_{jt}\right) = \frac{\eta}{1+\eta}\left(T_{jt} - kT_{jt}^{1+x}n_{jt}\right) \ . \tag{25}$$

Likewise, the first order condition for fertility delivers

$$n_{jt} = \frac{(1-\gamma)(T_{jt} - e_{jt})}{k(T_{jt})} = \frac{(1-\gamma)(T_{jt} - e_{jt})}{kT_{jt}^{1+x}} \ . \tag{26}$$

Substituting back, one obtains as optimal interior solutions

$$e_{jt}^* = \frac{\eta\gamma}{1+\eta\gamma}T_{jt} \tag{27}$$

for education and

$$n_{jt}^*|_{e_{jt}^*>0} = \frac{1-\gamma}{(1+\eta\gamma)k}T_{jt}^{-x} \tag{28}$$

for fertility, respectively. The respective expressions for the corner solution are

$$e_{jt}^* = 0 \tag{29}$$

for education and

$$n_{jt}^*|_{e_{jt}^*=0} = \frac{1-\gamma}{k}T_{jt}^{x} \tag{30}$$

for fertility, respectively.

Now notice that a positive level of education is optimal if and only if the indirect utility that arises from the interior solution is larger than the indirect utility that arises from the corner solution,

$$e_{jt}^* > 0 \Leftrightarrow U\left(e_{jt}^* > 0, n_{jt}^*|_{e_{jt}^*>0}\right) > U\left(e_{jt}^* = 0, n_{jt}^*|_{e_{jt}^*=0}\right) \ .$$

Substituting the respective optimal solutions and simplifying, one can show that the solution is indeed interior if and only if

$$T_{jt} > \underline{T} \equiv \left[\frac{(\eta\gamma)^{\eta\gamma}}{(1+\eta\gamma)^{(1+\eta\gamma)}}\right]^{\frac{1}{2x(1-\gamma)-\eta\gamma}} \ . \tag{31}$$

If, on the other hand, $T_{jt} < \underline{T}$, then the optimal interior investment in education (29) is not sufficient to provide an individual with as high a level of life time utility as that arising from supplying the baseline level of human capital.

C Derivation of Long-Run Effects

This appendix shows that the analysis of medium-run effects of life expectancy on aggregate and per capita income in the main text generalizes to a long-run scenario, in which the capital stock fully adjusts instead of remaining fixed at its initial level. We follow Acemoglu and Johnson (2007) in modeling this extension in the simplest possible way by making the usual assumption in OLG frameworks that capital is accumulated by the share of income that is not consumed but saved during work life by a generation in order to be consumed in old age. The savings constitute the capital stock available for production. Due to the log-utility specification, however, the optimal savings rate is independent of the interest rate that can be expected from production. Hence, savings will be a fixed share of consumable income, $S_i \in (0,1)$, which might differ across countries. Suppose also that capital depreciates at rate $\delta \in (0,1)$. Then the accumulation of physical capital in country i from time t to $t+1$ is $K_{it+1} = S_i Y_{it} + (1-\delta)K_{it}$. Restricting attention to steady states, we obtain $K_i = S_i Y_i/\delta$ as steady state level of capital. Using this the expressions for log per capita income that corresponds to expression (6), can be derived as

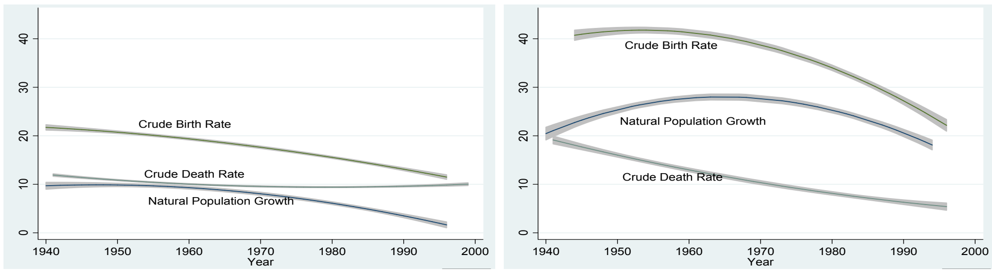
$$\ln y_{i\tau} = \frac{\alpha}{1-\beta}\ln A_{i0} + \frac{\beta}{1-\beta}\ln\frac{S_i}{\delta} + \frac{1-\alpha}{1-\beta}\ln N_{i0} + \frac{\alpha}{1-\beta}\ln h_{i\tau} + \frac{1-\alpha-\beta}{1-\beta}\ln L_i \quad (32)$$

$$(33)$$

Comparison with the medium-run effects discussed in the text reveals that considering long-run effects involving full adjustment of physical capital only add a proportional factor that is larger than 1. In other words, long-run effects merely augment the medium-run effects, without changing the main qualitative features of the model.

Figure 2: Demographic Transition: Crude Birth Rates

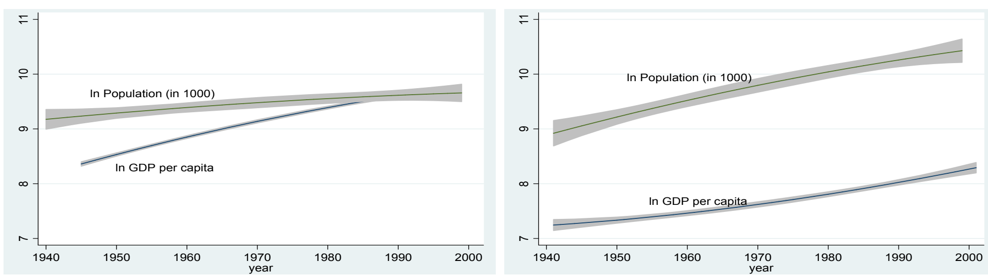
Figure 3: Demographic Dynamics in Pre-Transitional and Post-Transitional Countries



(a) Post-Transitional Countries (b) Pre-Transitional Countries

Classification according to criteria 1, 2, 3, see Table 11 and main text for detailed description of the classification criteria.

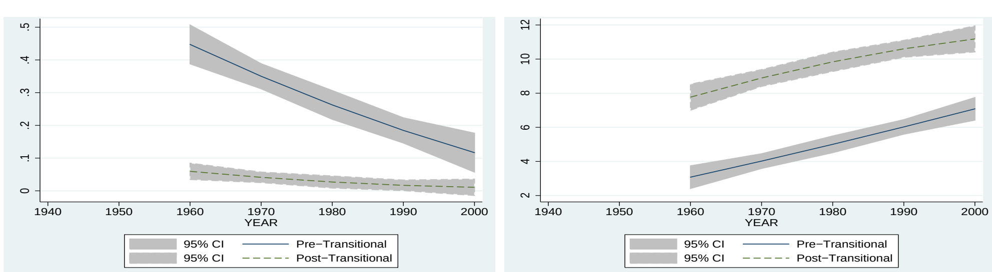
Figure 4: Income and Population Dynamics in Pre-Transitional and Post-Transitional Countries



(a) Post-Transitional Countries (b) Pre-Transitional Countries

Classification according to criteria 1, 2, 3, see Table 11 and main text for detailed description of the classification criteria.

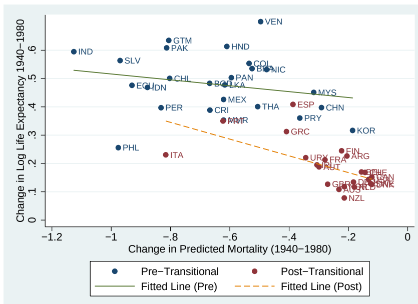
Figure 5: Education Dynamics in Pre-Transitional and Post-Transitional Countries



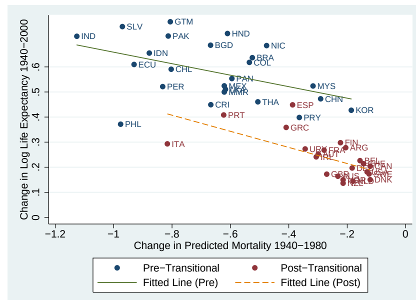
(a) % of Population > 15 Years with No Schooling (b) Average Years Schooling of Population 15 − 64

Classification according to criteria 1, 2, 3, see Table 11 and main text for detailed description of the classification criteria.

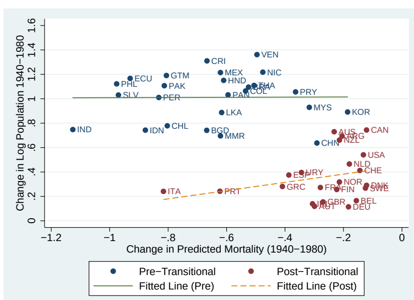
Figure 6: The Consequences of the Demographic Transition for Development



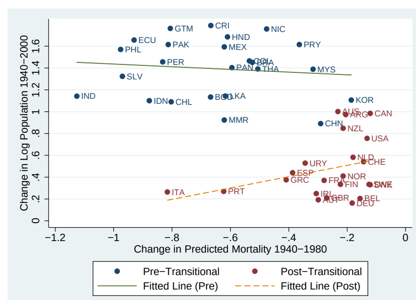
(a) Predicted Mortality Change and Change in Life Expectancy 1940-1980



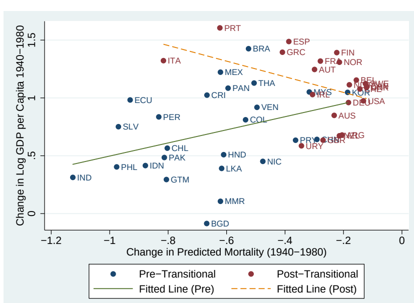
(b) Predicted Mortality Change and Change in Life Expectancy 1940-2000



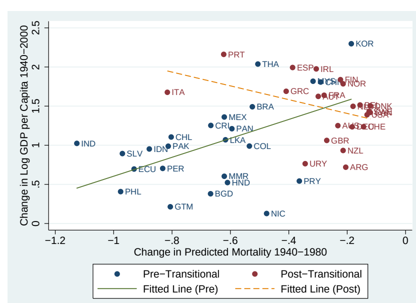
(c) Predicted Mortality Change and Change in log Population 1940-1980



(d) Predicted Mortality Change and Change in log Population 1940-2000



(e) Predicted Mortality Change and Change in log GDP per Capita 1940-1980



(f) Predicted Mortality Change and Change in log GDP per Capita 1940-2000

Classification according to criteria 1, 2, 3, see Table 11 and main text for detailed description of the classification criteria.

Table 11: List of Countries and their Classification

Post-Transitional according to:		Criteria 1, 2, 3 (1)	Criteria 1, 2a, 3 (2)	Criteria 1, 2, 3a (3)	Rich (4)
Argentina	ARG	1	1	0	0
Australia	AUS	1	1	1	1
Austria	AUT	1	1	1	0
Belgium	BEL	1	1	1	1
Bangladesh	BGD	0	0	0	0
Brazil	BRA	0	0	0	0
Canada	CAN	1	1	0	1
Switzerland	CHE	1	1	1	1
Chile	CHL	0	0	0	0
China	CHN	0	0	0	0
Colombia	COL	0	0	0	0
Costa Rica	CRI	0	0	0	0
Germany	DEU	1	1	1	1
Denmark	DNK	1	1	1	1
Ecuador	ECU	0	0	0	0
Spain	ESP	1	1	1	0
Finland	FIN	1	1	0	0
France	FRA	1	1	1	0
United Kingdom	GBR	1	1	1	1
Greece	GRC	0	1	1	0
Guatemala	GTM	0	0	0	0
Honduras	HND	0	0	0	0
Indonesia	IDN	0	0	0	0
India	IND	0	0	0	0
Ireland	IRL	0	1	1	0
Italy	ITA	1	1	1	0
Korea Republic	KOR	0	0	0	0
Sri Lanka	LKA	0	0	0	0
Mexico	MEX	0	0	0	0
Myanmar	MMR	0	0	0	0
Malaysia	MYS	0	0	0	0
Nicaragua	NIC	0	0	0	0
Netherlands	NLD	1	1	0	1
Norway	NOR	1	1	1	0
New Zealand	NZL	0	1	0	1
Pakistan	PAK	0	0	0	0
Panama	PAN	0	0	0	0
Peru	PER	0	0	0	0
Philippines	PHL	0	0	0	0
Portugal	PRT	1	1	0	0
Paraguay	PRY	0	0	0	0
El Salvador	SLV	0	0	0	0
Sweden	SWE	1	1	1	1
Thailand	THA	0	0	0	0
Uruguay	URY	1	1	1	0
United States	USA	1	1	1	1
Venezuela	VEN	0	0	0	0

List of 47 countries that represent the baseline sample in Acemoglu and Johnson (2007). "1" indicates if a country is coded as post-transitional according to the respective criteria, "0" corresponds to pre-transitional countries. Criteria 1, 2, 3 correspond to life expectancy at birth > 50, sustainded fertility drop and a crude birth rate $< \frac{30}{1000}$, respectively, by 1940. Criterion 2a codes Greece, Ireland and New Zealand as pre-transitional due to the unclear onset of their fertility drop. Criterion 3a considers a crude birth rate $< \frac{25}{1000}$ rather than $< \frac{30}{1000}$. "Rich" uses the classification proposed by Acemoglu and Johnson (2007). See also main text for description of the classification criteria.

Table 12: List of Countries and their Classification (Including Intermediate Countries)

		LE> 50			Sust. Fert. Drop			CBR< $\frac{30}{1000}$		
		Post	Intermediate	Pre	Post	Intermediate	Pre	Post	Intermediate	Pre
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Argentina	ARG	1	0	0	1	0	0	0	1	0
Australia	AUS	1	0	0	1	0	0	1	0	0
Austria	AUT	1	0	0	1	0	0	1	0	0
Belgium	BEL	1	0	0	1	0	0	1	0	0
Bangladesh	BGD	0	0	1	0	0	1	0	0	1
Brazil	BRA	0	0	1	0	1	0	0	0	1
Canada	CAN	1	0	0	1	0	0	0	1	0
Switzerland	CHE	1	0	0	1	0	0	1	0	0
Chile	CHL	0	1	0	0	1	0	0	1	0
China	CHN	0	1	0	0	1	0	0	1	0
Colombia	COL	0	1	0	0	1	0	0	0	1
Costa Rica	CRI	0	1	0	0	1	0	0	0	1
Germany	DEU	1	0	0	1	0	0	1	0	0
Denmark	DNK	1	0	0	1	0	0	1	0	0
Ecuador	ECU	0	0	1	0	1	0	0	0	1
Spain	ESP	1	0	0	1	0	0	1	0	0
Finland	FIN	1	0	0	1	0	0	0	1	0
France	FRA	1	0	0	1	0	0	1	0	0
United Kingdom	GBR	1	0	0	1	0	0	1	0	0
Greece	GRC	1	0	0	1	0	0	1	0	0
Guatemala	GTM	0	0	1	0	0	1	0	0	1
Honduras	HND	0	0	1	0	0	1	0	0	1
Indonesia	IDN	0	0	1	0	1	0	0	0	1
India	IND	0	0	1	0	1	0	0	0	1
Ireland	IRL	1	0	0	1	0	0	1	0	0
Italy	ITA	1	0	0	1	0	0	1	0	0
Korea Republic	KOR	0	1	0	0	1	0	0	1	0
Sri Lanka	LKA	0	1	0	0	1	0	0	0	1
Mexico	MEX	0	0	1	0	1	0	0	0	1
Myanmar	MMR	0	0	1	0	1	0	0	0	1
Malaysia	MYS	0	0	1	0	1	0	0	0	1
Nicaragua	NIC	0	0	1	0	0	1	0	0	1
Netherlands	NLD	1	0	0	1	0	0	0	1	0
Norway	NOR	1	0	0	1	0	0	1	0	0
New Zealand	NZL	1	0	0	1	0	0	0	1	0
Pakistan	PAK	0	1	0	0	1	0	0	0	1
Panama	PAN	0	0	1	0	1	0	0	0	1
Peru	PER	0	1	0	0	1	0	0	0	1
Philippines	PHL	0	0	1	0	1	0	0	0	1
Portugal	PRT	1	0	0	1	0	0	0	1	0
Paraguay	PRY	0	0	1	0	0	1	0	0	1
El Salvador	SLV	0	0	1	0	1	0	0	0	1
Sweden	SWE	1	0	0	1	0	0	1	0	0
Thailand	THA	0	0	1	0	1	0	0	0	1
Uruguay	URY	1	0	0	1	0	0	1	0	0
United States	USA	1	0	0	1	0	0	1	0	0
Venezuela	VEN	0	0	1	0	1	0	0	0	1

List of 47 countries that represent the baseline sample in Acemoglu and Johnson (2007). Classification according to criterion 1, LE> 50, in 1940 and in 1980 in column (1), LE< 50 in 1940 and LE> 50 in 1980 in column (2), and LE< 50 in 1940 and in 1980 in column (3). Classification according to criterion 2, sustained fertility drop, in 1940 and in 1980 in column (4), no sustained fertility drop in 1940 but sustained fertility drop in 1980 in column (5), and no sustained fertility drop in 1940 and in 1980 in column (6). Classification according to criterion 3, CBR< $\frac{30}{1000}$, in 1940 and in 1980 in column (1), CBR> $\frac{30}{1000}$ in 1940 and CBR< $\frac{30}{1000}$ in 1980 in column (2), and CBR> $\frac{30}{1000}$ in 1940 and in 1980 in column (3). See also main text for description of the classification criteria.

Table 13: Effect of Predicted Mortality Reduction on Log GDP Per Capita (Reduced Form)

Observation Period	**Panel (A): 1940-1980**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Predicted Mortality Change	0.59***	0.57***	-0.68**	0.60***	-0.60**	0.58***	-0.44**	0.72***	3.09***
	[0.15]	[0.20]	[0.26]	[0.19]	[0.25]	[0.17]	[0.17]	[0.20]	[0.47]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.18	0.13	0.16	0.15	0.15	0.15	0.09	0.18	0.71

Observation Period	**Panel (B): 1940-2000**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Predicted Mortality Change	0.84***	1.21**	-0.88**	1.20***	-0.78*	0.92***	-0.50*	1.15***	2.72***
	[0.20]	[0.49]	[0.39]	[0.41]	[0.39]	[0.31]	[0.24]	[0.32]	[0.64]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.20	0.25	0.15	0.27	0.14	0.19	0.07	0.24	0.51

Results from OLS regressions, the dependent variable is log GDP per capita, $\ln y$. Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007). Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 9B(3) and 9B(4), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 14: Effect of Predicted Mortality Reduction on Log Population (Reduced Form)

Observation Period	**Panel (A): 1940-1980**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Predicted Mortality Change	-0.74***	0.01	0.34**	-0.33	0.29*	-0.36**	0.13	-0.62***	0.14
	[0.15]	[0.18]	[0.15]	[0.22]	[0.14]	[0.16]	[0.12]	[0.21]	[1.70]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.29	0.001	0.08	0.08	0.07	0.12	0.02	0.17	0.001

Observation Period	**Panel (B): 1940-2000**								
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a		Income	
Sample	All	Pre	Post	Pre	Post	Pre	Post	Non-Rich	Rich
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Predicted Mortality Change	-1.09***	-0.12	0.52**	-0.58*	0.47**	-0.61**	0.23	-0.94***	0.04
	[0.21]	[0.25]	[0.20]	[0.30]	[0.19]	[0.22]	[0.17]	[0.29]	[2.34]
Number of countries	47	25	22	28	19	31	16	36	11
R^2	0.33	0.01	0.10	0.14	0.09	0.17	0.03	0.21	0.001

Results from OLS regressions, the dependent variable is log population, $\ln N$. Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country, for 1940 and 1980 in panel (A), and for 1940 and 2000 in panel (B), respectively. All specifications include a full set of year and country fixed effects. The samples in Panel (A) column (1) and Panel (B) column (1) correspond to the base sample of Acemoglu and Johnson (2007). Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). The classification in rich and non-rich countries in 1940 in columns (8) and (9) follows the classification by Acemoglu and Johnson (2007), the results in Panel (A) column (8) and Panel (B) column (8) replicate their results in Table 9B(3) and 9B(4), respectively. ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 15: Effect of Life Expectancy on Population Share Without Schooling

Observation Period	**Panel (A): Schooling 1960-1980, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.33***	0.07	-0.51***	-0.15	-0.51***	-0.24**	-0.46***
	[0.06]	[0.19]	[0.10]	[0.13]	[0.12]	[0.10]	[0.08]
Number of countries	45	23	22	26	19	29	16
R^2	0.37	0.01	0.67	0.05	0.63	0.15	0.68
Observation Period	**Panel (B): Schooling 1960-2000, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.76***	-0.01	-0.83***	-0.44**	-0.83**	-0.59***	-0.65***
	[0.08]	[0.19]	[0.24]	[0.18]	[0.30]	[0.14]	[0.15]
Number of countries	45	23	22	26	19	29	16
R^2	0.56	0.001	0.60	0.18	0.56	0.31	0.60
Observation Period	**Panel (C): Schooling 1960-2000, Life Expectancy 1940-2000**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.68***	-0.16	-0.81***	-0.46***	-0.80***	-0.56***	-0.64***
	[0.07]	[0.19]	[0.22]	[0.14]	[0.26]	[0.11]	[0.13]
Number of countries	45	23	22	26	19	29	16
R^2	0.62	0.03	0.61	0.26	0.57	0.40	0.61

Results from OLS regressions, the dependent variable is the percentage of the population aged 25 or over without schooling. Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country. Panel (A) displays results for changes in the share without schooling 1960-1980 on changes in life expectancy 1940-1980; panel (B) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-1980; Panel (C) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-2000. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 16: Causal Effect of Life Expectancy on Population Share Without Schooling

Observation Period	**Panel (A): Schooling 1960-1980, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.34***	0.96	-0.71***	0.01	-0.73***	-0.22	-0.62***
	[0.12]	[1.00]	[0.10]	[0.37]	[0.11]	[0.23]	[0.12]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.48	0.04	0.47	0.19	0.28	0.32	0.37
First Stage F-Stat.	43.5	0.8	5.5	5.8	4.8	13.2	3.4

Observation Period	**Panel (B): Schooling 1960-2000, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.87***	0.57	-1.20***	-0.47	-1.24***	-0.75**	-0.89***
	[0.17]	[1.24]	[0.24]	[0.50]	[0.28]	[0.31]	[0.18]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.48	0.04	0.47	0.19	0.28	0.32	0.37
First Stage F-Stat.	43.5	0.8	5.5	5.8	4.8	13.2	3.4

Observation Period	**Panel (C): Schooling 1960-2000, Life Expectancy 1940-2000**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-0.69***	0.27	-1.10***	-0.32	-1.12***	-0.55**	-0.80***
	[0.12]	[0.58]	[0.22]	[0.33]	[0.26]	[0.22]	[0.14]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.56	0.14	0.41	0.30	0.39	0.43	0.33
First Stage F-Stat.	54.1	3.4	6.5	8.8	5.8	19.8	4.3

Results from 2SLS regressions, the dependent variable is the percentage of the population aged 25 or over without schooling, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country. Panel (A) displays results for changes in the share without schooling 1960-1980 on changes in life expectancy 1940-1980; panel (B) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-1980; Panel (C) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-2000. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 17: Causal Effect of Life Expectancy on Average Years of Schooling

Observation Period	**Panel (A): Schooling 1960-1980, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	-1.72**	-12.9	-0.41	-3.54	-0.19	-2.58	-1.70
	[0.64]	[14.1]	[1.31]	[3.14]	[1.36]	[1.60]	[1.57]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.48	0.04	0.47	0.19	0.28	0.32	0.37
First Stage F-Stat.	43.5	0.8	5.5	5.8	4.8	13.2	3.4

Observation Period	**Panel (B): Schooling 1960-2000, Life Expectancy 1940-1980**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	0.85	-20.8	7.47**	-4.62	8.10*	-2.04	10.1*
	[1.24]	[22.7]	[3.34]	[5.35]	[3.88]	[2.88]	[5.01]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.48	0.04	0.47	0.19	0.28	0.32	0.37
First Stage F-Stat.	43.5	0.8	5.5	5.8	4.8	13.2	3.4

Observation Period	**Panel (C): Schooling 1960-2000, Life Expectancy 1940-2000**						
Classification Criterion		Criteria 1, 2, 3		Criteria 1, 2a, 3		Criteria 1, 2, 3a	
Sample	All	Pre	Post	Pre	Post	Pre	Post
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log life expectancy	0.67	-9.82	6.87**	-3.14	7.33**	-1.51	9.13**
	[0.97]	[7.80]	[2.86]	[3.56]	[3.23]	[2.13]	[4.06]
Number of countries	45	23	22	26	19	29	16
Shea Partial R^2	0.56	0.14	0.41	0.30	0.39	0.43	0.33
First Stage F-Stat.	54.1	3.4	6.5	8.8	5.8	19.8	4.3

Results from 2SLS regressions, the dependent variable is the average years of schooling in the population aged 15-64 that is not in education, the instrument is predicted mortality change (see text). Robust, small sample corrected standard errors are in brackets. All regressions are in long-difference specifications with two observations per country. Panel (A) displays results for changes in the share without schooling 1960-1980 on changes in life expectancy 1940-1980; panel (B) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-1980; Panel (C) displays results for changes in the share without schooling 1960-2000 on changes in life expectancy 1940-2000. Classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (2) and (3) is according to a country satisfying the three classification criteria 1 (life expectancy at birth in 1940 being above 50), 2 (sustained fertility drop by 1935) and 3 (crude birth rate in 1940 being below 30/1000) at the same time; the classification criterion 2 regarding the onset of the sustained fertility decline being prior to 1935 follows the classification of Reher (2004) in non-forerunner countries and forerunner countries, respectively. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (4) and (5) is according to criteria 1, 2a (same as 2 with Greece, Ireland and New Zealand coded as pre-transitional) and 3. The classification of Pre-Transitional in 1940 and Post-Transitional in 1940 in columns (6) and (7) is according to criteria 1, 2, and 3a (crude birth rate in 1940 being below 25/1000). ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.