New evidence on life expectancy and development: is Sub-Saharan Africa different?

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New Evidence on Life Expectancy and Development: Is Sub-Saharan Africa different?

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Abstract:

This paper applies the standard β-convergence analysis and the log-t test methods to compare the convergence process of life expectancy and per capita GDP, using a sample of 89 countries between 1960-2019 and analyse the interrelation and the dynamics of these phenomena in Sub-Saharan African (SSA) after the international epidemiological transition. We use life expectancy at birth and per capita GDP estimates from respectively the World Bank's Population Estimates and Projections and the Penn World Table. Our results show evidence of significant catching-up in life expectancy between SSA countries and the rich and the other poor world by 2019 after a slowdown period between 1985 and 2000 in which most SSA countries converge into multiple steady states. Further, we find that the world without SSA is converging economically in 2019 while significant cross-country variations and convergence clubs are noted when taking into consideration the region. Finally, our results indicate that the economic performances of SSA are not the only factors driving the health catch-up, the increasing convergence in the antimalarial policies' implementation in SSA after 2003 play great role in this process.

Keywords: life expectancy, per capita GDP, convergence, health, economic growth, Sub-Saharan Africa.

JEL-Codes: I15, O11, O55

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I. Introduction

The convergence issue has played a central role in the empirical growth literature (Du, 2017; Schnurbus, 2017; Pesaran, 2007) leading to the historical divergence, rich countries growing faster than poor (Kremer at al., 2022). In the past years, convergence analysis has been applied in topics such as cost of living and poverty (Phillips and Sul, 2007, Marrero et al., 2022), carbon dioxide emissions (Panopoulou and Pantelidis, 2009; Marrero et al., 2021), eco-efficiency (Camarero et al. 2013), house prices (Montañés and Olmos, 2013), corporate tax (Regis et al. 2015), demography and public health (Edwards and Tuljapurkar, 2005; Mackenbach, 2013) and recently in life expectancy (Gerry et al., 2018; Oeppen, 2019; Liou et al., 2020). Unlike the income convergence studies, these later authors both concluded on the global convergence in life expectancy (LE) at birth,[1] not considering possible different paths in the trends towards this global catch-up.

The convergence issue has also been applied to LE and per capita gross domestic product (GDP)[2] simultaneously (Clark, 2011; Ueda, 2008; Acemoglu and Johnson, 2007). Comparing the convergence process in these two macroeconomic dimensions, these authors put in serious doubt the causation of health across growth: they conclude that, at the macroeconomic level, health improvements are not causing GDP increases. The most influencing of these papers by Acemoglu and Johnson (2007) shows evidence of convergence in LE between rich and poor countries until 2000s, while they found no evidence of convergence in GDP in this period. They use this finding to motivate the absence of causality from heath to economic growth, the increase in LE - generated by a decrease in mortality rates - resulting to a flat or even reduction in GDP.[3] This result was more evident in less developed countries than in most developed ones, resulting in a lack of GDP convergence.

However, the last 20 years (between 2000 and 2019) are not included in the existing studies analysing jointly health and economic convergence.[4] Moreover, previous studies analysing simultaneously these macroeconomic dimensions mainly excluded Sub-

[1] From here on, we will refer to life expectancy at birth as 'life expectancy (LE)'.
[2] From here on, we will refer to per capita GDP as 'GDP'.
[3] According to the authors, the increase in LE during the period had a small positive effect on real income grows during the post epidemiological transition period. This positive effect was not enough to compensate for the notorious increase in population.
[4] The LE and income convergence analysis by Ueda (2008) ends in 2005.

Saharan Africa (SSA) region[5] whereas understanding their dynamic and convergence processes and how they correlate is relevant to design development and health policies in the region. Thus, it's necessary to question how have these convergence processes of health and development changed over time? And how are they related in SSA?

LE in SSA (the poorest region) faced considerable growths during the last decades which could be accelerating their convergence process towards healthier (and richer) regions (Cavusoglu and Gimba, 2021).[6] It's no longer a secret that improving the overall level of health has positive long-run impact on the economic development (Liou et al., 2020; Berthélemy and Thuilliez, 2013). Thus, the change in the economic convergence process at the worldwide level, moving towards a "converging to convergence" process emphasizes in recent studies (Kremer et al., 2022) may be the consequence of the previous health convergence (Oeppen, 2019).

In this paper, we compare the convergence process of LE and GDP between 1960 and 2019 using a sample of 89 countries and new data which accuracy has highly been demonstrated. While updating the existing literature on the joint analysis of LE and GDP performances until the pre covid-19 period, we also extend it, paying special attention to the peculiarities of SSA and analysing the interrelation and the dynamics of these phenomena in this region known to be the world poorest both in GDP and in global health (Gil-Alana et al., 2020; Kamanda et al., 2022; Piabuo and Tieguhong, 2017). We particularly emphasize on the period 2000-2019 which represents the period of great transformation in SSA. Thus, starting with a huge gap in both LE and GDP between SSA region and the richest countries in 2000 (Castelló-Climent and Doménech, 2008), we explore whether these dimensions have converged or not from 2000 and 2019, and whether new insights related with the relationship between health and growth have emerged.

We first follow Kremer et al., 2022 and undertake a standard β-convergence analysis, regressing the annualized variations in LE (or GDP) on its initial levels of 1960 to explore evidence of absolute convergence during three health episodes marking the LE trends in SSA. This regression allows to determine whether countries with initial low

[5] The common reason used to justify the exclusion of SSA region in the convergence studies is the inconsistency and poor quality of health data in the region. To come through out this shortcoming, we use the life expectancy estimates from the World Bank's Population Estimates and Projections database shown to be accurate, reliable, and comparable (Shaykheeva et al., 2016).

[6] In SSA, the average life expectancy in 2016 stood at 60.4 years while a child born earlier in 1960 would have lived on the average for just 40.4 years (Cavusoglu and Gimba, 2021).

health (or low GDP) grow faster on average than countries with better initial health (or economic) indicators. Next, we follow recommendations by Johnson and Papageorgiou (2020) and analyse the convergence patterns in the two dimensions by applying the panel convergence testing methodology of Phillip and Sul (2007, 2009). Built on a nonlinear factor model with time-varying loadings, this statistical approach allows distinguishing between different forms of convergence without imposing (a priori) any particular one; thus, we can simultaneously analyse absolute convergence, conditional convergence or club convergence (Marrero et al., 2022).

We encapsulate main findings of the analysis. Before 1985, the evidence is not of absolute or conditional convergence in LE, but of the existence of 3 convergence clubs. Until 2000s, our clustering analysis yields a distinct two club pattern that is reminiscent of the high mortality-low mortality dual regime model discussed by Bloom and Canning (2007). As state by Liou et al. (2020), countries without the means to achieve improved rates of diffusion of health technologies and implementation of public health measures (Cutler et al., 2006; Jamison et al., 2001) face a discouraging outlook of being stuck in a mortality trap (Bloom and Canning, 2007). Regarding income, there is evidence of economic divergence between 1985 and 2000. Although we found 3 and 4 economic convergence clubs respectively in 2000 and 2019, we show that poor countries (including SSA region) are growing faster than the rich world since the early 2000s.

Our study is rooted in an extensive literature on convergence (Oeppen, 2019; Johnson and Papageorgiou, 2020; Kremer et al., 2021) and particularly the ones analysing jointly health and development (Clark, 2011; Ueda, 2008; Acemoglu and Johnson, 2007). The literature is unanimous about the straight and global convergence in health since the epidemiological transition of the 1940s but our results, taking into account the SSA region show that between 1985 and 2000 there is a slowdown of the convergence process. The literature is also unanimous about the lack of global income convergence (Kant, 2019) but evidence of multiple steady states (Basel et al., 2021). We contribute to this literature by bringing the clubs' convergence perspective and offering a formal tests of club convergence in LE and confronting the obtained clubs to those obtained in GDP showing not only similitudes and divergences but also the impact of previous clustering behavior of these two dimensions on their future converging paths.

The other strand of the literature relevant in our context is about health inequality (Castelló-Climent and Doménech, 2008; Oeppen and Vaupel, 2002; Vaupel, 2019). Our

results are consistent with their findings. There is evidence that health inequality decreased over the last decades after the rapid increase in LE with the most important improvements starting in 1940 (Acemoglu et al., 2003). During the 1980s and 1990s, these improvements gave way to newly emerged patterns of regional health divergence (Gerry et al., 2018), some regions like SSA sawing their progress stalling and, in some cases, falling backwards because of the widespread of AIDS and malaria in the region. However, consistently with the results of Cavusoglu and Gimba (2021), this situation has reversed, LE being on a gradual and steady rise since 2000 in SSA. This last stage coincides with the rapid increase in the implementation of policies to fight against malaria (Bethencourt et al., 2021), the expansion of education and particularly the empowerment of women in the region (United Nations, 2014; World Bank, 2017) and the rise in the prevention and treatment of HIV/AIDS (WHO-UNAIDS, 2009).

Moreover, discussing the interrelation between health and economic development in SSA, our study brings back debate on the correlation between health and development. Our results are consistent with the lack of historical economic convergence (Kremer et al., 2022) and the issue of double causality between health and development stated in the literature (Berthélemy and Thuilliez, 2013; Audibert et al., 2012). There is a great consensus that large cross-country differences exist in per capita income and this gap is not only the consequence of poor health (Acemoglu et al, 2001, 2002, 2003). However, in the poorest part of the world, including SSA, poor health affects not just the level of income but also its growth rate (Bloom and Sachs, 1998; Spence and Lewis, 2010; Sachs and Malaney, 2002). As well, initial development conditions of countries are also at the root of their poor health situation (Pritchett and Summers, 1998; Wilkinson, 2007).

The rest of this paper is organized as follows. In section II, we present stylized facts on the trends of LE and GDP in SSA in comparison to other regions. In section III we use a simple regression method to show evidence of β-convergence in the two macroeconomic dimensions. Section IV presents the log-t test of convergence and analyses the convergence paths followed by SSA countries grouping them with others initially poor, middle income and rich countries into different converging clubs. Section V concludes this study.

II. Stylized facts: does SSA following other regions in terms of life expectancy and per capita GDP trends?

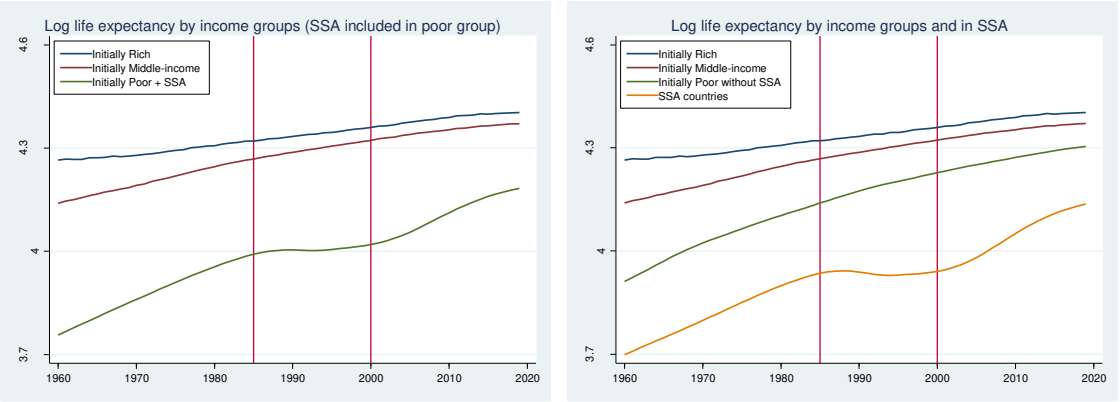
In this section, we document the evidence of catching up process of the predefined rich countries by the SSA and other poor countries in term of LE and GDP. For this and all the next sections, we use the life expectancy at birth estimates from the World Bank's Population Estimates and Projections (WB-PEP) database. This database includes multiple data sources and estimation methods based on data availability and reliability.[7] It considers population estimates and projections for nearly 200 economies and groups from 1960 to 2050 (see Shaykheeva et al., 2016). For per capita GDP, we use estimates from the Penn World Table (PWT) version 10.0, which contains information on relative levels of income; output, input and productivity, covering 183 countries between 1950 and 2019 (see Feenstra et al., 2015 for the description). Our sample includes 89 countries. We extend the Acemoglu and Johnson (2007) sample including 42 SSA countries as poor countries and follow their classification of countries according to their initial income level of 1940 (See notes in Figure 1).

II.1- Life expectancy in SSA in comparison to others: the African health episodes

Life expectancy has increased in poor, middle-rich and rich countries since 1960 following the so called international epidemiological transition of the 1940s (Figure 1, left). Low-income countries are catching up the leading countries but their race towards the LE levels of the middle-rich and rich ones was interrupted between the mid-1980s and the beginning of the 2000s. This group of countries faced a slowdown in the evolution of their average LE levels within this period. The slowdown in the period 1985-2000 is entirely attributable to SSA (Figure 1, right). The region did not only delay the catching up process of the poor group but contributed also to increase the gap in LE between the rich and the poor from 1985 to 2000 by a yearly average of 0.15 p.p..

[7] The main data sources used for the World Bank's demographic estimates and projections database include the United Nations Population Division's World Population Prospects; census reports and other statistical publications from national statistical offices; household surveys conducted by national agencies, ICF International, UNICEF, and the U.S. Centers for Disease Control and Prevention; Eurostat, Demographic Statistics; U.S. Bureau of the Census, International Database; United Nations Statistical Division's Population and Vital Statistics Report (various years); and Secretariat of the Pacific Community, Statistics and Demography Programme.

Figure 1. Log life expectancy for initially rich, middle-rich, and poor countries



Note: These figures are for illustration purposes and should be interpreted with caution, since convergence is not generally invariant to nonlinear transformations. In these figures and throughout the article, the classification of countries as initially rich, poor and middle-income follows Acemoglu and Johnson (2007).
In the left graphic, the initially poor group include the 16 other poor countries (see next note) and 42 SSA countries consisting of Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Congo, Cote d'Ivoire, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.
In the right graphic, the Poor countries (16) comprise Bangladesh, Brazil, China, Ecuador, El Salvador, Honduras, India, Indonesia, Korea Rep., Malaysia, Myanmar, Nicaragua, Pakistan, Philippines, Sri Lanka, and Thailand. Rich countries (11) include Australia, Belgium, Canada, Denmark, Germany, Netherlands, New Zealand, Sweden, Switzerland, United Kingdom, and United States. Middle-Income countries (19) consist of Argentina, Austria, Chile, Colombia, Costa Rica, Finland, France, Greece, Guatemala, Ireland, Italy, Mexico, Norway, Panama, Paraguay, Peru, Portugal, Spain, Uruguay, and Venezuela.
Source: Authors' construction using LE estimates from WB-PEP.

The literature links the big increase of LE from around 1940 to three main factors (Stolnitz, 1955; Davis, 1956; Preston, 1975; Acemoglu et al., 2003; Acemoglu and Johnson, 2007). First, there was a wave of global drug and chemical innovations, the most important being the discovery and subsequent mass production of penicillin, which provided an effective treatment against a range of bacterial infections (National Academy of Sciences, 1970; Easterlin, 1999). The second factor of the improvements in public health was the establishment of the World Health Organization (WHO), which greatly facilitated the spread of medical and public health technology to poorer countries. The third factor which consisted of a change in international values induced significant improvements in health conditions and LE in Central America, South Asia, and parts of eastern and southern Europe where the means for implementation existed.

Related to this, several authors agree that the afterwards convergence process derives from the rapid decline in mortality (and improvement in health) in poorer countries after 1940, most of which was driven by the fast spread of new technologies and practices around the world.[8] SSA region clearly benefited from the international epidemiological transition of the 1940s, but only till the mid-1980s. The annualized average growth of

[8] The seminal works on this episode include Stolnitz (1955), Omran (1971), and Preston (1975).

LE in the region during this period (0.91%) is higher than the ones of the other poor (0.88%), middle-income (0.49%) and rich (0.21%) countries (Table 1). From this date, the region faced new shocks which came to lower its health indicators. The region registered a shrink in its annualized growth of LE of about 0.9%.

The reduction of the LE levels in SSA region between 1985 and 2000 can be linked to the resurgence of mortality in the region during the 1980s. In effect, the increase of adult mortality (population of 20 – 49 years) in Africa in the 1980s due to the resurgence of malaria (Snow et al., 2017) and the emergence and the widespread of human immunodeficiency virus (HIV) brought a systematic break on the improvements in health indicators initiated since the international epidemiological transition in SSA. The inclusion of the region into the sample reduces the catching-up process of the poor group by 0.37 p.p. during the period and moreover this shock affected the entire effort of the poor group with a gap of 0.13 p.p. between 1960-2000. However, the urge improvements of health conditions in the region after 2000 (0.95 p.p.) seems to be reversing the situation making it ameliorating to the overall catching-up process of the poor between 1960-2019 by 0.44 p.p. when included (Table 1).

Table 1. Annualized growth rates of life expectancy between SSA and other income groups of countries

LE (in log)	Overall		Rich countries	Middle-income countries	Poor countries		SSA
	Including SSA	Excluding SSA	No SSA	No SSA	Including SSA	Excluding SSA	
Level in 1960	3.91	4.09	4.27	4.14	3.76	3.91	3.70
Annualized growth 1960-1985	0.72%	0.56%	0.21%	0.49%	0.90%	0.88%	0.91%
Annualized growth 1960-2000	0.55%	0.51%	0.23%	0.45%	0.64%	0.77%	0.59%
Annualized growth 1960-2019	0.58%	0.44%	0.23%	0.39%	0.71%	0.65%	0.73%
Level in 1985	4.09	4.24	4.32	4.27	3.99	4.14	3.94
Annualized growth 1985-2000	0.22%	0.39%	0.25%	0.34%	0.18%	0.55%	0.03%
Level in 2000	4.13	4.30	4.36	4.32	4.02	4.23	3.94
Annualized growth 2000-2019	0.61%	0.28%	0.22%	0.24%	0.82%	0.38%	0.98%
Level in 2019	4.25	4.36	4.40	4.37	4.18	4.30	4.14

Source: Authors' calculation using LE estimates from WB-PEP.

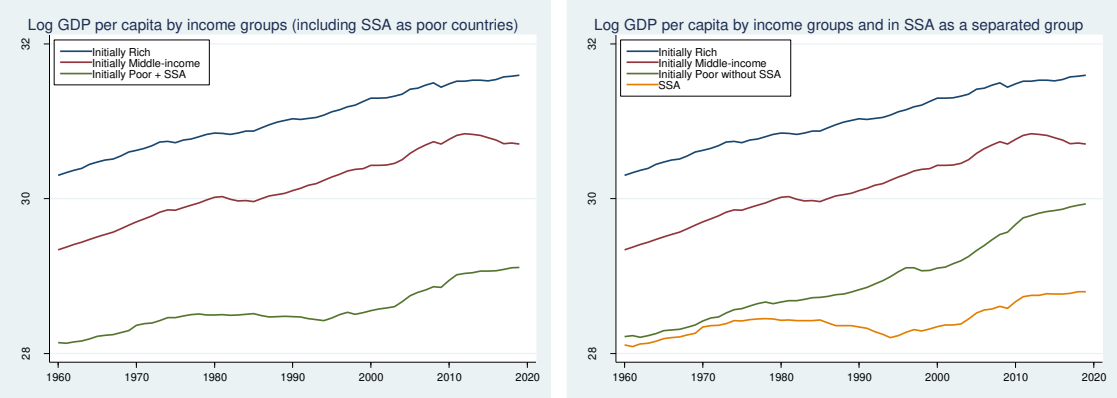
II.2- Per capita GDP trends during the African health episodes

GDP has increased in the poor, middle-rich and rich groups since 1960 but there is no evidence of catching-up of the rich and middle-rich by the poor in 2019 (Figure 2, left).[9]

[9] Our base specification uses income per capita adjusted for Purchasing Power Parity, from the Penn World tables v10.0. Specifically, for growth rates we use the variable "rdgpna", real GDP at constant

Before renewing with growth, the poor groups faced a period of decrease between the end of the 1970s and the mid-1990s. There is a change in their trajectories during this period as a result of a decline in the GDP of SSA countries (Figure 2, right). In this period, the region was committed to series of shocks including civil wars (Angola, Ethiopia, Democratic Republic of Congo, Sierra Leone, Liberia, as examples) and health epidemics (cholera, malaria, HIV, Ebola, as examples) with their corollary that are hunger crises, and the international economics crisis (energy crisis of the 1970s, the recessions of the 1980s and 1990s, as examples) that come to lower its economic development.

Figure 2. Per capita GDP for initially rich, middle-income, and poor countries



See notes in Figure 1 for the countries' initial income groups repartition.
Source: Authors' construction using GDP estimates from PWT.

With the purpose of assessing the similitude between health and income improvements in SSA, we summarize the growth performances of SSA countries given the health episodes documented previously. Before 1985, SSA region was doing bad, and the situation got worst between 1985-2000 where the average annualized growth rate was only 0.11% compared to 2.38% for the other poor countries. From 2000 on, even if SSA is doing better than the initially rich and middle-income countries (the yearly average growth rate is 2.01 p.p. compared to 1.06 p.p. and 1.30 p.p. respectively for the rich and middle-income groups), the rest of poor countries are still more performant (their yearly average growth rate is 3.27 p.p.). Although SSA countries are increasing the overall economic growth rate by 0.04 p.p. from the early 2000s, they are still delaying the poor in catching up the rich country by reducing their growth rate by 0.91 p.p. between 2000 and 2019.

2017 national prices (2017 USD), and for growth levels we use "rdgpo", output-side real GDP at chained PPPs (2017 USD), as recommended by the PWT user guide (Kremer et al. 2022).

Separating this group of countries from the poor group (Figure 2, right), it seems like poor countries are catching-up the rich world. There is sign of future convergence, the gap between rich and poor group of countries (without SSA) being intensely decreasing after 2000 by a yearly average of -2.15 p.p. (Table 2). Thus, despite all the health benefits until 1985 documented previously, the urge economic growth from the early 2000s (Table 2) and the urge health improvements observed in the 2000s, the economic performance of the region is still far away from the other poor countries as well as the developed world.

Table 2. Annualized growth rates of per capita GDP between SSA and other income groups of countries

Per capita GDP (in log)	Overall		Rich countries	Middle-income countries	Poor countries		SSA
	Including SSA	Excluding SSA	No SSA	No SSA	Including SSA	Excluding SSA	
Level in 1960	28.82	29.37	30.48	29.50	28.19	28.37	28.11
Annualized growth 1960-1985	1.48%	2.20%	2.35%	2.43%	1.29%	2.04%	1.02%
Annualized growth 1960-2000	1.38%	2.19%	2.19%	2.29%	1.10%	2.23%	0.69%
Annualized growth 1960-2019	1.60%	2.14%	1.85%	2.00%	1.54%	2.61%	1.14%
Level in 1985	29.20	29.94	31.09	30.14	28.52	28.90	28.37
Annualized growth 1985-2000	1.14%	2.05%	1.81%	1.91%	0.74%	2.38%	0.11%
Level in 2000	29.38	30.27	31.38	30.44	28.64	29.29	28.39
Annualized growth 2000-2019	1.96%	1.92%	1.06%	1.30%	2.36%	3.27%	2.01%
Level in 2019	29.78	30.65	31.60	30.70	29.11	29.94	28.80

Source: Authors' calculation using GDP estimates from PWT.

Summing up, it's worth noting that the average LE and GDP have steadily increased during the study period 1960–2019. Even if the initially rich countries still have the highest LE in 2000 and in 2019, poor countries have displayed remarkable LE improvements and there is evidence of catching up with the leading groups in the 2000 and 2019. SSA countries have not remained on the side-lines and albeit these later have persisted with the lowest LE during all the period (the queue of the distribution has always been occupied by a SSA country), their high performance after 2000, brings new hope to poor countries and they renew with the catching up process. The facts are different with GDP, the process of catching-up being evident only for the poor without SSA although this region did a lot of efforts during the period.

However, the convergence evidence here is built on known groups of countries which clustering methods is based on a priori information concerning their levels of

development. Next, we apply a traditional β-convergence (regression and scatter plots) to explore if there are supports of convergence or the existence of heterogeneity.

III. Global convergence or evidence multiple steady states in life expectancy and GDP?

In this section, we use a simple regression method and scatter plots to analyse the convergence process in LE and GDP, emphasizing the situation of the SSA region.

III.1- The β-convergence method

To explore if there is absolute convergence or evidence of heterogeneity supposing the presence of multiple convergence points, we undertake a standard β-convergence analysis in accordance with the work of Barro and Sala-I-Martin (1997), which determines whether countries with initial low health grow faster on average than countries with better initial health indicators. We regress the annualized variations in LE (GDP) between 1960-2000 and 1960-2019 (depending on the case) on its initial levels of 1960:

$$\log\left(\frac{X_{i,t+\Delta t}}{X_{i,t}}\right) = \alpha + \beta \log\left(X_{i,t}\right) + \varepsilon_{i,t} \qquad (1)$$

where $\log(X_{i,t})$ is Log LE (GDP) of country i at time t and ε_{it} has mean zero, finite variance, σ_{ε}^2, and is independent over t and i. We first hold t fixed at 1960 but vary Δt between 40- and 59-years period in order to update the existing literature emphasizing on the SSA region. Evidence of β-convergence is found when the estimated slope is negative and significant ($-1 < \beta < 0$).

III.2- Convergence in life expectancy: is SSA changing the converging paths?

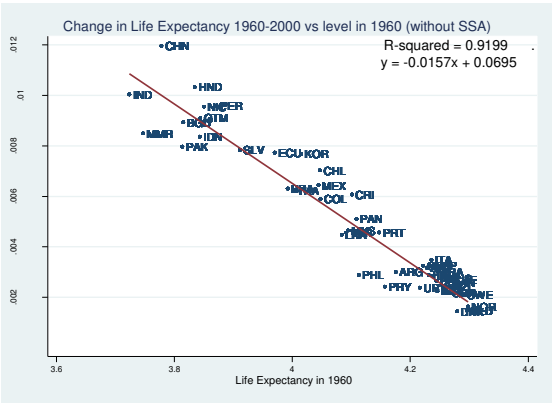
Figure 3 shows the graphical representation of the β-convergence analysis (scatter plot between the change for the entire period and initial conditions). We consider 4 samples resulting from combining the period and the number of countries, that is: ending at 2000 (left) or ending at 2019 (right); excluding SSA (top) or including SSA (bottom).

In all cases, the estimated beta is negative and significant, but its magnitude and the dispersion of the scatter plot (implying a lower precision in their estimates) is different. Excluding SSA from the sample leads basically to the same result when the sample ends

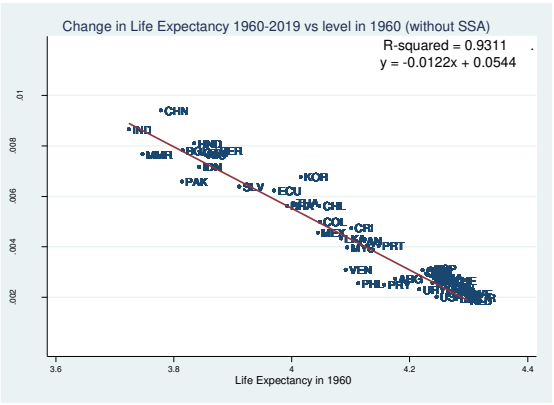
in 2000 or in 2019: the beta estimates and the R^2 are basically the same in both samples. However, including the SSA region clearly reduces both the magnitude of the beta and the precision in its estimation (lower R^2) in both samples, but especially when ending in 2000. Thus, when including SSA, the beta estimation ending in 2000 is in the limit of the significance, while it turns highly significant when the sample is extended until 2019. In this latter case, even when excluding SSA in the sample, we find strong evidence of LE convergence.

Figure 3. Life expectancy convergence: level in 1960 versus changes

Without SSA

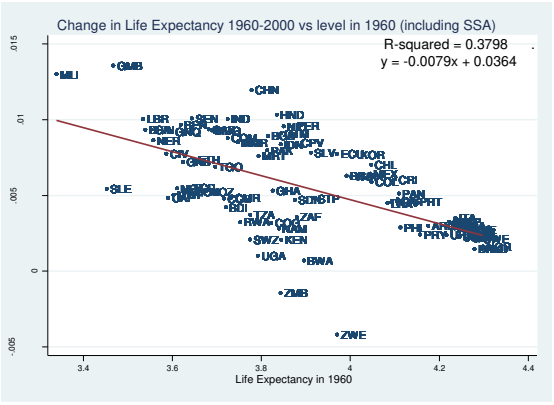


1960 levels versus 1960-2000 changes

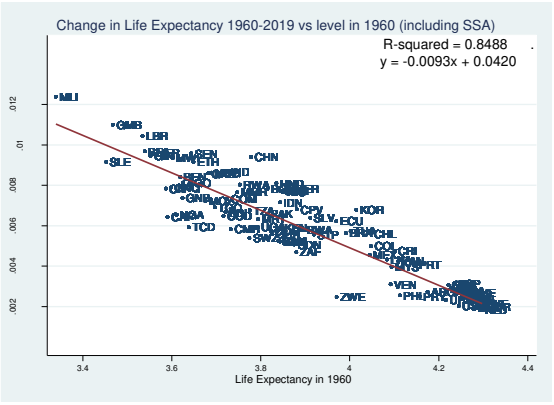


1960 levels versus 1960-2019 changes

Including SSA



1960 levels versus 1960-2000 changes



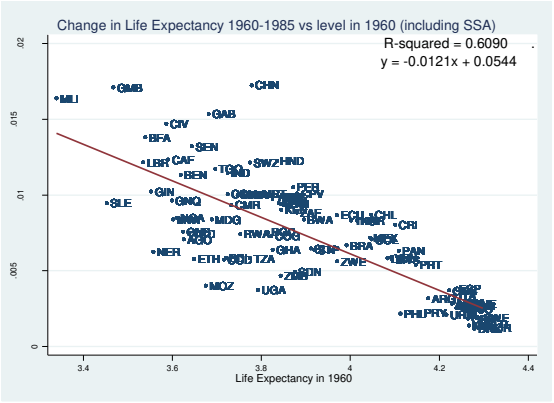
1960 levels versus 1960-2019 changes

Source: Authors' construction using LE estimates from WB-PEP.

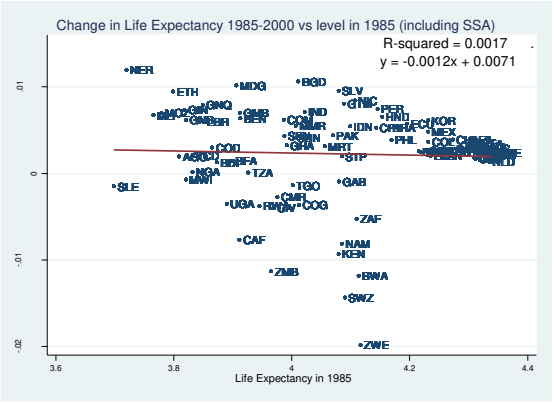
We analyse in further detail the sample including SSA countries. What is the period that is really behind the weak convergence process observed until 2000? Figure 4 plots the annualized change in LE within three pre-selected intervals: 1960-1985, 1985-2000 and 2000-2019. It confirms the existence of three health episodes with different converging behaviour: two periods of convergence (1960-1985 and 2000-2019) separated by a diverging period (between 1985 and 2000).

During the diverging period, SSA countries experienced a sluggishness in the evolution of their average LE (around 51 years old). Moreover, several SSA countries saw a decrease in their LE levels during the period (Zimbabwe, Swaziland, Botswana, Zambia, Kenya, Namibia, Central Africa Republic, South Africa, Côte d'Ivoire, Congo, Rwanda, Uganda, Cameroon, Togo, Gabon, Sierra Leone, and Malawi). Almost all of them are dispersed and very far from the regression line, instead of converging towards those with initial high LE levels in 1985, these countries are following different paths conditionally to certain common factors. This may denote the presence of multiple health convergence clubs within the 1985 and 2000 horizons (we will discuss this possibility in the next section).

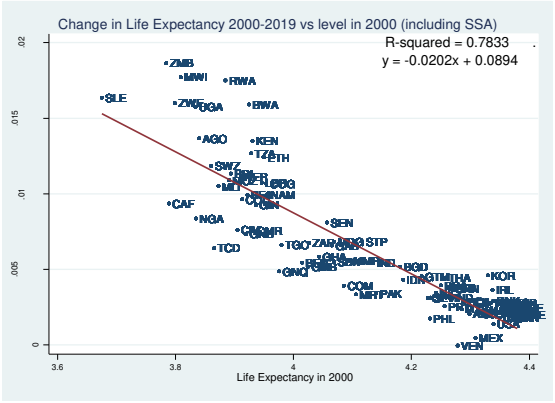
Figure 4. Change in life expectancy convergence process when including SSA



1960 levels versus 1960-1985 changes



1985 levels versus 1985-2000 changes



2000 levels versus 2000-2019 changes

Source: Authors' construction using LE estimates from WB-PEP.

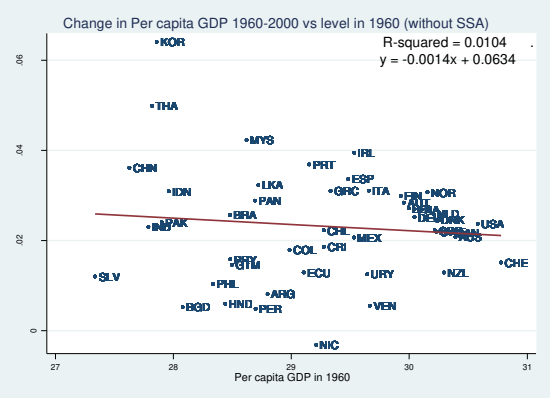
III.3- Convergence in per capita GDP: does the world without SSA converging?

Figure 5 shows the graphical representation of the regression of the change in GDP on the initial levels of 1960 (a beta-convergence analysis for GDP). There is no global

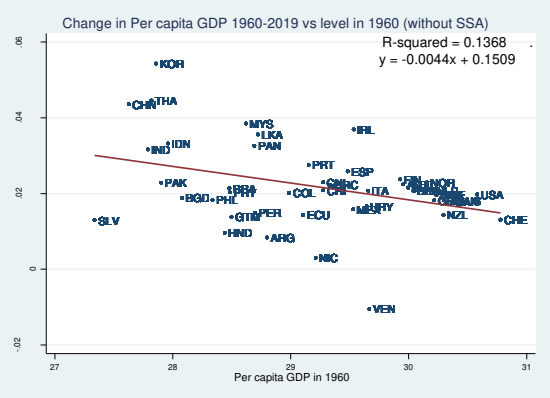
economic convergence between the rich and poor countries, as shown by the scatter plots of change in GDP in Figure 5. However, there is evidence of convergence (weaker than for LE) when ending in 2019 when excluding SSA.[10]

Figure 5. Per capita GDP convergence: levels in 1960 versus changes

Without SSA

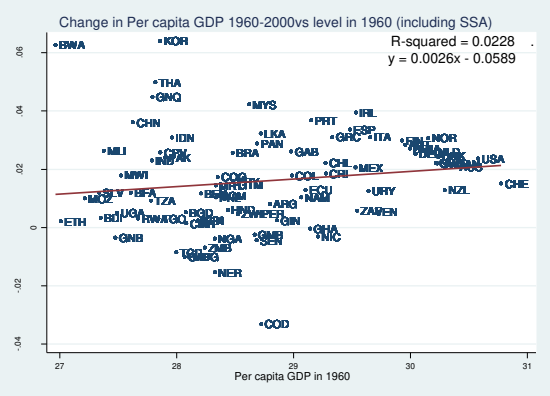


1960 levels versus 1960-2000 changes

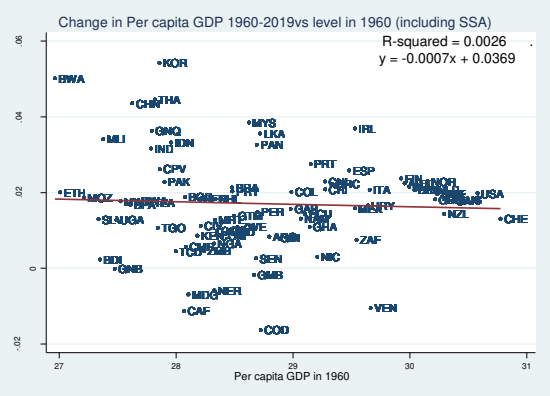


1960 levels versus 1960-2019 changes

Including SSA



1960 levels versus 1960-2000 changes



1960 levels versus 1960-2019 changes

Source: Authors' construction using GDP estimates from PWT.

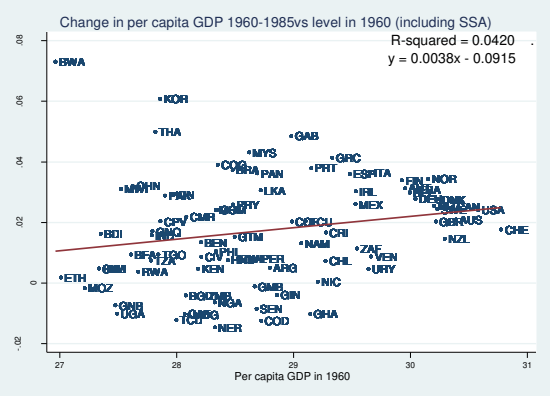
According to Figure 6, before 2000, there is no evidence of convergence (all the β coefficients are positive). Bloom and Sachs (1998) claim that poor health conditions in Africa explain a substantial part of the difference between African growth rates and the average growth rates of other countries. Our observations are consistent with this point of view since the health divergence observed between 1985 and 2000 may explains the high decrease in GDP in the region until the end of the 1990s.

Additionally, the first graphic of Figure 6 shows that before 1985, countries with initial high GDP face great growths contributing to increase the gap between them and the

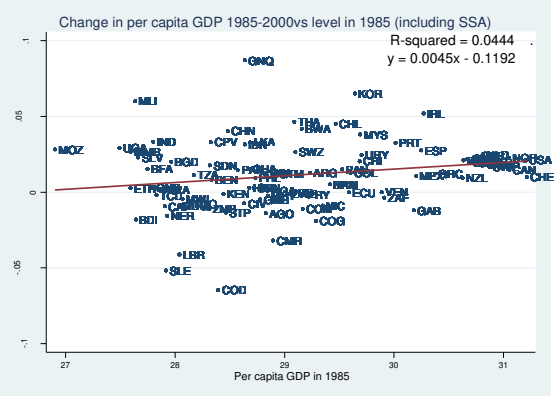
[10] Even if the sign of β at the 2019 horizons remains negative when SSA region is included into the sample, its amplitude is very small (The correlation seems to be really trivial) and the countries are very dispersed around the regression lines.

poor world. The health improvements in the poor group that yields to their catching-up with the rich world health levels in the same period did not contribute to reduce the income gap between them. This is consistent with the results of Acemoglu and Johnson (2007). Initial economic conditions also played a great role in the growth dynamics. However, this situation seems to be reversing since the early 2000s with most SSA countries following the same paths with rich and middle-income countries.

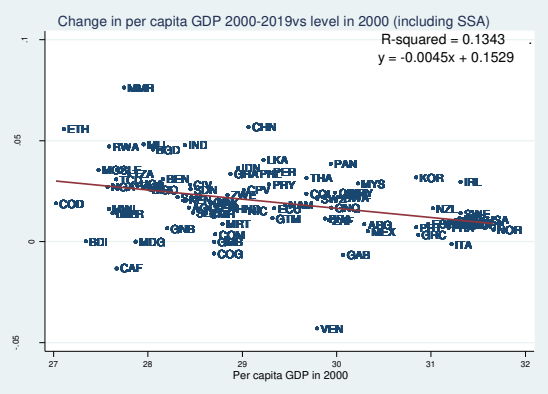
Figure 6. Change in per capita GDP convergence process when including SSA



1960 levels versus 1960-1985 changes



1985 levels versus 1985-2000 changes



2000 levels versus 2000-2019 changes

Source: Authors' construction using GDP estimates from PWT.

Summing up, the scatter plots (regression) show that there are supports of convergence, but existing heterogeneity in the paths raises some doubts whether convergence process in LE (GDP) is absolute, conditional or club convergence.

We next consider a more sophisticated convergence analysis (i.e., consider the possibility for club convergence) to explore in more details the LE and GDP trajectories and identify potential convergence-divergence patterns without any a priori consideration. Results will reinforce the ones provided in this section.

IV. Convergence clubs in life expectancy and per capita GDP

In this section, we analyse the convergence processes in LE and economic growth controlling by different sets of countries and various periods. We want to distinguish between different forms of convergence: absolute convergence (i.e., all countries tending to a common long-run equilibrium trajectory), conditional convergence (each country tending to their own long-run equilibrium), and club convergence (several groups of countries tending to a common, but different, long-run equilibrium trajectories). It is not easy to make this distinction using standard tools of analysis (Durlauf and Johnson, 1995; Johnson and Papageorgiou, 2020). We then rely our analysis on the panel clustering approach proposed by Phillips and Sul (2007), that can be easily adapted to almost any type of variable and allows us to evaluate this wide range of convergence processes. This approach is based on the estimation of what is called a log-t regression.

IV.1- The log-t regression test of convergence

To test for clubs' convergence in LE and GDP between 1960-2019, we use the log-t test proposed by Phillips and Sul (2007). This panel convergence testing methodology is based on the calculation of the country's transition path, which allows to measure both the country's individual behaviour in relation to others and the relative deviations from the common path (Marrero et al., 2022). Crucially, unlike Timonin et al. (2016), the methodology allows for β-convergence patterns to be defined by the data and so, the grouping which emerges is not pre-defined according to a priori beliefs but is a product of statistical testing.

The approach is based on a nonlinear time-varying factor model (Du, 2017). Assuming that where $X_{i,t}$ represents the LE (GDP) of country i at time t, the starting point is to decompose $X_{i,t}$ into its time varying factor-loading coefficient $\delta_{i,t}$ and its common trend component u_t as follows:

$$X_{i,t} = \delta_{i,t} u_t \qquad (2)$$

Equation (2) is a dynamic factor model where u_t captures some deterministic or stochastically trending behavior, and the time varying factor-loading coefficient $\delta_{i,t}$ measures the idiosyncratic distance between the common trend component u_t and $X_{i,t}$.

With a view to empirically testing for club convergence, it is convenient to define the relative transition coefficient $h_{i,t}$ which measures LE (GDP) relative to their cross-section average, eliminating the common trend u_t by rescaling the loadings $\delta_{i,t}$ in terms of their cross-section average. Thus, the transition coefficient measures both the behaviour of country i relative to the average and its deviation from the common path.

$$h_{i,t} = \frac{\delta_{i,t}}{\frac{1}{N}\sum_{i=1}^{N}\delta_{i,t}} \quad (3)$$

Phillips and Sul (2007) assume that δ_{it} takes the following form:

$$\delta_{it} = \delta_i + \sigma_{it}\xi_{it}, \text{ with } \sigma_{it} = \frac{\sigma_i}{Log(t)t^{\alpha}}, t \geq 1, \sigma_i > 0 \text{ for all } i \quad (4)$$

where σ_i is a time-invariant parameter, ξ_{it} is an iid standard normal random variable, $\mathrm{Log}(t)$ is a slowly varying function producing the least size distortion and the best test power and α is a parameter that can be positive or negative depending on whether there is convergence or not. For the case of convergence (with $\alpha \geq 0$), the higher is α, the faster σ_{it} tends to zero, and the faster is the convergence of δ_{it} towards δ_i.

Equation (3) indicates that the cross-sectional mean of $h_{i,t}$ is unity and its cross-sectional variance satisfies the following condition: $\sigma_{i,t}^2 = \frac{1}{N}\sum_{i=1}^{N}\left(h_{i,t} - 1\right)^2 \to 0$ if $\lim_{t\to\infty}\delta_{it} = \delta_i = \bar{\delta}$ for all i. Thus, as relative convergence holds when $\lim_{t\to\infty}\frac{X_{i,t}}{X_{j,t}} = 1$ for all i and j, this is equivalent in this case to $\lim_{t\to\infty}\delta_{it} = \delta_i = \bar{\delta}$ for all i (convergence of the time varying factor-loading coefficient δ_{it}).

The authors developed a regression t test for the null hypothesis of convergence $\delta_i = \bar{\delta}$ and $\alpha \geq 0$ against the alternative $\delta_i \neq \bar{\delta}$ and $\alpha < 0$. Specifically, the hypothesis test can be implemented through the following `log t' regression model:

$$\log\left(\frac{\sigma_1^2}{\sigma_t^2}\right) - 2\log\left(\log(t)\right) = a + b\log(t) + \varepsilon_t \quad (5)$$

where σ_1^2/σ_t^2 is the cross-sectional variance in the initial period relative to the variance in period t, $b = 2\alpha$, and α is the convergence term in (4).

Equation (5) implies the null hypothesis of convergence $b \geq 0$ that can be easily tested against the alternative $b < 0$ with a one-sided t-test on the estimated $\hat{b}$ using heteroskedasticity- and autocorrelation-consistent standard errors. Convergence is achieved for the first k that yields the test statistic of the log t regression $t_k > -1.65$

for the subgroup with individuals $\{k, k+1\}$.[11] The assignation of a country to a particular convergence club depends on the outcome of the one-sided t-test on b in the log-t regression performed for different sub-samples. In case of $k = N$, $\hat{b} \geq 2$ implies absolute convergence, while $0 \leq \hat{b} < 2$ implies conditional convergence (see Phillips and Sul, 2009).

IV.2- Convergence clubs' analysis in life expectancy.

Table 3 shows the results of the log-t convergence test for LE with and without SSA. We start showing the results for the set of 47 countries after excluding SSA in our sample. We first focus until 2000 and we extend next the sample until 2019. The results indicate evidence of conditional convergence until 2000 ($\hat{b}_{2000} = 0.55,\ \hat{t}_{k2000} = 12.07 > -1.65$). Furthermore, this result is robust (even more significant) when extending the time period until 2019 ($\hat{b}_{2019} = 0.68,\ \hat{t}_{k2019} = 72.08 > -1.65$). Thus, for LE (and global health in general), this evidence points out that initial conditions are not playing a relevant role in opposition to structural characteristics. This convergence is the consequence of the dramatic improvement in health in much of the world, especially in the less developed parts of the globe, starting in the 1940s (Central America, South Asia, and parts of eastern and southern Europe) commented previously.

At this stage of the analysis, it is interesting to question if the previous convergence results still hold if SSA countries are included into the sample. After including the region, we show that the catching up process observed is no longer observed before 2000 (Table 3). Recall that Figure 1 shows that there was a slowdown in the growing process of LE between the mid-1980s and early in the 2000s. At the end of 2000, most of the SSA countries were not following the same path with other. This divergence is confirmed by the log-t tests which reject the null hypothesis of absolute or conditional convergence and concludes on the existence of 3 convergence clubs for LE either between 1960-1985 or 1960-2000. The estimated parameters are respectively $\hat{b}_{1985} = -0.22$ ($\hat{t}_{k1985} = -9.05 < -1.65$) for the period 1960-1985 and $\hat{b}_{2000} = -0.59$ ($\hat{t}_{k2000} = -14.56 < -1.65$) between 1960-2000. Thus, it's worth noting that the situation gets worse between 1985-2000 and by 2000, 27 SSA countries are following different paths compared to only 18 by 1985.

[11] See Phillips and Sul (2009), Schnurbus et al. (2017) and Du (2017) for more details.

We now focus on the period 1960-2000 that is covering the health slowdown episode observed in SSA. The number of countries within each club between 1960-2000 is highly unbalanced: 62, 25 and 2 members (see Table 3). The club with only two members is composed by Rwanda and Sierra Leone, which have faced civil wars in the 1980s. All the 25 members of the middle club are SSA countries, that are following a different path than the leaders. These results are consistent with our observation in the previous sections, in which the evidence of divergence was entirely due to SSA countries that faced an increase in their mortality rates because of the appearance and widespread of HIV/AIDS and the resurgence of malaria in the region. However, it is relevant to emphasize that the leading club include also 15 SSA countries. Hence, regarding LE, some SSA countries have escaped from the divergence path. These countries are Benin, Burkina Faso, Comoros, Cabo Verde, Gabon, Ghana, Guinea, Gambia, Equatorial Guinea, Madagascar, Mali, Mauritania, Niger, Senegal, and South Africa (see Table A2 in Appendix).

There is an important gap in LE between the leading and the rest of countries. However, this situation has reversed between 2000-2019. Extending our analysis until 2019, we show that countries that were following divergent paths in 2000 are catching up with the others very swiftly (see Figure A1, Appendix). The log-t regression corroborates this observation, yielding a conditional convergence in LE in 2019 as attested by the following log-t regression estimated coefficient $\hat{b}_{2019} = 0.17$ ($\hat{t}_{k2019} = 2.89 > -1.65$). This is evidence that the initial conditions in LE by 2000 are not playing relevant role in the countries' performance in LE in the 2019 horizon.

In effect, in early 2000, the region experienced renewed interest in health improvement policies and practices which led to the decreasing mortality rate. This decrease of mortality trend is consistent with the large-scale implementation of antimalarial policies from 2005 (Bethencourt et al., 2022) and the improvement in the implementation of ART in the region from 2003 to come against the unprecedented high rate of HIV/AIDS (WHO-UNAIDS, 2009). It is also consistent with the increment in the education of population, particularly pregnant women, about the ways of preventing malaria using the mosquito's beds nets which distribution campaigns started the same period (Snow et al., 2017; United Nations, 2014; World Bank, 2017).

Table 3. The Log-t test of convergence in life expectancy

Year	Coef.	SE	T-value	Inference	Final classification	Coef.	T-value
Without SSA							
1960-2000	0.554 (0.549)	0.046 (0.043)	12.067 (12.732)	Conditional convergence	Club 1: 47 (43) members	0.554 (0.549)	12.067 (12.732)
1960-2019	0.682 (0.763)	0.010 (0.008)	72.080 (91.007)	Conditional convergence	Club 1: 47 (43) members	0.682 (0.763)	72.080 (91.007)
Including SSA							
1960-1985	-0.224	0.025	-9.045	Club convergence	Club 1: 71 members [24 SSA]	0.081	1.907
					Club 2: 12 members [both SSA]	0.272	3.567
					Club 3: 6 members [both SSA]	0.287	3.167
1960-2000	-0.595	0.041	-14.564	Club convergence	Club 1: 62 members [15 SSA]	0.286	25.597
					Club 2: 25 members [both SSA]	0.015	0.286
					Club 3: 2 members [both SSA]	0.365	0.336
1960-2019	0.170	0.059	2.891	Conditional Convergence	Club 1: 89 members [42 SSA]	0.170	2.891

Notes: Figures in brackets are for the restricted sample i.e., the sample without four countries facing political and civil instabilities during the last decades: Honduras, Nicaragua, Pakistan and Venezuela.
Source: Authors' estimation using LE values from WB-PEP.

IV.3- Convergence clubs' analysis in per capita GDP.

How are the convergence test results for GDP? In general, we cannot stipulate that the countries which are catching up with those with high levels of LE are doing the same in GDP and vice-versa. When looking at GDP trajectories, the convergence process is less clear, specially until 2000, but also until 2019 whether SSA is included or not. In effect, as opposed to the fairly clear trend of convergence in LE, the transition paths of GDP improvements seem to have no visible pattern and are quite heterogeneous during the entire periods (i.e., until 2000 and later in 2019) (recall the right graphic in Figure 2). The log-t convergence test confirms the lack of convergent transition paths in GDP gains.

Excluding SSA, the Phillips and Soul algorithm identifies 3 and 2 clubs when limiting the sample to 2000 and 2019 (Table 4), respectively. Table A1 in **Appendix** lists different members included in each club. The club membership allocations are determined in an unsupervised manner so that it is interesting to see how the GDP trajectories naturally reflect country-level patterns. Average GDP shows little change between 1960 and 2000 in the less performing club. Thus, the yearly average change in this group is 0.8 p.p. compared to 3.2 p.p. in the high performing club (2.0 p.p. in the middle performing club - the middle performing group comprises transition countries that are in the midst of a catching up phenomenon to match the high-performing countries). Between the other two clubs when extending the sample until 2019, the less performing group of countries include only 4 countries (Honduras, Nicaragua, Pakistan

and Venezuela), countries involved in political conflicts and/or wars for several decades. The negative $\hat{b}$ value -0.47 indicates that these four countries are not following the same path.[12]

Interestingly, removing these 4 countries from the sample without SSA, we obtain evidence of conditional convergence in GDP in 2019 (when limiting the sample to 2000, we still have 3 clubs) with more interesting changes in the less and middle performing clubs: 4.97% and 3.65% respectively compared to only 1.83% for the high performing club (see left Figure A2, Appendix).[13] This is a relevant result, and consistent with the recent idea of "converging to convergence" raised by Kremer et al. (2022).

What happens when including SSA countries in the analysis? Recall from the previous Figure 2 (Section II.2), it's shown that while overall average GDP have gained some intensity over time, several countries (particularly SSA countries) have experienced a stability and certain shocks that bring back their GDP to the levels in the 1960s. after including them into to log-t analysis, for either until 2000 or 2019, we find no evidence of global convergence over time. The resultant log-t regression estimates are both significantly negative in 2000 ($\hat{b}_{2000} = -1.12$, $\hat{t}_{k2000} = -39.52 < -1.65$) and in 2019 ($\hat{b}_{2019} = -0.81$, $\hat{t}_{k2019} = -43.95 < -1.65$). Our results indicate the existence of convergence clubs: 3 convergence clubs with varying number of countries within each cluster are obtained between 1960 and 2000, while we find 4 convergence clubs when extending the sample to 2019 (see Table 4 and the right graph in Figure A2, Appendix).

Interestingly enough, Botswana and Eswatini are the SSA countries belonging to the leading group, while 14 other SSA countries (Burundi, Benin, Central African Republic, Democratic Republic of Congo, Ethiopia, Liberia, Madagascar, Mozambique, Malawi, Niger, Nigeria, Rwanda, Tanzania, Zambia) are following different paths than all the other countries. They are both in the last third group with the lowest GDP by 2000. 26 other SSA countries are included in the intermediary group with GDP between the best

[12] It should be noted that with the four excluded countries, the less and middle performing clubs are still increasing more than de best performing club between 2000 and 2019 with average yearly changes of 4.33%, 1.97% compared to 1.83%, respectively.

[13] The third and less performing club is now comprised of 8 divergent countries as attested by the negative $\hat{b} = -0.10$.

and the worst. This group has a particularity to be composed of countries not following the same paths as attested by the negative coefficient $\hat{b} = -0.43$.[14]

The situation is similar when extending the sample until 2019. From the 4 convergence clubs generated, the worst performing one contains 3 SSA countries (Burundi, Central African Republic, and Democratic Republic of Congo) and Venezuela, all of them facing ongoing political and civil instabilities or at least during the last decades. The log-t test further shows that these 4 countries are not following the same path ($\hat{b} = -0.19$). In the other extreme, 4 SSA countries (Angola, Cabo Verde, Equatorial Guinea and again Botswana) belong to the leading club.

Table 4. The Log-t test of convergence in per capita GDP

Year	Coef.	SE	T-value	Inference	Final classification	Coef.	T-value
Without SSA							
1960-2000	-0.602 (-0.530)	0.013 (0.020)	-46.944 (-27.099)	Club convergence (Club convergence)	Club 1: 25 (25) members	0.465 (0.465)	5.713 (5.713)
					Club 2: 13 (10) members	0.573 (0.505)	5.528 (8.480)
					Club 3: 9 (8) members	0.346 (-0.103)	4.367 (-1.527)
1960-2019	-0.149 (0.206)	0.037 (0.052)	-4.001 (3.995)	Club convergence (Conditional convergence)	Club 1: 43 (43) members	0.206 (0.206)	3.995 (3.995)
					Club 2: 4 (0) members	-0.468	-0.909
Including SSA							
1960-1985	-0.836	0.004	-189.158	Club convergence	Club 1: 28 members [2 SSA]	0.078	3.978
					Club 2: 9 members [4 SSA]	0.312	2.159
					Club 3: 25 members [15 SSA]	-0.164	-2.760
					Club 4: 26 members [21 SSA]	0.154	1.612
					01 non convergent country		
1960-2000	-1.124	0.028	-39.516	Club convergence	Club 1: 27 members [2 SSA]	0.589	10.554
					Club 2: 48 members [26 SSA]	-0.431	-22.563
					Club 3: 14 members both SSA	0.319	2.643
1960-2019	-0.813	0.019	-43.951	Club convergence	Club 1: 41 members [4 SSA]	0.457	5.709
					Club 2: 20 members [12 SSA]	0.175	3.042
					Club 3: 24 members [23 SSA]	0.078	0.746
					Club 4: 4 members [3 SSA]	-0.186	-0.216

Source: Authors' estimation using GDP values from PWT.

IV.4- Growth-health dynamics: the peculiarity of SSA region

How does GDP and LE correlates between 2000 and 2019? In this section, we compare the convergence results for LE and GDP for different subsamples paying special attention to SSA and the post-2000 period i.e., the post epidemiological transition

[14] The log-t test between 1960 and 1985 also rejects the null hypothesis of global convergence but yields evidence of 4 convergence clubs, Botswana and Gabon belonging to the leading group, while Cameroon, Republic of Congo, Eswatini and South Africa are included in the second group with higher per capita GDP (See Table A2 in Appendix).

period characterized, as commented in the previous sections, by an African awareness and extraordinary and unprecedented increase in external health aid and policy implementation actions against Malaria and other diseases in the SSA region (United Nations, 2014; World Bank, 2017; WHO-UNAIDS, 2009; Bethencourt et al., 2022). This analysis complements the previous one to understand the growth-health dynamics in the region.

The interplay among LE and GDP is inevitably complex. Understanding the relation between economic development and health is one of the most intriguing problems facing public health. Preston (1976, 1980) found that there is a strong, positive correlation between national income levels and LE in poorer countries. After, Acemoglu and Johnson (2007) in their conclusion stated that poor countries benefit more from health technologies and improvements from high countries. Our result is consistent with this view, but it is evident that improvements in health policies and technologies are not sufficient to explain the large improvement in health indicators observed in SSA. Economic growth has played a non-negligeable role in the performance of countries in LE and vice-versa.

Living standards and longevity have improved together, but the relation between them is not straight forward. Despite the global convergence observed in LE when not considering the SSA region, our analysis put in evidence divergent paths among countries in terms of GDP until 2000 and later convergence paths extending the sample until 2019, after removing some countries facing political and civil instabilities these last decades. This evidence of convergence, common to both dimensions, could open again the debate regarding the absence (or not) of causality from health to development.

The interrelationship between the two dimensions is more complex when including SSA in the analysis. Among SSA countries with good or intermediate GDP paths between 1960-2000, several fails to trail leading group in LE when looking at the same period. Botswana and Eswatini which record excellent income performances are in a bad situation regarding LE. In opposite, three SSA countries (Benin, Madagascar, and Niger) recorded the best situation in LE but follow the worst group in the GDP. All the other SSA countries in the worst income group are found also in the worst LE group (Burundi, Central African Republic, Democratic Republic of Congo, Ethiopia, Liberia, Mozambique, Malawi, Nigeria, Rwanda, Tanzania and Zambia). Thus, the correlation

between GDP and LE club memberships is positive, but not perfect, and cast doubt about a causal impact.

Moreover, among the 15-best performing SSA countries in LE by 2000, 5 countries (Cabo Verde, Equatorial Guinea, Gabon, Ghana, Mali and South Africa) have also the best situation in GDP performance in the 2019 horizon (See Table 5).[15] Also, 15 out of the 25 SSA countries with bad performance in LE in 2000 are also among the bad performers in GDP by 2019.[16] This is evidence that initial conditions in LE by 2000 are playing non-negligeable role in the countries' performance in GDP by 2019. However, the relationship between health and economic growth is not straightforward in SSA, since 10 SSA countries (Angola, Botswana, Republic of Congo, Namibia, Nigeria, Sudan, Sao Tome and Principe, Eswatini, Uganda, and Zambia) that are not performing well in LE by 2000 are among the best-performing (Angola and Botswana) and the intermediate group in GDP in 2019. Moreover, among the high-performing countries in LE in 2000, 7 countries (Benin, Burkina Faso, Guinea, Gambia, Madagascar, Mauritania, Niger and Senegal) have the worst performance in GDP by 2019. Thus, the initial conditions in LE in 2000 are not the only factors behind the improvements in GDP in 2019.

Table 5. Convergence matrix of life expectancy performance in 2000 versus per capita GDP performance in 2019

		Clusters in GDP between 1960-2019								
		Best		Intermediate		Worst 1				Worst 2
Clusters in LE between 1960-2000	Best	Cabo Verde Equatorial Guinea		Ghana Gabon	Mali South Africa	Benin Burkina Faso Comoros Guinea Gambia	Madagascar Mauritania Niger Senegal			
	Worst 1	Angola Botswana		Congo Namibia Nigeria Eswatini	Sao Tome & Principe Sudan Uganda Zambia	Cote d'Ivoire Cameroon Ethiopia Guinea-Bissau Kenya Liberia	Mozambique Malawi Chad Togo Tanzania Zimbabwe			Burundi Central African Rep. Congo Dem. Rep.

[15] Note that 4 (Gabon, Ghana, Mali and South Africa) of the 6 SSA countries follow the second-best performing group in per capita GDP in 2019 while the first 2 (Cabo Verde and Equatorial Guinea) follow the richest countries of the world).

[16] Considering that the third and less performer club in LE in the 2000 horizon is composed by only two countries (Rwanda and Sierra Leone), historically involved in civil wars in the decades preceding the 2000s, we can literally remove this club and consider that between 1960 and 2000, we have only two convergence clubs that we name high-performing and less-performing club respectively.

Worst 2		Rwanda	Sierra Leone	

Source: Authors' construction using log-t test membership assignation results.

Initial economic growth performances in 2000 are also playing important role in the financial situation of SSA countries in 2019 but not in absolute way. Botswana with best economic performance in 2000 is also in the leading position in 2019. 9 SSA countries with intermediate situation in 2000 remain at that situation in 2019. And, apart from Nigeria and Zambia that gained some improvements during the period (moving from the worst in 2000 to the second best in 2019), all the remaining SSA countries with bad economic performances in 2000 are still in the bad situation in 2019 if removing the 3 countries involved in political and civil instabilities that form a non-convergent last group in 2019 (see Table 6). 3 SSA countries with intermediate economic performance (Angola, Cabo Verde and Equatorial Guinea) also gained some improvements during the period, moving towards the leading group. This is evidence that the relationship is not straightforward since many countries do not respect this rule. Other factors such as health are at the root of economic growth in the region.[17]

Table 6. Convergence matrix of per GDP performance in 2000 versus performance in 2019

		Clusters in GDP between 1960-2019			
		Best	**Intermediate**	**Worst 1**	**Worst 2**
Clusters in GDP between 1960-2000	**Best**	Botswana	Eswatini		
	Intermediate	Angola Cabo Verde Equatorial Guinea	Congo Gabon Ghana Mali Namibia Sudan Sao Tome & Principe Uganda South Africa	Burkina Faso Cote d'Ivoire Cameroon Comoros Guinea Gambia Guinea-Bissau Kenya Mauritania Senegal Sierra Leone Chad Togo Zimbabwe	
	Worst		Nigeria Rwanda Zambia	Benin Ethiopia Liberia Madagascar Mozambique Malawi Niger Tanzania	Burundi Central African Rep. Congo Dem. Rep.

Source: Authors' construction using log-t test membership assignation results.

Finally, the situation is different when confronting initial economic growth performances in 2000 to performances in health in 2019. The convergence obtained by

[17] Recall that the literature emphasizes on the double causality between health and economic growth.

the log-t test in 2019 demonstrates that all the countries, regardless of their income and growth levels by 2000, have converged towards the leading group in terms of LE. This result is consistent with the convergence observed between poor, middle-income and rich countries in terms LE in section II. Thus, initial income conditions as reflected by the three convergence clubs by 2000 are not the only factors driving the improvements in SSA countries' LE. Mortality seems to be more responsive to economic growth in low-income countries where economic-demographic interrelations are most critical for economic prospects. To improve their positions, countries need to associate their performance in LE and in GDP (see, for example, the case of Cabo Verde, Equatorial Guinea, Nigeria and Zambia).

V. Conclusion

In this paper, we compare the convergence processes of LE and GDP, using a sample of 89 countries between 1960 and 2019. Our aim is to analyse the interrelation and the dynamics of these phenomena in SSA after the international epidemiological transition which favoured great increase in the health determinants worldwide, hence, favouring the economic development. Using both standard β-convergence analysis and the log-t test methods, we show evidence of significant catching-up in LE between SSA countries, the other poor countries and the rich world by 2019 after a slowdown period between 1985 and 2000.

Our results provide us with three health episodes in SSA region marked by evidence of convergence before the slowdown started around 1985 and from this date until 2000 (a divergent period where most of SSA countries follow different paths). We document that the health slowdown period coincides with the resurgence of malaria and the apparition and widespread of HIV/AIDS in SSA region. And the wave of hope in the early 2000s, indicating the third health period which leaded to a convergence by 2019, is related to the African awareness, the change in health strategies and the increase in health spending through external funding which helped reducing considerably the mortality in the region (Bethencourt el al., 2021). The log-t test analysis corroborates the global health convergence by 2019 and shows that initial health conditions are no longer playing major roles in the SSA health dynamics since all the countries from the 3 health convergence clubs in 2000 converge to the same steady state.

We also show that the convergence in health did not drive the convergence in GDP since initial conditions, as well as health and other factors beyond the scope of our analysis are both playing major roles in development dynamics. The β-convergence analysis points out that the great economic growth of the SSA countries and the other poor region since the early 2000s is not yet sufficient to bring their GDP levels closed to the ones of the middle-income and rich countries. Given the three health episodes and referring to their initial economic conditions at the beginning of each of them, we show that there is evidence of "converging towards convergence" (Kremer et al., 2022) between 2000 and 2019. The log-t test analysis provides multiple steady economic convergence points. Thus, by 2000 and 2019, we obtain 3 and 4 convergence clubs testifying different behaviours of SSA countries and showing that initial economic conditions are still playing a major role in the growth dynamics. However, removing the SSA region and also four countries facing political and civil instabilities during the last decades (Honduras, Nicaragua, Pakistan and Venezuela), we show evidence of significant global convergence in GDP by 2019.

We finally discuss the health – development dynamics in SSA, comparing the countries' convergence paths in LE and GDP. We reach the conclusion that mortality seems to be more responsive to economic growth in poorer countries, where economic-demographic interrelations are most critical for economic prospects. Regardless their previous performance by 2000, all the countries have converged towards the leading group in LE in 2019. It is evident that improvements in health policies and technologies are not sufficient to explain the large improvement in health indicators observed in SSA. Economic growth has played a non-negligible but non-exhaustive role in the performance of countries in LE and vice-versa. Moreover, the initial conditions in LE and GDP in 2000 are playing considerable role in economic growth performance in SSA by 2019. To improve their economic position, countries need to associate their performance in LE and in GDP, since they mutually affect each other. This conclusion relaunched the debate on the dual causality between health and economic growth particularly in SSA where the real impact of one to another still needs to be further investigated.

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Appendix

Table A1. The Log-t test of convergence clubs' membership (without SSA)

Year	Inference	Clubs	Final classification: clubs' membership	Coef.	T-value
LE at birth					
1960-2000	Conditional Convergence		All the countries in our sample (without SSA).	0.554	12.067
1960-2019	Conditional Convergence		All the countries in our sample (without SSA).	0.682	72.080
GDP					
1960-2000	Club convergence	Club 1	Australia, Belgium, Canada, Switzerland, Germany, Denmark, United Kingdom, Netherlands, New Zealand, Sweden, United States, Argentina, Austria, Chile, Spain, Finland, France, Greece, Ireland, Italy, Norway, Portugal, Republic of Korea, Malaysia, Thailand.	0.465	5.713
		Club 2	Colombia, Costa Rica, Guatemala, Mexico, Panama, Paraguay, Uruguay, Venezuela. Brazil, China, Indonesia, Sri Lanka, Philippines.	0.573	5.528
		Club 3	Peru, Bangladesh, Ecuador, Honduras, India, Myanmar, Nicaragua, Pakistan, El Salvador.	0.346	4.367
1960-2019	Club convergence	Club 1	Australia, Belgium, Canada, Switzerland, Germany, Denmark, United Kingdom, Netherlands, New Zealand, Sweden, United States, Argentina, Austria, Chile, Colombia, Costa Rica, Spain, Finland, France, Greece, Guatemala, Ireland, Italy, Mexico, Norway, Panama, Peru, Portugal, Paraguay, Uruguay, Bangladesh, Brazil, China, Ecuador, Indonesia, India, Republic of Korea, Sri Lanka, Myanmar, Malaysia, Philippines, El Salvador, Thailand.	0.206	3.995
		Club 2	Venezuela, Honduras, Nicaragua, Pakistan.	-0.468	-0.909

Source: Authors' estimation using LE and GDP values from WB-PEP and PWT respectively.

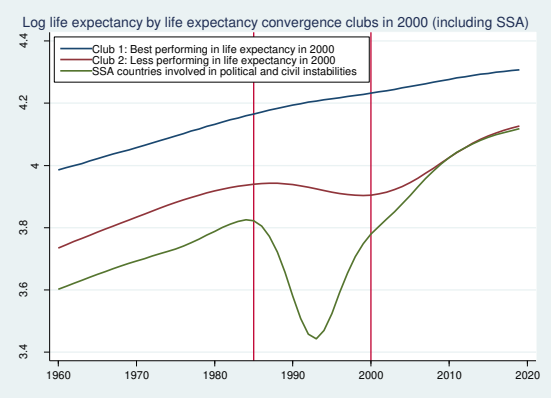
Table A2. The Log-t test of convergence clubs' membership (including SSA)

Year	Inference	Clubs	Final classification: clubs' membership	Coef.	T-value
LE at birth					
1960-1985	Club convergence	Club 1	All the other countries. SSA countries: Benin, Burkina Faso, Botswana, Central African Republic, Cote d'Ivoire, Cameroon, Republic of Congo, Comoros, Cabo Verde, Gabon, Guinea, Gambia, Kenya, Liberia, Mali, Mauritania, Namibia, Rwanda, Senegal, Sao Tome and Principe, Eswatini, Togo, South Africa, Zimbabwe.	0.081	1.907
		Club 2	Only SSA countries: Burundi, Ghana, Guinea-Bissau, Equatorial Guinea, Madagascar, Malawi, Nigeria, Sudan, Chad, Tanzania, Uganda, Zambia	0.272	3.567
		Club 3	Only SSA countries: Angola, Democratic Republic of Congo, Ethiopia, Mozambique, Niger, Sierra Leone.	0.287	3.167
1960-2000	Club convergence	Club 1	All the other countries. SSA countries: Benin, Burkina Faso, Comoros, Cabo Verde, Gabon, Ghana, Guinea, Gambia, Equatorial Guinea, Madagascar, Mali, Mauritania, Niger, Senegal, South Africa.	0.286	25.597
		Club 2	Only SSA countries: Angola, Burundi, Botswana, Central African Republic, Cote d'Ivoire, Cameroon, Democratic Republic Congo, Republic of Congo, Ethiopia, Guinea-Bissau, Kenya, Liberia, Mozambique, Malawi, Namibia, Nigeria, Sudan, Sao Tome and Principe, Eswatini, Chad, Togo, Tanzania, Uganda, Zambia, Zimbabwe.	0.015	0.286
		Club 3	Only SSA countries: Rwanda, Sierra Leone.	0.365	0.336
1960-2019	Conditional Convergence		All the countries in our sample (including SSA).	0.170	2.891
GDP					
1960-1985	Club convergence	Club 1	Australia, Belgium, Canada, Switzerland, Germany, Denmark, United Kingdom, Netherlands, New Zealand, Sweden, United States, Austria, Colombia, Spain, Finland, France, Greece, Ireland, Italy, Mexico, Norway, Paraguay, Indonesia, Republic of Korea, Malaysia, Thailand. SSA countries: Botswana, Gabon.	0.078	3.978
		Club 2	Costa Rica, Panama, Venezuela, Brazil, Ecuador. SSA countries: Cameroon, Republic of Congo, Eswatini, South Africa.	0.312	2.159
		Club 3	Argentina, Chile, Guatemala, Peru, Uruguay, China, Honduras, Nicaragua, Pakistan, Philippines. SSA countries: Angola, Cote d'Ivoire, Comoros, Cabo Verde, Guinea, Gambia, Equatorial Guinea, Kenya, Mauritania, Namibia, Nigeria, Sudan, Senegal, Sao Tome	-0.164	-2.760

			and Principe, Zimbabwe.		
		Club 4	Bangladesh, India, Sri Lanka, Myanmar, El Salvador. SSA countries: Burundi, Benin, Burkina Faso, Central African Republic, Democratic Republic of Congo, Ethiopia, Ghana, Guinea-Bissau, Liberia, Madagascar, Mali, Mozambique, Malawi, Niger, Rwanda, Sierra Leone, Chad, Togo, Tanzania, Uganda, Zambia.	0.154	1.612
		No club	Portugal is not converging towards any group.		
1960-2000	Club convergence	Club 1	Australia, Belgium, Canada, Switzerland, Denmark, Germany, United Kingdom, Netherlands, New Zealand, Sweden, United States, Argentina, Austria, Chile, Spain, Finland, France, Greece, Ireland, Italy, Norway, Portugal, Republic of Korea, Malaysia, Thailand. SSA countries: Botswana, Eswatini.	0.589	10.554
		Club 2	Colombia, Costa Rica, Guatemala, Mexico, Panama, Peru, Paraguay, Uruguay, Venezuela, Bangladesh, Brazil, China, Ecuador, Honduras, Indonesia, India, Sri Lanka, Myanmar, Nicaragua, Pakistan, Philippines, El Salvador. SSA countries: Angola, Burkina Faso, Cote d'Ivoire, Cameroon, Republic of Congo, Comoros, Cabo Verde, Gabon, Ghana, Guinea, Gambia, Guinea-Bissau, Equatorial Guinea, Kenya, Mali, Mauritania, Namibia, Sudan, Senegal, Sierra Leone, Sao Tome and Principe, Chad, Togo, Uganda, South Africa, Zimbabwe.	-0.431	-22.563
		Club 3	Only SSA countries: Burundi, Benin, Central African Republic, Democratic Republic of Congo, Ethiopia, Liberia, Madagascar, Mozambique, Malawi, Niger, Nigeria, Rwanda, Tanzania, Zambia.	0.319	2.643
1960-2019	Club convergence	Club 1	Australia, Belgium, Canada, Switzerland, Germany, Denmark, United Kingdom, Netherlands, New Zealand, Sweden, United States, Argentina, Austria, Chile, Costa Rica, Spain, Finland, France, Greece, Ireland, Italy, Norway, Panama, Peru, Portugal, Paraguay, Uruguay, Brazil, China, Indonesia, India, Republic of Korea, Sri Lanka, Myanmar, Malaysia, El Salvador, Thailand. SSA countries: Angola, Botswana, Cabo Verde, Equatorial Guinea.	0.457	5.709
		Club 2	Colombia, Guatemala, Mexico, Bangladesh, Ecuador, Honduras, Pakistan, Philippines. SSA countries: Republic of Congo, Gabon, Ghana, Mali, Namibia, Nigeria, Sudan, Sao Tome and Principe, Eswatini, Uganda, South Africa, Zambia.	0.175	3.042
		Club 3	Nicaragua. SSA countries: Benin, Burkina Faso, Cote d'Ivoire, Cameroon, Comoros, Ethiopia, Guinea, Gambia, Guinea-Bissau, Kenya, Liberia, Madagascar, Mozambique, Mauritania, Malawi, Niger, Rwanda, Senegal, Sierra Leone, Chad, Togo, Tanzania, Zimbabwe.	0.078	0.746
		Club 4	Venezuela SSA countries: Burundi, Central African Republic, Democratic Republic of Congo.	-0.186	-0.216

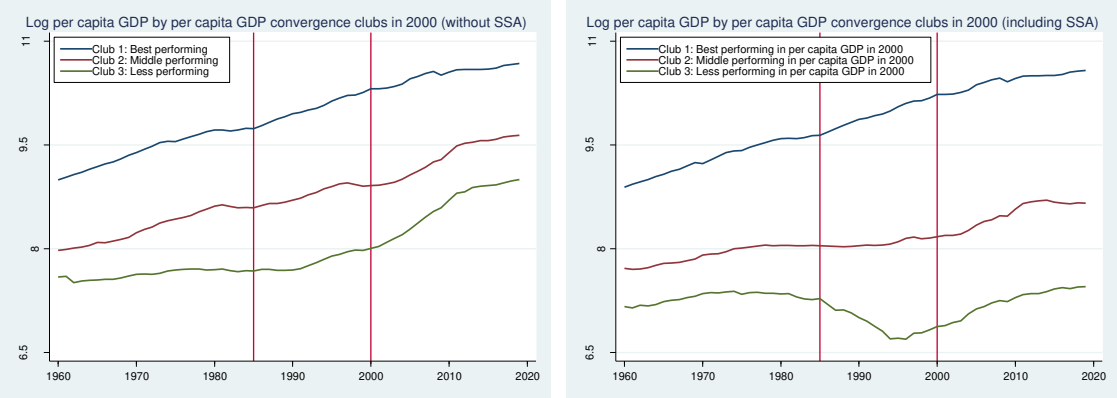
Source: Authors' estimation using LE and GDP values from WB-PEP and PWT respectively.

Figure A1. Life expectancy trends by 2000 converging clubs



Note: Different clubs are obtained after Log-t test of convergence in LE between 1960-2000.
Source: Authors' construction using LE estimates from WB-PEP.

Figure A2. Per capita GDP trends by 2000 converging clubs



Without SSA ***Including SSA***

Notes: Different clubs' memberships are obtained after Log-t test of convergence in GDP between 1960-2000 when SSA is excluded (left graphic) or included (right graphic).
Source: Authors' construction using GDP estimates from PWT.