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Matteo Cervellati, Uwe Sunde and Klaus F. Zimmermann

Demographic Dynamics and Long-Run Development: Insights for the Secular Stagnation Debate

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Walter-Flex-Straße 3
D – 53113 Bonn
Germany
Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
www.zef.de

The author[s]:
Matteo Cervellati, University of Bologna, IZA Bonn. Contact: m.cervellati@unibo.it
Uwe Sunde, University of Munich, CEPR London, IZA Bonn. Contact:
uwe.sunde@econ.lmu.de
Klaus F. Zimmermann, Princeton University, UNU-MERIT Maastricht, ZEF Bonn. Contact:
klaus.f.zimmermann@gmail.com

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Abstract

This paper takes a global, long-run perspective on the recent debate about secular stagnation, which has so far mainly focused on the short term. The analysis is motivated by observing 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 singular changes during the economic and demographic transition, growth is likely to become more moderate once the transition is completed. At the same time, a similar transition is on its way in most developing countries, with profound consequences for the development prospects in these countries, but also for global comparative development. The evidence presented here suggests that long-run development dynamics have potentially important implications for the prospects of human and physical capital accumulation, the evolution of productivity and the question of secular stagnation.

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

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

1. Introduction

The experience of the 2007 financial crisis and its fallout in terms of slow growth in Western economies 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. Summers’ discussion was mainly concerned about appropriate macroeconomic policies. In his view, 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 This assessment initiated a discussion whether the US, or indeed the entire developed world, were up for “secular stagnation”, drawing parallels to the original context of the Great Depression in which the term “secular stagnation” was used by Hansen (1939) as well as to Japan’s development since the 1990s.

The debate about this “new secular stagnation hypothesis” has gained momentum and many facets have 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 recently experienced delayed recovery reflects a one-off crisis-related drop in potential output, a phenomenon of delayed recovery from cyclical fluctuations, a prolonged drop in GDP below its long-run potential, or a reduction in long-run growth potential (Teulings and Baldwin, 2014b).

Most of this debate has been confined to the question of a recovery from a recession in developed countries, in particular of the US economy, with some reflections on Europe and Japan, and the focus has been almost exclusively on empirical patterns in the domain of capital markets and interest rates. An issue that has received almost no attention is whether the observed slow-down in income growth can be understood as a purely economic phenomenon, or whether it is part of a much broader pattern of global long-term development dynamics that also includes global changes in demographic conditions.

In this paper we offer a broader view on these questions, and on the secular stagnation debate as a whole, by investigating the global patterns of long-run development. The long run and global perspective taken in this paper addresses aspects similar to those emphasized by

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

[2] See, e.g., 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 activities by the OECD (2015), as well as more formal quantitative work by Eggertsson and Mehrotra (2014).

Hansen (1939). In particular, the analysis investigates the possibility of secular stagnation as part of the nonlinear dynamics of the demographic transition and the economic transition that typically occur simultaneously. The underlying framework is based on unified growth theory that has been developed in the last 15 years and that provides a formal background for a long-run perspective of the issue. Following the seminal contribution of Galor and Weil (2000), an increasing body of unified growth theories has modelled the entire process of the endogenous exit from long-term economic stagnation and the following transition and convergence to balanced growth (see, e.g., Galor, 2011 for a survey). According to this framework the demographic transition is the central mechanism behind the transition from stagnation to growth. From a historical perspective, economic performance has indeed been closely linked to demographic development. Populations becoming increasingly more educated, wealthy, and older, but displaying lower fertility, characterize this transition. Modern economic growth has 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.

Adopting the perspective of unified growth theory offers new insights into the patterns of cross-country comparative development and sheds new light on the question about the emergence of a secular decline in growth as well as its determinants with implications that are surprisingly reminiscent of Hansen's (1939) considerations.

The analysis here 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 explicitly considering 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 for 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 the development path of less developed countries, whose economic and demographic transition follow similar patters although with substantial delays.

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 half century 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, Africa and Asia 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 also relates to two papers and a recent book by Gordon (2012, 2014a, 2016) that emphasize the importance of accounting for "headwinds" in US growth potential and growth prospects. These "headwinds" reflect unfavorable changes in environmental conditions, particularly demographic changes, education and globalization, which might unfold negative effects that could be stronger than productivity improvements. While some have criticized this view for being too pessimistic about the scope for productivity improvements, Gordon's emphasis on the other headwinds has not resonated throughout the literature.3 In this paper we complement and extend Gordon's view which is exclusively focused to the development of the US, by 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 patterns 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. The analysis suggests that these patterns are unlikely to be solely a business cycle phenomenon, or a matter of delayed recovery from the recent crisis. This perspective can also help shedding 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 on the 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. We conclude that 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.

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.

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

2. Global Patterns of Economic and Demographic Development: Stylized Facts.

The debate on secular stagnation has mainly focused on the recent experience of the aftermath of the financial crisis in developed countries, in particular the US. In this Section we take a broader perspective by extending the analysis to a larger set of countries and a longer time horizon. After presenting the data sources in Section 2.1, we provide a first exploration of the evolution of income per capita and productivity in a global perspective in the last half century in Section 2.2. The patterns of economic development are linked to educational attainment and demographic change in Section 2.3.

2.1 Data

The analysis exploits cross-country panel data over the period 1950-2010.[4] Data on income per capita, total factor productivity, share of gross capital formation and population are extracted from the Penn World Table version 8.1 (see Feenstra, Inklaar and Timmer, 2015). We consider different measures of educational attainments (in terms of share of population with different education levels and average years of schooling) from Barro and Lee (2010) and the human capital index (again from PWT 8.1). Data on mortality rates and life expectancy at different ages and fertility patterns (in terms of total fertility rates and age at first birth) are taken from the UN Mortality and Fertility Statistics, respectively. Finally, information on old age dependency ratios are from the UN World Population prospects (United Nations, 2015).

2.2 Income and Growth from a Global Perspective

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 but has, in fact, increased slightly over the last 15 years.

Next we replicate the same exercise, but restrict attention to only developed countries (Europe and Western offshoots). In the developed countries, income growth indeed 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-

[4] The data are extracted from standard publicly available sources. These sources, and the links for the download of the data, are listed in Table 7 in the Appendix.

Saharan Africa where, if anything, income growth appears to have accelerated in the last decades, with a more visible trend in Africa.[5] A very similar picture emerges for total factor productivity, as documented by Figure 2.

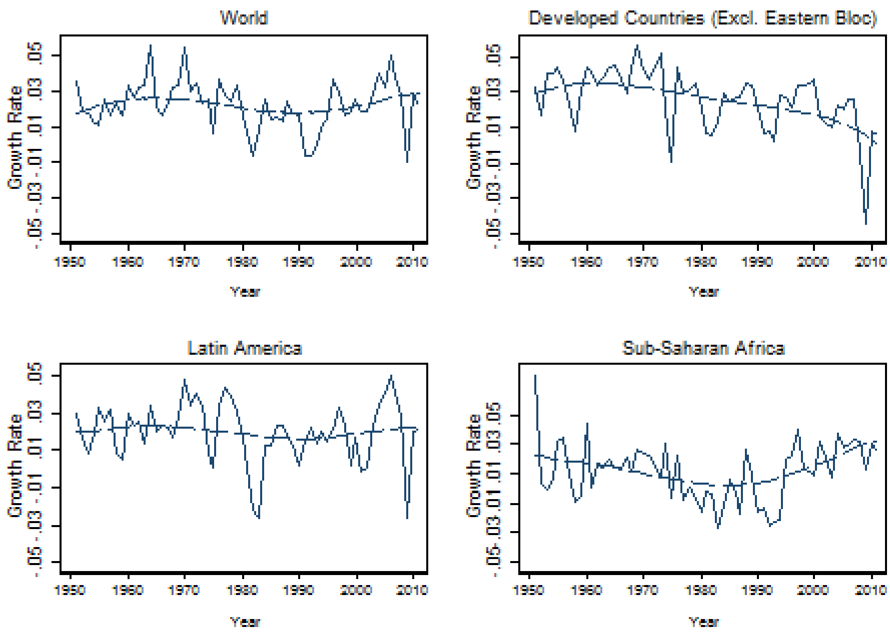


Figure 1: Global Growth Performance: GDP per capita

(*Source*: Penn World Tables)

[5] We refrain from plotting Asia separately. In terms of income and TFP growth, Asia displays a qualitatively similar pronounced increase after the end of the 1970s, but at higher rates than Africa throughout the observation period.

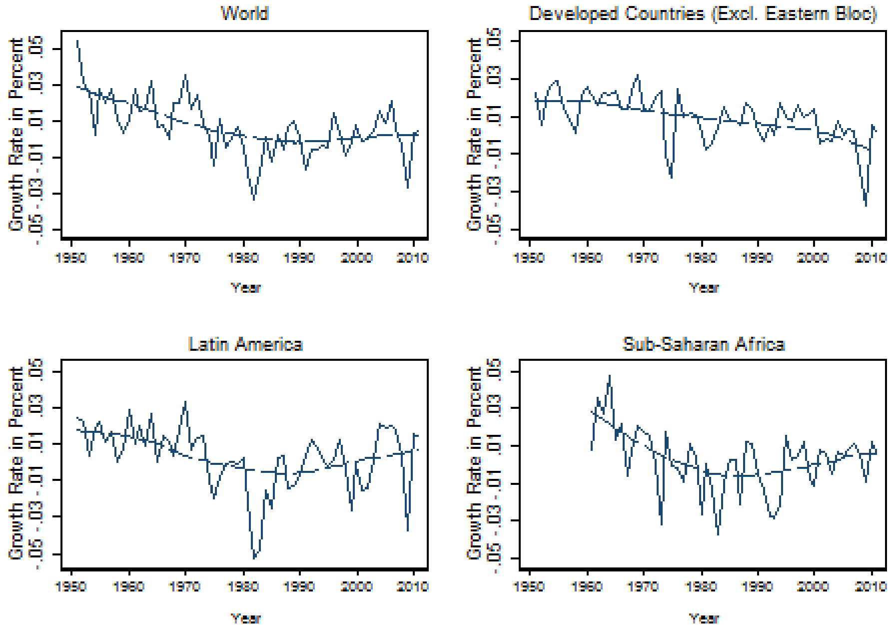


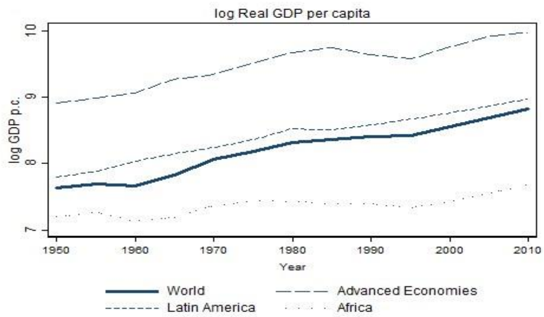
Figure 2: Global Growth in Total Factor Productivity

(*Source*: Penn World Tables)

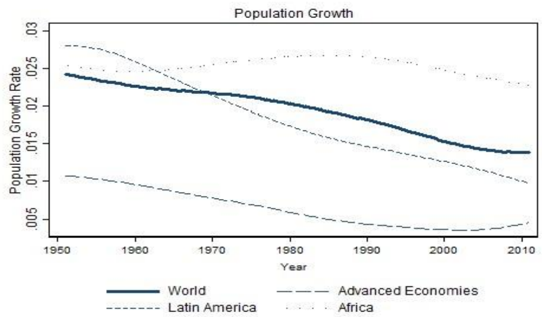
2.3 Economic Development and Demographic Changes.

The argument that this paper puts forward regarding the debate on secular stagnation is that the differential evolution of income and productivity in the last decades across different groups of countries is consistently related to the different phases of economic development and demographic change.

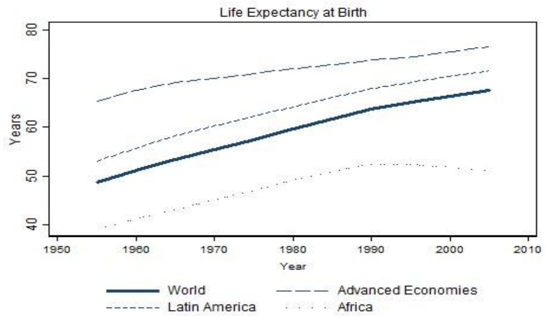
As a first step to develop this argument, Figure 3 displays the development trajectories in several different economic and demographic dimensions. Figure 3(a) displays the trajectories of log GDP per capita in levels over the same time period from 1950 to 2010 (using 5-year averages). This figure illustrates that on average across the globe, incomes have been steadily increasing since at least around 1960. The increase is visible in the developed countries, which exhibit the highest levels of living standards, but 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. In 2010 the income per capita in the world as a whole is roughly comparable to the level of income per capita in the advanced economies half a century ago.



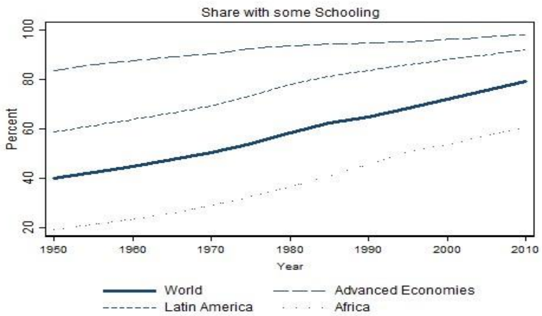
(a) Log Income per Capita
(*Source*: Penn World Tables)



(b) Population Growth
(*Source*: Penn World Tables)



(c) Life Expectancy at Birth
(*Source*: UN Statistics)



(d) Share Skilled
(*Source*: Barro and Lee, 2010)

Figure 3: Global Development Patterns

Another dimension of long-run development patterns refers to demographic rather than economic development. Figure 3(b) complements 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 countries 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 that has continued ever since. 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) are 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.

Figure 3(c) replicates the exercise of Figure 3(a) in terms of life expectancy at birth rather than income per capita. The Figure illustrates the different levels of life expectancy in different regions of the world, as well as the delay in the timing. In particular, the figure documents 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 healthcare 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 ever 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.[6] 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 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.

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 in terms of the timing of the transition. 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 of 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

[6] For additional evidence on gender-specific mortality and infant mortality, see Figure 9 in the Appendix.

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 with an average schooling attainment of 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.[7] When considering the development 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, but education has also been substantially increasing there. 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. Both secondary and tertiary education attainment are on the rise, but the increase is still very moderate, particularly for tertiary education.

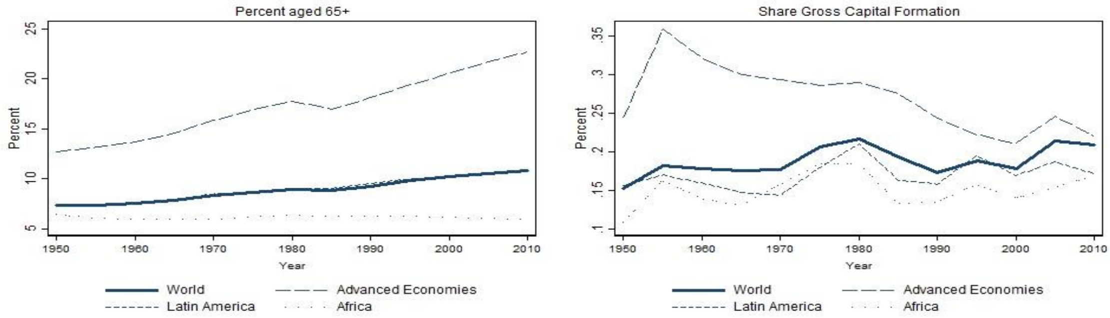
Taken together, Figure 3 illustrates that different groups of countries appear to follow similar pattern in terms of income, life expectancy and education, which are the main components of the human development index, although with substantial delays in the timing across groups of countries.

Another stylized pattern that is related to the change in demographic conditions, is the process of aging and the reduction in the active population. More specifically, 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 implication for the age structure 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 begun, the old-age dependency ratio has been relatively stable at very low levels.

A possible 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

[7] See Figure 10 in the Appendix.

elderly consumption, reducing the scope for capital formation at the aggregate level. Figure 4(b), 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.



(a) Share of the Population Aged 65+
(*Source*: World Population Prospects)

(b) Share of Gross Capital Formation
(*Source*: Penn World Tables)

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

3. Unified Growth and Long-Run Development

How can we combine these empirical patterns in a coherent framework to address the secular stagnation question? The secular stagnation discussion begins with the conjecture that the recent experience of delayed recovery foreshadows a regime of low growth. Naturally, standard models of economic growth eventually predict a decline in growth rates as the economy converges to the balanced growth path. In the context of the ongoing debate, the questions that have been raised refer to whether the recent growth slowdown is due to converge dynamics, due to a decline in growth potential (or the equilibrium rate of growth), or due to growth rates that, for some reason, fall short of the growth potential. These questions are rooted in a standard perspective of balanced growth under the assumption that the steady state has been attained by Western economies. The unified growth view provides a different perspective by focusing on non-linear dynamics along the long-run growth path. 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.[8] 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 the literature has appreciated less 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.

3.1 The Phases of the Demographic Transition

The general pattern of the demographic transition is strikingly similar across all countries, as noticed by demographers (e.g., Chesnais, 1992). Essentially without exception, the demographic transition begins with a sustained decline in mortality. A reduction of fertility follows with some delay. The consequence is a temporary increase in population growth between the onset of the mortality transition and the beginning of the fertility transition. Figure 5 depicts the usual representation of the demographic transition, with a drop in the crude death rate, the delayed decline in birth rates, and the consequential inverse u-shape dynamics of the natural population growth.

[8] The question about inefficiently low growth also has a normative component that requires the formulation of an efficient benchmark. The analysis here is deliberately kept positive and avoids normative statements.

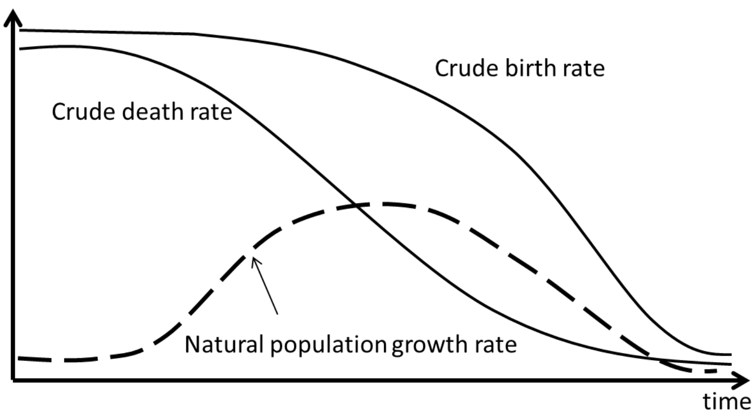


Figure 5: The Typical Pattern of the Demographic Transition

The different levels of population growth and life expectancy, depicted in Figure 3(b) and Figure 3(c) respectively, can be interpreted in light of Figure 5. All countries are initially in a pre-transitional phase with large mortality (low life expectancy) and low population growth. The onset of the demographic transition goes along with an increase in life expectancy and a temporary increase in population growth rates. Once the fertility transition eventually sets in, this pattern reverses and population growth rates decline.

3.2. A Prototype Unified Growth Theory as Conceptual Framework

According to unified growth models, the demographic dynamics illustrated in Figure 5 and documented in Figure 3 have important consequences for economic development. Lower mortality increases the amortization period of education investments and can trigger a fertility transition that reduces the number of births and a shift of resources that parents spend on their children’s health and education, away from sustaining a large number of offspring. Eventually, these behavioral changes might trigger an economic transition from stagnation to growth.

To illustrate these predictions in more details, we apply the insights from the prototype unified growth theory proposed by Cervellati and Sunde (2015a). This simple dynamic general equilibrium framework with inter-temporal spillovers can account for the transition in the different dimensions illustrated in Figure 3. While the specific mechanisms driving the transition in the model are not crucial for the argument and the following analysis, we use the model for the more general argument relating to the similarity of the transition patterns and the importance of delays. Using this specific model has the advantage of providing a simulation of the transition in the different dimensions that can be used to highlight the testable implications of the main argument.[9]

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.

An important implication of this modeling strategy is that sufficiently 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. Thus,

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9 Earlier models that feature an endogenous demographic transition following an exogenous decline in mortality include the pioneering work by Ehrlich and Lui (1991). Related work by Becker, Murphy and Tamura (1990), predicts non-linear patterns in fertility, education and development, but does not incorporate the role of mortality. The model considered here has the advantage of providing a parsimonious framework that is able to generate the transition in the different dimensions while lending itself readily to a quantitative simulation in the spirit of unified growth models of the transition from stagnation to growth. This literature originates with the seminal work by Galor and Weil (1999, 2000), see also Galor (2011) for an extensive survey of the unified growth literature. In contrast to the earlier models that feature multiple steady states and the need for exogenous forces to bring about a transition, unified growth models exhibit an endogenous change of the dynamic system that generates the transition, and therefore provide a more appropriate framework for the purpose of this paper.

overall the equilibrium relationship between longevity and the share skilled is S-shaped as illustrated in Figure 6.

Next, consider this simple occupational choice 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 versus unskilled human capital. In such a setting, endogenous improvements in longevity and skill-biased technological change are linked to the share of those skilled in the previous generation. As a consequence of the shape of the equilibrium relationship between the skilled share and longevity, it spans a dynamical system that exhibits nonlinearities.

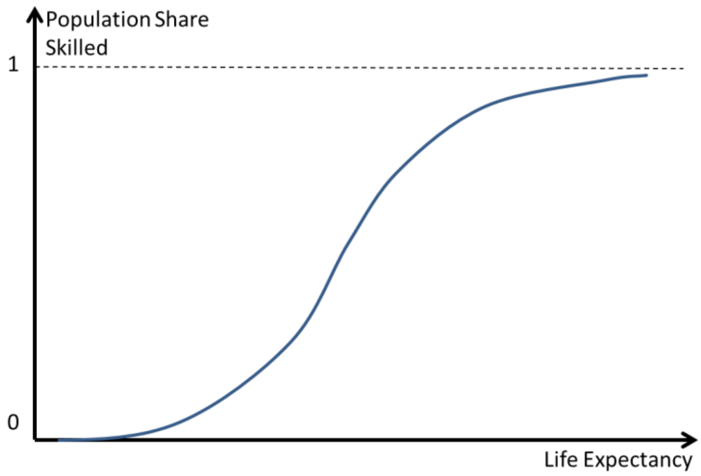


Figure 6: The Equilibrium Relation between Life Expectancy and Education

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 skilled share 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. Larger 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 a few generations the economy undergoes the demographic transition and converges to a balanced growth path, resembling that of a standard endogenous growth model.

3.3 Towards Testable Predictions: Simulating the Development Path

Cervellati and Sunde (2015a) show that the development paths obtained by simulating a simple quantitative version of the prototype unified growth theory deliver empirical patterns that closely match the historical time series for countries such as Sweden or England. From this paper's perspective, however, the more important insight of the quantitative analysis 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 governing 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 pattern.

In the following, we borrow the baseline quantitative version of the model to simulate the evolution of the economy over the long run.[10] The baseline simulation is obtained from a version of the model that is calibrated by targeting data moments for Sweden. An alternative simulation is obtained for an identical model economy that differs in only one aspect, namely that it exhibits a higher extrinsic mortality.[11] As a consequence, the counterfactual economy exhibits a later (but otherwise a qualitatively almost identical) economic and demographic transition. The data obtained from the simulation are used to illustrate the evolution of long-run development in all central dimensions, including income per capita, education, fertility, and longevity.

Figure 7 plots the resulting dynamic evolution of these two simulated economies over the period 1600-2000. The figure provides four main insights that one can extract from the recent results in unified growth theory, and that can be applied to the investigation of global comparative development patterns as seen above.

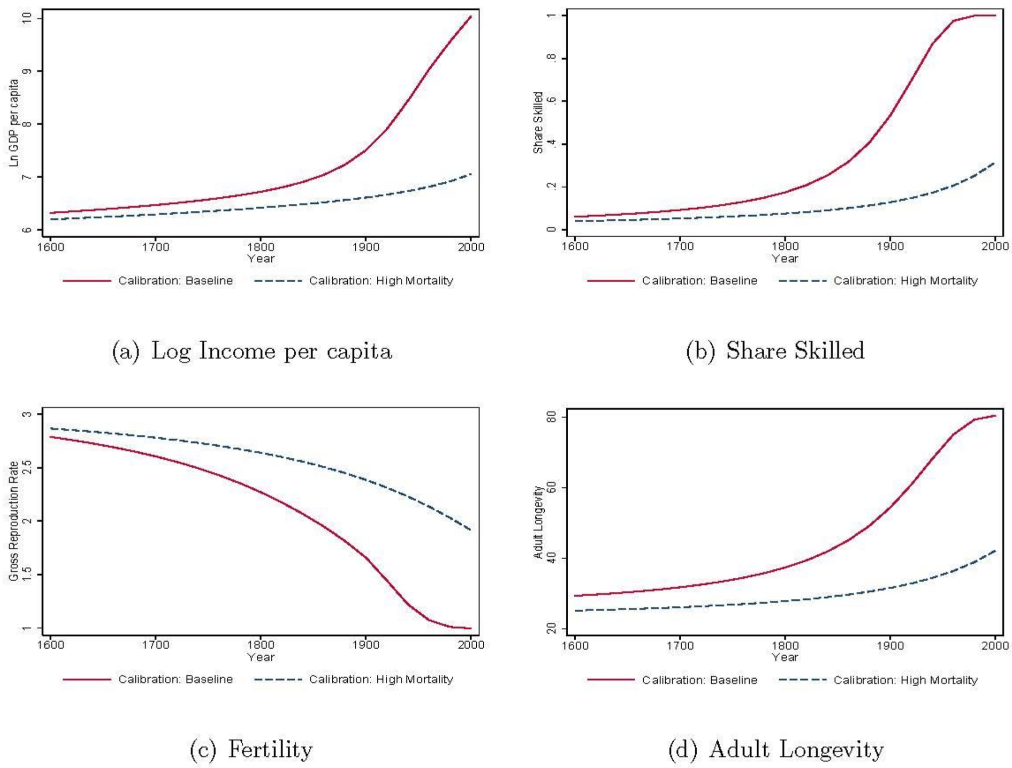
First, the results suggest that the dynamic evolution of income, population dynamics, mortality and education can be interpreted as resulting from dynamic interactions between these different dimensions, which eventually, after a long period of slow (quasi-stagnant) growth, lead to a period of relatively rapid development during the transition to sustained

[10] Technically, the simulation covers the period 0-2000, but the analysis is conducted over the period 1600-2000.

[11] The baseline model assumes that 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 45 years. 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.

growth. Ultimately, the transition experiences a slowdown in the process of converging to the balanced growth path.[12]

Second, the simulated data shed new light on the differential patterns of income growth across different countries over the last decades, as depicted in Figure 1. In particular, we argue that the increase in income growth in developing countries and the slow-down in the advanced economies can be interpreted as being related to the fact that these countries are in different phases of the demographic and economic development process.



(a) Log Income per capita (b) Share Skilled

(c) Fertility (d) Adult Longevity

Figure 7: The Role of Transition Delays for Comparative Development

(*Source*: Cervellati and Sunde, 2015a)

Third, 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 timing and, for some regions of the world, substantial delays in the take-off. Specifically, the simulation illustrates that differences in baseline mortality imply a substantial delay, of more than a century, in the onset of the economic and demographic transition.

Taken together these observations imply that countries taking off earlier 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

[12] These predictions are also consistent with findings by Zhang and Zhang (2005) that life expectancy has a positive but decreasing effect on savings, school enrolment and growth, as well as a negative effect on fertility.

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 of the qualitative similarity in the long-term development patterns. Figure 7 also allows for an interpretation of the global demographic patterns from Figure 3. In particular, it allows us to interpret the observed patterns in the OECD countries' growth slowdown, as well as Latin America and Africa's acceleration, as compatible with the view that these countries are in different phases of their demographic transition which, in turns, affects their development prospects.

4. Empirical Implications

Irrespective of the reason why it occurred, the delay in the transition to sustained growth (illustrated in Figure 7) is an important element for understanding global development patterns and the prospects within the context of the secular stagnation question. The insights from the conceptual framework and the simulation presented in Section 3 have relevant implications for the secular stagnation debate in Western countries and suggest some predictions that can be tested with cross-country panel data.

4.1 Demographic Transition, Human Capital and Long-term Development

Life Expectancy and Changes in Education. The first empirical implication that follows from the conceptual framework is that education and human capital - which are the main factors behind growth in the long-term development literature - exhibit nonlinear dynamics during the different phases of economic and demographic development. As illustrated in Figures 7 (b) and (d), and consistent with the data in Figures 3(c) and (d), human capital accumulation only gains momentum once life expectancy is sufficiently large. At the same time, this accumulation process slows down once the majority of the population acquires substantial amounts of human capital, as reflected by the large shares of skilled within the population, whereas life expectancy keeps increasing but at slower pace.

Changes in human capital should therefore be expected to be large in the early development phases (after the exit from Malthusian stagnation) and slows down as the economy develops, exhibiting a hump-shaped relationship with life expectancy, which is the central state variable behind the demographic and economic transition.

Figure 8 illustrates this prediction using the simulation of the prototype unified growth theory and compares the predicted patterns with actual cross-country panel data. The figure plots the change in human capital (measured by the population share with some formal schooling) over a 20-year horizon, against life expectancy at birth at the beginning of this 20-year period and contrasts this with the simulated data of the calibrated unified growth model's baseline version discussed above. The hump-shaped relationship is clearly visible and strikingly similar. This issue is relevant for the secular stagnation debate in developed countries since it implies the prediction of a slowdown in the rate of increase in education attainment, and thus also in income growth, during the late phases of the demographic transition. The simplest way of testing this 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 in Figure 8.

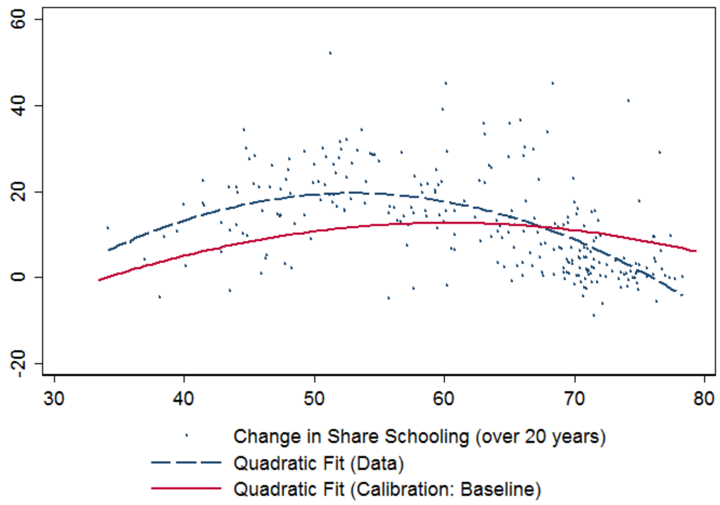


Figure 8: The Relationship between Life Expectancy and Subsequent Human Capital Accumulation

(*Source*: Barro and Lee, 2010; Data from the simulation of the model by Cervellati and Sunde, 2015a)

The hypothesis is that the higher the level of life expectancy, the smaller the subsequent change in a country's acquisition of human capital. This is because 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 average years of schooling, a human capital index and the share of individuals with schooling as alternative variables of interest.[13]

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.

In view of theoretical insights, each developing country should follow the same nonlinear pattern over time. To specifically test this prediction, Panel B in Table 1 replicates the same exercise but exploits within-country variation over time in specifications with country and period fixed effects. Besides identification issues, this specification has the advantage of being closely linked to the conceptual idea of identifying nonlinearities along a given country's development path that lies behind the simulation in Figure 7. The results confirm the main findings and also suggest that income levels do not significantly affect future changes in

[13] 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).

education once one accounts for the nonlinear relation behind life expectancy and education during different development phases.

The structural slowdown in the process of human capital formation once economies get to the demographic transition's mature stages is by itself an interesting observation for the question on the existence of a secular growth slowdown. The results even indicate a non-monotonicity in the effect with a maximum effect occurring between 60 and 75 years of life expectancy, at least when considering the human capital index or the share of the population with some schooling.

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***	0.016***	0.016***	0.80***	0.84***
	(0.011)	(0.011)	(0.002)	(0.002)	(0.080)	(0.101)
Life Expectancy at Birth (sq.)/100	-0.040***	-0.044***	-0.013***	-0.013***	-0.743***	-0.770***
	(0.008)	(0.010)	(0.002)	(0.002)	(0.070)	(0.091)
log GDP p.c.		0.012		0.006*		0.017
		(0.017)		(0.003)		(0.223)
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***	0.590***	0.470***
	(0.013)	(0.015)	(0.003)	(0.003)	(0.136)	(0.172)
Life Expectancy at Birth (sq.)/100	-0.014	-0.017	-0.010***	-0. 008***	-0.480***	-0. 340**
	(0.011)	(0.014)	(0.003)	(0.003)	(0.116)	(0.155)
log GDP p.c.		0.053		0.003		-0.32
		(0.040)		(0.010)		(0.336)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes	No	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	0.102	0.046	0.076	0.029	0.028

Notes: OLS estimates (Panel A), fixed effects estimates (Panel B), robust 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: Penn World Tables, UN Statistics and Barro-Lee (2010), see Table 7 for details.

Education and Income Growth. Another implication of the conceptual unified growth framework, illustrated by the simulated data shown in Figure 7, is that the effect of education on growth is also nonlinear. Most importantly, the effect of education varies across the different development phases. This can be illustrated by jointly considering Panels (a) and (b) of Figure 7. 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), $k_{i,t}$ is the stock of physical capital per capita, and the vector X includes other controls considered in the empirical growth literature. The corresponding coefficient vectors are α for the productivity component, β and γ for human and physical capital, as well as Γ for the vector of controls.[14]

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 7, which 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 additional years of schooling (or education) is expected to be reduced. Specifically, as implied by the simulated data shown in Figure 7, the relationship between education and future income is positive and convex in the early development phases (during growth take-off) but concave in the later phases (while converging to the balanced growth path).[15]

A purely statistical, theory-free, approach that is often used to account for nonlinearities in the standard specification (1) involves including nonlinear (e.g. quadratic) education effects on income growth. Column (1) in Table 2 reports the results of such a nonlinear 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 indeed suggest the existence of some nonlinearities, the interpretation of these patterns,

[14] 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 logs, one can derive an estimation equation as in (1); for a differenced version see also Benhabib and Spiegel (1994).

[15] 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 and a more detailed discussion of cohort-specific effects.

which appear to change depending on different human capital measures, is not obvious. The lack of consistent patterns obtained with the pure statistical approach suggests that accounting for the unified growth theory implications requires extending the standard specification in line with theoretical insights. In fact, according to the theoretical predictions the effect should not just be nonlinear but should also depend on the different stages of the demographic transition. To explicitly test this specific prediction, the remaining columns in 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. 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 an appropriate indicator to identify different economic and demographic development phases. This categorization follows the demographic literature that looks at the levels and changes of life expectancy and fertility to identify the turning points of the demographic transition process illustrated in Figure 5. In particular, demographers suggest a threshold of approximately 50 years above which a country is considered to be post-transitional (see, e.g., Chesnais, 1992, p.19, and the discussion in Cervellati and Sunde, 2011b).

In the empirical analysis, we adopt two different approaches to account for a country's demographic development stage. The first is a time-invariant categorization of countries into early and late transition countries, based on whether the threshold has been surpassed by 1960 or not, using Reher's (2004) dating of transitions. The second approach is to allow for a change in the demographic status of a country, depending on the year in which the respective threshold is reached. In the empirical analysis, we again use Reher's (2004) classification of when a country underwent the demographic transition.

Table 2: The Demographic Transition: Human Capital on Income

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
	(0.036)	(0.047)	(0.052)	(0.038)	(0.047)
Av. Years of Schooling (sq.)	0.0016	-0.005**	).008***	-0.0016	0.010**
	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)
log Capital p.c.	0.58***	0.50***	0.58***	0.52***	0.66***
	(0.054)	(0.084)	(0.068)	(0.063)	(0.070)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1316	592	724	735	581
R^2	0.736	0.856	0.652	0.820	0.686
Adjusted R^2	0.733	0.853	0.645	0.817	0.678
	Panel B: Effect of Human Capita (Index)				
Human Capital Index (SH)	0.098	0.71**	-0.63	0.36	-0.87***
	(0.302)	(0.331)	(0.447)	(0.313)	(0.375)
Human Capital Index (SH) (sq.)	0.056*	-0.15**	0.26***	-0.043	0.28***
	(0.061)	(0.069)	(0.090)	(0.059)	(0.102)
log Capital p.c.	0.57***	0.50***	0.56***	0.52***	0.63***
	(0.054)	(0.085)	(0.063)	(0.064)	(0.074)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1324	592	732	735	589
R^2	0.738	0.857	0.659	0.822	0.684
Adjusted R^2	0.736	0.853	0.652	0.818	0.676
	Panel C: Share of Population with Formal Schooling				
% with formal schooling	-0.006	0.020***	-0.016**	0.005	-0.024**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)
% with formal schooling (sq.)/100	0.008	-0.011**	0.015***	-0.002	0.021***
	(0.005)	(0.004)	(0.005)	(0.005)	(0.007)
log Capital p.c.	0.59***	0.50***	0.60***	0.52***	0.63***
	(0.056)	(0.082)	(0.071)	(0.064)	(0.064)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1316	592	724	735	581
R^2	0.737	0.867	0.649	0.822	0.694
Adjusted R^2	0.734	0.864	0.642	0.818	0.686

Notes: Fixed effects estimates, robust 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. Classification "Early"/"Late" codes countries having completed the demographic transition before/after 1960 according to the classification in Reher (2004); Classification "Pre-Trans."/Post-Trans." corresponds to a time-varying classification of 5-year country observations. *Data Sources*: Penn World Tables and Barro-Lee (2010), see Table 7 for details.

The remainder of Table 2 presents the results once the empirical framework is extended to explicitly consider the role of the transition phases. Columns (2) and (3) adopt the time-invariant classification and 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 Column (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, Column (3) shows that the effect is convex for the countries that were still underdeveloped as of 1960 (labeled “Late”). Alternatively, the empirical models estimated in Table 2, Columns (4) and (5) exploit variation in 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. The results 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; conversely, 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 in Table 2.

4.2 Aging and Dependency Ratios: Implications for Savings and Productivity

The unified growth literature has extensively investigated another typical demographic pattern that can be highly relevant for a country’s ability to sustain capital accumulation during the different development phases.

The change in life expectancy that triggers the demographic transition is initially characterized by large increases in intermediate, working age, survival rates with limited changes in young and old age survival (see Cervellati and Sunde, 2013). A relevant implication of this pattern is an increase in the share of the working age population that leads to a reduction in old age dependency ratios.

The further increases in life expectancy are more than proportionally related to increases in old age survival rates through the well-known process of rectangularization of the survival function. This phase is also typically associated with a sharp reduction in fertility rates and the increase in schooling documented in the previous section. As a result of these joint demographic patterns, the share of working age population— compared to retirees as well as the young who have not yet entered the labor force— experiences a sharp decline, leading to an increase in dependency ratios. As a result increased life expectancy is expected to affect the dependency ratios non-monotonically. This discussion therefore has important implications for the secular stagnation debate since the dependency ratio is relevant for the ability and tendency of an economy to produce and save. In particular, the rise in life expectancy might have non-linear effects on savings and growth as it unambiguously increases savings for old age in a population where the old age dependency ratio is still moderate. With increasing dis-savings as the population ages, the effect of further increases in life expectancy on savings weakens.[16]

To explore these issues, we proceed in two steps. First, we investigate how the change in life expectancy, and the associated process of population aging, affects old-age dependency ratios. In a second step we relate the dependency ratio to the process of human capital accumulation, savings and productivity.

Life Expectancy and Old Age Dependency Ratios. Table 3 displays the results obtained when exploring the prediction of a U-shaped effect of life expectancy to the old-age dependency ratios.

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 funnel into higher shares of retired individuals in the population.[17] 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. The effect is reinforced by the fact that for high longevity, the fertility transition also reduces the inflow of both newborns and the working age population. On average the empirical reversal of the effect is around life expectancy at birth of 60–65 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). These results are a reflection of the phenomenon that the demographic transition might unfold particularly suitable conditions for economic development for a limited period of time, which has become known as the “Demographic Dividend” (Bloom, Canning, and Sevilla, 2003).

[16] The effect of demographic change on savings was at the core of the arguments by Hansen (1939). The non-linear effect of increases in life expectancy on savings and growth has been predicted in theoretical work, e.g., by Zhang, Zhang, and Lee (2003). Lee and Mason (2010) provide a discussion of these issues in the context of global population aging.

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

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	-0.77***	-0.77***	-1.25***	-0.45***	-0.98***	-0.60*
	(0.161)	(0.161)	(0.450)	(0.157)	(0.385)	(0.238)
Life Expectancy at Birth (sq.)/100	0.610***	0.650***	0.950**	0.42***	0. 84**	0. 51**
	(0.122)	(0.147)	(0.421)	(0.146)	(0.352)	(0.221)
log GDP p.c.		0.62***	1.49***	0.25	1.04***	0.35
		(0.299)	(0.488)	(0.302)	(0.375)	(0.488)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1771	1472	567	905	764	708
R^2	0.387	0.433	0.618	0.227	0.603	0.350
Adjusted R^2	0.382	0.428	0.609	0.216	0.597	0.338

Notes: Fixed effects estimates, robust 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*: UN Statistics and UN World Population Prospects, see Table 7 for details.

Old Age Dependency Ratios and Gross Capital Formation. As a second step we link the population's age structure to savings and productivity. [18] The discussion above and a considerable literature on the implications of aging on savings behavior points towards potential non-linear effects. Ceteris paribus, an increasing life expectancy requires more savings by the working age population for old age consumption. However, on the aggregate, an increasing fraction of elderly who dis-save tends to reduce aggregate capital accumulation. This implies that longevity and the age structure are expected to have distinct effects on savings, as has been pointed out by Li, Zhang, and Zhang (2007).

Following their approach, Table 4 investigates the hypothesis that a higher old-age dependency ratio may reduce gross capital formation, while life expectancy might increase gross capital formation. The results support this hypothesis. As one would expect, the negative effect of population aging in terms of the old age dependency ratio is stronger, and more statistically significant, in those countries that underwent their economic and demographic transition early on and are largely post-transitional. Countries with a delayed transition or that are still pre-transitional do not show a significant effect. This pattern is mirrored by a positive

[18] The quantitative version of the unified growth theory presented in Section 3 does not explicitly account for the endogenous evolution of savings, and accordingly physical capital accumulation, during the different development phases. While the theory therefore does not deliver explicit predictions, it is interesting to explore the empirical patterns in light of the focus on interest rates in the secular stagnation debate.

effect of life expectancy on gross capital formation, which is also stronger among countries that underwent their demographic transition early.

Panel B of Table 4 replicates the same analysis using life expectancy at age 15 rather than at birth, reflecting the fact that the discussion mainly refers to adult longevity instead of child mortality. The overall patterns are similar, but the distinction between early (or post-)transitional and late (or pre-)transitional countries is even more pronounced.[19]

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 emerging from the developing world's increasing incomes—paired with populations exhibiting higher aggregate savings—might well lead to lower interest rates in the medium run, in particular if the increase in capital formation outweighs the slow-down in the developed, post-transitional countries. The rates may remain low until population aging induces a slowdown in capital formation and capital supply produced in developing countries.[20]

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.[21]

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[19] In light of the previous discussion and the fact that education also represents an investment, one might speculate that the distinct roles of life expectancy and old age dependency might also apply to the estimates in Table 1. Table 1B in the Appendix contains corresponding estimates for an extended specification that also controls for the old age dependency ratio. The main finding of a hump-shaped effect of life expectancy on changes in education attainment remains unaffected.

[20] The emphasis on exceedingly low (zero or negative) interest rates in the recent secular stagnation debate is related to the prolonged phase of seemingly ineffective expansionary monetary policy in response to the financial crisis of 2007/8. This aspect of stabilization policy in response to a recession further complicates the picture but goes beyond the long-run perspective taken here. Nevertheless, it should be noticed in this context that the focus on low interest rates was not at the core of the original secular stagnation hypothesis. In fact Hansen emphasizes the role of population dynamics for output and capital formation, mentioning that "the deepening of capital results partly from cost-reducing changes in technique, partly (though this is probably a much less significant factor) from a reduction in the rate of interest" (Hansen, 1939, p.7).

[21] See Cervellati and Sunde (2016) for a detailed theoretical and empirical analysis of this point.

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)
	Panel A: Life Expectancy at Birth					
Old-Age Dependency Ratio	-0.004*	-0.004**	-0.004	-0.003	-0.006**	-0.002
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)
Life Expectancy at Birth	0.004***	0.003***	0.005***	0.003*	0.003**	0.004
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)
log GDP p.c.		-0.001	0.005	-0.003	-0.006	-0.002
		(0.012)	(0.022)	(0.015)	(0.017)	(0.024)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1565	1472	567	905	764	708
R^2	0.058	0.06	0.124	0.052	0.092	0.050
Adjusted R^2	0.051	0.052	0.103	0.038	0.076	0.032
	Panel B: Life Expectancy at Age 15					
Old-Age Dependency Ratio	-0.005**	-0.005***	-0.006***	-0.005	-0.007***	-0.003
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)
Life Expectancy at Age 15	0.003***	0.003**	0.002	0.004**	0.002**	0.0024
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
log GDP p.c.		0.006	0.020	-0.001	-0.001	0.003
		(0.012)	(0.023)	(0.015)	(0.017)	(0.023)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1609	1508	602	906	777	731
R^2	0.048	0.048	0.071	0.053	0.074	0.042
Adjusted R^2	0.040	0.039	0.049	0.038	0.057	0.024

Notes: Fixed effects estimates, robust 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: Penn World Tables and UN World Population Prospects, see Table 7 for details.

Demographic Dynamics and Productivity. The other central factor behind growth in the simple empirical framework (1) refers to changes in technology and productivity. Table 5 shows the results from regressions of total factor productivity on life expectancy at birth (Panel A) and life expectancy at age 15 (Panel B).[22] The findings reveal that increases in life

[22] Life expectancy at the beginning of working age might be more appropriate to conduct this analysis than life expectancy at birth, which contains information on child mortality. We thank a referee for pointing this out.

expectancy significantly affect productivity dynamics, particularly during the early demographic transition phases, i.e., in countries that undergo their transition late. 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 in terms of productivity gains.[23] 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.

The literature on long-term development recently pointed out potential positive effects of aging. While, as documented above, aging countries experience growth slowdowns in schooling and education achievements, that can be interpreted as measures of human capital quantity: They do not necessarily experience a slowdown in the growth of human capital quality, which is also acquired with on the job experience and non-school skill acquisitions. In fact, in view of the literature (see, e.g., Hanushek and Woessmann, 2015), one should rather expect the quality of human capital acquired by experience to increase with longevity. While human capital quality is hard to measure (to the best of our knowledge, no comparable cross-country panel data is available on this dimension), one should expect the quality of human capital to positively affect workers' productivity.

As a final step, we therefore investigate the implications of population aging, in terms of the old-age dependency ratio, for productivity. The results, which are reported in Table 6, 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, despite the ongoing aging process, does not necessarily become unproductive. The findings are confirmed in specifications that jointly include old-age dependency and life expectancy.[24]

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

[24] See Table 6B in the Appendix for details.

Table 5: Life Expectancy and Productivity

Dependent variable:	Total Factor Productivity				
Sample	Full	Early	Late	Post-Trans.	Pre-Trans.
	(1)	(2)	(3)	(4)	(5)
	Panel A: Life Expectancy at Birth				
Life Expectancy at Birth	-0.058***	0.005	-0.047*	-0.048	-0.061*
	(0.018)	(0.036)	(0.027)	(0.029)	(0.031)
Life Expectancy at Birth (sq.)/100	0.050***	-0.045	0. 040	0.043*	0.057**
	(0.016)	(0.031)	(0.024)	(0.025)	(0.024)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1064	573	491	669	395
R_2	0.249	0.430	0.131	0.366	0.282
Adjusted R^2	0.239	0.415	0.106	0.353	0.258
	Panel B: Life Expectancy at Age 15				
Life Expectancy at Age 15	-0.13***	-0.041	-0.17***	-0.048	-0.16**
	(0.034)	(0.053)	(0.052)	(0.037)	(0.066)
Life Expectancy at Age 15 (sq.)/100	0.13***	0.051	0. 18***	0.055	0.18***
	(0.033)	(0.051)	(0.054)	(0.038)	(0.061)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1064	573	491	669	395
R_2	0.255	0.430	0.162	0.368	0.312
Adjusted R^2	0.245	0.415	0.137	0.354	0.289

Notes: Fixed effects estimates, robust 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.
Data Sources: Penn World Tables and UN Statistics, see Table 7 for details.

Table 6: Population Aging and Productivity

Dependent variable:	Total Factor Productivity				
Sample	Full	Early	Late	Post-Trans.	Pre-Trans.
	(1)	(2)	(3)	(4)	(5)
Old Age Dependency Ratio	0.027***	0.019***	0.039***	0.019***	0.017
	(0.006)	(0.006)	(0.011)	(0.006)	(0.013)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1090	562	528	658	432
R^2	0.270	0.452	0.174	0.384	0.291
Adjusted R^2	0.261	0.439	0.153	0.372	0.269

Notes: Fixed effects estimates, robust 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. *Data Sources*: Penn World Tables and UN World Population Prospects, see Table 7 for details.

5. Outlook: Will there be a "Secular Stagnation"?

Ever since the end of the 19th century, the world has witnessed fast economic growth and economic development has made its way 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. We have argued that high growth rates in the past 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.[25] Indeed, international capital flows across countries appear to be linked to demographics, particularly aging patterns (see, e.g. Domeij and Floden, 2006).[26] 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 transitions, the forerunners have incidentally been able to balance this slowdown and continue to grow at relatively high rates. They have done so by expanding their markets through globalization, effectively attracting capital and benefitting from the demographic development potential of the less developed countries. Ultimately, 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, while the demographic transition induces greater savings also in the latecomer countries. In a world of global capital markets, this leads to an excess supply of capital, declining marginal productivity, and thus very low interest rates as compared to the

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

[26] 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).

past. While a decline in interest rates and growth is qualitatively consistent with convergence dynamics in standard neoclassical growth models, the speed as well as the consistency of the empirical patterns across different dimensions of economic and demographic development suggest that the observed patterns reflect a broader set of massive and singular transitions in the global development process. Based on the findings reported in this paper, it appears plausible that the ongoing global demographic transition, with a decline in fertility and an increase in longevity, tends to increase the global savings. The more countries undergo this transition, the more savings need to be invested, leading to an accumulation of capital and declining returns, with the consequence of lower interest rates.

However, this does not mean that the world economy will necessarily stagnate. Once the influence of transitional dynamics on economic development becomes less important, economic 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 than the role of demographic factors. First, productivity improvements are harder to achieve in countries that operate at the technology frontier compared to countries that have scope for catching up. This already implies the possibility of slower growth in productivity in developed countries. Second, opinions disagree as to the scope for productivity improvements, and whether innovations will stagnate, accelerate or decelerate in developed countries (see, e.g., Gordon, 2014b, 2016, 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.[27] 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.[28]

This paper's aim was two-fold: first, to give a qualitative assessment of the growth contribution of different factors, including demographic factors, market size effects, and innovation, and second, to point out implications for future development. The findings are broadly in line with the predictions from a prototype unified growth model exhibiting nonlinear development patterns like the demographic transition. In particular, the empirical patterns are consistent with the hypothesis that the recent slow-down can be understood as reflection of the long-run dynamics of the transition from stagnation to growth that is associated with substantial demographic changes, in combination with heterogeneity in the dynamics of this transition across the world. In this sense, the focus on the 2008 financial crisis and the following Great Recession might be misplaced, as it neglects the broader development pattern of temporary phenomena that cannot be repeated.

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

[28] Zaiceva and Zimmermann (2016) provide a review of the issues related to aging and migration.

Incidentally, this view appears to be very closely related to the concerns that led Hansen (1939) to coin the term "Secular Stagnation". In fact, demographic changes (in particular the slow-down in population growth) played an important role for his argumentation when he wrote that "*[f]undamental to an understanding of this problem [the Secular Stagnation] are the changes in the "external" forces, if I may so describe them, which underlie economic progress – changes in the character of technological innovations, in the availability of new territory, and in the growth of population*" (Hansen, 1939, p.4). His fear was that these, in his view "external forces", which had contributed to growth and capital accumulation before the Great Depression, were losing momentum (see, e.g. Hansen, 1939, p.9). To the extent that many forecasts disregard the nonlinearities inherent to long-run development dynamics that are at the focus of the present analysis, we hope that the findings shed some new light on the recent secular stagnation debate.

Clearly, policies and institutions are factors that can aggravate or mitigate the consequences of these processes. The recent focus on very low interest rates and monetary policy witnesses this, even though the arguments made above suggest that a business cycle perspective on the global dynamics might be misguided. Incorporating these issues is beyond the scope of this paper, but clearly an interesting and highly relevant agenda for future research. In this sense the call for increased research effort in understanding the pattern of development in long-term and global perspective that Hansen made back in 1939 is still valid: "*There are no easy answers to the problems that confront us. And because this is true, economists will not perform their function if they fail to illuminate the rapidly shifting course of economic development*" (Hansen, 1939, p.15).

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A 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

B Additional Figures and Tables (not intended for publication)

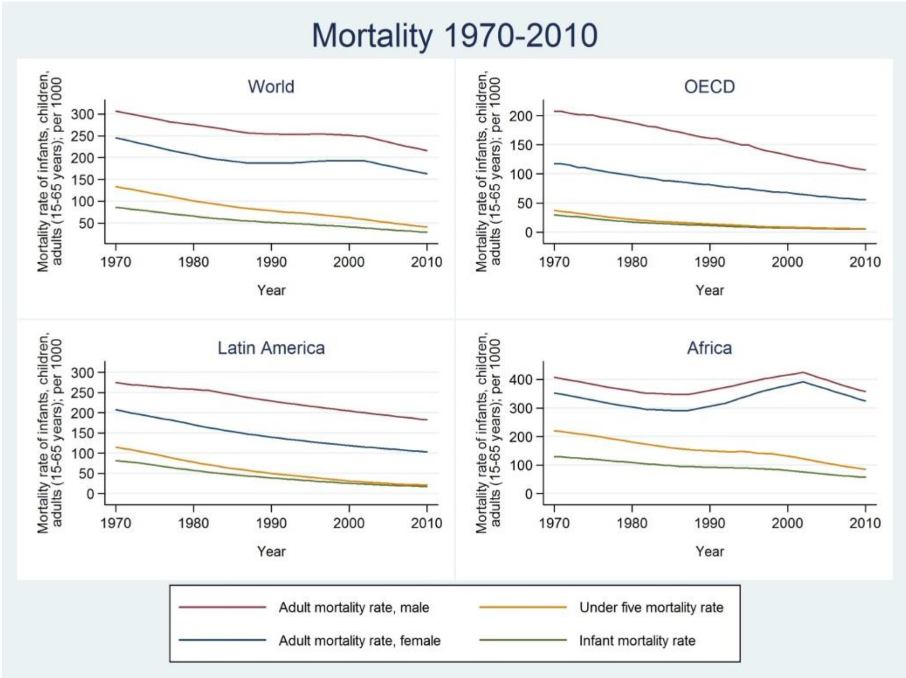

Figure 9: Improvements in Health: Mortality Patterns

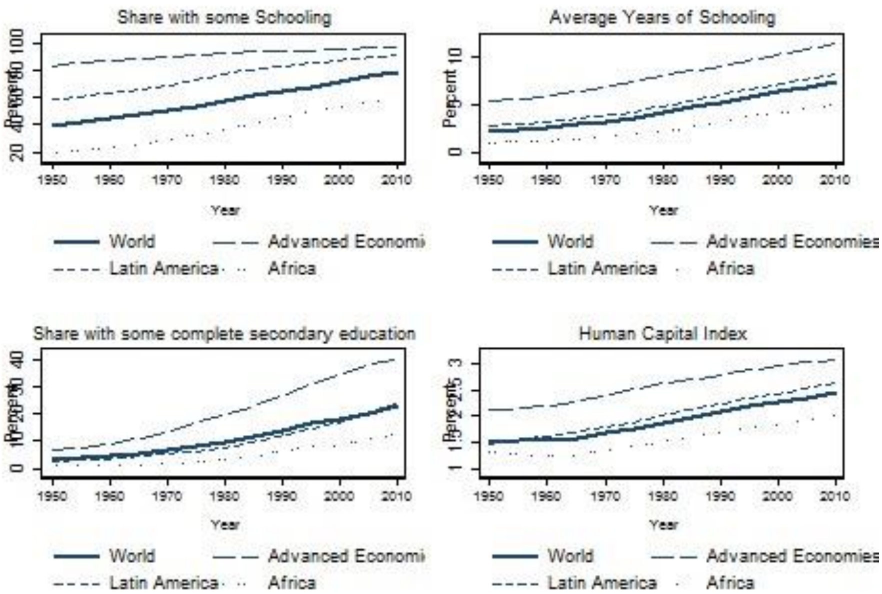

Figure 10: Global Education Attainment: Different Measures

Table 1B: 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	0.048***	0.050*	0.011***	0.014***	0.057***	0.058***
	(0.010)	(0.012)	(0.002)	(0.002)	(0.095)	(0.110)
Life Expectancy at Birth (sq.)/100	-0.031***	-0.034***	-0.010***	-0.011***	-0.49****	-0.50***
	(0.013)	(0.015)	(0.003)	(0.003)	(0.137)	(0.172)
Old-Age Dependency Ratio	-0.006**	-0.007**	-0.001***	-0.001***	-0.18***	-0.018***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.034)	(0.037)
log GDP p.c.		0.015		0.006**		0.091
		(0.017)		(0.003)		(0.223)
Country FE	No	No	No	No	No	No
Year Trend	No	No	No	No	No	No
Observations	1430	1242	1250	1250	1430	1242
R^2	0.121	0.099	0.078	0.082	0.142	0.144
Adjusted R^2	0.119	0.096	0.076	0.079	0.141	0.141
			Panel B			
Life Expectancy at Birth	0.035**	0.024	0.012***	0.010***	0.059***	0.052***
	(0.014)	(0.017)	(0.003)	(0.004)	(0.015)	(0.019)
Life Expectancy at Birth (sq.)/100	-0.016	-0.012	-0.009***	-0.007**	-0.48***	-0.38**
	(0.013)	(0.015)	(0.003)	(0.003)	(0.137)	(0.172)
Old-Age Dependency Ratio	0.002	-0.001	-0.001	-0.002	0.002	0.097
	(0.006)	(0.008)	(0.002)	(0.002)	(0.006)	(0.009)
log GDP p.c.		0.062		0.005		-0.42
		(0.040)		(0.008)		(0.400)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year Trend	No	Yes	No	Yes	No	Yes
Observations	1430	1242	1250	1250	1430	1242
R^2	0.092	0.111	0.049	0.087	0.030	0.039
Adjusted R^2	0.090	0.101	0.046	0.077	0.028	0.028

Notes: OLS estimates (Panel A), fixed effects estimates (Panel B), robust 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: Penn World Tables, UN Statistics and Barro-Lee (2010), see Table 7 for details.

Table 6B: Population Aging and Capital Accumulation

Dependent variable:	Total Factor Productivity				
Sample	Full	Early	Late	Post-Trans.	Pre-Trans.
	(1)	(2)	(3)	(4)	(5)
Old Age Dependency Ratio	0.022***	0.018***	0.032**	0.017**	0.010
	(0.007)	(0.006)	(0.016)	(0.007)	(0.017)
Life Expectancy at Age 15	-0.078**	-0.002	-0.12*	-0.016	-0.140**
	(0.035)	(0.049)	(0.065)	(0.037)	(0.066)
Life Expectancy at Age 15 (sq.)/100	0.081**	0.011	0.120*	0.020	0.016**
	(0.035)	(0.049)	(0.065)	(0.038)	(0.063)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1053	562	491	658	395
R^2	0.284	0.460	0.189	0.387	0.316
Adjusted R^2	0.273	0.445	0.164	0.373	0.290

Notes: Fixed effects estimates, robust 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.

Data Sources: Penn World Tables and UN World Population Prospects, see Table 7 for details.