# Demographic Dynamics and Long-RunDevelopment: Perspectives for the Secular Stagnation Debate*

Matteo Cervellati
University of Bologna
IZA, Bonn

Uwe Sunde
University of Munich
CEPR, London
IZA, Bonn

Klaus F. Zimmermann
IZA, Bonn
University of Bonn
CEPR, London

June 3, 2015

Draft prepared for the ***IMF Economic Review*** conference on "Secular Stagnation, Growth and Real Interest Rates" at the EUI, 18 - 19 June 2015

**Abstract**

*This paper takes a global perspective on the recent debate about secular stagnation. The analysis is motivated by the observation of the interplay between the economic and demographic transition that has occurred in the developed world over the past 150 years. To the extent that high growth rates in the past have partly been the consequence of changes during the economic and demographic transition, growth is likely to become more moderate as the transition is completed. At the same time, a similar transition is on its way in most developing countries, with profound consequences for the prospects for development in these countries, but also for global comparative development. The evidence presented here suggests that the long-run development dynamics have potentially important implications for the prospects of human and physical capital accumulation, and the question of secular stagnation.*

JEL-classification: C54, E10, J11, J 13, J18, N30, O10, O40

Keywords: secular stagnation, long-term development, income growth, demographic transition

* The authors thank Lukas Rosenberger for excellent research assistance and Vicki Finn for editorial comments.

# 1 Introduction

The experience of the financial crisis of 2007 and its fallout in terms of slow growth in Western countries has initiated an ongoing debate about medium-run macroeconomic outlooks. In a speech at the IMF in fall 2013, Larry Summers used the phrase "secular stagnation" when pointing out the surprising resistance of US GDP to return to its potential, despite substantial financial and monetary policy interventions. Instead, he argued, US GDP fell further behind its potential, employment did not increase substantially, inflation remained low, and capacity utilization did not become tight. Drawing parallels to Japan's development since the 1990s, this discussion raised concerns whether the US, or indeed the entire developed world, were up for "secular stagnation." Summers' discussion was mainly concerned about the appropriate macroeconomic policies. The possibility that the short-term real interest rate that is consistent with full employment might have fallen to zero or even to negative levels poses a challenge to traditional monetary policy. At the same time, this might call for a new role of fiscal policy, while the debt crisis put limits on the potential for creating fiscal stimuli.[1]

The debate about the "new secular stagnation hypothesis" has gained momentum and many facets have recently been added.[2] The core of the debate is about whether the real interest rate that is consistent with full employment has indeed fallen to zero or negative levels, focusing on the demand and supply of capital. At a broader level, the debate is concerned with the question of whether the delayed recovery recently experienced reflects a reduction in long-run growth potential (a prolonged drop in GDP below its long-run potential) , a phenomenon of delayed recovery from cyclical fluctuations, or a one-off crisis-related drop in potential output (Teulings and Baldwin, 2014b). Most of this debate has focused on capital markets and interest rates in the US economy, with some reflections on Europe and Japan.

This paper offers a broader view on these questions from the perspective of unified growth theory, according to which the demographic transition is the central mechanism

[1] See Summers (2014) for a detailed account of this view.

[2] See the recent book edited by Teulings and Baldwin (2014a), the session on "The Economics of Secular Stagnation" at the Allied Social Science Associations Conference 2015, and the OECD (2015).

behind the transition from stagnation to growth. Unified growth theories model the entire process of the endogenous exit from long-term economic stagnation and the following transition and convergence to balanced growth. Populations becoming increasingly more educated, wealthy, and older characterize this transition. Through a historical perspective, economic performance has been closely linked to demographic development. Modern economic growth typically accelerated at the same time as the demographic transition occurred, with its secular decline in mortality, the emergence of mass education and unprecedented human capital accumulation.

We adopt the perspective of unified growth theory to obtain new insights into the patterns of cross-country comparative development and to discuss the existence and determinants of a secular decline in growth. The analysis thereby extends that of Cervellati and Sunde (2015a), which demonstrated that a simulated prototype unified growth model not only matches the nonlinear long-run development dynamics of a given country but also provides important insights into the patterns of comparative development differences in the world today.

We put forward the argument that the explicit consideration of the long-term global development patterns may be necessary, or very useful at the least, to get a deeper understanding of the growth prospects in different countries and regions during the coming years and decades. The main hypothesis underlying our analysis is that the nonlinear dynamics of developed countries' long-run development also provide an appropriate qualitative description of less developed countries' development path, whose economic and demographic transition is delayed. As a first step, we revisit the stylized facts on income growth in a broader perspective both in terms of time horizon and units of observation. The cross-country panel data for the last fifty years suggest increasing incomes and relatively stable average growth rates worldwide. However, the patterns differ across different world regions. Advanced countries appear to have experienced a growth slowdown in the last two decades whereas developing countries in Latin America and Africa have not, or have seen less of a slowdown. These patterns are coupled with similar and uneven demographic development and education trends.

We then use insights from a simple prototype unified growth theory and show that the stylized patterns are compatible with the view that different countries follow similar (nonlinear) economic and demographic development paths but differ substantially in the timing of the takeoff from stagnation. The resulting conceptual framework is used to derive testable predictions for the evolution of mortality, human capital accumulation (and their interactions) and income growth during the different development phases. Results from cross-country panel regressions support the main predictions.

Our contribution relates to two papers by Gordon (2012, 2014a) emphasizing the importance of accounting for "headwinds" in US growth potential and growth prospects, meaning unfavorable changes in environmental conditions, particularly demographic changes, education, and globalization. These headwinds might unfold negative effects that could be stronger than productivity improvements. While some have criticized his papers for being too pessimistic about the scope for productivity improvements, his emphasis on the other headwinds has not resonated throughout the literature.[3] In this paper we complement and extend Gordon's US-focused view while taking a step towards a more global view of comparative development, with a specific focus on the role of demographic change and education from the unified growth theory perspective.

The results document consistent changes in income growth during the process of long-term development and suggest that the observation of a secular decline in growth in OECD countries can be related to the global process of long-term development. Additionally, these changes are not solely a business cycle phenomenon, or a matter of delayed recovery from the recent crisis. This perspective can help provide new light on the question of an existent growth slowdown in middle-income countries (see, e.g., Eichengreen, Park, and Shin, 2013) by focusing on the interplay between the economic and demographic transition and the emergence of nonlinearities in the development process. The analysis also suggests the need for further research on the global structural development process in the economic and demographic domains. The implications of this process will likely gain importance as the world continues to integrate in terms of trade, capital flows, and human migration. In short: integrating the short-term (business cycle) and the long-term (unified growth) perspective appears to be a needed, and potentially very fruitful, direction for academic research and policy analysis.

[3] See, e.g., the discussions by Gordon (2014b) and Mokyr (2014a, 2014b).

The paper is structured as follows. Section 2 gives an overview of the global economic and demographic development patterns. Section 3 presents the conceptual framework and derives empirical implications. Section 4 presents empirical evidence and Section 5 concludes.

# 2 Global Patterns of Economic and Demographic Development

As discussed in the Introduction, the recent debate on possible secular stagnation has mainly focused on developed countries, particularly the US, Europe and Japan. In this section we begin our analysis by documenting the stylized patterns of global economic and demographic development in the last half of the century.[4] Figure 1 plots the annual growth rates of GDP per capita for the world over the period 1950–2010, together with a 5-year moving average. The figure's first panel suggests that, from a global perspective, the average growth rate has been around 3 percent per year, with sizable variation during periods of global booms and recessions. However, there is no indication for an obvious downwards trend in growth over the last ten years. Overall average growth rates have been fairly stable over this long period and if anything, they have increased lately. Also, the variability in growth rates has not slowed down, in fact it has increased slightly during the last 15 years.

The second panel replicates the same exercise, but restricting attention to only developed countries (Europe and Western offshoots). In the developed countries, income growth indeed seems to have experienced a slowdown. In a global perspective this slowdown does not appear to be confined to the recent post-crisis period, even though the crisis has clearly accelerated it. Finally, the figure's bottom panels show the average growth rates for Latin America and Sub-Saharan Africa where, if anything, income growth appears to have accelerated in the last one or two decades, with a more visible trend in Africa. A very similar picture emerges for total factor productivity, as Figure 2 documents.

[4] The data are taken from the standard sources listed in Table 7 in the Appendix.

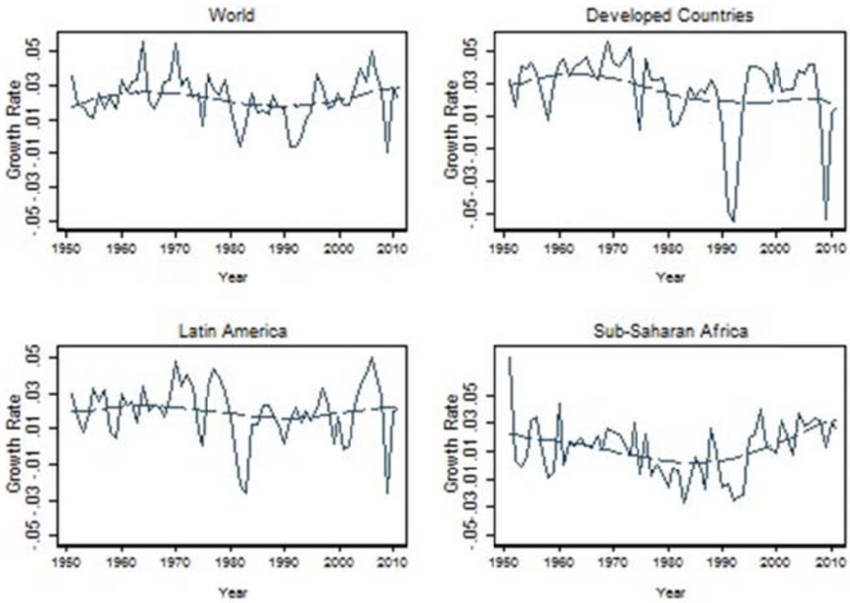



Figure 1: Global Growth Performance: GDP per capita

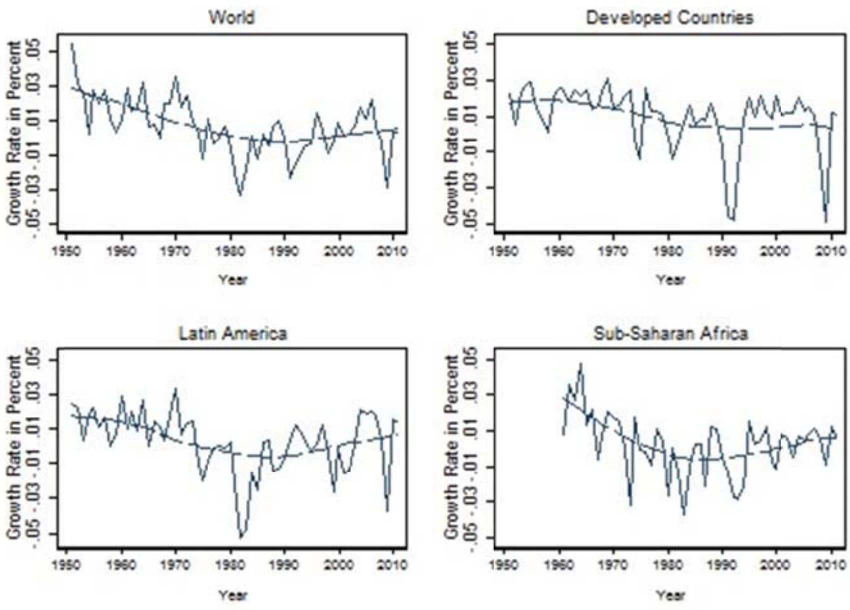
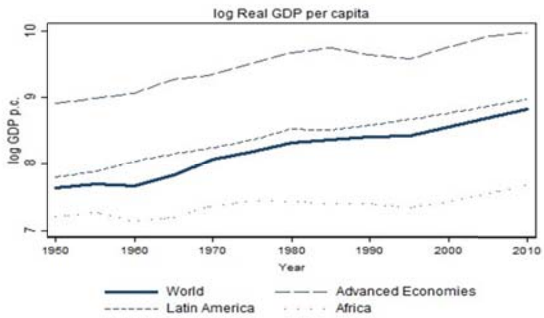
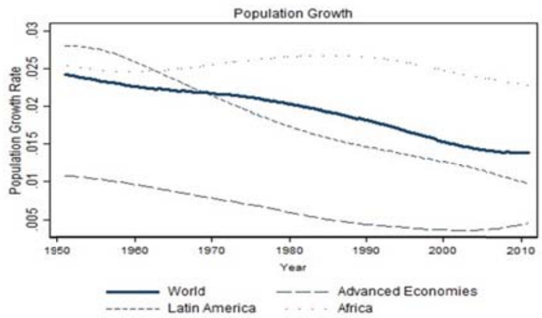



Figure 2: Global Growth Performance: TFP

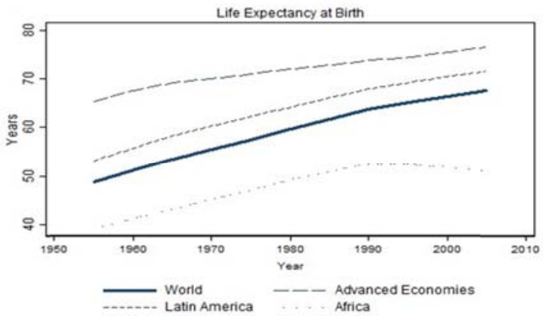
Taking a broader perspective of development, Figure 3 displays the trajectories of development in several different economic and demographic dimensions. Figure 3(a) provides a more long-run perspective of economic development and displays the trajectories of log GDP per capita in levels over the same time period from 1950 to 2010 (using 5-year averages). This figure illustrates that on average across the globe, incomes have been steadily increasing at least since around 1960. The increase is visible in the developed countries, which exhibit the highest levels of living standards, but it is also visible in Latin American countries. There is less development in Africa, where incomes are by far the lowest, even though there appears to be an upward tendency beginning in the mid-1990s.



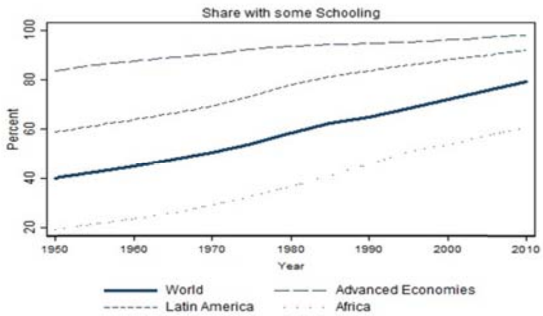

(a) Log Income per Capita




(b) Population Growth




(c) Life Expectancy at Birth




(d) Share Skilled

Figure 3: Global Development Patterns

Figure 3(b) complements the economic development by graphing the demographic dynamics in terms of population growth rates. While positive, world population growth has been slowing down since the 1960s, with more pronounced reductions since the 1980s. Population growth is lowest in developed countries, despite considerable immigration, and many of these have seen fertility fall below replacement levels. In Latin American countries, population growth rates were at high levels until the 1960s, when a downward trend began and has continued. In Africa, on the other hand, population growth rates are comparably high and have only recently begun to decline, mostly due to the beginning fertility transition, but also due to emigration. Taken together, the patterns in Figures 3(a) and 3(b) appear consistent with the view that economic development in terms of income levels began much earlier in Western countries than in other parts of the world, with developing regions such as Latin America and Africa exhibiting similar patterns, but with a substantial delay.

Another dimension of long-run development patterns refers to demographic rather than economic development. Figure 3(c) shows the improvements in life expectancy at birth over the period 1950–2005. At a global scale mortality has fallen across all ages, for men and women alike, over the past 40 years, with the most pronounced decline for mortality at young ages. Adult mortality has also fallen, mainly thanks to the epidemiological transition leading to better health technology and better access to health care and disease prevention. The figure shows this by plotting the standard aggregate measure of life expectancy at birth. When again considering different parts of the world, it is clear that the increase in longevity (like the increase in income) has been a global phenomenon. In OECD countries, life expectancy was already at the highest levels worldwide in the 1960s. Since then the increase in longevity has continued, but at a slower pace, in particular due to declines in mortality at older ages; infant and child mortality had already been approaching very low levels since the early 1990s.

Latin America displays a similar picture, but somewhat delayed. Adult as well as child and infant mortality were at substantially higher levels than in the OECD in 1970, but since then mortality has fallen substantially. Life expectancy has increased from just above 50 in the 1950s to around 70 today and child and infant mortality have converged to very low levels, yet not quite as low as in the OECD. Contrarily Africa shows a different picture: adult mortality rates were twice as high and child mortality almost four times as high as in the OECD in 1970.[5] Life expectancy was around 40 years in the late 1950s. Also the dynamics are different. Infant and child mortality have fallen substantially, but remain at levels many times higher than those in the OECD or even in Latin America. Adult mortality has not even shown a marked decline over the period 1970–2010, with the HIV/AIDS epidemic in the 1990s leading to an increase in adult mortality that is unparalleled in the world. This epidemic is mainly responsible for the slowdown in the increase in life expectancy in African countries, and even in the world, during this period.

[5] For additional evidence on gender-specific mortality and infant mortality rates, see Figure 6.

Figures 1, 3(a), 3(b), and 3(c) together illustrate the existence of similar patterns of economic and demographic development in different regions, with Western countries and African countries at the opposite extremes of the spectrum. Western countries have experienced a slowdown in economic development, population dynamics, as well as in health improvements; meanwhile the developing countries appear to be just beginning their transition, showing accelerating economic and demographic development.

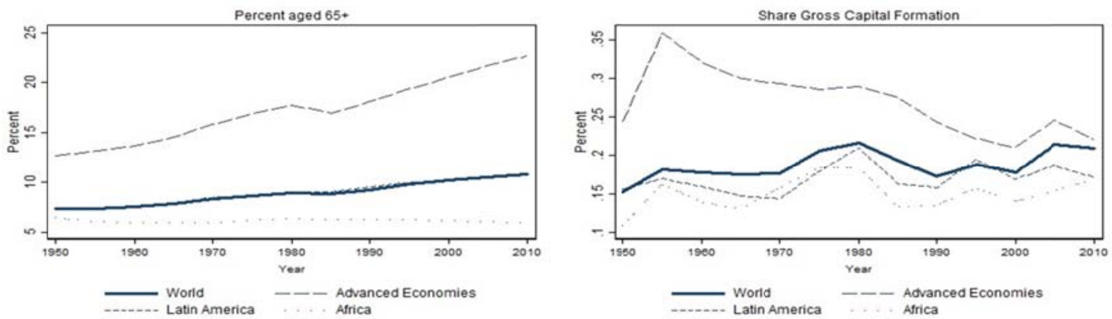
Historically, Europe's economic takeoff from stagnation to growth was closely linked not only to increased longevity and a slowdown in population growth, but also to an acceleration in education attainment. The global view replicates this pattern, with global economic and demographic development changes going hand in hand with acquiring education and human capital. Figure 3(d) displays this pattern using the population share aged 25 and older with some formal schooling as the basic measure of education. The figure documents a substantial increase in education at the global level. This is true for the developed countries, where in particular, the shares of adults with secondary and tertiary education have been increasing substantially over the past 50 years. Yet the dynamics in education appear to slow down towards the end of the observation window, with almost all individuals above the age of 25 having had some schooling, and the average schooling attainment is 12 years. In Latin America, the increase in education is even more pronounced. In Africa the education increase only began during the 1980s, and has continued at substantial speed, despite some attenuation as of late.

Very similar patterns emerge when looking at alternative measures of education.[6] When considering the developments of education in different parts of the world, the patterns closely parallel those in mortality and population dynamics. In the OECD countries, the share of adults without formal schooling had already been very low in the 1950s, but has since fallen to essentially zero. At the same time, even the share of adults with only primary education has been falling, while the shares with secondary or tertiary education have been increasing rapidly, with tertiary education exhibiting an almost exponential pattern. Education levels were much lower in Latin America in 1970. Also there, however, education has been increasing substantially. In Africa, the process is substantially delayed. Whereas the share of adults with no formal schooling has been decreasing over time, the share of adults with only primary education is still increasing.

[6] See Figure 7 in the Appendix.

Both secondary and tertiary education are on the rise, but the increase is still very moderate, particularly for tertiary education.

As countries undergo the demographic transition, the sustained increases in longevity, coupled with the reduction in population growth due to lower fertility, imply that the population ages. Figure 4(a) illustrates this age structure implication by plotting the old-age dependency ratio, i.e., the share of the population aged 65 and older. In parallel with the increase in life expectancy, old-age dependency ratios worldwide have been trending upwards since 1950. If anything, there is a slight acceleration, mainly due to the developed countries where the old-age dependency ratio has almost doubled over the past 65 years. In contrast, in Africa, where the demographic transition has barely been established, the old-age dependency ratio has been relatively stable at very low levels.




(a) Share of the Population Aged 65+ (b) Share of Gross Capital Formation

Figure 4: Old-age Dependency Ratios and Gross Capital Formation

A direct consequence of population aging is the greater need for resources to finance consumption at old ages. Intuitively, as populations age, larger fractions of income go to elderly consumption, reducing the scope for capital formation at the aggregate level. This can be seen in Figure 4(b), which depicts the share of gross capital formation (at current Purchasing Power Parity). While on average capital formation has been trending upwards at a global level, the developed countries exhibit a clear downward trend that reflects the increase in the old-age dependency ratio. Latin American and African countries, in contrast, exhibit an increasing trend in capital formation.

# 3 Patterns of Long-Run Development: Unified Growth and Delayed Transitions: A Conceptual Framework

How can we combine these empirical patterns in a coherent framework to address the secular stagnation question? This section's approach is to consider the long-run development process at the global level from the perspective of a prototype unified growth model of the economic and demographic transition. Unified growth models capture the underlying forces behind different dimensions of economic and demographic development, typically focusing on one country's time series evolution. What has been less appreciated in the literature is that, from the perspective of such a model, comparative development differences across the world can be seen as the consequence of delays in the transition along otherwise identical development paths. To illustrate this point we use Cervellati and Sunde's (2015a) calibrated version of the prototype unified growth model, which characterizes and simulates the endogenous evolution of income, demographic conditions (particularly mortality) and education over long time periods.

The analysis is based on a simple dynamic general equilibrium framework with inter-temporal spillovers. To fix ideas, we build on Cervellati and Sunde's (2015a) model, noting that the precise mechanisms behind the working of this model are not crucial for the argument and the following analysis. The basis is an occupational choice framework in which individuals decide to acquire skilled or unskilled human capital, as well as decide their fertility. Acquiring skills, as well as bringing up children in terms of basic needs and effort spent on educating the children, are time-intensive activities. However, longevity, the length of adult life, is limited (and individuals are aware of this). Since becoming skilled involves a strictly larger cost in terms of time than becoming unskilled, the returns for becoming skilled in terms of income must be sufficiently high for an individual to bear this investment. On the aggregate, skilled and unskilled human capital are used to produce a consumable commodity. The technology used in this production process is given, and wages for skilled and unskilled human capital are determined competitively.

The general equilibrium allocation is then given by aggregate conditions, reflected by longevity and technology, as well as by individual decisions. The population's skill choices and fertility decisions are mutually consistent with quantities and prices, in terms of aggregate stocks of skilled and unskilled human capital as well as the corresponding wages for skilled and unskilled labor. Due to the differential time cost for education, and because of declining marginal productivity of each input, it turns out that the equilibrium relationship between the share of skilled individuals and longevity is nonlinear. In particular, for low longevity, the share of skilled is small as a consequence of the time cost for becoming skilled; this implies that only a small part of the population receives sufficient lifetime earnings from becoming skilled, e.g., because they have higher cognitive skills and thus higher productivity when skilled. Consequentially, large increases in longevity are needed to induce larger and larger shares of the population to acquire skilled human capital. In this range, the equilibrium relationship between life expectancy and the share of skilled is convex. If longevity is large, decreasing relative marginal productivity of skilled human capital compared to unskilled human capital implies that increasingly larger improvements in longevity are needed to induce even higher population shares to become skilled. This implies a concave relationship between longevity and the share skilled, so that overall the equilibrium relationship between longevity and the share skilled is s-shaped.

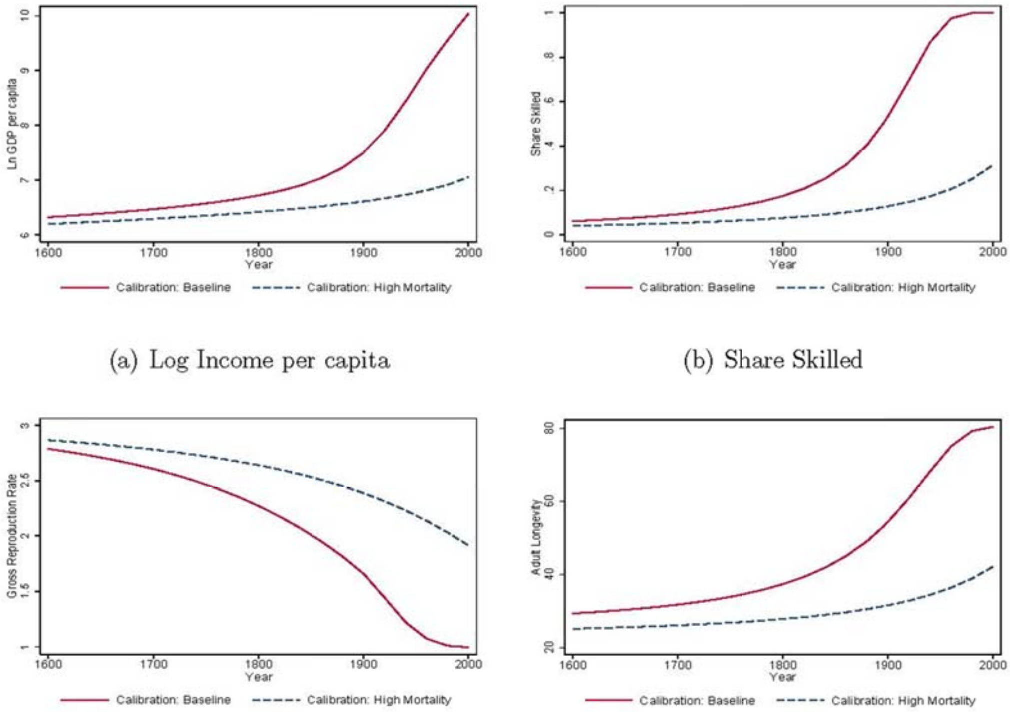
Now we consider this model in an overlapping generations setting. Through intergenerational spillovers, the parent generation's education composition affects their respective children's longevity and technology, in terms of the relative importance and productivity of skilled and unskilled human capital. In such a setting, endogenous improvements in longevity and skill-biased technological change are linked to the share of skilled in the previous generation. As a consequence of the shape of the equilibrium relationship between the share skilled and longevity, it spans a dynamical system that exhibits nonlinearities.

In a situation where technology is not sufficiently developed, skilled human capital is not very productive relative to unskilled human capital, implying relatively low returns for becoming skilled. At the same time longevity is low, imposing a large cost for becoming skilled. As a consequence, the equilibrium share of skilled individuals is low, and the dynamic spillovers are not very strong. If over time technology improves and thus increases the returns to skills, the education composition shifts very slowly towards a higher share of skilled across generations. Ultimately, however, at some point the subsequent and mutually reinforcing improvements in skill composition, longevity and technology trigger a transition in the education composition. Large shares of the population start becoming skilled, with corresponding bidirectional feedbacks with longevity and technology. This transition affects all dimensions of individual decisions, in terms of skill acquisition and fertility choice, and within few generations the economy converges to a balanced growth path, which resembles that of a standard endogenous growth model.

The model exhibits no corner solutions and the dynamic equilibrium path's simulation is relatively straightforward. The simulated model generates data that allow for a systematic quantitative investigation of long-run development in all central dimensions, including education, fertility, longevity and income per capita. In particular, as Cervellati and Sunde (2015a) show, this development path's patterns closely match the historical time series for countries such as Sweden or England. From our paper's perspective, however, the more important fact is that differences in country-specific features can lead to a transition delay, without affecting the transition dynamics qualitatively. Cervellati and Sunde (2015a) give the example of differences in geo-climatological conditions that imply differences in the disease environment that governs longevity. Everything else equal, a lower baseline longevity (with any health technology and other factors related to development absent) leads to a delay in an otherwise very similar transition context. Figure 5 illustrates this by contrasting two model economies, a baseline economy (corresponding to Sweden) and a synthetic economy that is identical to the baseline economy except that it exhibits a higher extrinsic mortality, and thus a later transition.[7] The delay in the transition is substantial.

[7] The extrinsic longevity, the average longevity of an adult who has survived to age 5 without access to any health care or other factors—thus resembling the situation in an entirely undeveloped state of the world—is assumed to be 45 years in the baseline model. The high mortality scenario corresponds to the same environment, but with an extrinsic longevity of only 40 years. See Cervellati and Sunde (2015a) for the calibration and simulation details.

Figure 5 provides four main insights that one can extract from the recent results in unified growth theory and from applying them to the investigation of global comparative development patterns.




(a) Log Income per capita

(b) Share Skilled

(c) Fertility

(d) Adult Longevity

Figure 5: The Role of Transition Delays for Comparative Development

First, the dynamic evolution of income, population dynamics, mortality and education can be interpreted as resulting from dynamic interactions between these different dimensions that eventually, after a long period of slow (quasi-stagnant) growth, lead to a relatively rapid transition to sustained growth. Ultimately, the transition experiences a slowdown in the process of converging to the balanced growth path. Second, different country groups or global regions appear to follow very similar development trajectories (in terms of income, mortality and education), although with substantial differences in the timing and for some regions of the world, substantial delays in the takeoff. Third, resulting from the observed delays, it appears plausible that already in 1960 the different world regions were in different phases of a potentially quite similar process of development. Fourth, and crucially, these different phases imply that countries taking off earlier will also experience an earlier slowdown in transition dynamics, particularly regarding income growth rates. The slowdown occurs when the region is completing demographic and education transitions and approaching a balanced growth path characterized by universal education, low mortality, and aging populations with greater longevity.

Qualitatively, the simulated data patterns closely resemble those in the actual data shown in the previous section. Of course, there are discrepancies in the quantitative match and the simulated data do not account for the existence of shocks and random events like crises. Nonetheless this should not distract attention from the more important point that follows from the qualitative similarity of the long-term development patterns. In this regard, Figure 5 puts the global growth and development patterns from Figure 3 into perspective. In particular, it allows us to interpret the observed patterns of the OECD countries' growth slowdown, as well as Latin America and Africa's acceleration, as compatible with a global process of long-term development.

# 4 Empirical Implications

Irrespective of the reason why it occurred, Figure 5 shows that the delay in the transition to sustained growth is an important element for understanding global development patterns in general, and particularly the prospects within the context of the secular stagnation question. The insights from the conceptual framework, and the simulation, presented in the previous section have relevant implications for the secular stagnation debate in Western countries and suggest some testable predictions.

The conceptual framework's first empirical implication is that education and human capital, which are main growth engines in the long-term growth literature, exhibit nonlinear dynamics during the different phases of economic and demographic development. As illustrated in Figure 5(d), and consistent with the data in Figure 3(d), the change in human capital is large in the early development phases (after the exit from Malthusian stagnation) and slows down as the economy develops. A very similar remark applies to the improvements in life expectancy, which is the central state variable behind the demographic and economic transition. The recent literature in economics and demography has made the point that looking at the level of life expectancy attained at a certain point in time is the best way to identify different economic and demographic development phases .[8]

The simplest way of testing the prediction that human capital increases at a decreasing rate (that is in a concave fashion) during the development process is to combine the dynamics of life expectancy and education as suggested by the simulated data illustration reported in Figure 5. The hypothesis is that the higher the level of life expectancy, the smaller the subsequent change in a country's human capital. This is since better educated populations have less scope for further improvements in education attainment. We test this hypothesis by regressing different measures of education on life expectancy while allowing for a nonlinear (quadratic) relationship. For education measures, we use the average years of schooling, a human capital index and the share of individuals with schooling as alternative variables of interest.[9] Panel A in Table 1 reports the results for Pooled OLS specifications for 131 countries over the period 1950–2010 in five-year frequencies. Higher life expectancy is associated with subsequent increases in education, but at a decreasing rate. The results hold also accounting for the past level of GDP per capita.

Panel B in Table 1 replicates the same exercise but exploiting within country variation over time in specifications with country and period fixed effects. Besides identification issues, this specification has the advantage that it is closely linked to the conceptual idea of identifying nonlinearities along a given country's development path that lies behind the simulation in Figure 5. The results confirm the main findings and also suggest that income levels do not significantly affect future changes in education once one accounts for the nonlinear relation behind life expectancy and education during different development phases. As economies get to the mature stages of the demographic transition, the structural slowdown in the process of human capital formation is by itself an interesting observation regarding the question on the existence

[8] The evolution of life expectancy at birth over time has been shown to most precisely identify the timing of the demographic transition onset, with demographers suggesting a threshold of approximately 50 years (see, e.g., Chesnais, 1992, p.19, and the discussion in Cervellati and Sunde, 2011b).

[9] We take years of schooling and the share of individuals aged 25+ with some formal schooling from Barro and Lee (2010), whereas the human capital index is from the Penn World Table (see Feenstra, Inklaar, and Timmer, 2015).

of a secular slowdown in growth. The results even indicate a non-monotonicity in the effect, at least when considering the human capital index or the share of the population with some schooling, with a maximum effect occurring between 60 and 75 years of life expectancy.

**Table 1: Relation between Life Expectancy and Changes in Education**

| Dependent variable: Change in: | Years Schooling | | HC Index | | Share with Schooling | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | **Panel A** | | | |
| Life Expectancy at Birth | 0.056*** | 0.060*** | 0.015*** | 0.016*** | 0.80*** | 0.84*** |
| | (0.01) | (0.01) | (0.00) | (0.00) | (0.08) | (0.10) |
| Life Expectancy at Birth (sq.) | -0.00040*** | -0.00044*** | -0.00012*** | -0.00013*** | -0.0074*** | -0.0077*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| log GDP p.c. | | 0.012 | | 0.0057* | | 0.017 |
| | | (0.02) | | (0.00) | | (0.17) |
| Country FE | No | No | No | No | No | No |
| Year FE | No | No | No | No | No | No |
| Observations | 1441 | 1253 | 1261 | 1261 | 1441 | 1253 |
| $R^2$ | 0.118 | 0.095 | 0.073 | 0.076 | 0.110 | 0.112 |
| Adjusted $R^2$ | 0.117 | 0.093 | 0.071 | 0.073 | 0.109 | 0.109 |
| | | | **Panel B** | | | |
| Life Expectancy at Birth | 0.034*** | 0.031** | 0.014*** | 0.011*** | 0.59*** | 0.47*** |
| | (0.01) | (0.01) | (0.00) | (0.00) | (0.10) | (0.13) |
| Life Expectancy at Birth (sq.) | -0.00014 | -0.00017 | -0.00010*** | -0.000079*** | -0.0048*** | -0.0034*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| log GDP p.c. | | 0.053 | | 0.0029 | | -0.32 |
| | | (0.03) | | (0.01) | | (0.33) |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1441 | 1253 | 1261 | 1261 | 1441 | 1253 |
| $R^2$ | 0.093 | 0.111 | 0.048 | 0.086 | 0.031 | 0.038 |
| Adjusted $R^2$ | 0.092 | -0.003 | -0.065 | -0.033 | -0.067 | -0.086 |

OLS estimates (Panel A), fixed effects estimates (Panel B), standard errors shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Observations are 5-year country observations for the period 1950–2010. All time-varying explanatory variables are lagged by 5 years. Data Sources: See Table 7.

Another direct implication of the conceptual unified growth framework, illustrated by Figure 5's simulated data, is that the effect of education on growth is also nonlinear. Most importantly, the effect of education changes during the different development phases. This can be illustrated by jointly considering Panels (a) and (b) of Figure 5. Having in mind a canonical representation of a standard human capital augmented neoclassical production framework, one can decompose growth performance by applying a growth accounting exercise along the lines of Benhabib and Spiegel (1994). Then, income per capita can be written as

$$ln\, y_{it} = \alpha + \beta\, g(H_{it}) + \gamma\, ln\, k_{it} + \Gamma X'_{it} + \varepsilon_{it} \qquad (1)$$

where $y_{i,t}$ is real per capita GDP, $y$, in country $i$ in period $t$,. $g(h_{i,t})$ is a function of the average stock of human capital per capita (using a measure $h$), ln $k_{i,t}$ is the stock of physical capital per capita, and the vector $X$ includes other controls that have been considered in the empirical growth literature. The corresponding coefficient vectors are $\alpha$ and include the productivity component, $\beta$ and $\gamma$ for human and physical capital, as well as Γ for the vector of controls.[10]

The standard decomposition in (1) clarifies that, everything else equal, income growth depends on the dynamics of human capital accumulation. The specification (1) is typically derived from the balanced growth path of (non-unified) endogenous growth models, however. The simulation in Figure 5, that plots the predicted long-term evolution of a prototype economy undergoing the economic and demographic transition, suggests the existence of possible nonlinearities in the return to human capital during the different development phases. As the economy matures, the marginal contribution of further years of schooling (or education) is expected to be reduced. Specifically, as implied by the simulated data shown in Figure 5, the relationship between education and future income is positive and convex in the early development phases (during growth takeoff) but concave in the later phases (during the convergence to the balanced growth path).[11]

[10] To derive this empirical model, suppose that aggregate income, $Y$ is given by a neoclassical production function $Y_{it} = K_t^{\gamma} (A_t H^{\delta}_t)$ that uses physical capital $K$, human capital $H$ and productivity $A$, where human capital is given by $H_{it} = e^{g(hit)} L_{it}$ with $h$ as average years of schooling and where $L$ is the population. Dividing by population and taking log differences, one can derive an estimation equation as in (1); for a differenced version see also Benhabib and Spiegel (1994).

[11] After the demographic transition onset, greater longevity accelerates the expansion of education, thereby reducing fertility and population growth, with positive effects on income per capita. See Cervellati and Sunde (2011a, 2011b, 2015b) for a more structured derivation of these predictions.

Accounting for these implications and testing these predictions is not straightforward. A first, purely statistical attempt, may involve extending the standard specification (1) to the inclusion of nonlinear (e.g. quadratic) effects of education on income growth. Columns (1) in Table 2 report the results of the nonlinear (quadratic) version of the standard linear specification (1) for years of schooling, the human capital index and the share of population with some formal education in Panels A, B and C, respectively. While the results suggest the existence of some nonlinearities, it is not obvious to interpret the patterns, which appear to change slightly depending on different human capital measures.

According to the theoretical predictions, the effect should not just be nonlinear but should also depend on the different stages of the demographic. To explicitly test this specific prediction, the remaining columns of Table 2 move one step further to allow for the possibility that the human capital effect is nonlinear and changes depending on the development stages. This is done in two ways. First, we investigate the (nonlinear) education effect on income growth by splitting the sample depending on whether countries are forerunners (early developers) or latecomers in terms of their demographic development as of 1960. The results in Columns (2) show that for the countries that had already started developing in 1960 (labeled as "Early" in Table 2), the education effect on income growth in the next half a century is positive but concave. Parallel to this, Columns (3) show that the effect is positive and convex for the countries that were still underdeveloped as of 1960 (labeled "Late"). Alternatively, one can evaluate a country's position during its development process period by period by verifying whether a country is pre- or post-transitional according to the criteria adopted by demographers to identify the demographic transition onset.[12] The results reported in Columns (4) and (5) indeed suggest that the relationship between human capital and growth is positive but concave in countries that developed earlier or that were already post-transitional, while the relationship is convex for late developers and pre-transitional countries. Once one explicitly accounts for the different demographic development stages, the results become consistent for all the different human capital measures, as seen from Columns (2) to (5) in Panels A, B and C of Table 2.

[12] We follow the usual criteria used in the literature (see, e.g., Reher, 2004).

## Table 2: The Demographic Transition: Human Capital on Income Growth

| Dependent variable: | log REAL GDP p.c. (2005 USD) | | | | |
|---|---|---|---|---|---|
| Sample | Full | Early | Late | Post-Trans. | Pre-Trans. |
| | (1) | (2) | (3) | (4) | (5) |
| | **Panel A: Effect of Years of Education** | | | | |
| Av. Years of Schooling | 0.030* | 0.044** | -0.020 | 0.024 | -0.055* |
| | (0.02) | (0.02) | (0.03) | (0.02) | (0.03) |
| Av. Years of Schooling (sq.) | 0.0016 | -0.0050*** | 0.0082*** | -0.0016 | 0.0097*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| log Capital p.c. | 0.58*** | 0.50*** | 0.58*** | 0.52*** | 0.66*** |
| | (0.02) | (0.03) | (0.03) | (0.03) | (0.04) |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Observations | 1316 | 592 | 724 | 735 | 581 |
| $R2$ | 0.736 | 0.856 | 0.652 | 0.820 | 0.686 |
| Adjusted $R^2$ | 0.703 | 0.838 | 0.602 | 0.789 | 0.610 |
| | **Panel B: Effect of Human Capita (Index)** | | | | |
| Human Capital Index (SH) | 0.098 | 0.71*** | -0.63*** | 0.36** | -0.87*** |
| | (0.14) | (0.16) | (0.22) | (0.16) | (0.25) |
| Human Capital Index (SH) (sq.) | 0.056* | -0.15*** | 0.26*** | -0.043 | 0.28*** |
| | (0.03) | (0.03) | (0.05) | (0.03) | (0.05) |
| log Capital p.c. | 0.57*** | 0.50*** | 0.56*** | 0.52*** | 0.63*** |
| | (0.02) | (0.03) | (0.03) | (0.03) | (0.05) |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Observations | 1324 | 592 | 732 | 735 | 589 |
| $R2$ | 0.738 | 0.857 | 0.659 | 0.822 | 0.684 |
| Adjusted $R^2$ | 0.706 | 0.839 | 0.609 | 0.791 | 0.607 |
| | **Panel C: Share of Population with Formal Schooling** | | | | |
| % with formal schooling | -0.0060*** | 0.020*** | -0.016*** | 0.0053* | -0.024*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| % with formal schooling (sq.) | 0.000075*** | -0.00011*** | 0.00015*** | -0.000023 | 0.00021*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| log Capital p.c. | 0.59*** | 0.50*** | 0.60*** | 0.52*** | 0.63*** |
| | (0.02) | (0.03) | (0.03) | (0.03) | (0.04) |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Observations | 1316 | 592 | 724 | 735 | 581 |
| $R2$ | 0.737 | 0.867 | 0.649 | 0.822 | 0.694 |
| Adjusted $R^2$ | 0.705 | 0.850 | 0.599 | 0.791 | 0.620 |

Fixed effects estimates, standard errors shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Observations are 5-year country observations for the period 1950–2010. All time-varying explanatory variables are lagged by 5 years. Data Sources: See Table 7.

The aforementioned theoretical investigations on the role of demographic development has another implication relating to the role of changing life expectancy for dependency ratios and, accordingly, for savings and physical capital investments. To explore these issues, we proceed in two steps. First, we investigate how population aging, measured in terms of life expectancy at birth, affects old-age dependency ratios.[13] Table 3 displays the results.

**Table 3: Life Expectancy and Old-Age Dependency Ratio**

| Dependent variable: | Old-Age Dependency Ratio (Share Pop. 65+) | | | | | |
|---|---|---|---|---|---|---|
| Sample | Full | | Early | Late | Post-Trans. | Pre-Trans. |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Life Expectancy at Birth | -0.68*** | -0.53*** | -1.07*** | -0.33*** | -1.03*** | -0.31*** |
| | (0.04) | (0.05) | (0.14) | (0.05) | (0.15) | (0.06) |
| Life Expectancy at Birth (sq.) | 0.0052*** | 0.0043*** | 0.0077*** | 0.0032*** | 0.0088*** | 0.0027*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| log Capital p.c. | | 1.29*** | | | | |
| | | (0.17) | | | | |
| log GDP p.c. | | 0.16 | 1.68*** | 0.40*** | 1.13*** | 0.67*** |
| | | (0.16) | (0.27) | (0.12) | (0.22) | (0.16) |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1771 | 1365 | 544 | 821 | 673 | 692 |
| $R^2$ | 0.375 | 0.481 | 0.649 | 0.226 | 0.688 | 0.325 |
| Adjusted $R^2$ | 0.307 | 0.406 | 0.597 | 0.100 | 0.619 | 0.159 |

Fixed effects estimates, standard errors shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Observations are 5-year country observations for the period 1950–2010. All time-varying explanatory variables are lagged by 5 years. Data Sources: See Table 7.

In line with the predictions from unified growth, life expectancy has a convex effect on population aging in terms of the old-age dependency ratio. For low life expectancy levels (and demographic development), an increase in life expectancy initially leads to longer life during working ages (and increased fertility and population growth), thereby reducing the old-age dependency ratio. At later demographic development stages, life expectancy mostly increases in old (non-working) ages; the effect of further longevity increases does not necessarily fuel larger working age populations but rather into higher

[13] Data for the old-age dependency ratio are from the United Nations (2015).

shares of retired individuals in the population.[14] As a result, the effect of increases in life expectancy eventually turns positive as aging leads to a more than proportional increase in the share of elderly.[15] On average the empirical reversal of the effect is around life expectancy at birth of 60–64 years. The results in Table 3 show that a nonlinear effect is present even for countries that were still underdeveloped as of 1960, although the effect tends to be stronger for those that experienced the demographic transition early on (and that are now largely post-transitional).

The second step links the population's age structure to savings and capital formation. Table 4 investigates the possibility that a higher old-age dependency ratio may reduce gross capital formation and shows that this indeed appears to be the case. As one can expect the effect is stronger, and more statistically significant, in the aging countries that underwent their economic and demographic transition early on and are largely post-transitional.

**Table 4: Population Aging and Capital Accumulation**

| Dependent variable: | Share gross capital formation (current PPP) | | | | | |
|---|---|---|---|---|---|---|
| Sample | Full | | Early | Late | Post-Trans. | Pre-Trans. |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Old-Age Dependency Ratio | -0.0040*** | -0.0041*** | -0.0056*** | -0.0036 | -0.0056*** | -0.0032 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| log Capital p.c. | | 0.0023 | | | | |
| | | (0.01) | | | | |
| log GDP p.c. | | 0.0046 | 0.019* | 0.00074 | -0.00064 | 0.0049 |
| | | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1705 | 1542 | 602 | 940 | 783 | 759 |
| $R^2$ | 0.031 | 0.039 | 0.066 | 0.041 | 0.073 | 0.040 |
| Adjusted $R^2$ | -0.080 | -0.085 | -0.057 | -0.095 | -0.099 | -0.173 |

Fixed effects estimates, standard errors shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Observations are 5-year country observations for the period 1950–2010. All time-varying explanatory variables are lagged by 5 years. Data Sources: See Table 7.

[14] The precise relationship between increases in life expectancy and retirement depends on the age-specific mortality changes (see D'Albis, Lau, and Sanchez-Romero, 2012).

[15] The effect is reinforced by the fact that for high longevity the fertility transition also reduce the inflow of new born and of the working age population.

In the context of the secular stagnation, these findings overall imply that, as the less developed countries enter and proceed with their economic and demographic transition, they will experience a fast growth rate phase similar to what the advanced countries experienced in the past. In terms of interest rates and capital flows, this means that the supply of capital that emerges from the developing world's increasing incomes, paired with populations exhibiting higher aggregate savings, might well lead to low interest rates in the medium run. The rates may remain low until population aging induces a slowdown in capital formation and capital supply produced in developing countries.

Another implication following from the preceding discussion is that human and physical capital might have heterogeneous effects on post-transitional countries' growth rates, as well as on countries still amidst the transition. The role of physical capital might change as the economy develops from a more industry-focused to a more innovation-driven regime.[16]

The other central factor behind growth in the simple empirical framework (1) refers to changes in technology and productivity. The results from the total factor productivity on life expectancy regressions shown in Table 5 reveal that increases in life expectancy significantly affect productivity dynamics, particularly during the early demographic transition phases.

**Table 5: Life Expectancy and Productivity**

| Dependent variable: | Total Factor Productivity | | | | | |
|---|---|---|---|---|---|---|
| Sample | Full | | Early | Late | Post-Trans. | Pre-Trans. |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Life Expectancy at Birth | -0.048*** | -0.048*** | 0.0053 | -0.061*** | -0.017 | -0.062*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.02) | (0.02) |
| Life Expectancy at Birth (sq.) | 0.00040*** | 0.00040*** | -0.000066 | 0.00051*** | 0.00013 | 0.00063*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 959 | 959 | 499 | 460 | 572 | 387 |
| $R_2$ | 0.184 | 0.184 | 0.327 | 0.142 | 0.278 | 0.271 |
| Adjusted $R^2$ | 0.066 | 0.066 | 0.233 | -0.015 | 0.144 | 0.059 |

Fixed effects estimates, standard errors shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Observations are 5-year country observations for the period 1950–2010. All time-varying explanatory variables are lagged by 5 years. Data Sources: See Table 7.

[16] See Cervellati and Sunde (2015c) for a detailed theoretical and empirical analysis of this point.

This implies that health improvements have a profound effect on output through productivity increases in countries that are undergoing the demographic transition. The effect even appears to be convex, so that, consistent with a Malthusian perspective, life expectancy must increase to sufficiently high levels before it starts to materialize productivity gains.[17] However, as seen in Columns (3) and (5), this effect loses momentum (and significance) in countries that have completed the demographic transition, as well as in those where population aging has begun.

As a final step, Table 6 presents results for the implications of population aging, in terms of the old-age dependency ratio, for productivity. The results suggest that there is no reason to expect productivity to suffer from aging. In fact, the findings point towards a positive effect that shows no clear differences between countries at various demographic development stages. This implies that even though the increase in human capital might slow down as the demographic transition reaches its final stages, the human capital embodied in the population, even an aging one, does not necessarily become unproductive.

**Table 6: Population Aging and Productivity**

| Dependent variable: | Total Factor Productivity | | | | | |
|---|---|---|---|---|---|---|
| Sample | Full | | Early | Late | Post-Trans. | Pre-Trans. |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Old Age Dependency Ratio | 0.027*** | 0.027*** | 0.019*** | 0.039*** | 0.019*** | 0.017** |
| | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1090 | 1090 | 562 | 528 | 658 | 432 |
| $R^2$ | 0.270 | 0.270 | 0.452 | 0.174 | 0.384 | 0.291 |
| Adjusted $R^2$ | 0.178 | 0.178 | 0.385 | 0.043 | 0.288 | 0.109 |

Fixed effects estimates, standard errors shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Observations are 5-year country observations for the period 1950–2010. All time-varying explanatory variables are lagged by 5 years. Data Sources: See Table 7.

[17] The results in Columns (4) and (6) imply the quadratic relationship's minimum is 60 years of life expectancy.

# 5 Outlook: Will "Secular Stagnation" Occur?

Ever since the end of the 19th century, the world has witnessed fast economic growth and economic development has made its ways from Europe across the globe. More recently, growth rates have stabilized and even fallen in the Western world. In analogy to the famous Club of Rome study in 1972, economists have recently resumed the discussion about the prospects for economic growth. This paper takes a unified growth theory perspective, according to which the demographic transition is the central mechanism behind the transition from stagnation to growth. It has argued that past high growth rates have to some extent been the consequence of singular, non-recurrent mortality and fertility changes, coupled with dramatic demographic change in terms of population dynamics, education attainment, and labor force participation. These one-off developments took several generations to take effect, but as they abate, growth eventually slows down during the later transitional stages to the balanced growth path.

An important aspect for the context of secular stagnation is the observation of capital flows and capital account imbalances due to differential timing in development across countries, with the consequence of asynchronous savings patterns. Forerunner countries that are now more developed might enjoy increased capital inflows from countries where increased longevity has just set in, resulting in increased savings rates.[18] Indeed, international capital flows across countries appear to be linked to demographics, particularly aging patterns (see, e.g. Domeij and Floden, 2006).[19] There is, however, also an effect on the differential timing of economic and demographic development that is more directly linked to the population aging process. Aging populations in regions with an increased dependency ratio should expect to deplete their savings for old-age consumption, which directly reduces the internal availability of resources for physical capital investments.

In terms of demographic and economic transition, the forerunners have incidentally been able to balance the slowdown and continue to grow at relatively high

[18] See Börsch-Supan, Ludwig, and Winter (2006) for a simulation exercise that illustrates this mechanism.

[19] This depresses the returns on capital and thus real interest rates, in particular if savings are massive due to countries with large populations that face rapidly aging populations, such as China. By themselves, capital flows might affect the development dynamics by interfering with the convergence to the balanced growth path (see, e.g., Birchenall, 2007).

rates. They have done so by expanding their markets through globalization, effectively gaining capital and effectively reaching demographic development potential from the less developed countries. Ultimately, however, as globalization reaches even the most remote parts of the world and as latecomer countries undergo the demographic transition, the transitional growth sources lose momentum at the global level. However, this does not mean that the world economy will necessarily stagnate. When the influence of transitional dynamics on economic dynamics become less important, growth will be based more exclusively on productivity improvements and technological change than in the past. The scope for future productivity changes is more difficult to quantify and predict. Opinions disagree as to the scope for productivity improvements, and whether innovations will stagnate, accelerate or decelerate (see, e.g., Gordon, 2014b, and Mokyr, 2014). However, if the human capital stock is important for innovation, as in models of human capital driven endogenous growth, the innovation potential might remain high or increase even post-transition.[20] Similarly, the expected human capital reallocation around the world (through migration), mobility's contributions to resource optimization, and the potential economic benefits from ethnic diversity may all affect and stimulate growth in ways we have not discussed here.[21]

This paper's aim was two-fold: to give a qualitative assessment of different factors' contribution to growth, including demographic factors, market size effects, and innovation, as well as to point out implications for future development. The findings are broadly in line with the predictions from a prototype unified growth model that exhibits nonlinear development patterns like the demographic transition. To the extent that many forecasts disregard these inherent development dynamics nonlinearities, the findings shed some new light on the recent secular stagnation debate.

[20] For evidence on the distinct role of human capital changes and stocks in terms of growth, see, e.g., Sunde and Vischer (2015).

[21] Zaiceva and Zimmermann (2014) provide a review of the issues related to aging and migration.

## References


Barro, R., and J.-W. Lee, 2010, "A New Data Set of Educational Attainment in the World, 1950-2010," *Journal of Development Economics*, Vol. 104, pp. 184–98.

Benhabib, J., and M. Spiegel, 1994, "The role of human capital in economic development: Evidence from aggregate cross-country data," *Journal of Monetary Economics*, Vol. 34, No. 1, pp. 143–73.

Birchenall, J.A., 2007, "Equilibrium, convergence, and capital mobility in neoclassical models of growth," *Economics Letters*, Vol. 99, pp. 10–13.

Börsch-Supan, A., A. Ludwig, and J. Winter, 2006, "Ageing, Pension Reform and Capital Flows: A Multi-Country Simulation Model," *Economica*, Vol. 73, No. 292, pp. 625–58.

Cervellati, M., and U. Sunde, 2011a, "Disease and Development: The Role of Life Expectancy Reconsidered," *Economics Letters*, Vol. 113, pp. 269–72.

———, 2011b, "Life Expectancy and Economic Growth: The Role of the Demographic Transition," *Journal of Economic Growth*, Vol. 16, pp. 99–133.

———, 2015a, "The Economic and Demographic Transition, Mortality, and Comparative Development," *American Economic Journal: Macroeconomics*, Vol. 7, No. 3, pp. 1–39.

———, 2015b, "The Effect of Life Expectancy on Education and Population Dynamics," *Empirical Economics*, Vol. 48, No. 4, pp. 1445–78.

———, 2015c, "The Timing of the Demographic Transition and the Determinants of Growth," mimeo.

Chesnais, J.-C., 1992, *The Demographic Transition: Stages, Patterns and Economic Implications. A Longitudinal Study of Sixty-Seven Countries Covering the Period 1720–1984*. (Oxford, Clarendon Press).

D'Albis, H., S.-H. P. Lau, and M. Sanchez-Romero, 2012, "Mortality Transition and Differential Incentives for Early Retirement," *Journal of Economic Theory*, Vol. 147, No. 1, pp. 261–83.

Domeij, D., and M. Floden, 2006, "Population Aging and International Capital Flows," *International Economic Review*, Vol. 47, No. 3, pp. 1013–32.

Eichengreen, B., D. Park, and K. Shin, 2013, "Growth Slowdowns Redux: New Evidence on the Middle-Income Trap," NBER Working Paper No. 18673 (Cambridge, Massachusetts, National Bureau of Economic Research).

Feenstra, R. C., R. Inklaar, and M. P. Timmer, 2015, "The Next Generation of the Penn World Table," *American Economic Review*, forthcoming.

Gordon, R. J., 2012, "Is U.S. Economic Growth Over? Faltering Innovations Confront the Six Headwinds," NBER Working Paper No. 18315 (Cambridge, Massachusetts, National Bureau of Economic Research).

———, 2014a, "The Demise of U.S. Economic Growth: Restatement, Rebuttal, and Reflections", NBER Working Paper No. 18315 (Cambridge, Massachusetts, National Bureau of Economic Research).

———, 2014b, "The turtles progress: Secular stagnation meets the headwinds," in *Secular Stagnation: Facts, Causes, and Cures*, ed. by Coen Teulings and Richard Baldwin (London, CEPR Press).

Lucas, R. E., 1988, "On the Mechanics of Economic Development," *Journal of Monetary Economics*, Vol. 22, No. 1, pp. 3–42.

Mokyr, J., 2014a, "Secular Stagnation? Not in your life," in *Secular Stagnation: Facts, Causes, and Cures*, ed. by Coen Teulings and Richard Baldwin (London, CEPR Press).

———, 2014b, "Secular Stagnation: US hypochondria, European disease?," in *Secular Stagnation: Facts, Causes, and Cures*, ed. by Coen Teulings and Richard Baldwin (London, CEPR Press).

OECD, 2015, Escaping the Stagnation Trap: Policy Options for the Euro Area and Japan. Organization for Economic Cooperation and Development.

Reher, D., 2004, "The Demographic Transition Revisited as a Global Process," *Population, Space and Place*, Vol. 10, No. 1, pp. 19–41.

Summers, L., 2014, "U.S. Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bound," *Business Economics*, Vol. 49, No. 2, pp. 65–73.

Sunde, U., and T. Vischer, 2015, "Human Capital and Growth: Specification Matters," *Economica*, forthcoming.

Teulings, C., and R. Baldwin, 2014a, “Introduction,” in *Secular Stagnation: Facts, Causes, and Cures*, ed. by Coen Teulings and Richard Baldwin (London, CEPR Press).

_________, 2014b, *Secular Stagnation: Facts, Causes, and Cures*. (London, CEPR Press).

United Nations, 2015, “World Population Prospects: The 2012 Revision,” United Nations, Department of Economic and Social Affairs, Population Division.

Zaiceva, A., and K. F. Zimmermann, 2014, “Migration and the Demographic Shift,” IZA Discussion Paper No. 8743 (Bonn, Germany, Institute for the Study of Labor).

# A Additional Figures and Tables

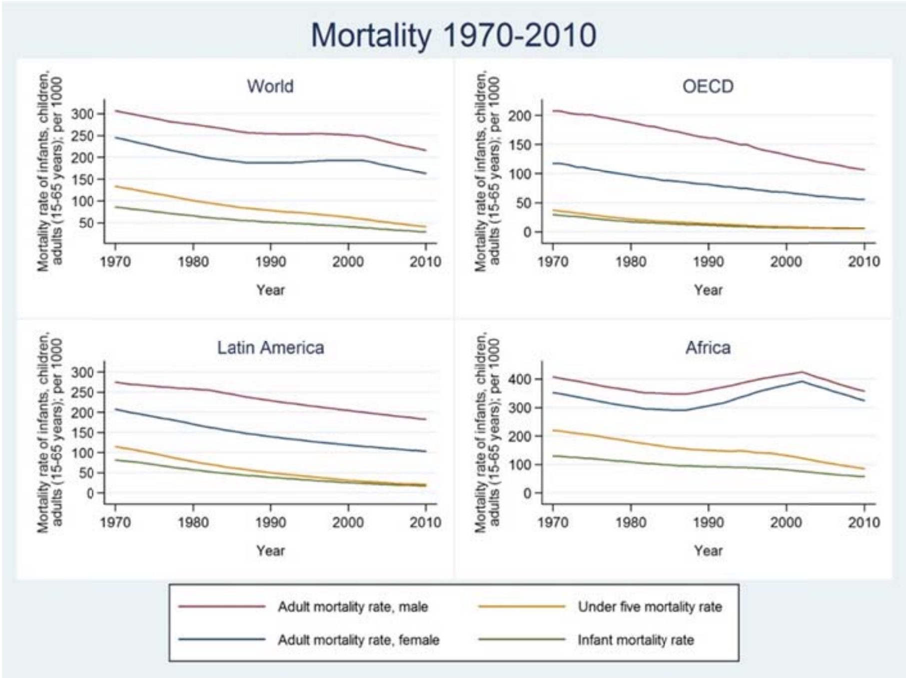



Figure 6: Improvements in Health: Mortality Patterns

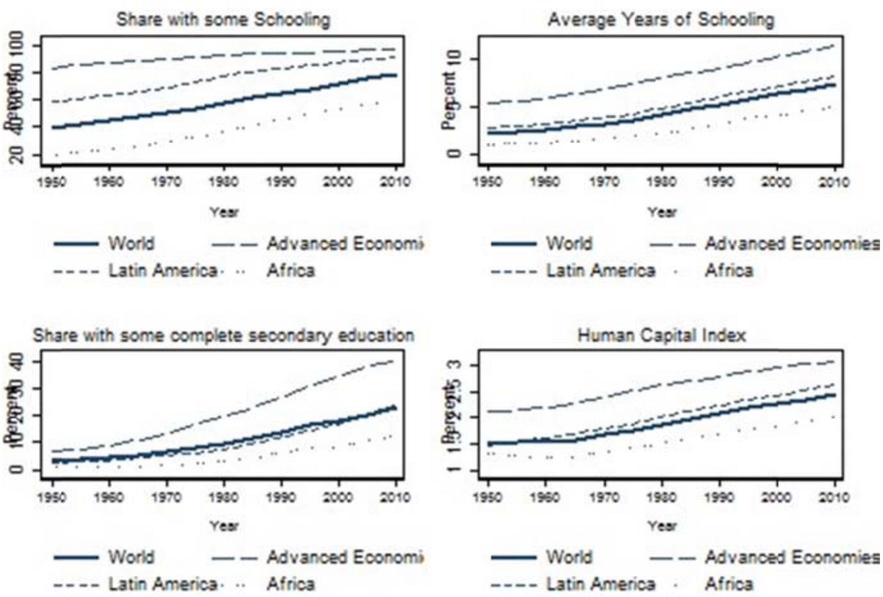



Figure 7: Global Education Attainment: Different Measures

# B Data Sources

Table 7: Data and Sources

| Variable | Description and Source |
| --- | --- |
| GDP, Capital, Population, Human Capital index | Penn World Table (PWT) Version 8.1, Source: http://www.ggdc.net/pwt |
| Fertility (TFR, age at first birth) | UN World Fertility data, Source: http://www.un.org/esa/population/publications/WFD2012/MainFrame.html |
| Mortality (mortality rates, life expectancy at different ages) | UN Mortality Data, Source: http://unstats.un.org/unsd/demographic/sconcerns/mortality/mort2.htm |
| Education (population shares with different education levels, years of schooling) | Barro and Lee (2010), Source: http://www.barrolee.com |
| Old Age Dependency Ratio | UN World Population Prospects: (2012 Revision), Source: https://data.un.org/Data.aspx |