What Remains of Cross-Country Convergence?

PAUL JOHNSON AND CHRIS PAPAGEORGIOU*

August 2018

We examine the record of cross-country growth over the past 50 years and ask if developing countries have made progress on closing income gap between their per capita incomes and those in the advanced economies. We conclude that, as a group, they have not and then survey the literature on absolute convergence with particular emphasis on that from the last decade or so. That literature supports our conclusion of a lack of progress in closing the income gap between countries. We close with a brief examination of the recent literature on cross-individual distribution of income which finds that, despite the lack of progress on cross country convergence, global inequality has tended to fall since 2000. (JEL E01, E13, O11, O47, F41, F62)

***** Johnson: Vassar College. Papageorgiou: International Monetary Fund. Papageorgiou acknowledges financial support from the U.K.'s Department for International Development (DFID). The views expressed in this paper are those of the authors and do not necessarily represent those of the International Monetary Fund. We are grateful to the Editor and five referees for very useful comments on earlier drafts. We also thank Philippe Aghion, George Akerlof, Andy Berg, Olivier Blanchard, Angus Deaton, Branko Milanovic, Maurice Obstfeld, Lant Pritchett, Dani Rodrik, Jeff Sachs, and Andy Warner for helpful discussions. Nitya Aasaavari and Freddy Rojas provided outstanding research assistance.

I. INTRODUCTION

Few topics in applied economic research have received as much attention as the convergence hypothesis, over the last three decades. The hypothesis in its simplest form states that initial conditions have no implications for a country's per capita income level in the long-run. In practice, the hypothesis is often taken to mean that per capita incomes in different countries are getting closer to each other in some sense, which implies that poorer countries are catching up with richer countries. Conceptually scrutinizing and empirically testing this hypothesis became prominent with the emergence of modern growth theory in the mid-eighties, as tackling this hypothesis was seen as an important part of the project of unlocking the mechanics of economic growth; as Lucas (1988) eloquently argued in his pioneering article "The consequences for human welfare involved in questions like these are simply staggering."

This review aims at providing a critical assessment of this substantive but elusive concept that has generated an extensive literature that is at the heart of growth theory, empirics and policy. What makes an old concept once again topical is the changing landscape of the global economy, the heterogeneity of growth experiences only recently being unraveled, and the emergence of superpowers that unexpectedly challenged what we think is possible and under what conditions.

Given the vast literature on this topic it is important to clarify at the outset what this review does and does not do. While key ideas from previous work will have to be explained again, this review will place more emphasis on work done in the last ten to fifteen years, or that was missed, omitted or given less emphasis by earlier surveys. For example, in terms of conceptual framework we aim to emphasize papers which have a tighter connection between theory and evidence than has been the norm in the literature, or where predictions about convergence go beyond the neoclassical model. It should also be stressed here that while regional convergence is a large area in itself, the emphasis of this survey is squarely on international income convergence. Also, while examining convergence in other key macro variables, such as welfare and health, is as interesting and important our focus here is on per capita income convergence as we do not want to risk a further loss of focus.

According to Maddison (2007) the industrial revolution and colonialism brought about great divergence in incomes across countries. Milanovic (2012) estimates that between the early 1800s and 1950, the average per capita income gap between industrial and less developed countries rose from a factor of 3 or 4 to a factor of 20 or more. This divergence slowed after World War II, which also coincided with the end of colonialism. Since the early 1990s the pace of growth of income per capita in many developing economies has accelerated to unprecedented levels and is substantially above that in high income countries. This wave of potential catching up behavior coincides with another key global fact: namely that in many of the same countries that have experienced rapid growth, the distribution of income has become more unequal because the share of top earners' income has often risen dramatically. The same period has seen dismal growth in a group of very poor fragile states that have been unable to participate in the recent wave of country growth described above, owing to wars and political unrest. It is unclear exactly how these developments have impacted the global distribution of

income across individuals. Pinkovskiy and Sala-i-Martin (2009, 2014), for example, argue that world Gini coefficients and poverty rates have fallen since the mid-1970s while others such as Chen, and Ravallion (2010) find less evidence of poverty reduction and argue that there are important regional differences in the extent of progress.[2]

The proposition that initial conditions have no implications for the long-run distribution of per capita income is motivated by the single stable steady state of the neoclassical model with a globally diminishing marginal product of capital.[3] By contrast, models with constant or increasing returns can exhibit a multiplicity or absence of stable steady states.[4] In the latter case, a country's long-run distribution of per capita income can depend on its initial conditions; for example, a model with a feedback loop from income to population growth that has a high population growth-low income steady state and a low population growth-high income steady state with countries being selected to move to one steady state or the other based on their initial level of per capita income. Against this background, a statistical test with a null hypothesis of non-convergence of and an alternative hypothesis of convergence, can be seen as potentially informative about the sorts of models best suited to the study of economic growth.

The convergence issue has important policy implications because, if there is a single stable steady state, small scale policy interventions can be helpful to the extent that they hasten the transition of the poor countries to inevitable prosperity. However, if there are multiple stable steady states, then large scale policy interventions may be required to push poor economies from one basin of attraction to another. In such a world, small scale policy interventions that fail to push countries into a different basin of attraction will eventually be undone as economies fall back to the steady state associated with the basin of attraction in which they lie. In broad terms, a multiplicity of steady states can lead to the sorts of poverty traps discussed by Collier (2007) or the hypothesized middle-income trap studied by Eichengreen et. al. (2013).

The plan for this review is as follows: We start Section II by demonstrating the key facts and patterns of per capita GDP growth across countries over the last fifty years. We consider not only differences in growth across countries but also differences over time with a view to getting a sense of the varied evolution of the per capita incomes in different subgroups of countries. In Section III, we first consider the definition and operationalization of the convergence concept, before discussing the theoretical foundations of the catching-up process in the closed-economy neoclassical growth model and in a more realistic open-economy model. Having examined different concepts and theoretical models of convergence, in Section IV we provide a brief summary of the tests employed in the empirical growth literature to estimate

---

[2] Sudhir, Segal, and Stiglitz (2010) contains several analyses of the measurement issues involved and the conclusions of this debate.

[3] Strictly speaking, something like the Inada (1963) conditions are needed to guarantee a unique stable steady state in this model.

[4] Azariadis (1996) and Galor (1996) present surveys of theoretical mechanisms that can produce a multiplicity of steady states.

convergence. In Section V we briefly touch on econometric issues facing estimation of convergence, before turning to empirical evidence in Section VI. Given how vast the literature is on the subject we chose to focus attention to only a selected set of key papers from panel, time series and distributional approaches. Section VII concludes with our assessment of the evidence and a discussion on the lessons learned so far from this voluminous literature.

II. PATTERNS AND FACTS ON GROWTH OVER THE PAST HALF CENTURY

Context

This section presents what are, in our view, some of the more important growth patterns and facts from the past half century. We concentrate on reporting differences in growth across countries but also differences over time. The objective is to contextualize in a very intuitive way, patterns of convergence, divergence, and other interesting growth dynamics using some very basic statistics and figures.

While it would be unreasonable to claim that 50 years' worth of data is nearly enough to draw out the main facts about long-run growth, we believe that this data can adequately and meaningfully reflect modern facts on growth.[5] In this short period of time, by historical standards, the world has seen unprecedented economic progress that has spanned the globe. The past half century has witnessed large improvements in living standards across many parts of the world that have transformed the prevailing landscape of economic thinking and policy. From this perspective we aim to exposit some of the key growth trends that emerged over the past half century, as parsimoniously as possible.

The analysis below is based on the Penn World Table version 7.1 (PWT 7.1) database, covering 182 countries over the period 1950 – 2010.[6] This dataset has been the gold standard of cross-country datasets and has been used extensively in the empirical growth literature, including tests of convergence – roughly 70 percent of cross-country empirical work is based on PWT, followed by World Bank's World Development Indicators (WDI), and the IMF's World Economic Outlook (WEO) dataset placed a distant third. This is largely because the Penn World Table has managed to curb well-known measurement issues related to cross-country

[5] The identification problem discussed by Durlauf et. al. (2005, pp 622-3) is relevant here.

[6] The main contribution of the Penn World Table was to convert national measures of GDP and income into internationally comparable PPP estimates. This is done by collecting prices for the same or similar goods in different countries and deriving price indices that can be used to compare what people can actually buy. The massive undertaking of price collection, known as the International Comparison Programme/Project (ICP) is at the heart of PWT – see, Deaton and Heston (2010) and Johnson et al. (2013) for detailed discussions on methodological challenges facing PWT. The PWT has reported on eight rounds of data, starting in 1970 (for more details see the pioneering papers by Kravis, Heston, and Summers, 1978, and Summers and Heston, 1980). There are other datasets we could use, most notably Angus Maddison's historical GDP data but unfortunately that dataset, as extensive as it is in the time dimension, it only covers a limited number of developing countries.

(continued)

comparability, through more than 40 years of continuous improvements in data collection and methodologies.[7]

Global growth

The world as a whole has experienced unprecedented economic growth over the last half century. Average per capita PPP adjusted GDP across the globe increased from US$4,155 in 1960 to US$13,368 in 2014 implying an average annual growth of 4 percent (see Figure 1).[8] While hard evidence to corroborate this claim is at best patchy, there exists a consensus amongst social scientists that the past half century has been the most prosperous in terms of world economic growth and welfare. At the same time, growth has been uneven across countries and also across different time periods. We consider this heterogeneity as a defining feature of the modern growth experience as we take a closer look at country experiences across income and time next.

Heterogeneity across geographical regions

Table 1 reports average decadal growth rates in six geographical regions as commonly classified by the IMF and the World Bank (East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, North America, South Asia, and Sub-Saharan Africa) during the period 1960 – 2010. Global growth was relatively stable in the 1960s and 1970s with all regions having positive average growth rates in the range of about 3–4 percent with the exception of Sub-Saharan Africa and South Asia that grew below 2 percent per year.

Growth rates in all regions experienced a significant decline in the 1980s, with the exception of South Asia, resulting in world growth taking a large dip. Latin America, Middle East and North Africa, and Sub-Saharan Africa experienced the greatest declines, with growth falling into negative territory. For these regions the 1980s was a "lost decade" but with the exception of Sub-Saharan Africa, these regions began to recover in the 1990s and 2000s.

South Asia followed a different pattern; it continued the growth of the 1960s and 1970s into the 1980s but saw decelerating growth in the 1990s. This was followed by a dramatic bounce back in the 2000s, during which it was the fastest growing region, recording an annual growth of 4.5 percent, something only seen previously in the 1960s in Europe. Notable also is Sub-Saharan Africa's bounce back in the 2000's after very poor performances in the previous two decades (see Johnson, Ostry and Subramanian, 2007). The strong performance of some African

[7] For the stylized facts presented in this section we consider countries with populations above 1 million, to exclude small states that are likely to follow unique growth experiences. The time horizon of our analysis below is 1960 – 2010 as the 1950s data is quite fragmented and mostly available for industrialized economies. Using the latest published version of the Tables, PWT 9.0 released in August 2016, does not change our assessment of cross-country trends.

[8] Global growth rates were calculated by taking the mean of real PPP adjusted per capita GDP growth across countries.

countries (such as Rwanda, Tanzania, and Botswana) had generated sentiments of optimism by some economists (see Miguel, 2009; Radelet, 2010), while others flagged the sharp rise in commodity prices as the main driver of this experience. Figure 2a provides an illustration of regional progress from 1960 to 2010 with South and East Asia showing remarkable improvements in per capita GDP while Sub-Saharan Africa fell behind (see also Figure 3).

Heterogeneity across income groups and exporter type

Table 2 presents average growth in three income groups – High-Income Countries (HICs), Middle-Income Countries (MICs) and Low-Income Countries (LICs) – along with a group of countries classified as commodity exporters.[9] The data reveal that the three income groups followed distinct growth patterns in the past half century.

HICs began as the fastest growing set of economies, with an average annual growth of 4.7 percent in the 1960s, but have gradually become the slowest growing group in the 2000s, at 1.7 percent annual growth. In contrast, both MICs and LICs saw growth deteriorate drastically in the 1980s, before experiencing a recovery in the 2000s. Specifically, MICs suffered a severe reduction of average annual growth, from around 3 percent in the 1960s and 1970s to a dismal 0.4 percent in the 1980s. They have since then recorded a strong recovery reaching an average of 3.4 percent in the 2000s.

LICs, on the other hand, faced continuous decline every decade from, the 1960s to the 1990s, with negative growth rates in the 1980s and 1990s, before the surprising and unprecedented resurgence in the 2000s with 2.4 percent growth. Given recent growth successes, some LICs went from countries associated with disaster in the pre-2000 era to success stories in the post-2000 era. While many policy makers and commentators have hailed LICs recent achievements, researchers are still trying to understand where this newly found growth is coming from. More broadly, during the 2000s we observe some convergence in relative income levels as MICs and LICs showed a considerably higher growth rates than HICs. Recent data unfortunately casts doubt as to whether this upward growth trend will continue as growth in many commodity exporting LICs started to decelerated as commodity prices declined sharply.

The bottom panel of Table 2 reports average growth rates in each of the decade in our sample for commodity exporting group of countries including oil and precious mineral exporters. These countries had negative growth in the 1980s and 1990s, but saw a marked reversal of fortunes in the 2000s with commodity prices exploding during the same period – for example crude oil prices shot up from around US$19 per barrel in 2000 to over US$130 in the first quarter of 2008 before plummeting to under US$40 in 2016; similarly, the price of gold climbed from US$274 per ounce in 2000 to a record high of US$1,405 in 2010).

[9] See Appendix Table A.1 for a list of countries in each grouping.

Figure 2b illustrates the way that HICs and MICs have opened the gap that separates them from income levels in LICs. In addition, Figure 3, which plots per capita GDP in a few selected countries and income groups relative to that in the US, paints a similar picture.

Figure 4 plots the growth rate over 1960–2010 against the 1960 level of real per capita GDP for all countries for which data exist in PWT 7.1. Different versions of this plot, which presents one of the most well documented features of cross-country growth experience, have appeared in many books and papers. Some interesting observations are immediately apparent. First, countries early in their development process exhibit much more diverse growth experiences over the period compared to more advanced countries. Second, once LICs, MICs and HICs are indicated in different colors, catching-up behavior, in the form of a negative relationship between initial income and subsequent growth, is evident among the HICs. To some extent, this behavior is evident among the MICs but not at all among the LICs.[10]

Figures 5 and 6 present estimated cross-country per capita income distributions for 1960 and 2010, and standard deviations for the distribution for 1960-2010, respectively. Calculations in both figures used a balance sample of 110 countries for which data were available. Notwithstanding the crude nature of these two figues, they reveal some notable patterns. The good news from Figure 5 is that the median country income improved markedly between 1960 and 2010, from US$2161 to US$6682 (in constant prices, a growth rate of 2.3 percent per year), as indicated by the rightward shift of the center of the distribution. In 2010, only 30 percent of the countries had per capita incomes below the 1960 median providing some evidence of the transition of some low- and middle-income countries to higher income status. However, the figure also contains bad news in as much as the distribution of per capita income in countries around the world has become more disbursed over this period as the distribution elongated and became flatter.

Figure 6 shows a continuous increase in the cross-country standard devations from 1960 until the mid-1990s followed by a notable slowing and reversal of this trend in the mid to late 2000s. The implied ceastion of the rise in the cross-country dispersion of per capita income sits well with the narrative regarding the remarkable growth spurt experienced by many emerging market and developing economies since the mid-1990s – a narative also consistent with the 2010 cross-country income distribution depicted in Figure 5.

Heterogeneity within LICs

Table 2 also makes a distinction between, what are commonly called, fragile and non-fragile LICs, with the former comprising about 1/3 of the LICs. Fragile states are defined as countries facing political fragility, characterized by weak institutional capacity, poor governance and

[10] It is important to be mindful of De Long's (1988) criticism of Baumol's (1986) early observation of the different growth behavior in LICs, MICs and HICs on the basis of sample selection and measurement error bias.

(continued)

conflict.[11] It is important to make this distinction, as there is significant variation in the experience between fragile states and the rest of LICs especially in the last two decades of our sample period. Concretely, there is a difference of over 2 percent annual growth between the two groups in the both decades. This relatively recent development is quite important because it highlights that while there is a lot of optimism over the most recent growth acceleration in LICs, aggregating their experience masks a large differential the performance of fragile and non-fragile states. The story that emerges is one of divergence within the LIC group. Put differently, the unprecedented growth acceleration observed in the LIC group as a whole over the past decade, after a long period of poor performance, masks the fact that only about half of these countries are contributing to the resurgence while the rest of the countries are stagnant.

Top and bottom growth performers across time

Table 3 reports the top 10 and bottom 10 growth performers for each decade in our sample. There are a number of observations that are worth making using this data. First, it is quite stunning how China moved from one of the ten worst growth performers in the 1960s (with -0.32 percent annual growth rate) to claim the first place in the list of top performers in the 1990s and 2000s (see Subramanian, 2011, for an articulate and convincing account of China's rise to economic prominence). The growth experience of South Korea which managed to make the top-10 list in three consecutive decades – 1970s, 1980s and 1990s – before slowing down in the 2000s was also very impressive.

More broadly, Table 3 demonstrates the dominating growth performance of Asian economies. Since the 1970s almost half of the top 10 growth performers come from Asia, a truly remarkable achievement. On the other hand, some of the poorest countries in the world, many of them fragile states, continued to record negative growth rates decade after decade. The encouraging news for developing economies emerges in the 2000s when unexpectedly some LICs make the top-10 list for the first time in decades. Unfortunately, consistent with the very poor growth performance among fragile states discussed previously, Table 3 also shows that the bottom-10 list is mainly composed of these countries.

Convergence of LICs to middle-income status

How many years would it take LICs to reach MICs income levels? To answer this question, we consider a scenario in which we assume that the average annual growth rate for each country in the past decade will prevail for the indefinite future. Then we calculate the number of years that would be required for each LIC to reach the middle-income threshold of a little over $3000. Table 4 reports these calculations and lists countries in ascending order of years to middle-income status. According to this simple approach, which is arguably quite optimistic in nature, Vietnam and Laos have almost reached middle income status while Moldova, Sudan and Cambodia are within reach in less than ten years. Countries in East Africa that exhibit

[11] We use the World Bank's definition of fragility (see Appendix Table A.1 for the list of countries which formed the baseline sample of fragile states in the analysis). On a cautionary note, we are agnostic as to whether fragile states are growing less due to their fragility, or causality might go the other way around.

strong growth rates nowadays such as Rwanda, Tanzania, and Uganda would need about three decades to reach middle-income status, whereas Congo, Benin and Sierra Leone are far behind, being a century or more away based on recent growth performance. This exercise serves as a reminder that huge cross-country income disparities are not likely to be easily mitigated, even under favorable assumptions.

Episodic growth

An important fact in the literature of economic development is that growth in many countries and particularly in LICs is highly episodic and characterized by periods of accelerated growth followed by sharp decelerations often leading to disasters. Figure 7a illustrates this claim by plotting the growth rate of each developing and advanced country in our sample for each of the 1970s, 1980s, 1990s, and 2000s against that in the previous decade. The wide dispersion of these points around the 45-degree line reflects the unpredictability of growth from one decade to another. Figure 7b demonstrates that the instability of growth across decades is even larger in LICs. Over the past few decades, the typical growth rate for a LIC in one decade has generally been a poor predictor of its growth rate during the next decade, while many policies and country characteristics have beenmore stable (Easterly et al., 1993).[12,13]

The empirical literature on growth spells took off after Pritchett (2000) demonstrated that the growth process, especially in developing economies, tends to be episodic. Hausmann, Pritchett and Rodrik (2005), proposed a heuristic approach for identifying growth breaks while more recent research has focused on improving the methodology for obtaining growth breaks. For example, Jerzmanowski (2006) estimates Markov-switching regressions to characterize four distinct growth regimes and transitions between them. Jones and Olken (2008) use the structural break econometric technique of Bai and Perron (1998, 2003), which locates and tests for multiple structural breaks within a time series, to identify dates of turning points. Berg, Ostry and Zettelmeyer (2012) turn attention to the challenge of sustaining growth accelerations by searching for determinants of the duration of growth spells.

Table 5 presents spells of growth accelerations and deceleration across decades using the methodology developed in Berg et al. (2012) and data from PWT 7.1. This table confirms that the growth experience in many countries is not smooth but rather erratic with the table featuring almost as many accelerations as decelerations. Both kinds of growth spell have been observed in all five decades in our sample, but the1970s are dominated by decelerations and the 1990s by accelerations. It is also evident that growth is most episodic in developing economies (LICs and MICs), with there being only a few examples of growth spells of either kind in advanced

[12] The correlations coefficient in LIC growth rates for the 60s versus 70s is 0.011, for the 70s versus 80s is -0.118, for the 80s versus 90s is 0.025, and for the 90s versus 00s is -0.212.

[13] While this type of growth nonlinearity is related to the existing theoretical literature on poverty traps, it is important to recognize that it is also quite different in that countries need not fall into persistent underdevelopment once they experience a growth down break. Rather, the experience has been that countries tend to grow in spells and even for the very poor countries growth is not constantly low but rather start-and-stop.

economies. In terms of geographical dispersion, countries in Sub-Saharan Africa are the most prone to episodic growth. This evidence suggests that whether convergence or divergence characterizes the long-run behavior of growth, the process is highly fragmented in developing and low-income economies.

Based on these very basic facts, broad-based international convergence is hard to witness but there are countries that have enjoyed very successful convergence experiences. Those typically come from the middle stages of economic development, and mostly from South and East Asia, with notable examples being China and S. Korea - China managed a leap from negative growth in the 1960s to become the highest growing county in the world in the course of the next few decades, while S. Korea was propelled from low-income status to high-income status within the short span of 50 years. However, the majority of the poorer countries, mostly in Africa but elsewhere too, show no movement in closing the gap which has been increasing as more advanced economies grow at a faster pace (Figure 3).

III. THEORETICAL CONSIDERATIONS

The convergence hypothesis is often taken to be the proposition that per capita incomes in different countries are somehow getting closer to each other but it is more precisely understood as the proposition that the long-run cross-country distribution of per capita income is independent of initial conditions. This was originally conceptualized in the basic Solow-Swan neoclassical growth model where, outside of the steady state, economic growth is driven by the accumulation of physical capital. As the marginal product of capital is diminishing, this accumulation should come to a stop so that, as a result, rich countries' growth will slow, allowing poorer countries to catch up. Much of modern growth economics introduces other sources of heterogeneity, notably technological progress (both innovation and adoption) and human capital accumulation as well as differences in geography, institutions, and policy, which may slow down or speed up the process of convergence.

In this section, we briefly review the theoretical underpinnings of convergence by providing a sketch of how dynamics should be thought about under the basic Solow model and other more modern theories. The section is then rounded off with "economically interesting" notions of convergence which fall into two logically distinct convergence concepts that are predominant in the literature: one suggesting that disparities between countries simply disappear with time; the other advocating that convergence is inherently dependent on a given country's limiting behavior from certain initial conditions. This naturally leads to the question of absolute versus conditional dissipation of initial disparities.

The original theoretical foundation of the convergence hypothesis is the unique stable steady state in the standard one-sector neoclassical growth model. This property follows from the standard conditions on the production function of a strictly diminishing marginal product of capital, that takes all values between infinity and zero as the capital stock rises from zero to infinity. Ignoring population growth and technological progress, in the Solow-Swan version of the neoclassical model with an exogenous saving rate of *s*, the growth rate of capital per worker, *k*, is given by $g_k = sf(k)/k - \delta$ where $f(k)$ is the (intensive form of the) production

function and δ is the depreciation rate. The assumptions on $f(k)$ ensure that $f(k)/k$ declines monotonically from infinity to zero as k rises so that $g_k > 0$ for small positive k pushing k toward the single value of k, independent of the initial quantity of capital per worker, where $sf(k)/k = \delta$. This ensures the existence of a unique, stable steady state that is eventually reached for any initial $k > 0$ and it is in this sense that the long-run outcome of the economy is independent of its initial conditions.

To move beyond the basic Solow-Swan model we can draw on growth and development accounting calculations showing that growth is driven by the accumulation of both human and physical capital as well as improvements in technology or total factor productivity. To fix ideas, suppose that the aggregate production function can be written as $Y = AF(K, hL)$ where Y is GDP, A is the level of technology, K is the stock of physical capital, L is the labor force, h is human capital per worker, and F is a production function which we assume to exhibit constant returns to scale in its two arguments. Using that assumption, we can write per capita output as $y = AF(k, h)$ where $y = Y/L$ and $k = K/L$. As in the basic Solow-Swan model, the assumption of diminishing returns to the accumulable factors of production k and h yields convergence to a steady-state and the addition of the assumption of a common level of technology A implies that the steady state is common across countries.[14]

The assumption of diminishing returns to human capital is justified by the observation that higher education is bounded from above and as well as by studies in labor economics finding that human capital's contribution to income is diminishing (see, e.g., Becker 1994).[15] Nonetheless, as a voluminous literature has shown, this is not clear at all with respect to productivity improvements stemming from technological innovation and adoption (see e.g., Schumpeter, 1950; Aghion and Howitt, 1992; Zeira, 1998). The assumption of a common level of technology is not innocuous but was implicit in much of the early convergence literature.[16] As we discuss below, more recent work has emphasized the inability of some countries to reach the technological frontier as an obstacle to convergence.

To go beyond the exogenous technological progress of the basic Solow-Swan model, we follow a very simple formulation proposed in Aghion (2004). In this model, a country's productivity A grows over time according to $\dot{A} = \lambda\varphi(A^{\max} - A)$ where $A^{\max}$ is the world-wide technological frontier and $\lambda\varphi$ is the rate of creative destruction (λ measures the productivity of

[14]See, for example, the exposition in Durlauf and Johnson (1995).

[15]As a voluminous literature has shown, it is far from clear that this assumption is warranted with respect to productivity improvements stemming from technological innovation and adoption (see e.g., Schumpeter, 1950; Aghion and Howitt, 1992; Zeira, 1998).

[16]Mankiw (1995, p. 301), for example, argues that for "understanding international experience, the best assumption may be that all countries have access to the same pool of knowledge, but differ by the degree to which they take advantage of this knowledge by investing in physical and human capital". Romer (1993) offers a contrasting view.

R&D; φ is the R&D intensity, measured as the productivity-adjusted quantity of final output devoted to R&D). Defining $a = A / A^{\max}$ and letting g denote the growth rate of $A^{\max}$ yields $\dot{a} = \lambda\varphi(1-a) - ag$ as the differential equation describing knowledge transfers generate convergence to the global growth rate. Similar to the law of diminishing returns in the neoclassical growth model, as the gap between the country's average productivity and the world-wide leading-edge, $1-a$, narrows, innovations will raise productivity at a decreasing rate.

Embedded in a version of the Solow-Swan model with technological progress, this setup yields $g_k = sf(k)/k - [\delta + \lambda\varphi(a^{-1} - 1)]$ as the rate of the growth rate of capital per intensive worker, $k = K / AL$. While this equation seems similar to that above derived from the standard Solow-Swan model, there are two drivers of convergence behavior here. As before, there is the declining marginal product of capital but, in addition, there is the adoption of technologies that propel growth by pushing the level of technology in a country toward the world-wide technological frontier. Perhaps more importantly, this model also admits the possibility of convergence club behavior. In countries where there are sufficiently high barriers to technological innovation or adoption due to, for example, corrupt institutions, poorly defined intellectual property rights, low supply of skilled workers, and credit constraints, (see Aghion et al., 2016; Howitt and Mayer-Foulkes, 2005), φ will be zero. Such countries will be left behind while those counties with positive φ move towards the technological frontier, thus creating two groups of countries with group membership dependent on initial conditions.

Despite its fundamental insights, the elementary Solow-Swan model suffers at least one potentially important drawback in the convergence context in that it is a closed-economy model while most countries, even some of the poorest and the smallest, have, at least to some extent, borders open to trade and capital flows. Some of the recent literature has introduced open economy growth models that consider trade and capital flows to be elemental drivers of globalization and growth. Examples of such models that consider the issue of convergence include Barro, Mankiw, and Sala-i-Martin (1995), Ventura (1997), and Cuñat and Maffezzoli (2004), Oxborrow and Turnovsky (2016). Of course, in an open-economy growth model with perfect international capital mobility convergence would happen instantly because incipient cross-country differences in rates of return on capital would be immediately eliminated. To explain why we do not observe equalization of cross-country return on capital and therefore immediate convergence, we need to consider possible frictions in international capital markets that slow convergence or eliminate it all together.

To exposit these ideas, we use an elementary open economy model from Obstfeld and Rogoff's (1996) textbook on which allows for international borrowing and lending under credit market imperfections. In this overlapping generations model, a small open economy faces a fixed world interest rate *r*. Individuals in this economy live two periods, working only in the first period and earning wage w_t. Individuals can borrow in the world capital market an amount b_t

(up to a fraction $\eta > 0$ of their earnings). Savings is based on individual choice rather than being a constant fraction of income as in the Solow-Swam model.

As in the standard neoclassical model, the equilibrium domestic interest rate r^d is equal to net marginal return to domestic investment, $r^d = f'(k) - \delta$. This rate can exceed the world rate r if the international borrowing constraint is binding. An individual at the first period of life maximizes the standard logarithmic utility function, $U_t = \log(c_t) + \theta\log(c_{t+1})$, subject to the constraints $k_{t+1} + b_{t+1} = w_t - c_t$ and $c_{t+1} = (1 + r^d_{t+1})k_{t+1} + (1 + r)b_{t+1}$ where c_t is the individual's consumption in period t and b_{t+1} is an individual's assets abroad which are subject to the constraint $b_{t+1} \geq -\eta w_t$. For simplicity of exposition, we omit the details of this standard maximization problem and proceed as in Obstfeld and Rogoff (1996) with considering the three possible cases that are implied by the model for a country that opens itself to world capital markets after having reached its autarkic steady state.

If $r^d < r$ initially, then the small open economy becomes a net creditor in the international capital market and r^d converges to r in one period implying absolute and rapid convergence in the steady state. However, if $r^d_{t+1} > r$, the borrowing constraint will bind so that $b_{t+1} = -\eta w_t$ which yields

$$k_{t+1} = w_t - c_t - b_{t+1} = \left[\frac{\theta(1+\eta)}{1+\theta} + \frac{(1+r)\eta}{(1+\theta)(1+r^D_{t+1})}\right] w_t . \qquad (2)$$

It is interesting to note that setting $\eta = 0$ the model collapses to one resembling a closed economy Solow growth model albeit with log utility maximizing agents (and noticing that w_t represents savings out of output). Equation (2) implies that greater capital inflows from international markets would speed up convergence because easing the borrowing constraint would lower r^d, thereby increasing the rate of capital accumulation. Letting k^d_{ss} denote steady-state capital stock under constrained borrowing and k^u_{ss} that in the absence of a borrowing constraint, one can show that $k^d_{ss} > k^u_{ss}$ is the same as $k^u_{ss} < \frac{\varphi w_{ss}}{1+\varphi} + \eta w_{ss}$ where w_{ss} is the wage of the agent in the first period of life in the unconstrained steady state. This condition offers an intuitive explanation of convergence dynamics in this model, as it states that if the individuals' saving (w_{ss}) plus maximum amount possible from international capital markets are sufficient to finance k^u_{ss}, then the economy will achieve convergence to the unconstrained steady state k^u_{ss}. If, however, this inequality is reversed the economy will not ever converge to steady state k^u_{ss} simply because the wage and maximum possible foreign borrowing would not be sufficient to finance k^u_{ss}. In sum, this model demonstrates in a very tenable and intuitive way how market imperfections can deliver convergence dynamics that are compatible with the reality of more

integrated global economy and consistent with evidence from the various empirical approaches that we discuss below.[17]

These and other theoretical growth models provide a variety of sources of heterogeneity in long-run outcomes. The empirical challenge is to determine if that heterogeneity represents the long run-effect of initial conditions and so is at odds with the convergence hypothesis or if it merely represents cross-country microeconomic variation. An example of latter case would be something that can be conceived of as parameter variation in the Solow-Swan model, such as different exogenous saving rates, the removal of which would permit a common long-run outcome in the absence of differences in initial conditions. In the former case, the obstacle to convergence between two countries would be membership of different basins of attraction of the process describing the evolution of per capita income so that the initial conditions defining that membership have long-run effects. We now turn to an outline of the empirical convergence concepts that have been employed in response to this challenge.

IV. Convergence Concepts

The most elementary convergence tests are the so-called β-convergence tests. Often these tests use a log-linearized version of the neoclassical growth model to motivate estimation of equations of the form

$$\log(y_t / y_{t-\tau}) = \alpha + \beta \log(y_{t-\tau}) + u \qquad (3)$$

where $\tau > 0$, α and β are parameters, and u is an error term. A test of the hypothesis $\beta = 0$ against the alternative $\beta < 0$ is then construed as a test for convergence, as the neoclassical model implies that a country will grow more quickly the further it is from the steady state which is implied by $\beta < 0$. This approach to testing the convergence hypothesis has been widely implemented as a cross-section test for a group of countries as well as a panel test for a group of countries over time. Durlauf et. al. (2005) contains an extensive survey of this literature and discusses at length its econometric and conceptual pitfalls.

As a test of convergence as the irrelevance of initial conditions, such β-convergence tests require that initial income be a sufficient statistic for a country's initial conditions. To the extent that initial conditions are also reflected in cross-country variation in α, these tests can have low power against non-convergent alternatives, a point originally developed in Bernard and Durlauf (1996). Several studies, among them Durlauf and Johnson (1995), Tan (2010), and Fiaschi et. al. (2018) have found that variables other than initial income (literacy, institutional quality, ethnic fractionalization, life expectancy, share of Catholics) are capable

[17] In developing a theory of gradual adjustment of capital in an open economy, an alternative to imperfect capital markets model presented above is the model of convex adjustment costs to investment and Tobin's q (see e.g., Battisti, Di Vaio and Zeira, 2016).

of defining groups of countries in which exhibit similar within-group long-run behavior but different across-group long-run behavior. Such results imply that initial income does not contain all of the information needed to determine the long-run distribution of a country's per capita output.

While the neoclassical model is the motivation for tests of the convergence hypothesis in early work such as Barro (1991), Barro and Sala-i-Martin (1992), and Mankiw et. al. (1992), still earlier work such as Abramovitz (1986) and Baumol (1986) was motivated by considerations of technology transfers and capital flows from "leader" to "follower" countries.[18] Under this view, countries that are further behind the leader are potentially able to make a larger leap forward and grow relatively faster than the leader as they catch up. This is a potentially important driver of convergence, and Sachs and Warner (1995) cite a lack of openness as major obstacle to development and hence convergence. Delong and Dowrick (2003) argue that while periods of increased globalization such as those prior to WW1 and after WW2 tended to foster convergence in that the "convergence club" tended to grow in these periods, the effects were far from universally felt. They note that many countries were unable to join the club or, if they did, were unable to maintain foothold in it. They reexamine Sachs and Warner's estimates of the effect of openness on growth and conclude that while openness does promote growth, the benefits of doing so seem to have declined since 1980.[19]

Following Barro (1991) and Mankiw et.al. (1992), equation (3) is sometimes augmented with a term such as $\lambda'\mathbf{x}$, where λ is a vector a parameters and $\mathbf{x}$ is a vector of conditioning variables that determine the steady state value of output per capita – variables such as rates of physical and human capital accumulation and population growth as well as a wide variety of others.[20] In this case, countries are assumed to have different steady states only because of the microeconomic variation controlled for by the inclusion of $\mathbf{x}$ and a negative estimated value of β is taken as evidence that each is converging to its particular steady state. Such tests are called tests of "conditional convergence" to distinguish them from tests of "absolute convergence" based on equation (3).[21]

---

[18] While not concerned primarily with the convergence hypothesis per se, another early study, Kormendi and Meguire (1985), include initial income levels in their growth regressions motivated by the neoclassical model and note the catching-up implications of the negative estimated coefficient. As they point out, Barro (1984, pp288-94) studies graphically the catching-up behavior of a small group of industrialized countries in the post-war period. See also Marris (1982).

[19] Alesina et. al. (2005) find that openness and country size are substitutes in promoting growth. Di Vaio and Enflo (2011) discuss the literature on theoretical and empirical motivations for range of possible effects of globalization on the cross-country distribution of income.

[20] The inclusion of these variables raises important concerns about endogeneity as discussed by Cho (1996), Temple (1999), Easterly (2004), Durlauf et. al. (2005), Rodrik (2012), and Lenkoski et al. (2014), among others.

[21] While Mankiw et. al. (1992) derive a set of $\mathbf{x}$ variables from a version of the Solow growth model, economic theory is largely silent with respect to the set of variables to be included. As a result, empirical studies often abuse

(continued)

The implication of this finding of conditional convergence is that a poor country can be made to converge to prosperity simply by adopting the value of **x** of a rich country. Dowrick and DeLong (2003, p. 204) describe the presumption that a poor country could do this as the "joker in the deck" arguing that "a moment's thought will convince anyone that many of the right-hand-side variables used by Barro (1996) could never be brought to the mean values found in the industrial core of the world economy in any country that has not already attained the productivity level and socioeconomic structure found in the industrial core." There is another critique of the conditional convergence concept that is a bit more technical in character yet equally powerful: If indeed per capita GDP converges to different steady states, then the income distribution itself should converge to a limit distribution, which is not consistent with the evidence presented in the empirical section above. For these reasons, we mostly consider the absolute version of the convergence in this article.

While divergence is an obvious alternative to convergence, another economically interesting possibility is club convergence, in which groups of countries with similar initial conditions exhibit similar long-run outcome so that, for example, the cross-country distribution of per capita income can have two or more peaks as found by Quah (1993). This can reflect a law of motion for the evolution of output per capita that has more than one stable steady state as can occur in a model with a feedback loop from income to some other state variable. In such cases, club convergence can occur as economies converge to the steady state associated with the basin of attraction in which they begin. A country's long-run per capita income will then depend on its initial conditions as measured by the state variables determining its basin of attraction with countries having similar initial conditions having similar long-run per capita income and so forming a convergence club.

Bernard and Durlauf (1996) and Durlauf and Johnson (1995) have argued that the β-convergence tests have that low power against this type of alternative with the latter paper finding that the club convergence hypothesis is consistent with the Mankiw et. al. (1992) data. Following Quah (1993) and Durlauf and Johnson (1995) a large group of authors have examined the convergence hypothesis using methods that have club convergence as the alternative hypothesis. Some of this research follows Quah and studies the dynamics of the entire cross-country distribution of per capita income while other researchers have used a variety of clustering approaches to divide their samples into groups of counties that represent putative convergence clubs because of similarities in initial conditions.

The absence of a role for initial conditions in long-run outcomes implies that contemporary differences in per capita incomes are transitory suggesting that the dispersion of per capita

---

the resulting flexibility for selecting among the potential candidates. So much so that Durlauf and Quah (1999) report that over 90 different variables have been used despite the fact that no more than 120 country observations were available for the regression analysis using early versions of Penn World Data (version 4.0). This was part of the motivation for the literature aimed at eliminating model uncertainty (see, e.g., Levine and Renelt, 1992; Raftery, 1995; Doppelhofer, Miller, and Sala-i-Martin, 2000; Fernandez, Ley and Steel, 2001; Brock and Durlauf, 2001, Ley and Steel, 2009; Eicher et al. 2011; Leamer, 2016a.b). One of the key findings of this literature is that the initial per capital GDP level is the most effective of all variables tried in explaining growth.

incomes across economies should fall if convergence is occurring. Barro and Sala-i-Martin, (1992) refer to this notion as σ-convergence which is said to occur between t and $t+\tau$ if $\sigma_t^2 > \sigma_{t+\tau}^2$ where σ_t^2 is the cross-country variance of y_t. While β-convergence is not sufficient for σ-convergence as shocks can cause σ_t^2 to be constant or increase over time, even if β-convergence is occurring, Young, et. al. (2008) show that β-convergence is necessary for σ-convergence. Friedman (1992), Quah (1993) and Hart (1995) caution against committing Galton's fallacy as β-convergence may be observed even if there is a constant, or even increasing, variance between two points in time. Accordingly, Friedman (1992), Hart (1995), Lichtenberg (1994), and Carree and Klomp (1997), emphasize that tests for convergence should investigate whether the variance indeed decreases between two points in time, i.e. whether there is σ-convergence (Barro and Sala-i-Martin, 1995).

A different approach is taken by Bernard and Durlauf (1995, 1996) who offer definitions of convergence based on the time series behavior of output. They represent the idea that initial conditions have no implications for a country's per capita income level in the long-run by saying that two countries converge if the current long-run forecasts of their log per capita income levels are equal.[22] That is, if

$$\lim_{T\to\infty} E\left(y_{i,t+T} - y_{j,t+T} \,|F_t\right) = 0\,, \qquad (4)$$

where $y_{i,t}$ denotes the log of per capita income in country i at time t and F_τ denotes the history of $y_{i,t}$ and $y_{j,t}$ up to time τ. This definition implies that the deviation between the two counties is expected to decrease: $E\left(y_{i,t+T} - y_{j,t+T} \,|F_t\right) < y_{i,t} - y_{j,t}$ for some T when $y_{i,t} > y_{j,t}$, so that convergence can be thought of as "catching up" also in the time series context. As definition (4) implies the absence of stochastic or deterministic trends in the cross-country difference of log per capita income levels, convergence has often been tested in the time series context by testing the stationarity of that difference. For countries with log of per capita income obeying integrated processes this test can implemented as a test of the cointegration of country pairs of $y_{i,t}$ and $y_{j,t}$ with cointegrating vector [1, -1]. Applied to a group of such countries, this notion of convergence implies that the log per capita income levels are generated by a process with a single stochastic trend although that alone is not sufficient to imply convergence in the sense of definition (4) above. Bernard and Durlauf (1995) conclude that, while the number of common trends among 15 industrialized countries over the period 1900-1987 is small, it exceeds one and so they can not reject the null hypothesis of no convergence despite De Long's (1988) acknowledged observation that use of this sample ought to bias the results towards a finding of convergence. As we describe later on, there have arisen variations of this time-series approach to convergence.

[22] This equality holds as the absence of a role for initial conditions in determining the long-run distributions of per capita output in two countries implies that the two countries will have identical limiting distributions of per capita output. See Durlauf et. al. (2005) for details.

V. EMPIRICAL EVIDENCE

This section visits the recent evidence on the convergence hypothesis. While we focus on the research of the last decade or so that has examined the hypothesis using cross-country data rather than data on regions as economic units, earlier work is briefly mentioned in places to provide appropriate context.[23]

Linear models

The early contributions to the convergence literature estimate versions of equation (3) above and test for a negative β, or equivalently, a negative correlation between initial per capita income and its subsequent growth rate. Baumol (1986), Barro (1991), Dowrick (1992), and others fail to find a negative correlation when the sample is a broad group of countries, implying a rejection of the absolute convergence hypothesis.

A striking result by Rodrik (2013) regarding unconditional convergence suggests that unlike economies as a whole, manufacturing industries exhibit strong unconditional convergence in labor productivity. The result holds at various levels of disaggregation for a large sample covering more than 100 countries over recent decades. Rodrik's interpretation of this result is that sustaining growth requires active policies that promote economic diversification and structural change from low-productivity activities to mostly tradable higher-productivity activities. The challenge is then to identify these automatic-convergence industries in each country and to expand domestic employment around these high-productivity industries. Of course, as Rodrik readily admits in several of his recent writings on growth and convergence (2011, 2013, 2014, 2015), the problem is that mobilizing the productive sectors most often requires hard economic choices and even harder political decisions that rarely amount to what is necessary to get structural change going in many developing economies and especially in LICs.

Abramovitz (1986) emphasized that 'Social Capabilities' including the ability to absorb existing technologies, and to attract capital are prerequisites and must be in place in an economy before catch-up growth can take place. Contributions such as Barro (1991), Barro and Sala-i-Martin (1992), Dowrick (1992), and Mankiw et. al., (1992), show that the addition of conditioning variables such as rates of capital accumulation, population growth rates, and policy variables renders a statistically significant negative partial correlation between initial per capita income and its subsequent growth rate, evidence consistent with the conditional convergence hypothesis. Notably, Mankiw et. al. (1992) was the first contribution to derive

[23] Earlier discussions and examinations of the convergence hypothesis can be found in review articles such as Temple (1999), Islam (2003), and Abreu et al. (2005), the Handbook of Economic Growth Volumes I and II by Aghion and Durlauf (2005, 2014, respectively), and in various textbooks including Grossman and Helpman (1991), Barro and Sala-i-Martin (1995), Jones (1998); Aghion and Howitt (2009), and Acemoglu (2011).

(continued)

the set of conditioning variables from an explicit growth model. Indeed, the foundational papers by Barro and Sala-i-Martin (1992) and Mankiw et al. (1992) initiated a huge literature attempting to empirically test the extent of conditional β-convergence in various contexts.

A likely influential culprit impeding nations from converging, is openness to international markets. According to Sachs and Warner (1995),[24] convergence is not occurring everywhere because of the closed economic policy of some developing countries. According to these authors "…open economies tend to converge, but closed economies do not. The lack of convergence in recent decades results from the fact that the poorer countries have been closed to the world." The original results obtained by these studies were generally affirmed by studies using panel data such as Islam (1995) and Caselli et. al. (1996). Subsequent contributions also introduced various adjustments to the original estimation strategy including a spatial dimension (see e.g. Baumont et al., 2003 or Dall'erba and Le Gallo, 2006), to mitigate concerns that the omission of space from the analysis of the β-convergence process could produce biased results.

As pointed out by Sala-i-Martin (1996), one of the striking results obtained in these studies is the speed of convergence with which economies converge to their steady-state, is roughly 2 percent a year. To this day, the 2 percent convergence rate continues to make headlines. For example, in recent work Barro (2015) shows that in a panel of countries panel since 1960 the estimated annual convergence rate for GDP is 1.7 percent, conditional on various explanatory variables. With data starting in 1870, he estimates the convergence rate at 2.6 percent; therefore, combining the two estimates Barro calculates conditional convergence close to what he calls the 'iron-law' rate of around 2 percent (see also Lee, 2016, who considers convergence in the context of Chinese growth experience).

Similarly, the restriction of the sample to a group of sufficient similar countries such as the industrialized countries (Abramovitz, 1986; Baumol, 1986; Dowrick and Nguyen, 1989) or the individual states of the United States (Barro and Sala-i-Martin, 1991, 1992) also yields a negative correlation between initial per capita income and its subsequent growth rate. Importantly, DeLong (1988) points out that Baumol's finding of convergence in a group of ex post successful countries may reflect sample selection issues as unsuccessful countries that have thus not converged were excluded from the group of countries studied in Madison (1982), the source of Baumol's data.

Bernard and Durlauf (1996) question the power of the β-convergence test based on equation (3) and argue that rejection of the null hypothesis that $\beta = 0$ in favor of the alternative that $\beta < 0$ is likely, even if the data are generated by a model with multiple steady states. This means that, even if the data are generated by a model in which countries follow locally linear but globally nonlinear laws of motion, the standard β-convergence test may still lead a

[24] A Google Scholar search reports 5628 citations of this paper as of October 2016.

researcher to conclude that convergence to a single steady state is occurring. In other words, the standard test has relatively low power against the alternative of multiple steady states.

To improve the power of the β-convergence test against this alternative, Durlauf and Johnson (1995) use the regression tree method of Brieman et. al (1984) to estimate a version of the human-capital-augmented Solow growth model introduced by Mankiw et. al. (1992) that allows (endogenously determined) subgroups of countries to obey different growth equations. They show that such a model fits the Mankiw et. al. (1992) data better than the linear model used by those authors. This finding is consistent with the view that there are multiple basins of attraction in the process describing the evolution of output per capita. In this case, initial conditions (the determinants of which basin each country belongs) rather than just cross-country variation in the variables that determine the steady state in the Solow model, may be necessary to explain long-run differences in cross-country growth behavior.

Nonlinear models

A desire to model the potential deviations from β-convergence and improve upon tests of it based on equation (3) has given rise to a variety of nonlinear models as they admit the economically-interesting possibilities of divergence and club convergence. The possibility that different subsamples might display behavior consistent with different long-run outcomes had been considered as early as Baumol (1986) who divides his sample into the industrialized countries, the centrally planned economies and the rest (depending on their status in 1950) to explore the possibility of nonlinearities in the relationship between initial income per capita and subsequent growth and so the implied existence of more than one “convergence club”. Other examples of exogenous sample splitting include Baumol and Wolff (1988), Grier and Tullock (1989) and Dowrick (1992) all of whom find evidence consistent heterogeneous behavior across different subsamples in their data.

Many other papers have considered a wide variety of nonlinearities using an equally wide variety of statistical models. We consider them in three not entirely distinct groups: a) models that cluster the data into groups of countries that obey common models; b) models with smoothly varying parameters so that while a continuous equation describes the data the equation is non-linear; and c) methods that consider the shape and evolution of the cross-country distribution of per capita income.

Models with smoothly varying parameters

This approach to parameter heterogeneity permits the parameters of the growth regression to vary smoothly across countries. Again, Baumol and Wolff (1988) provide an early example by allowing the coefficient on initial income to vary with its square and find that the negative coefficient required by the catch-up hypothesis is evident only for higher values of initial income. Chatterji (1992) estimates a cubic relationship between (the log of) income per capita (relative to its level in the US) in 1985 and that in 1960, and concludes that the implied nonlinear difference equation for relative income has two basins of attraction with countries belonging to one or the other (and hence displaying divergent long-run behavior) depending

on whether or not their initial income per capita is greater or less than about 1/6 of the US value.

Liu and Stengos (1999) estimate a semi-parametric additive partially linear growth regression that allows the coefficients on a measure of human capital accumulation and initial income to vary smoothly with the levels of the respective variables and, like Baumol and Wolff (1988), they find that the coefficient on initial income is negative only for higher values of that variable.

Arguing that the "homogeneity assumptions" imposed on growth regressions were not envisaged by the original crafters of the theory on which they are based, Durlauf et. al. (2001) extend the approach of Liu and Stengos (1999) to allow all of the coefficients of the growth regression implied by the augmented Solow model of Mankiw et.al. (1992) to vary with initial income, so that while the model is locally (i.e. for any value of initial income) Solow, globally it (potentially) exhibits parameter heterogeneity. This extension confirms the finding that the coefficient on initial income is negative only for higher values of initial income, and also reveals strong evidence of substantial heterogeneity in the parameters relating the Solow variables to economic growth. Henderson (2010) proposes estimation of the density of the coefficient on initial income in a nonparametric growth regression, and finds a multimodal density with a mode centered on negative values of β and two others centered on positive values, implying β-convergence for some countries (identified as the OECD) but not for most. The evidence on heterogeneity is further strengthened by Kourtellos (2011) who allows the coefficients to depend on initial literacy and initial life expectancy. Related work includes Banerjee and Duflo (2003), Ketteni et. al. (2007a, 2007b), Minier (2007a, 2007b), and Sirimaneetham and Temple (2009) all of which find evidence of nonlinear relationships between growth and its determinants.

Nonparametric estimation methods provide a way to investigate the existence and nature of nonlinearities without the need to specify the variables that govern parameter heterogeneity, as is the case for the partially linear regression model. Maasoumi at. al. (2007) use a nonparametric local linear estimator to estimate growth regressions with the "Solow variables" on the right hand side for both OECD and non-OECD samples. They find considerable variation in the relationships between growth and its determinants across the two samples, as well as in deviations from linearity within each sample. Owen et. al. (2009) estimate a finite mixture model for the conditional distribution of growth rates and conclude that the growth process is characterized by multiple regimes with institutional quality being an important determinant of which countries obey which regimes. Henderson, et.al. (2012) employ nonparametric estimation of regression functions in the presence of 'irrelevant' regressors with results that underscore the importance of nonlinearities in growth regressions.

Distributional models

Critical of the fact that the existing methods of studying convergence considered only a few moments of the distribution of output per capita, Quah (1993a, 1993b, 1993c, 1996a, 1996b, 1996c, 1997) pioneered the "distribution dynamics" approach to studying the role of

nonlinearities in economic growth. These methods originally employed Markov chains to study the evolution of the cross-country distribution of income per capita but the required discretization of the state space of a continuous random variable (typically per capita income) changes the probabilistic properties of the data and more recent applications employ almost exclusively continuous state space methods. This body of research has found substantial evidence of convergence clubs when data from a large group of countries is used.[25] Quah's work demonstrated the existence of "twin peaks" in the long-run cross-country income distribution – two modes, indicative of two basins of attraction in the growth process. Henderson et. al. (2008) confirm the multimodality of the cross-country distribution of per capita output using a variety of measures of the concept and a variety of statistical tests.[26]

More recent work has suggested the existence of more than two basins of attraction.[27] Pittau et. al. (2010) point out that multimodality is neither necessary nor sufficient for the existence of convergence clubs and, following Paap and van Dijk (1998), Tsionas (2000), Pittau (2005), and Pittau and Zelli (2006), estimate a finite mixture model of the cross-country income distribution. They find that it has three (data-selected) components, a result confirmed by Battisti and Parmeter (2013) who generalize the approach of Pittau et. al. (2010) and exploit the panel nature of the data set.[28]

As they find little movement between the three components, Pittau et. al. (2010) interpret them as evidence of three basins of attraction in the growth process and note that the gap between the implied middle-income and high-income groups has become wider and more pronounced since the early 1970's. Anderson et. al. (2016) take a related approach and attribute the recent growth in the gap between the rich and other countries to the tendency for many middle income

---

[25] A selection of the research applying and extending Quah's ideas, in addition to the research cited in Durlauf et. al. (2005), includes Fiaschi and Lavezzi (2003, 2007), Fotopoulos (2006, 2008), Maasoumi et. al. (2007), Fischer and Stumpner (2008), and Bandyopadhyay (2011).

[26] Several authors, including Beaudry et. al. (2005), Johnson (2005), Feyrer (2008), Barseghyan and DiCecio (2011), and Badunenko et. al. (2013) have sought the proximate causes of the shape of the cross-country distribution of per capita and its changes but there is no apparent consensus regarding the relative importance of cross-country variation in total factor productivity (TFP) or physical or human capital accumulation. Battisti et.al (2016) extend the conditional β-convergence approach by modelling the technology adoption of each country and relaxing the assumption that all countries follow the global technology frontier. While they find that output per worker in each country converges to its own productivity path, they conclude that many countries are diverging from the global technology frontier which, they suggest, is an important source of the lack of convergence in cross-country income levels. See also Comin and Mestieri (2018).

[27] Krause (2016) uses the critical bandwidth (the largest bandwidth allowing for a finding of bimodality) as measure of the coalescence of countries around the peaks in the cross-country distribution of per capita income. Analyzing data from 1970 to 2011, she finds a tendency for the countries of the world to converge to two groups which has weakened since 2000. While this approach can be criticized for conflating peaks and convergence clubs, it is interesting to note that the author attributes this "de-clubbing" to the rapid growth recently observed in some low income counties discussed in Section II above. See also Anderson et. al. (2012).

[28] See also Vollmer et. al. (2013a) and Pittau et. al. (2016).

countries to fall back into the poor group. Pittau et. al. (2010) also present evidence of an increase in the gap between the typical poor country and the typical rich country. This is partly due to an increase in the gap between the mean incomes of these two components but, more importantly, to a decrease in the dispersion of the two groups of countries around their respective component means. Together, these two changes drive a documented rise in polarization in the cross-country income distribution.

Epstein et. al. (2003) apply Quah's distribution dynamics methods to data from 17 OECD countries covering 1870-1992. While the pre-1914 and 1914-1950 periods appear to be characterized by persistence within the cross-country distribution of per capita incomes, mobility and some convergence is observed in the post-1950 period using data for the larger group of 24 countries available for that period. However, this gives way to some divergence beginning in the early 1970s. The contrast between the two eras of increased economic openness, 1870-1914 and post-1950, is affirmed by Di Vaio and Enflo (2011) who estimate a mixture model for the growth rate of per capita GDP using data from 1870-2003 for a larger group of countries. Their approach specifies a standard growth regression for each of the (data-determined) regimes with regime membership being determined stochastically, and the estimated coefficient on initial income being used to perform a standard (within regime) convergence test.

These papers can all be considered as part of the literature that searches for evidence of multiple basins of attraction using various clustering algorithms. Earlier work of that type includes Desdoigts (1999) and Kourtellos (2003) who use projection pursuit methods and find evidence of multiple steady states although, apart from the OECD countries, those in the former paper are closely linked to geography. Canova (2004) uses initial per capita income to order the OECD countries and finds that there are two clusters with an “economically large” implied difference in the long-run incomes and little mobility between them.

A common aspect of much of the literature considered so far in this section is the use of per capita income as the variable defining basins of attraction on the growth process. As noted above, the case can be made that per capita income is not a sufficient statistic for a country’s initial conditions inviting the use of other variables in defining convergence clubs. For example, Durlauf and Johnson (1995) found that literacy rates as well as initial per capita income were useful in identifying convergence clubs. More recently, Tan (2010) uses a regression-tree method that generalizes that used in Durlauf and Johnson (1995) and attributes a dominant role to similarities in institutional quality and ethnic fractionalization in identifying countries with similar long-run behavior. Importantly, he finds no such role for geographic factors. Battisti and Parmeter (2013) use mixture models to model the joint distribution of output per capita and its proximate determinants – physical and human capital and TFP – and find evidence of multiple clusters. Fiaschi et. al. (2018) consider a large number and wide variety of possible deep determinants of variation in output per capita as candidates for defining growth clusters. Using a method based on the AIC they find that initial conditions define three clusters according to life expectancy in 1960 and the share of Catholics in the population in 1965. The former is considered a measure of human capital while the latter is considered to be a measure of culture.

Vollmer et. al. (2013b) argue for the emergence of three "human development clubs" during the 1990's using a finite mixture model of the joint distribution of income per capita, educational attainment and life expectancy which they also conclude has three components. They note the coherence between these findings of three components and the recent literature discussing the "middle income trap" which, as Kharas and Kohli (2011) discuss, is the name given to the phenomenon wherein many countries experience abrupt slowdowns following periods of rapid growth. These countries become trapped between the low income countries, with whom they are unable to compete because their wage structure is too high, and the advanced countries, with whom they are unable to compete because their technology structure is not sufficiently advanced. As Vollmer et. al. (2013b) note, the middle income trap may well prove to be a transitory stage of development – an example of the identification problem discussed by Durlauf et. al. (2005, pp 622-3). El-Gamal and Ryu (2012) document the appearance, disappearance, and reappearance of a "stochastically stable" middle income group over the 1960-2009 period. This could reflect the lack of stationarity in the transition dynamics that they observe, complex nonlinearities, or a dynamic process of higher than first order. The dynamic process followed by the cross country distribution of per capita income has only ever being modeled as a first-order process so the implied misspecification if the process is of higher order could manifest as a lack of stationary.

In studying σ-convergence, another body of research has focused on the dispersion of the cross-country distribution of per capita incomes.[29] The most commonly used measures of dispersion are the standard deviation and the coefficient of variation of the log of cross country income (see e.g. Barro and Sala-i-Martin, 1991; Ben-David, 1993; and Slaughter, 1997). However, other indices exist with interesting properties (see, Cowell, 1995), including spatial properties that affect measures of σ-convergence (Bode and Rey, 2006; Egger and Pfaffermayr, 2009). It is important to note that σ-convergence tests lack power against the club convergence alternative in much the same way as do β-convergence, as there is no reason why the dispersion of the cross-country distribution of per capita income cannot decline as when countries lie in two or more basins of attraction.

The σ-convergence concept has seen a host of recent applications at the regional level but far fewer at the global level. Barro (2012) reports a tendency for the standard deviation of the logs of per capita GDP and consumption to decline since the mid-1970s for a group of mostly industrialized countries. Madsen and Timol (2011) use the tests of Lichtenberg (1994) and Carree and Klomp (1997) to examine the σ-convergence hypothesis using data on labor productivity in the manufacturing sectors of 19 OECD countries since 1870, and conclude that σ-convergence (and also β-convergence) occurred, a result that is subject to De Long's (1988) critique.[30] Rodrik (2013) finds σ-convergence in labor productivity in the manufacturing sector at the two-digit level for a smaller sample of countries. The time-series convergence tests that

[29] Durlauf et al. (2009) discuss some of the econometric issues that arise in the application of the σ-convergence concept.

[30] See also Bernard and Jones (1996) and Wu (2009).

allow for transition dynamics formulated by Phillips and Sul (2007a, 2007b, 2009) can be considered as tests of σ-convergence and we discuss these below.

The conclusion that we take away from the research on nonlinear models of growth is that, once the alternative hypothesis of club convergence is explicitly considered, there is strong evidence for a rejection of the view that initial conditions do not matter for long-run outcomes in favor of the view that they do and that, as a result, the cross-country distribution of per capita income exhibits characteristics consistent with the existence of two or more convergence clubs. We are, however, mindful of an important identification caveat emphasized by Durlauf and Johnson (1995) that needs to be attached to convergence tests: Given the finite spans of data available, it is impossible to unequivocally distinguish between a model in which there are multiple steady states and a model in which countries transition through different stages of development before reaching a common steady state.

Time series models

So far the evidence we presented relates to the strand of literature that focuses on country cross sections or panels. Next we turn attention to covering time series approaches that have recently been quite prevalent notwithstanding transitional data constraints.

Structural Breaks

Perron (1989) shows that trend or structural breaks reduce the power of unit-root tests and many researchers have found that permitting structural breaks in the form of mean or trend shifts, either exogenously or endogenously determined, makes it less more likely that the null hypothesis of a unit root will be rejected.[31] That is, as statistical matter, the inclusion of trend or structural breaks, that are often found to coincide with the Great Depression or the Second World War, or restricting the data used to that from the post-war period, tends to produce test results more favorable to the convergence hypothesis.[32]

It is not clear, however, how to interpret these results, in part because the interpretation of the breaks is unclear. Do the breaks represent large exogenous shocks? Or are they the manifestation of the persistent effects of shocks? Or do they reflect un-modeled nonlinearities or transition dynamics in the growth process? Answering these questions would require a model of the growth process that allows a role for such shocks to inform the empirical work. Moreover, the implications of the general finding that allowing trend breaks reduces the tendency to not reject the unit root null hypothesis for the convergence hypothesis itself are

[31] Stock (1994) surveys the literature on the relationship between structural breaks and unit-root tests.

[32] A selection of the research studying the role of structural breaks in convergence tests includes Carlino and Mills (1993), Oxley and Greasley (1995), Loewy and Papell (1996), Greasley and Oxley (1997), Li and Papell (1999), Strazicich et. al. (2004), Dawson and Sen A (2007), Dawson and Strazicich (2010), Costantini and Sen (2012), King and Ramlogan-Dobson (2014), and Ghoshray and Khan (2015).

also not clear. If the process for $y_{i,t} - y_{j,t}$ is found to be stationary once a structural break is permitted, a conclusion of convergence is then conditional on the occurrence of the break.

Long-memory approaches

Michelacci and Zaffaroni (2000) argue that the early time series tests of convergence are flawed because $y_{i,t}$ obeys a long-memory process which, following Granger (1980), they motivate by considering a Solow growth model for an economy with heterogeneous sectors. The original time series tests of convergence assume that $y_{i,t}$ is either I(0) or I(1), perhaps around a deterministic trend. Fractionally differenced, I(*d*), models allow *d*, the exponent on the first difference operator in *ARIMA* representation of $y_{i,t}$, to differ from the polar cases of zero and one, which imply, respectively, a rapid decay in the effects of shocks or none at all. For $0 < d < 1$, $y_{i,t}$ is mean reverting but it exhibits "long-memory" and is more persistent that a standard ARMA process.[33]

While they do not explicitly test for convergence in a long-memory framework, Michelacci and Zaffaroni (2000) do find evidence of long-memory behavior in output data from the OECD countries in the form of estimates of *d* between 0.5 and 1.0 which they claim is both consistent with the 2 percent rate of convergence commonly found in earlier cross-country analyses; and damaging to the reliability of unit-root tests of convergence.

Silverberg and Verspagen (2003) offer a motivation for long-memory representations of output by suggesting that evolutionary models of economic behavior can endogenously generate the cross-sectional heterogeneity that drives Granger's (1980) aggregation rationale. They employ a variety of empirical approaches designed to overcome many of the criticisms of the Michelacci and Zaffaroni (2000) data analysis, and their conclusions about the suitability of long-memory representations of output are far more agnostic. One important difference between the two papers is how the trend is modeled. Michelacci and Zaffaroni (2000) assume a linear trend in the log of per capita incomes while Silverberg and Verspagen (2003) first-difference their data prior to analysis.

---

[33] Specifically, if x_t is a zero mean stochastic process with the representation $A(L)(1-L)^d x_t = B(L)u_t$, where $A(L)$ and $B(L)$ are lag polynomials with roots outside the unit circle and u_t is a white-noise process, then d can take any real value rather than being constrained to 0 or 1. For $d = 0$, x_t is a standard ARMA process with short memory, but for $0 < d < .5$, x_t is a covariance-stationary long-memory process because its autocorrelation function decays hyperbolically rather than geometrically. For $.5 \le d < 1$, x_t is also long-memory process that, while mean reverting, is no longer covariance stationary; and for $d > 1$, x_t is explosive. See Baillie (1996) for a survey of fractional integration and long memory processes.

(continued)

Mean reversion in per capita incomes implies that Definition (4) above could still be satisfied, but standard tests of the unit root null in the $y_{i,t} - y_{j,t}$ process will have low power against a long-memory alternative because of the relatively slow decay of the effects of shocks under the alternative hypothesis. Cunado et. al. (2006) test for convergence by examining the (possibly fractional) order of integration of the deviation of log per capita income in 14 OECD countries from that in the US: $y_{i,t} - y_{US,t}$. Using a data set beginning in the late 19th century, they are unable to reject the hypothesis of a unit root for almost all countries but restricting the analysis to the post-war period leads to confidence intervals for *d* the lie in (.5, 1), consistent with convergence in the sense of definition (4) above, for almost all of the 14 countries.[34] Silverberg and Verspagen (1999) report similar results. Dufrénot et. al. (2011) investigate the behavior of $y_{i,t} - y_{j,t}$, where country *j* is a regional benchmark country (selected as the country in the region with the highest per capita GDP at the end of the sample) using post-war data on a group of 98 developing countries. They find considerable variation the time-series properties of $y_{i,t} - y_{j,t}$ across countries within regions and across regions. Cunado et al. (2006) and Dufrénot et al. (2011) include a time trend in their time-series representations for $y_{i,t} - y_{US,t}$ and $y_{i,t} - y_{j,t}$ which, as we discuss below, permits some transition dynamics but apparently does not increase the power of their tests. For example, Cunado et al (2006)'s confidence intervals for *d* for the entire sample are little changed by the introduction of intercept and trend terms while those for the post-war data become wider.

To avoid the problem of choosing a benchmark country, Stengos and Yazgan (2014) follow Peseran (2007) in considering pairwise convergence by examining the value of *d* for all possible values of $y_{i,t} - y_{j,t}$ for 139 countries in the post-war period. They find $d > 0.5$ but cite a "lack of power" in concluding that the distinction between I(0) and I(1) processes adequately describes the behavior of log per capita output levels. That is, they conclude against convergence despite allowing for smooth structural breaks by including a Fourier function of time in the representation for $y_{i,t} - y_{j,t}$. Stengos et. al. (2016) take a multivariate approach to the estimation of d and find stronger evidence of mean reversion (i.e. $0.5 < d < 1$) and hence convergence than Stengos and Yazgan (2014).

While the finding that data from the post-war period is more likely to be favorable to the convergence hypothesis than data over from the first half of the 20th Century is noteworthy, one difficulty in interpreting these results is the inclusion of trends (Cunado et al., 2006); Dufrénot et al., 2011) and trend breaks (Stengos and Yazgan, 2014; Stengos et al., 2016) or first differences (Silverberg and Verspagen, 1999) in the representations for the income gaps which have an undocumented effect on the results and raises the same sorts of issues as the trend-break literature discussed above. Further complicating matters, Diebold and Inoue (2001) show that, as a matter of theory, apparent long memory can be the manifestation of

[34] That the countries for which the unit root cannot be rejected in the post-war period are Austria, Germany, and Japan may underscore the importance of transition dynamics as we discuss below.

some types of structural change in I(0) or I(1) processes and Granger and Hyung (2004) show that distinguishing between fractionally integrated processes and processes with occasional breaks can be difficult.

Another concern with this literature is the lack of strong theoretical reasons to believe that per capita outputs obey fractionally integrated processes. Michelacci and Zaffaroni (2000) and Silverberg and Verspagen (2003) suggest reasons why fractionally integrated processes might arise from growth models, whereas Lau (1999) shows that integrated and cointegrated processes arise naturally under in a wide class of growth models.

Transition dynamics

As Bernard and Durlauf acknowledge, tests based on the co-integration of cross country income levels are more appropriately regarded as tests that convergence has occurred, than tests that convergence is occurring. It is possible, for example, that the expected difference in two countries' log per capita incomes at any time $t+T$, $E\left(y_{i,t+T} - y_{j,t+T} \middle| F_t\right)$ includes a deterministic term $\mu_{t+T} \neq 0$ where $\lim_{T\to\infty} \mu_{t+T} = 0$ so that convergence definition (4) above is satisfied despite a contemporary non-zero expected difference in incomes because at least one of the countries has not yet reached its steady state. Data generated by such a process may be less likely to produce a rejection of a unit root null hypothesis in the $y_{i,t} - y_{j,t}$ process if $\mu_{t+1} \approx \mu_t$ because convergence is slow as the difference in incomes will then have a highly persistent component.

Oxley and Greasley (1995) add a time trend to the representation for $y_{i,t} - y_{j,t}$ which, omitting higher order lagged terms, they write as $y_{i,t} - y_{j,t} = \mu + \alpha(y_{i,t-1} - y_{j,t-1}) + \beta t + \varepsilon_t$. They define long-run convergence as $\alpha < 1$ and $\beta = 0$ (although to satisfy Definition (4) above $\mu = 0$ is also necessary) while $\alpha < 1$ and $\beta \neq 0$ is defined as "catching-up". Using data for the US, UK, and Australian economies from the late 19th to the late 20th centuries, and allowing for the possibility of discontinuities in the trend, they find a role for the catch up term for the US/UK and US/Australia pairs but not for the UK/Australia pair which they conclude have converged. Chong et. al. (2008) estimate a non-linear version of this model using post-war data on $y_{i,t} - y_{US,t}$ where i is an OECD country. For those 12 countries with apparently non-linear income gaps to the US, the unit-root null is not rejected in eight cases suggesting that transition dynamics per se are not the entire reason for the rejections of convergence found in time series-tests. King and Ramlogan-Dobson (2013) find that allowing for breaks in the trend function that captures the transition dynamics weakens the statistical case against convergence found using this approach.

A related approach is taken by Nahar and Inder (2002) who model the deviation of per capita output in country i from that in the US at time t, $y_{i,t} - y_{US,t}$, as a polynomial in t and test the hypothesis that the derivative of the polynomial with respect to t is zero against that alternative

that it is positive which implies that country i is catching up to the US. Bentzen (2005) modifies this approach to allow the rate of convergence to vary over the sample period. While this approach does highlight the possible richness of transition paths for different countries, it specifies the non-convergence null hypothesis as the overly restrictive requirement that $y_{i,t} - y_{US,t}$ is an i.i.d. random variable so it is not clear how this test performs when the non-convergence of $y_{i,t} - y_{US,t}$ causes it to follow an integrated process. Datta's (2003) time-varying parameter approach to modeling transition dynamics also finds evidence of catching up using post-war data from the OECD countries but is subject to a similar criticism.

Phillips and Sul (2007a, 2007b, 2009) present a time-series test of convergence that allows for substantial cross-country heterogeneity in the transition dynamics. They write $y_{i,t} = b_{it}\mu_t$ where μ_t is the hypothesized steady-state growth path common to all counties and b_{it} describes the transition path of economy *i* to the steady state growth path. Convergence is said to occur if $\lim_{t\to\infty} h_{it} = 1$ for all i where $h_{it} = ny_{i,t} \Big/ \sum_{i=1}^{n} y_{i,t} = n\, b_{it} \Big/ \sum_{i=1}^{n} b_{it}$. Phillips and Sul then propose testing for convergence by specifying a model of the transition path that yields a test based on a conventional one-sided t-test of the hypothesis $\gamma = 0$ (no convergence) against the alternative $\gamma > 0$ (convergence) in the regression $\log \frac{H_1}{H_t} - 2\log(\log t) = a + \gamma \log t + u_t$, where $H_t = n^{-1}\sum_{i=1}^{n}(h_{it} - 1)^2$.[35] They show that γ is twice the speed of convergence and that, when μ_t follows a random walk with drift or trend stationary process, $0 < \gamma < 2$ implies convergence in growth rates (conditional convergence) while $2 \le \gamma$ implies convergence in levels (absolute convergence), that is in the sense of Definition (4) above. Phillips and Sul (2009) apply this test to data from the US States, the Western OECD countries, and 152 countries from the PWT and, consistent with much of the literature, find evidence of convergence in growth rates, but not in levels, for the US states (1929-1998) and the Western OECD countries (1870-2001 and 1940-2001 but not 1870-1929 nor 1911-1970) nor for the PWT countries.

Clustering Approaches

There have also been some applications of clustering approaches in the time series context to check for club convergence. Phillips and Sul (2007a) develop a clustering algorithm designed to divide the countries in a data set into groups less heterogeneous than the sample as a whole and then to test for convergence within groups using the method described above. Having rejected convergence for the 1970-2003 sample of 152 PWT countries, Phillips and Sul (2008) apply this approach to that data set and conclude that it can be split into four convergence clubs

[35] Observe that $n^{-1}\sum_{i=1}^{n} h_{it} = 1$ so that H_t is the sample variance of h_{it} implying that the Phillips and Sul approach may also be considered as a test of σ-convergence.

(continued)

(three of which exhibit growth rate or conditional convergence) and a small group of diverging countries.[36] Finding between two and five convergence clubs is common and consistent with the results of those who've studied the evolution of the cross-country distribution of per capita income such as Pittau et. al (2010).

By contrast, Beylunioglu et. al. (2016) extend Peseran's (2007) pair-wise time series approach using a "maximal clique" approach that, like that of Hobijn and Frances (2000), is also based on time-series convergence concepts, and finds a large number of very small clusters that the authors call "convergence clubs". While these results are evidence against convergence the large number of clusters found makes the convergence clubs interpretation difficult to sustain. Moreover, it is likely that the groups found reflect countries between which convergence has occurred rather than those between which convergence is occurring. A test along these lines that also took into account transition dynamics would, no doubt, produce fewer groups as do, for example, Phillips and Sul (2008).

Our reading of the recent time-series tests of the convergence hypothesis is broadly in accord with that of the non-linear cross-section studies of the hypothesis discussed above. While there may be some weak support for the proposition that gaps between per capita income levels have fallen in some groups of countries in the post-war period, the interpretation of whatever support that there is for the convergence hypothesis is fraught with difficulty because of the lack of consensus about how to treat the trends in the data and, in particular, for the meaning for convergence of the structural and trend breaks that are often found. Importantly, as we observed above, once the alternative hypothesis of convergence clubs is considered by use of a clustering algorithm, there is evidence in favor of that view that is consistent with that found using other clustering approaches.

Cross-individual distribution of income

Beyond the analysis of the rich literature presented above that is based on country convergence – unit of analysis being the country - recent work attempts to assess global inequality by considering the distribution of incomes of individual households from different countries around the globe. The advantage of a global approach lies in the detail with which we can observe and analyze the effects of globalization in different segments of the global income distribution. These studies combine micro and macro data coming from hundreds of household surveys from over 100 countries in the world, covering more than 90 percent of the world population and income. Advocates of this approach argue that using individuals or households rather than countries as units of analysis, is more useful if one is concerned about human welfare because different countries have different population sizes. As stated by Sala-i-Martin (2006), “After all, there is no reason to down-weight the well-being of a Chinese peasant

[36] The memberships of the clubs different from those found by Durlauf and Johnson (1995) using a regression tree algorithm on data from 98 countries for 1960-85 from an antecedent to the PWT but it is not clear whether these differences can be attributed to the different number of countries, the different time periods, or the different clustering algorithm.

relative to a Senegalese farmer just because the population in China is larger than that of Senegal."

Excellent examples on world income distribution and global inequality include Milanovic's early paper (1997) that lays down many of the issues discussed by the subsequent literature, Bourguignon and Morrisson (2002), Atkinson and Brandolini (2004), Sala-i-Martin (2006), Deaton (2010), Pinkovskiy and Sala-i-Martin (2014), Atkinson (2015), Bourguignon (2015), Lakner and Milanovic (2015).

Branko Milanovic's recent book *Global Inequality: A New Approach for the Age of Globalization* (2016a) may well summarize the most current thinking on global inequality. Milanovic's book, like Bourguignon's (*The Globalisation of Inequality*, 2015), concludes with one key fact: while inequality is rising within most countries, notably the high-income ones, global inequality of incomes, though huge, has been falling, particularly since 2000. This comes as no surprise given the millions of Chinese lifted from poverty during China's historic growth acceleration of the last three decades discussed previously. Yet many economists argue that this positive trend might not continue, once global favourable conditions slow down and as China's wages rise further. Prospects would depend on whether China's economic progress can be replicated and African or other Asian nations (e.g. India, Bangladesh, Vietnam) can follow suit.

Another interesting fact from Milanovic's work is illustrated in Figure 8 showing the proportional rise in real per capita incomes across the world income distribution between 1988 to 2011. Income is measured in 2005 international dollars and individuals are ranked by their real household per capita income. On the one hand, points A and C on the cumulative distribution plot reflect large real income gains made by individuals around the global median, and by those who are part of the global top 1 percent, respectively. On the other hand, those at the bottom part of the distribution have done relatively poorly, and those between the 80th and 95th percentiles have seen stagnant real incomes (point B). In the words of Milanovic (2016b), "The people around the global median are, however, still relatively poor by Western standards. This emerging 'global middle class' is composed of individuals with household per capita incomes of between 5 and 15 international dollars per day. The contrast between the unambiguous success of people at point A and the relative failure of people at point B allows us to look at the effects of globalization more broadly."

Angus Deaton in his book, *The Great Escape* (2013), offers a novel insight on global inequality. He argues that the world is a better place than it used to be but that the enormous progress that resulted in catching up of some countries was also responsible for opening up gaps and setting the stage for today's disproportionately unequal world. In the words of Deaton "… the escape from destitution by so many has left gaping inequalities between people and nations."

VI. CONCLUSION

In its simplest form, convergence suggests that poor countries have the propensity to grow faster than the rich so to eventually catch up to them. The idea of convergence has its formal origins in Solow (1956) but its empirical treatment really begins in the mid-80's being further motivated by the modern growth theory and empirics; it remains today a perennial research topic although only, perhaps, under the new lamppost of global inequality.

The voluminous literature that has emerged seeking answers to the convergence question is a testimony to the interest that the hypothesis has generated – a crude internet search reveals that over the last 30 years there have been thousands of papers written on the subject; in addition, four of the most influential papers in the growth literature focus on convergence and account for almost 11,000 citations (according to Google scholar).[37] Despite the concept of the long-run irrelevance of initial conditions being straightforward, empirically testing convergence and understanding its mechanics proved quite elusive. As shown in this survey, convergence is hard to pin down, first, because the concept can be operationalized in many ways and second, because econometric approaches and data measurement issues remain a challenge in empirical tests of convergence. Ultimately, understanding convergence would get us closer to understanding the process of economic growth – a truly humbling endeavor. So, what is the evidence on convergence and what have we learned from it thus far?

With the exception of some early studies that have been criticized extensively due to econometric problems, there is a broad consensus of no evidence supporting *absolute convergence* in cross-country per capita incomes – that is poor countries do not seem to be unconditionally catching up to rich ones. The only glimmer of hope for this hypothesis is provided by Rodrik's (2013) finding of unconditional convergence in particular *manufacturing* industries. Of course, whether this result will hold up to the scrutiny of subsequent researchers, armed with more sophisticated methods and better data, is unknown.

A more definitive conclusion from this survey is that the process of growth and so, potentially, of convergence, is not smooth but rather start and stop, and is characterized by significant country heterogeneity. Such realization must not come as a surprise given that the notion of convergence is only a theoretical construction that characterizes part of the broader dynamic growth process across countries. Under such a framework, it is then possible that several mechanisms of divergence and convergence are concurrently at work across countries in different stages of their development process. For example, the divergence process may tend to dominate the convergence process at early stages of economic growth while the reverse could hold true for later stages (Steger, 2006, and World Economic Outlook, 2017, make a similar observation). In this regard, exploring those mechanisms which induce convergence and those which result in non-convergence or divergence would be central to understanding such phenomena. Also, focusing attention to potential mechanisms that determine growth

[37] As of October 24, 2016, Barro and Sala-i-Martin (1990) 4,262 citations; Baumol (1986) 3,939; De Long (1988) 1,464; and Bernard and Durlauf (1996) 1,188.

dynamics (linear and nonlinear) or the distribution of global inequality, as it is done in recent studies, maybe more tenable and informative than seeking evidence on convergence.

Our reading of the evidence, then, is that recent optimism in favor of rapid and sustainable convergence is unfounded. The last two decades of an unprecedented wave of growth in many LICs and emerging markets led to many analysts claiming prematurely, in our view, success with slogans such as “lions on the move,” “the next convergence,” and “no shortage of economic growth in Africa” (McKinsey Global Institute, 2010; Spence, 2011; Economist, 2013, respectively). Many observers are led to believe that “this time is different.” We have come to the conclusion that with the exception of a few countries in Asia which exhibited transformational growth, most of the economic achievements in developing economies have been the result of removing inefficiencies, especially in governance and in political institutions. But as is now well known these are merely one-off *level* effects that, while not unimportant, and in fact necessary in the process of development, nonetheless do not stimulate ongoing economic growth.

Tables and Figures

Table 1: Decadal average per capital GDP growth (%) by geographical region

Geographical Region	1960s	1970s	1980s	1990s	2000s
East Asia & Pacific	3.9	3.3	3.2	3.0	3.6
Europe & Central Asia	4.7	3.5	1.8	0.5	3.6
Latin America & Caribbean	2.2	2.7	-0.6	1.5	2.2
Middle East & North Africa	3.7	2.7	-0.9	2.0	2.0
North America	3.1	2.5	1.9	1.8	0.9
South Asia	1.6	1.4	2.1	0.5	4.5
Sub-Saharan Africa	1.8	1.3	-0.2	-0.4	1.8
World	*2.8*	*2.4*	*0.6*	*0.9*	*2.7*

Source: Penn World Tables version 7.1

Table 2: Decadal average per capita GDP growth (%) by income and exporter groups

	1960s	1970s	1980s	1990s	2000s
Income Group					
HIC	4.7	3.3	2.4	2.1	1.7
MIC	2.8	3.4	0.4	1.4	3.4
LIC (all)	1.4	0.7	-0.2	-0.5	2.4
LIC (fragile)	1.7	0.7	-0.5	-1.5	1.3
LIC (non-fragile)	1.1	0.7	0.2	0.6	3.6
Exporter Group					
Commodity Exporters	2.1	2.0	-0.8	-0.4	3.0
Others	3.0	2.5	1.1	1.3	2.7
World	*2.8*	*2.4*	*0.6*	*0.9*	*2.7*

Source: Penn World Tables version 7.1.

Table 3: Country rankings for each decade by per capita GDP growth (%)

Decade	rank	country	decade avg gdp (per Capita) growth (%)	rank	country	decade avg gdp (per Capita) growth (%)
1960s	1	Japan	8.98	93	China	-0.32
	2	Mauritania	8.16	94	Rwanda	-0.74
	3	Greece	7.75	95	Algeria	-0.79
	4	Romania	7.73	96	Mauritius	-0.96
	5	Morocco	7.68	97	Haiti	-1.51
	6	Hong Kong	7.48	98	Guinea	-1.58
	7	Spain	6.92	99	Senegal	-1.76
	8	Iran	6.51	100	Nigeria	-2.13
	9	Cyprus	6.47	101	Bangladesh	-2.14
	10	Portugal	5.92	102	Mali	-2.25
1970s	1	Botswana	10.85	111	Madagascar	-1.44
	2	Romania	8.99	112	Central Africa	-1.69
	3	Singapore	7.76	113	Liberia	-1.85
	4	Iraq	7.75	114	Congo, Dem. F	-1.94
	5	Korea	7.19	115	Chad	-3.32
	6	Malaysia	7.1	116	Uganda	-3.84
	7	Swaziland	6.82	117	Zambia	-3.88
	8	Hong Kong	6.71	118	Nicaragua	-4.25
	9	Bulgaria	6.51	119	Lebanon	-5.2
	10	Indonesia	6.34	120	Cambodia	-6.52
1980s	1	China	7.34	116	Togo	-3.27
	2	Botswana	6.93	117	Venezuela	-3.33
	3	Korea	6.54	118	Iraq	-4.17
	4	Egypt	5.61	119	Nigeria	-4.19
	5	Hong Kong	5.25	120	Libya	-4.38
	6	Thailand	5.11	121	Bahrain	-4.6
	7	Cyprus	4.61	122	Niger	-4.72
	8	Singapore	4.55	123	Iran	-5.11
	9	Kuwait	4.22	124	Lebanon	-5.13
	10	Lao	4.08	125	Trinidad &Tob	-5.16
1990s	1	China	8.64	138	Azerbaijan	-4.63
	2	Lebanon	7.22	139	Russia	-5.27
	3	Ireland	6.02	140	Moldova	-5.93
	4	Armenia	5.96	141	Ukraine	-6.72
	5	Vietnam	5.39	142	Liberia	-7.11
	6	Eritrea	5.31	143	Sierra Leone	-7.23
	7	Chile	5.11	144	Serbia	-7.93
	8	Korea, Republ	4.94	145	Afghanistan	-9.1
	9	Malaysia	4.88	146	Tajikistan	-9.9
	10	Singapore	4.31	147	Congo, Dem. F	-10.85
2000s	1	Azerbaijan	13.19	139	Guinea	-0.35
	2	Kazakhstan	9.2	140	Congo, Repub	-0.45
	3	China	9.13	141	Madagascar	-1.09
	4	Armenia	8.26	142	Togo	-1.14
	5	Trinidad &Tob	8.25	143	Gabon	-1.48
	6	Afghanistan	8.08	144	Central Africa	-1.53
	7	Belarus	7.81	145	Timor-Leste	-1.73
	8	Angola	7.65	146	Cote d`Ivoire	-1.82
	9	Albania	7.22	147	Zimbabwe	-3.4
	10	Lao	6.59	148	Eritrea	-4.62

Source: Penn World Tables version 7.1

Table 4: Number of years required for selected low-income countries to achieve middle-income status

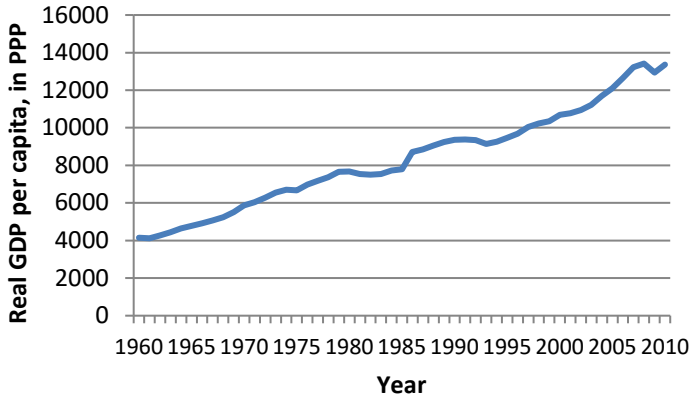
Country	Year
Vietnam	2.5
Lao	3.7
Moldova	6.5
Sudan	7.6
Cambodia	9.5
Ghana	13.1
Kyrgyzstan	14.4
Papua New Guinea	14.8
Tajikistan	18.1
Nigeria	20.0
Nicaragua	22.0
Bangladesh	24.9
Mauritania	27.2
Liberia	28.7
Rwanda	33.9
Uganda	36.5
Nepal	43.0
Senegal	46.2
Cameroon	47.7
Mali	50.9
Burkina Faso	51.7
Malawi	86.8
Gambia	90.0
Congo	95.6
Benin	118.0
Sierra Leone	120.1
Haiti	149.5
Guinea	228.9
Niger	734.3

Source: Penn World Tables version 7.1.
Note: Future growth projections are based on the average per capita GDP growth over the period 1995-2010. Countries with negative growth rates 1995-2010 are not reported.

Table 5: Growth breaks by decade

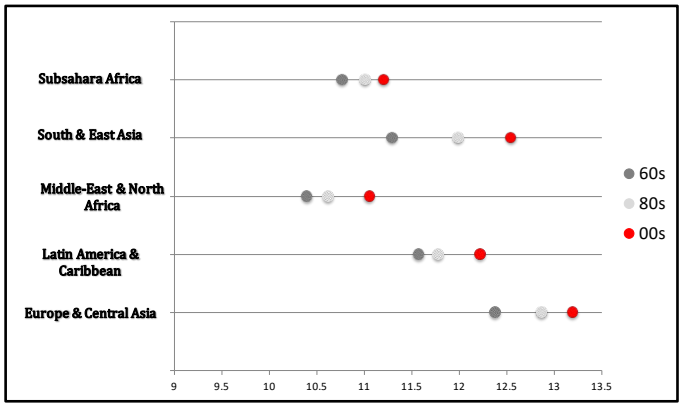
Decade	Accelerations		Decelerations	
1960				
	Guatemala	1962	Hong Kong	1965
	Indonesia	1967	Morocco	1963
	Korea	1962	Togo	1969
	Pakistan	1960	Zambia	1968
	Portugal	1967		
1970				
	Bangladesh	1975	Austria	1979
	Cameroon	1973	Belgium	1974
	China	1977	Botswana	1973
	Ecuador	1970	Cameroon	1978
	Egypt	1976	Cote d`Ivoire	1978
	Gabon	1971	Ecuador	1978
	Mauritius	1971	El Salvador	1978
	Paraguay	1973	France	1974
	Vietnam	1975	Gabon	1976
			Greece	1973
			Hungary	1978
			Indonesia	1973
			Iran	1976
			Israel	1973
			Italy	1974
			Jamaica	1972
			Japan	1970
			Mauritius	1977
			Poland	1979
			Portugal	1973
			Romania	1978
			Spain	1974
			Swaziland	1975
			Switzerland	1970
			Tanzania	1971
1980				
	Cambodia	1982	Albania	1988
	El Salvador	1984	Brazil	1980
	Guatemala	1987	Bulgaria	1988
	Iran	1981	Cameroon	1984
	Jamaica	1980	Egypt	1984
	Tanzania	1985	Guatemala	1980
	Uganda	1988	Mexico	1981
			Paraguay	1980
			Romania	1987
			South Africa	1980
			Trinidad &Tobago	1980
1990				
	Albania	1992	Eritrea	1998
	Angola	1993	Japan	1991
	Bangladesh	1996	Korea	1996
	Bulgaria	1997	Kuwait	1993
	Cameroon	1994	Norway	1998
	Czech Republi	1992	Sierra Leone	1994
	Ireland	1993	Slovak Republic	1990
	Kazakhstan	1998	Tajikistan	1999
	Kyrgyzstan	1995	Tanzania	1990
	Liberia	1996	Thailand	1995
	Moldova	1994		
	Mozambique	1995		
	Poland	1991		
	Romania	1992		
	Serbia	1993		
	Sierra Leone	1999		
	Slovak Republi	1992		
	South Africa	1993		
	Tajikistan	1997		
	Tanzania	1997		
	Trinidad &Toba	1993		
	Turkmenistan	1995		
	Uzbekistan	1994		
	Zambia	1994		
2000				
	Ethiopia	2003	Ireland	2003
	India	2002	Kazakhstan	2006
	Kazakhstan	2000	Liberia	2000
	Laos	2004		
	Mongolia	2002		
	Uzbekistan	2003		

Figure 1. Average global per capita GDP (1960-2010)



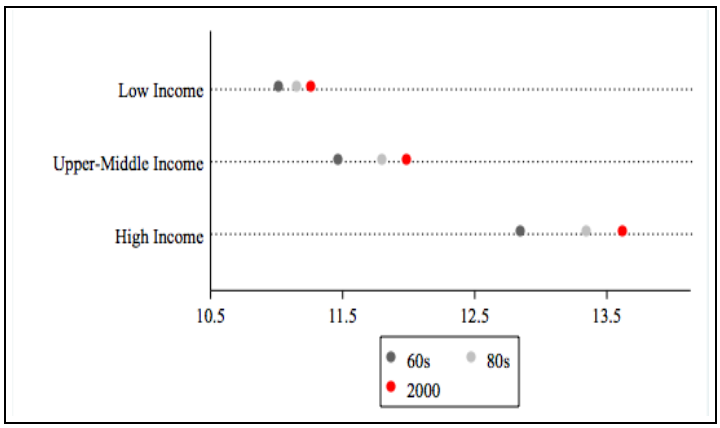
Source: Penn World Tables version 7.1.

Figure 2a. Log of per capita income by region (1960-2010)



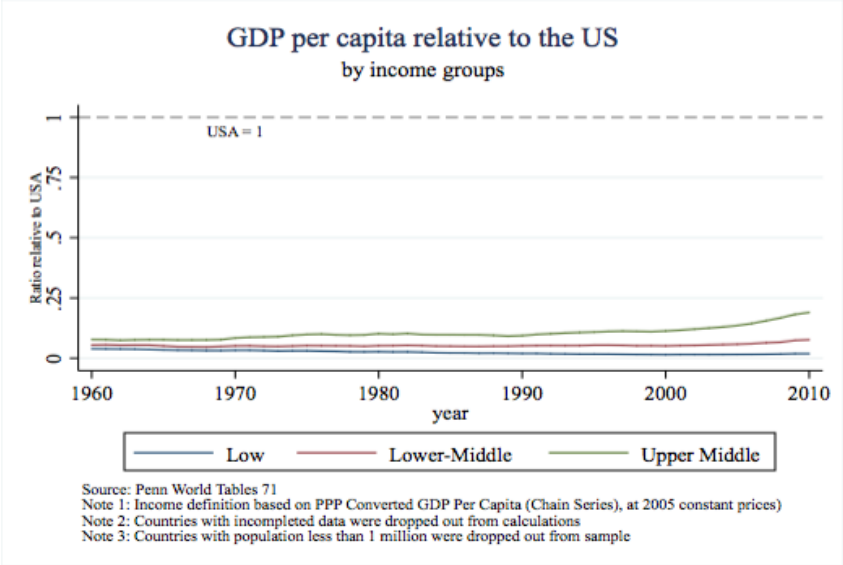
Source: Penn World Tables version 7.1 based on balanced sample of countries. Countries with population below 1 million were dropped from the sample.

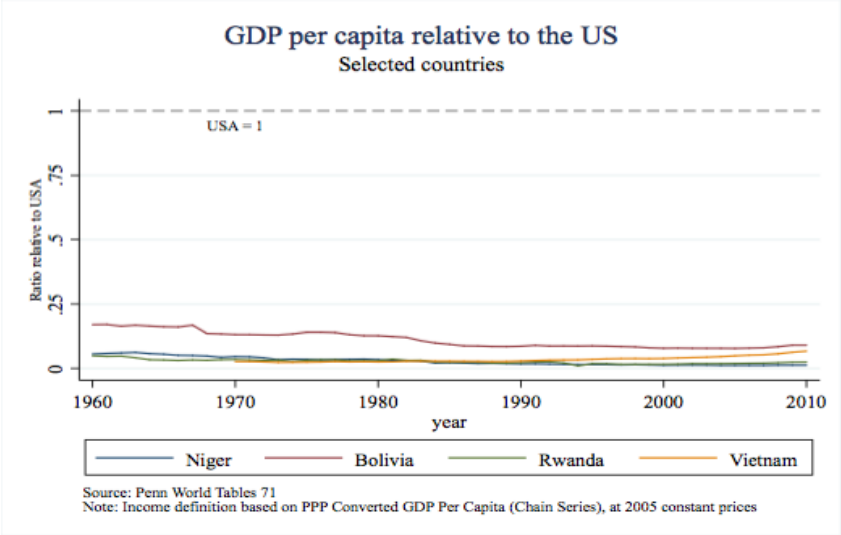
Figure 2b. Log of per capita income by income group (1960-2010)



Source: Penn World Tables version 7.1 based on balanced sample of countries. Countries with population below 1 million were dropped from the sample.

Figure 3. Income levels relative to the US (1960-2010)





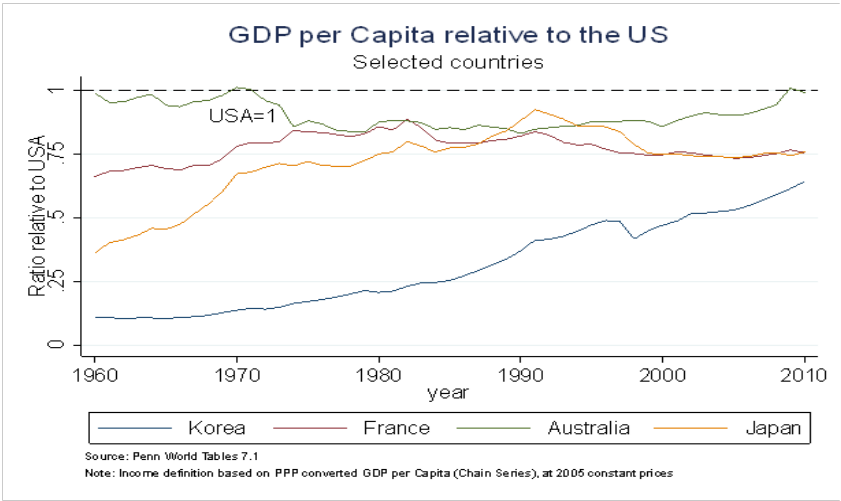
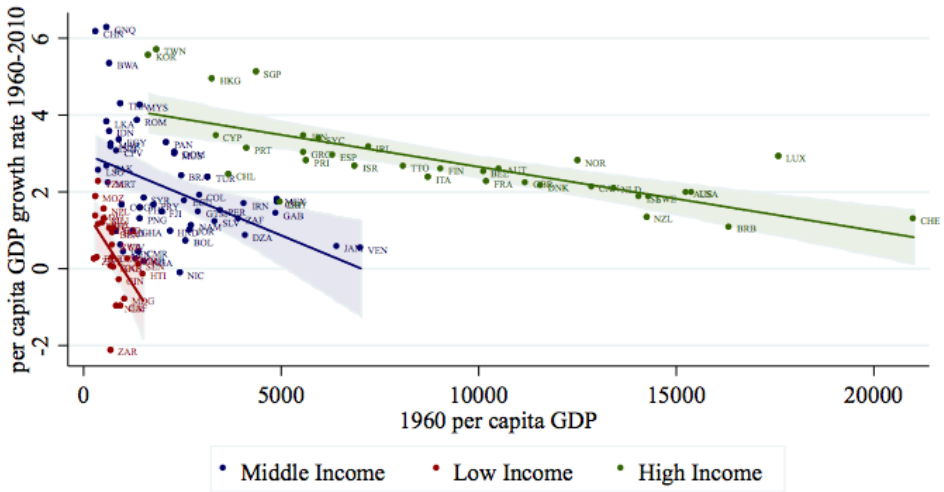
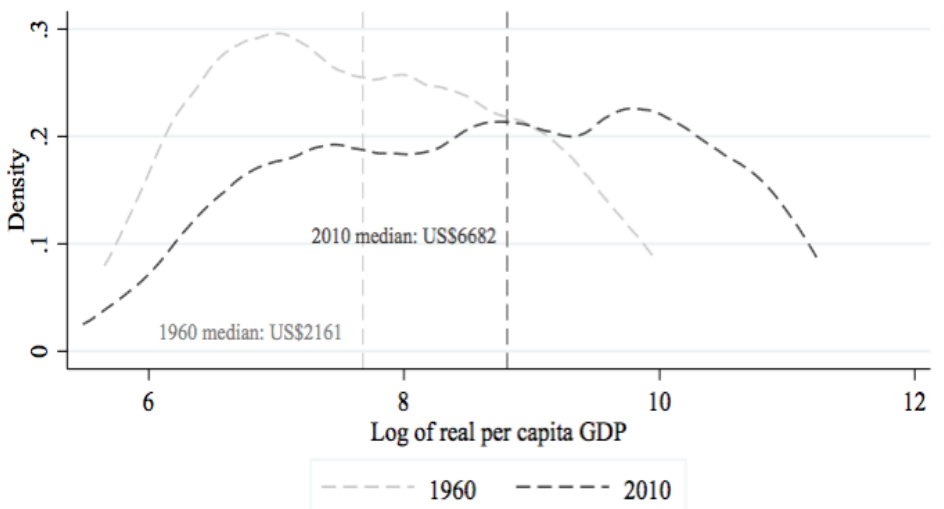


Figure 4. Growth against initial income



Source: Penn World Tables 71
Note 1: Income definition based on PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices)
Note 2: Fitted values are shown for each group

Figure 5. Cross-country income distribution against log per capita GPD (1960, 2010)



Source: Penn World Tables 71
Note 1: Income definition based on PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices)
Note 2: Vertical lines denote median of values for respective year
Note 3: Sample of countries constant across years
Note 4: The densities shown are standard kernel density estimators calculated using the Epanechnikov kernel

Figure 6. Cross-country income dispersion (1960-2010)

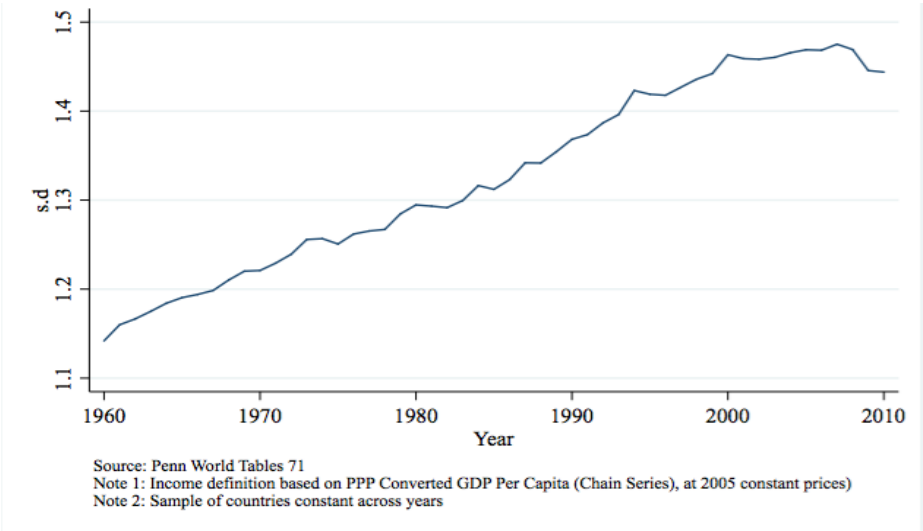


Figure 7a. Correlations of per capita GDP growth in consecutive decades (all countries)

Figure 7b. Correlations of per capita GDP growth in consecutive decades (LICs)

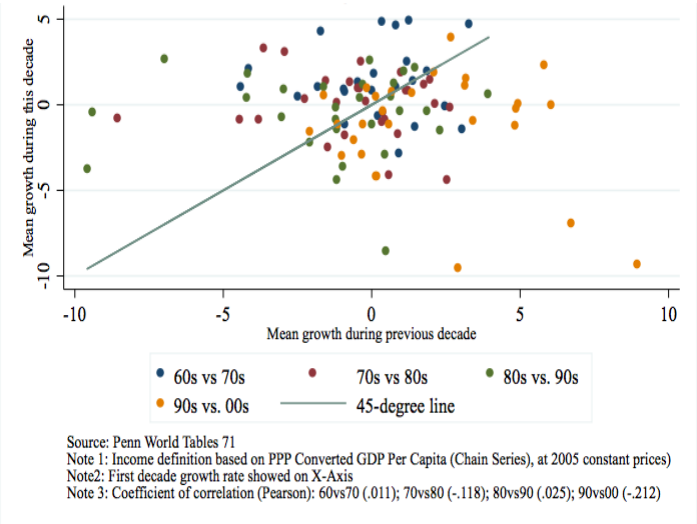
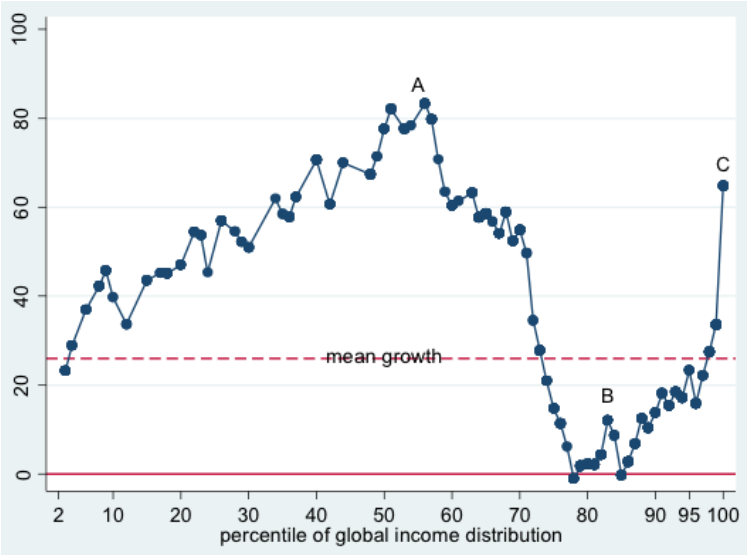


Figure 8. Cumulative real per capita income growth at various percentiles of the global income distribution (1988–2011)



Source: Milanovic (2016a)

References

[1] Abramovitz, M. (1986). "Catching Up, Forging Ahead, and Falling Behind," *The Journal of Economic History*, 46, 385-406.

[2] Abreu, M., H.L.F. De Groot and R.J.G.M. Florax. (2005). "A Meta-Analysis of β-Convergence: The Legendary 2%," *Journal of Economic Surveys*, 19, 389-420.

[3] Acemoglu, D. (2009). *Introduction to Modern Economic Growth*. Princeton University Press.

[4] Aghion, P. (2004). "Growth and Development, A Schumpeterian Approach," *Annals of Economics and Finance*, 5, 1-25.

[5] Aghion, P. and S.N. Durlauf. (2004). *Handbook of Economic Growth*, Volume 1, Elsevier, North Holland.

[6] Aghion, P. and S.N. Durlauf. (2014). *Handbook of Economic Growth*, Volume 2, Elsevier, North Holland.

[7] Aghion, P. and D.P. Howitt. (1992). "A Model of Growth through Creative Destruction," *Econometrica*, 60, 323-351.

[8] Aghion, P. and D.P. Howitt. (2009). *Economic Growth*. MIT Press.

[9] Aghion, P., D. Comin, D.P. Howitt, and I. Tecu. (2016). "When Does Domestic Savings Matter for Economic Growth?" *IMF Economic Review*, 64, 381-407.

[10] Alesina, A., E. Spoloare, and R. Wacziarg (2016). "Trade, Growth and the Size of Countries" in: P. Aghion and S.N. Durlauf (ed.), *Handbook of Economic Growth*, Edition 1, Volume 1, Chapter 23, Elsevier.Anand, A. and P. Segal. (2008). "What Do We Know About Global Income Inequality," *Journal of Economic Literature*, 46, 57-94.

[11] Anand, S., P. Segal and J. E. Stiglitz. (ed.), (2010). "*Debates on the Measurement of Global Poverty*"

[12] Anderson, G., O. Linton and T.W. Leo. (2012). "A Polarization-cohesion Perspective on Cross-country Convergence," *Journal of Economic Growth*, 17, 49-69

[13] Anderson, G., M.G. Pittau, and R. Zelli. (2016). Assessing the Convergence and Mobility of Nations without Artificially Specified Class Boundaries. *Journal of Economic Growth*, 21, 283-304.

[14] Andrade, M., R. Madalozzo, and P.L. Valls Pereira. (2004). “Convergence Clubs among Brazilian Municipalities,” *Economics Letters*, 83, 179-184.

[15] Andres, J. and A. Lamo. (1995). “Dynamics of the Income Distribution across OECD Countries,” London School of Economics, Centre for Economic Performance Discussion Paper No. 252.

[16] Apergis, N., E. Panopoulou, and C. Tsoumas. (2010). “Old Wine in A New Bottle: Growth convergence dynamics in the EU,” *Atlantic Economic Journal*, 38, 169-181.

[17] Atkinson, A.B. and A. Brandolini. (2004). “*Global World Inequality: Absolute, Relative or Intermediate?*” Paper Presented for the 28th Generation Conference of the International Association for Research in Income and Wealth. Cork, Ireland.

[18] Atkinson, A.B. (2015). *Inequality: What Can Be Done?* Harvard University Press.

[19] Azariadis, C. and A. Drazen, (1990). “Threshold Externalities in Economic Development,” *Quarterly Journal of Economics*, 105, 501-526.

[20] Azariadis, C. (1996). "The Economics of Poverty Traps: Part One: Complete Markets," *Journal of Economic Growth*, 1, 449-496.

[21] Azariadis, C. and J. Stachurski. (2005). “Poverty Traps,” in: P. Aghion and S.N. Durlauf (ed.), *Handbook of Economic Growth*, Edition 1, Volume 1, Chapter 5, Elsevier.

[22] Azomahou T., R. Boucekkine, and P. Nguyen-Van. (2011). “Vintage Capital and the Diffusion of Clean Technologies,” Working Papers halshs-00599092, HAL.

[23] Badunenko, O., D.J. Henderson and R.R. Russell. (2013). Polarization of the Worldwide Distribution of Productivity,” *Journal of Productivity Analysis*, 40, 153-171.

[24] Bai, J. and P. Perron. (1998). “Estimating and Testing Linear Models with Multiple Structural Changes,” *Econometrica*, 66, 47-78.

[25] Bai, J. and P. Perron. (2003). “Computation and Analysis of Multiple Structural Change Models,” *Journal of Applied Econometrics*, 18, 1-22.

[26] Baillie, R.T. (1996). “Long Memory Processes and Fractional Integration in Econometrics,” *Journal of Econometrics*, 73, 5-59.

[27] Bandyopadhyay, S. (2011). “Rich States, Poor States: Convergence and Polarisation across Indian States,” *Scottish Journal of Political Economy*, 57, 414-436.

[28] Bandyopadhyay, S. (2014). “Twin Peaks – Distribution Dynamics of Economic Growth across Indian States,” in *Growth, Inequality and Poverty: Prospects for Pro-Poor Growth*, edited by A. Shorrocks and R. van der Hoeven, Oxford University Press.

[29] Banerjee, A. and E. Duflo. (2003). “Inequality and Growth: What can the Data Say?” Working Paper MIT.

[30] Barro, R.J. (1991). “Economic Growth in a Cross-Section of Countries,” *Quarterly Journal of Economics*, 106, 407-443.

[31] Barro, R.J. (2012). “Convergence and Modernization Revisited,” NBER Working Paper No. 18295.

[32] Barro, R.J. (2015). “Convergence and Modernisation,” *Economic Journal*, 125, 911-942.

[33] Barro, R.J. and X. Sala-i-Martin. (1991). “Convergence Across States and Regions,” *Brooking Papers on Economic Activity*, 1, 107-182.

[34] Barro, R.J. and X. Sala-i-Martin. (1992). “Convergence,” *Journal of Political Economy*, 100, 223-251.

[35] Barro, R.J. and X. Sala-i-Martin. (1995). *Economic Growth*, McGraw-Hill.

[36] Barro, R.J. and J. Lee. (2010). "A New Data Set of Educational Attainment in the World, 1950–2010," Working Paper Harvard University.

[37] Barseghyan, L. and R. DiCecio. (2011). Cross-country Income Convergence Revisited, *Economics Letters*, 113, 244-247.

[38] Battisti, M., G. Di Vaio and J. Zeira. (2016). "A New Way to Measure Divergence of Output across Countries" downloaded from https://josephzeira.weebly.com/uploads/5/7/3/4/57342721/bdz_march_2016.pdf

[39] Battisti, M. and C.F. Parmeter. (2012). "GDP Clustering: A Reappraisal." *Economics Letters*, 117, 837-840.

[40] Battisti, M. and C.F. Parmeter. (2013). Clustering and Polarization in the Distribution of Output: A Multivariate Perspective," *Journal of Macroeconomics*, 35, 144-162.

[41] Baumol, W.J. (1986). "Productivity Growth, Convergence, and Welfare, What the Long-Run Data Show," *American Economic Review*, 76, 1072-1085.

[42] Beaudry, P., F. Collard and D.A. Green. (2005). Changes in the World Distribution of Output per Worker, 1960-1998: How a Standard Decomposition Tells an Unorthodox Story," *Review of Economics and Statistics*, 87, 741-753.

[43] Becker, S.G. (1994). "Investment in Human Capita: Rate of Returns" in G.S. Becker, ed., *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*, NBER (3rd edition).

[44] Ben-David, D. (1993). "Equalizing Exchange: Trade Liberalization and Income Convergence." *Quarterly Journal of Economics*, 108, 653-679.

[45] Ben-David, D. (1996). "Trade and Convergence among Countries," *Journal of International Economics*, 40, 279-298.

[46] Bentzen, J. (2005). "Testing for Catching-up Periods in Time-series Convergence. *Economic Letters*, 88, 323-328.

[47] Berg, A., J.D. Ostry, and J. Zettelmeyer. (2012). "What Makes Growth Sustained," *Journal of Development Economics*, 98, 149-166.

[48] Bernard, A. and S.N. Durlauf. (1995). "Convergence of International Output Movements," *Journal of Applied Econometrics*, 10, 97-108.

[49] Bernard, A. and S.N. Durlauf. (1996). "Interpreting Tests of the Convergence Hypothesis," *Journal of Econometrics*, 71, 161-173.

[50] Bernard, A. and C.I. Jones. (1996). "Productivity across Industries and Countries: Time Series Theory and Evidence," *The Review of Economics and Statistics*, 78, 135-146.

[51] Beylunioglu, F.C., T. Stengos, and M.E. Yazgan. (2016). "Detecting Convergence Clubs," Working Papers 1604, University of Guelph, Department of Economics and Finance.

[52] Bianchi, M. (1997). "Testing for Convergence: Evidence from Non-Parametric Multimodality Tests," *Journal of Applied Econometrics*, 12, 393-409.

[53] Binder, M. and M.H. Pesaran. (1999). "Stochastic Growth Models and Their Econometric Implications," *Journal of Economic Growth*, 4, 139-83.

[54] Bloom, D., D. Canning, and B. Graham. (2003). Longevity and Life Cycle Savings," *Scandinavian Journal of Economics*, 105, 319-338.

[55] Bode, E. and S. J. Rey. (2006). "The Spatial Dimensions and Economic Growth and Convergence," *Regional Science*, 85, 171-176.

[56] Bourguignon, F. and C. Morrisson. (2002). "Inequality among World Citizens: 1820-1992," *American Economic Review*, 92, 727-744.

[57] Bourguignon, F. (2015). *The Globalisation of Inequality*. NJ: Princeton University Press.

[58] Bowles, S., S.N. Durlauf, and K. Hoff. (2006). "Poverty Traps," Edited by S. Bowles, S.N. Durlauf and K. Hoff. Princeton Press. Russell Sage Foundation.

[59] Brock, W.A. and S.N. Durlauf. (2001). "Discrete Choice with Social Interactions," *Review of Economic Studies*, 68, 235-60.

[60] Bulli, S. (2001). "Distribution Dynamics and Cross-Country Convergence: A New Approach," *Scottish Journal of Political Economy*, 48, 226-243.

[61] Burnside C. and D. Dollar. (2000). "Aid, Policies, and Growth," *American Economic Review*, 90, 847-868.

[62] Caner, M. and B. Hansen. (2004). "Instrumental Variable Estimation of a Threshold Model," *Econometric Theory*, 20, 813-843.

[63] Canova, F. (2004). "Testing for Convergence Clubs in Income per Capita: A Predictive Density Approach," *International Economic Review*, 45, 49-77.

[64] Canova, F. (2004). "What Explains the Great Moderation in the US? A Structural Analysis," Economics Working Papers 919, Department of Economics and Business, Universitat Pompeu Fabra, revised Dec. 2007.

[65] Carlino, G.A. and L.O. Mills. (1993). "Are U.S. Regional Incomes Converging? A Time-series Analysis." *Journal of Monetary Economics*, 32, 335-346.

[66] Carlino, G.A. and L.O. Mills. (1996). "Convergence and the U.S. States: A Time-series Analysis," *Journal of Regional Science*, 36, 597-616.

[67] Carree, M. and L. Klomp. (1997). "Testing the Convergence Hypothesis: A Comment," *Review of Economics and Statistics*, 79, 683-686.

[68] Carree, M., L. Klomp, and A.R. Thurik. (2000). Productivity Convergence in OECD Manufacturing Industries," *Economic Letters*, 66, 337-345.

[69] Carvalho, V. and A. Harvey, (2002). "*Models for Converging Economies*," Working Paper, University of Cambridge.

[70] Carvalho, V. and A. Harvey. (2005a). "Convergence in the Trends and Cycles of Euro Zone Income," *Journal of Applied Econometrics*, 20, 275-289.

[71] Carvalho, V. and A. Harvey. (2005b). "Growth, Cycles, and Convergence in US Regional Time Series," *International Journal of Forecasting*, 21, 667-686.

[72] Carvalho, V., A. Harvey, and T. Trimbur. (2007). "A Note on Common Cycles, Common Trends and Convergence," *Journal of Business and Economic Statistics*, 25, 12-20.

[73] Cass D. (1965). "Optimum Growth in an Aggregative Model of Capital Accumulation," *The Review of Economic Studies*, 32, 233-240.

[74] Chatterji, M. (1992). "Convergence and Growth Amongst Rich and Poor," Working Paper, Economics Department, Vassar College.

[75] Cho, D. (1996). "An Alternative Interpretation of Conditional Convergence Results," *Journal of Money, Credit and Banking*, 28, 161-73.

[76] Choi, C. and X. Wang. (2015). "Discontinuity of Output Convergence within the United States: Why Has the Course Changed?" *Economic Inquiry*, 53, 49-71.

[77] Chong, T.T., M.J. Hinich, V.K. Liew, and K.-P. Lim. (2008). "Time Series Test of Nonlinear Convergence and Transitional Dynamics," *Economic Letters*, 100, 337-339.

[78] Cohen-Cole, E.B., S.N. Durlauf, and G. Rondina. (2010). "Nonlinearities in Growth: From Evidence to Policy," *Journal of Macroeconomics*, 34, 42-58.

[79] Comin, D., and Mestieri, M., (2018), "If Technology Has Arrived Everywhere, Why has Income Diverged?", *American Economic Journal: Macroeconomics* 10(3),137-178.

[80] Costantini, M. and A. Sen. (2012). "New Evidence on the Convergence of International Income from a Group of 29 Countries," *Applied Economics Letters*, 19, 425-429.

[81] Cowell, F. (1995). *Measuring Inequality*. Harvester Wheatsheaf, London.

[82] Cuaresma, C.J. and G. Doppelhofer. (2007). "Nonlinearities in Cross-country Growth Regressions: A Bayesian Averaging of Thresholds (BAT) Approach," *Journal of Macroeconomics*, 29, 541-554.

[83] Cunado, J., L. Gil-Alana, and D.G. Perez. (2006). "Additional Empirical Evidence on Real Convergence: A Fractionally Integrated Approach," *Review of World Economics*, 142, 67-91.

[84] Cuñat, A. and M. Maffezzoli. (2004). "Neoclassical Growth and Commodity Trade," *Review of Economics Dynamics*, 7, 707-736.

[85] Datta, A. (2003). "Time-series Tests of Convergence and Transitional Dynamics," *Economic Letters*, 81, 233-240.

[86] Dawson, J.W. and A. Sen. (2007). "New Evidence on the Convergence of International Income from A Group of 29 Countries," *Empirical Economics*, 33, 199-230.

[87] Dawson, J.W. and M. C. Strazicich. (2010). "Time-series Tests of Income Convergence with Two Structural Breaks: Evidence from 29 Countries," *Applied Economics Letters*, 17, 909-912.

[88] De Long, B. (1988). "Productivity Growth, Convergence, and Welfare: Comment," *American Economic Review*, 78, 1138-1154.

[89] Deaton, A. (2010). "Price Indexes, Inequality, and the Measurement of World Poverty," *American Economic Review*, 100, 5-34.

[90] Deaton, A. (2013). *The Great Escape*, Princeton Press.

[91] Deaton, A. and A. Heston. (2010). "Understanding PPPs and PPP-Based National Accounts," *American Economic Journal: Macroeconomics*, 2, 1-35.

[92] Deidda, L. and B. Fattouh. (2002). "Non-linearity between Finance and Growth," *Economics Letters*, 74, 339-345.

[93] Desdoigts, A. (1999). "Patterns of Economic Development and the Formation of Clubs," *Journal of Economic Growth*, 4, 305-330.

[94] Di Vaio, G., and K. Enflo. (2011) "Did globalization drive convergence? Identifying cross-country growth regimes in the long run," *European Economic Review*, 55, 832-844.

[95] Dobson, S. and C. Ramlogan. (2011). "Convergence and Divergence in Latin America, 1970-1998," *Applied Economics*, 34, 465-470.

[96] Doppelhofer G., R.I. Miller, and X. Sala-i-Martin. (2000). "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," NBER Working Papers No. 7750.

[97] Dowrick, S. (1992). "Technological Catch Up and Diverging Incomes: Patterns of Economic Growth 1960-88," 102, 600-610.

[98] Dowrick, S. (2003). "Ideas and Education: Level or Growth Effects?" NBER Working Papers No. 9709.

[99] Dowrick, S. and J.B. DeLong. (2003). In Bordo M.D., A.M. Taylor and J.G. Williamson, eds (Eds.), *Globalization and Convergence* NBER Conference Report series. Chicago and London: University of Chicago Press.

[100] Dowrick, S. (2004). "Income-based Measures of Average Well-being," Working Paper Series UNU-WIDER Research Paper, World Institute for Development Economic Research (UNU-WIDER).

[101] Dufrénot, G., V. Mignon, and T. Naccache. (2012). "Testing Catching-Up between the Developing Countries: 'Growth Resistance' and Sometimes 'Growth Tragedy'," *Bulletin of Economic Research*, 64, 470-508.

[102] Durlauf, S.N. (1993). "Nonergodic Economic Growth," *Review of Economic Studies*, 60, 349-366.

[103] Durlauf, S.N. and P.A. Johnson. (1995). "Multiple Regimes and Cross-Country Growth Behavior," *Journal of Applied Econometrics*, 10, 365-284.

[104] Durlauf, S.N., and D. Quah. (1999). "The New Empirics of Economic Growth," in J.B. Taylor and M. Woodford, eds., *Handbook of Macroeconomics*, Vol. 1A, Amsterdam: North Holland Elsevier Science, Chapter 4, 231-304.

[105] Durlauf, S.N., A. Kourtellos, and A. Minkin. (2001). "The Local Solow Growth Model," *European Economic Review*, 45, 928-940.

[106] Durlauf, S.N., P.A. Johnson, and J.R.W. Temple. (2005). "Growth Econometrics," in P. Aghion and S.N. Durlauf, eds., *Handbook of Economic Growth*, Amsterdam, North-Holland, 555-677.

[107] Durlauf S.N., P.A. Johnson and R.W.J. Temple. (2009). "The Econometrics of Convergence," in Palgrave Handbook of Econometrics, Mills T, Patterson K (eds), Applied Econometrics, vol. 2. Palgrave Macmillan: Basingstoke, UK; 1087-1118.

[108] Easterly, W., M. Kremer, L. Pritchett, and L. Summers. (1993). "Good Policy or Good Luck? Country Growth Performance and Temporary Shocks," *Journal of Monetary Economics*, 32, 459-483.

[109] Easterly, W. (2004). "National Economic Policies and Economic Growth: A Reappraisal," in P. Aghion and S.N. Durlauf, eds., *Handbook of Economic Growth*, Amsterdam, North-Holland, 1, 1015-1059.

[110] Egger, P. and M. Pfaffermayr. (2009). "On Testing Conditional Sigma-Convergence," *Oxford Bulletin of Economics and Statistics*, 71, 453-473.

[111] Eichengreen, B., D. Park, and K. Shin. (2013). "Growth Slowdowns Redux: New Evidence on the Middle-Income Trap," NBER Working Paper No. 18673.

[112] Eicher, T., S. Schubert, and S. Turnovsky. (2008). "Dynamic Effects of Terms of Trade Shocks: The Impact on Debt and Growth," *Journal of International Money and Finance*, 27, 876-896.

[113] Eicher, T., C. Papageorgiou, and A.E. Raftery. (2011). "Default Priors and Predictive Performance in Bayesian Model Averaging, with Application to Growth Determinants," *Journal of Applied Econometrics*, 26, 30-55.

[114] El-Gamal, M. and D. Ryu. (2013). "Non-Stationarity and Stochastic Stability of Relative Income Club," *Review of Income and Wealth*, 59, 756-775.

[115] Epstein, P., P. Howlett and M. Schulze. (2003). "Distribution Dynamics: Stratification, Dolarization, and Convergence among OECD Economies, 1870-1992." *Explorations in Economic History*, 40, 78-97.

[116] Estrin, S., G. Urga and S. Lazarova. (2001). Testing for Ongoing Convergence in Transition Economies, 1970 to 1998," *Journal of Comparative Economics*, 29, 677-691.

[117] Fernandez, C., E. Ley, and M. Steel. (2001). "Model Uncertainty in Cross-Country Growth Regressions," Journal of Applied Econometrics, 16, 563-576.

[118] Feyrer J.D. (2008). "Convergence by Parts," *B.E. Journal of Macroeconomics*, 8, 1-35.

[119] Fiaschi, D. and A.M. Lavezzi. (2003). "On the Determinants of Growth Volatility: A Nonparametric Approach," Discussion Papers 2003/25, Dipartimento di Economia e Management (DEM), University of Pisa, Pisa, Italy.

[120] Fiaschi, D. and A.M. Lavezzi. (2003). "Distribution Dynamics and Nonlinear Growth," *Journal of Economic Growth*, 8, 379-401.

[121] Fiaschi, D. and A.M. Lavezzi. (2007a). "Nonlinear Economic Growth: Some Theory and Cross-country Evidence," *Journal of Development Economics*, 84, 271-290.

[122] Fiaschi, D. and A.M. Lavezzi. (2007b). "Appropriate Technology in A Solovian Nonlinear Growth Model," *Oxford Review of Economic Policy*, 23, 115-133.

[123] Fiaschi, D., Lavezzi, A.M., and Parenti, A., (2018), *Deep and Proximate Determinants of the World Income Distribution*, University of Pisa

[124] Fischer, M. and P. Stumpner. (2008). "Income Distribution Dynamics and Cross-region Convergence in Europe," *Journal of Geographical Systems*, 10, 109-139.

[125] Fleissig, A. and J. Strauss. (2001). "Panel Unit-root Tests of OECD Stochastic Convergence," *Review of International Economics*, 9, 153-162.

[126] Fotopoulos, G. (2008). "European Union Regional Productivity Dynamics: A 'Distributional' Approach," *Journal of Regional Science*, 48, 419-454.

[127] Friedman, M. (1992). "Do Old Fallacies Ever Die?" *Journal of Economic Literature*, 30, 2129-2132.

[128] Furceri, D. (2005). "β and σ-convergence: A Mathematical Relation of Causality," *Economic Letters*, 89, 212-215.

[129] Galor, O. (1996) "Convergence? Inferences from Theoretical Models," *Economic Journal*, 106, 1056-1069.

[130] Galor, O. and J. Zeira. (1993). "Income Distribution and Macroeconomics," *Review of Economic Studies*, 60, 35-52.

[131] Galvão, A.F. and F.A.R. Gomes. (2011). "Convergence or Divergence in Latin America? A Time Series Analysis," *Applied Economics*, 39, 1353-1360.

[132] Georgios, F. (2006). "Nonparametric Analysis of Regional Income Dynamics: The Case of Greece," *Economics Letters*, 91, 450-457.

[133] Ghosh, M., A. Ghoshray, and I. Malki. (2013). "Regional Divergence and Club Convergence in India," *Economic Modelling*, 30, 733-742.

[134] Ghoshray, A. and F.A. Khan (2015). "New Empirical Evidence on Income Convergence," *Empirical Economics*, 49, 343-361.

[135] Granger, C.W.J. (1980). "Long Memory Relationships and the Aggregation of Dynamic Models," *Journal of Econometrics*, 14, 227-238.

[136] Granger, C.W.J. and R. Joyeux. (1980). "An Introduction to Long Memory Time Series Models and Fractional Differencing," *Journal of Time Series Analysis*, I, 15-39.

[137] Granger, C.W.J. and N. Hyung. (2004). "Occasional Structural Breaks and Long Memory with an Application to the S&P 500 Absolute Stock Returns," *Journal of Empirical Finance*, 11, 399-421.

[138] Greasley, D. and L. Oxley. (1995). "A Time-series Perspective on Convergence: Australia, UK and USA since 1870," *Economic Record*, 71, 259-270.

[139] Greasley, D. and L. Oxley. (1997). "Time-Series Tests of the Convergence Hypothesis: Some Positive Results," *Economic Letters*, 56, 143-147.

[140] Grier, K. and G. Tullock. (1989). "An Empirical Analysis of Cross-national Economic Growth, 1951-1980," *Journal of Monetary Economics*, 24, 259-276.

[141] Grossman, G.M. and E. Helpman. (1991). *Innovation and Growth in the Global Economy*, Cambridge: MIT Press.

[142] Hall, A., A. Inoue., K. Jana, and C. Shin. (2007). "Information in Generalized Method of Moments Estimation Entropy Based Moment Selection," *Journal of Econometrics*, 138, 488-512.

[143] Hall, P., Q. Li and J.S. Racine. (2007). "Nonparametric Estimation of Regression Functions in the Presence of Irrelevant Regressors," *Review of Economics and Statistics*, 89, 784-89.

[144] Hamit-Haggar, M. (2013). "A Note on Convergence across Canadian Provinces: New Insights from the Club Clustering Algorithm," *Annals of Regional Science*, 50, 591-601.

[145] Hansen, B.E. (2000). "Sample Splitting and Threshold Estimation," *Econometrica*, 68, 575-604.

[146] Hart, P.E. (1995). "Galtonian Regression across Countries and the Convergence of Productivity," *Oxford Bulletins of Economics and Statistics*, 57, 287-293.

[147] Hauser, M.A., B.M. Potscher, and E. Reschenhofer. (1999). "Measuring Persistence in Aggregate Output: ARMA Models, Fractionally Integrated ARMA Models and Nonparametric Procedures," *Empirical Economics*, 24, 243-269.

[148] Hausmann, R., L. Pritchett, and D. Rodrik. (2005). "Growth Accelerations," *Journal of Economic Growth*, 10, 303-329.

[149] Henderson, D.J., C.F. Parmeter and R.R. Russell. (2008). Modes, Weighted Modes, and Calibrated Modes: Evidence of Clustering Using Modality Tests," *Journal of Applied Econometrics*, 23, 607-638.

[150] Henderson, D.J., C. Papageorgiou and C.F. Parmeter. (2012). "Growth Empirics without Parameters," *Economic Journal*, 122, 125-154.

[151] Henderson J.V., A. Storeygard and D.N. Weil. (2012). "Measuring Economic Growth from Outer Space," *American Economic Review*, 102, 994-1028.

[152] Hobijn, B. and P.H. Franses. (2000). "Asymptotically Perfect and Relative Convergence of Productivity," *Journal of Applied Econometrics*, 15, 59-81.

[153] Howitt, P. and D.M. Foulkes. (2005). "Implementation and Stagnation: A Schumpeterian Model of Convergence Clubs," *Quarterly Journal of Economics*, 37, 147-177.

[154] Inada, K.-I. (1963). "On a Two-Sector Model of Economic Growth: Comments and a Generalization," *The Review of Economic Studies*, 30, 119-127.

[155] Islam, N. (2003). "What Have We Learnt from the Convergence Debate?" *Journal of Economic Surveys*, 17, 309-362.

[156] Jerven, M. (2013). "Poor Numbers: How We Are Misled by African Development Statistics and What to Do About It," Cornell University Press.

[157] Jerzmanowski, M. (2006). "Empirics of Hills, Plateaus, Mountains and Plains: A Markov-switching Approach to Growth," *Journal of Development Economics*, 81, 357-385.

[158] Johnson, P.A. (2000). "A Non-Parametric Analysis of Income Convergence Across The US States," *Economic Letters*, 69, 219-223.

[159] Johnson, P.A., and Takeyama L.N. (2001). "Initial Conditions and Economic Growth

[160] in the US States," *European Economic Review*, 45, 919-927.

[161] Johnson, P.A. (2005). "A Continuous State Space Approach to 'Convergence by Parts'," *Economics Letters*, 86, 317-321.

[162] Johnson, S., J.D. Ostry and A. Subramanian. (2007). "The Prospects for Sustained Growth in Africa; Benchmarking the Constraints," IMF Working Papers 07/52, International Monetary Fund.

[163] Johnson, S., L. William, C. Papageorgiou and A. Subramanian. (2013). "Is Newer Better? Penn World Table Revisions and their Impact on Growth Estimates," *Journal of Monetary Economics*, 60, 255-274.

[164] Jones, B.F. and B.A Olken. (2008). "The Anatomy of Start-Stop Growth," *Review of Economics and Statistics*, 90, 582–587.

[165] Jones, C. (1997). "On the Evolution of the World Income Distribution," *Journal of Economic Perspectives*, 11, 19-36.

[166] Jones, C. (1998). *Introduction to Economic Growth*. W. W. Norton & Company.

[167] Kalaitzidakis, P., T.P. Mamuneas, and T. Stengos. (2010). "An Updated Ranking of Academic Journals in Economics," Working Papers 1009, University of Guelph, Department of Economics and Finance.

[168] Kharas, H. and H. Kohli (2011). "What Is the Middle Income Trap, Why Do Countries Fall into It, and How Can It Be Avoided?" *Global Journal of Emerging Market Economies*, 3, 281-289.

[169] King, A. and C.R. Dobson. (2011). "Nonlinear Time-Series Convergence: The Role of Structural Breaks," *Economic Letters*, 110, 238-240.

[170] King, A. and C.R. Dobson. (2014). "Are income differences within the OECD diminishing? Evidence from Fourier unit root tests," in: Mizrach, Bruce (ed.), *Studies in Nonlinear Dynamics & Econometrics*, 18, 185-199.

[171] King, R. G., and R. Levine (1993). "Finance and Growth: Schumpeter Might Be Right," Policy Research Working Paper Series 1083, The World Bank.

[172] Koopman, T.C. (1963). "On the Concept of Optimal Economic Growth," Cowles Foundation Discussion Paper No 163.

[173] Kormendi, R.C. and P.G. Meguire. (1985). "Macroeconomic Determinants of Growth: Cross-Country Evidence," *Journal of Monetary Economics*, 16, 141-163.

[174] Kourtellos, A., S.N. Durlauf, and C.M. Tan. (2008). "Are Any Growth Theories Robust?" *Economic Journal*, 118, 329-346.

[175] Kourtellos A., T. Stengos, and C.M. Tan. (2009). “Structural Threshold Regression,” *Econometric Theory*, 32, 827-860.

[176] Kourtellos, A., T. Stengos, and C.M. Tan. (2010). “Do Institutions Rule? The Role of Heterogeneity in The Institutions vs. Geography Debate,” *Economics Bulletin*, 30, 1710-1719.

[177] Kourtellos, A. (2011). “Modeling Parameter Heterogeneity in Cross-Country Regression Models,” Discussion Paper 11-2011, Department of Economics, University of Cyprus.

[178] Kramer, W. and P. Sibbertson. (2002). “Testing for Structural Changes in the Presence of Long Memory,” *International journal of Business and Economics*, 1, 235-242.

[179] Kravis, I.B., A. Heston, and R. Summers. (1978). “Real GDP Per Capita for More Than One Hundred Countries,” *Economic Journal*, 88, 215-242.

[180] Krause, M. (2016). “The Millennium Peak in Club Convergence: A New Look at Distributional Changes in The Wealth of Nations,” *Journal of Applied Econometrics, forthcoming*, doi: 10.1002/jae.2542.

[181] Lakner, C. and B. Milanovic. (2015). “Global Income Distribution: From the Fall of the Berlin Wall to the Great Recession,” *World Bank Economic Review*, 30, 203-232.

[182] Lamo, A. (2000). “On Convergence Empirics: Same Evidence for Spanish Regions,” Investigaciones Economicas, Fundación SEPI, 24, 681-707.

[183] Lau, S.P. (1999). “I(0) in, Integration and Co-Integration Out: Time Series Properties of Endogenous Growth Models,” *Journal of Econometrics*, 93, 1-24.

[184] Lenkoski, A., T.S. Eicher, and A.E. Raftery. (2014). “Two-Stage Bayesian Model Averaging in Endogenous Variable Models,” *Econometric Reviews*, 33, 1-4.

[185] Levine, R. and D. Renelt. (1992). “A Sensitivity Analysis of Cross-Country Growth Regressions,” *The American Economic Review*, 82, 942-963.

[186] Ley, E. and M. Steel. (2007). “On the Effect of Prior Assumptions in Bayesian Model Averaging with Applications to Growth Regression,” *Journal of Applied Econometrics*, 24, 651-674.

[187] Ley, E. and M. Steel. (2009). "Comments on ‘Jointness of Growth Determinants’," *Journal of Applied Econometrics*, 24, 248-251.

[188] Ley, E. and M. Steel. (2011). “Mixtures of G-priors for Bayesian Model Averaging with Economic Applications,” *Journal of Econometrics*, 171, 251-266.

[189] Li, Q. and D. Papell. (1999). “Convergence of International Output: Time series Evidence for 16 Countries,” *International Review of Economics and Finance*, 8, 267-280.

[190] Lichtenberg, F.R. (1994). “Testing the Convergence Hypothesis,” *Review of Economics and Statistics*, 76, 576-679.

[191] Liu, Z. and T. Stengos. (1999). “Non-Linearities in Cross-Country Growth Regressions: A Semiparametric Approach,” *Journal of Applied Econometrics*, 14, 527-538.

[192] Loewy, M. and D.H. Papell. (1996). “Are U.S. Regional Incomes Converging? Some Further Evidence,” *Journal of Monetary Economics*, 38, 587-598.

[193] Lucas, R. (1988). “On the Mechanics of Economic Development,” *Journal of Monetary Economics*, 22, 3-42.

[194] Maasoumi, E., J.S. Racine, and T. Stengos. (2007). “Growth and Convergence: A Profile of Distribution Dynamics and Mobility,” *Journal of Econometrics*, 136, 483-508.

[195] Maddison, A. (2007). *Contours of the World Economy, 1-2030AD: Essays in Macro-Economic History*, Oxford University Press.

[196] Mamuneas T.P., A. Savvides, and T. Stengos. (2006). "Economic Development and The Return to Human Capital: A Smooth Coefficient Semiparametric Approach," *Journal of Applied Econometrics*, 21, 111-132.

[197] Mankiw, N.G., D. Romer, and D.N. Weil. (1992). "A Contribution to the Empirics of Economic Growth," *The Quarterly Journal of Economics*, 107, 407-437.

[198] Marris, R. (1982). "How Much of the Slow-Down Was Catch-Up?" in *Slower Growth in the Western World*, London: Heinemann

[199] McKinsey Global Institute. (2010). *Lions On the Move: The Progress and Potential of African Economies.* McKinsey & Company

[200] McCoskey, S.K. (2002). "Convergence in Sub-Saharan Africa: A Nonstationary Panel Data Approach," 34, 819-929.

[201] Michelacci, C. and P. Zaffaroni. (2000). "(Fractional) Beta Convergence," *Journal of Monetary Economics*, 45, 129-153.

[202] Miguel, E. (2009). *Africa's Turn?* MIT Press, Cambridge Massachusetts.

[203] Milanovic, B. (2002). "True World Income Distribution, 1988 and 1993: First Calculation Based on Household Surveys Alone," *Economic Journal*, 112, 51-92.

[204] Milanovic, B. (2012). "Global Inequality: From Class to Location, from Proletarians to Migrants," *Global Policy*, 3, 125-134.

[205] Milanovic, B. (2016a). *Global Inequality: A New Approach for the Age of Globalization*, Harvard University Press.

[206] Milanovic, B. (2016b). "The Greatest Reshuffle of Individual Incomes since the Industrial Revolution" VoxEU July 1, 2016.

[207] Minier, J. (2007a). "Nonlinearities and Robustness in Growth Regressions," *American Economic Review: Papers and Proceedings*, 97, 388-392.

[208] Minier, J. (2007b). "Institutions and Parameter Heterogeneity," *Journal of Macroeconomics*, 29, 595-611.

[209] Monfort, M., J. C. Cuestas and J. Ordonez. (2013). "Real Convergence in Europe: A Cluster Analysis," *Economic Modelling*, 33, 689-694.

[210] Nahar, S. and B. Inder. (2002). "Testing Convergence in Economic Growth for OECD Countries," *Applied Economics*, 34, 2011-2022.

[211] Nyong, M.O. and O.A. Omobitan. (2013). "Nonlinear Income Convergence and Structural Breaks: Further Empirical Evidence," *International Journal of Economics and Finance*, 5, 81-88.

[212] Obstfeld, M. and K. Rogoff. (1996). *Foundations of International Macroeconomics*, Cambridge MA: MIT Press.

[213] Owen, A., J. Videras, and L. Davis. (2009). "Do All Countries Follow the Same Growth Process?" *Journal of Economic Growth*, 14, 265-286.

[214] Oxborrow, D. and S.J. Turnovsky. (2016). "Closing the Small Open Economy Model: A Demographic Approach," *Review of International Economics*, forthcoming.

[215] Paapaa, R. and H.K. Van Dijk. (1998). "Distribution and Mobility of Wealth of Nations," *European Economic Review*, 42, 1269-1293.

[216] Papageorgiou, C. (2002). "Trade as a Threshold Variable for Multiple Regimes," *Economics Letters*, 77, 85-91.

[217] Masanjala, W. and C. Papageorgiou. (2004). "The Solow Model with CES Technology: Nonlinearities and Parameter Heterogeneity," *Journal of Applied Econometrics*, 19, 171-201.

[218] Penn World Tables. (2012). University of Pennsylvania. June 2012 Version No 7.

[219] Perron, P. (1989). "The Great Crash, The Oil Price Shock, And The Unit Root Hypothesis," *Econometrica*, 57, 1361-1401.

[220] Phillips, P.C.B. and D. Sul. (2007a). "Transition Modeling and Econometric Convergence Tests," *Econometrica*, 75, 1771-1855.

[221] Phillips, P.C.B. and D. Sul. (2007b). "Some Empirics On Economic Growth Under Heterogeneous Technology," *Journal of Macroeconomics*, 29, 455-469.

[222] Phillips, P.C.B. and D. Sul. (2009). "Economic Transition and Growth," *Journal of Applied Econometrics*, 24, 1153-1185.

[223] Pinkovskiy, M. and X. Sala-i-Martin. (2009). "Parametric Estimations of the World Distribution of Income," *NBER Working Paper No. 15433*.

[224] Pinkovskiy, M. and X. Sala-i-Martin. (2014). "Africa Is On Time," *Journal of Economic Growth*, 19, 311-338.

[225] Pinkovskiy, M. and X. Sala-i-Martin. (2016). "Newer Need Not Be Better: Evaluating the Penn World Tables and the World Development Indicators Using Night-time Lights," NBER Working Paper No. 22216.

[226] Pittau, M.G. (2005). "Fitting Regional Income Distributions in The European Union," *Oxford Bulletin of Economics and Statistics*, 67, 135-161.

[227] Pittau M.G. and R. Zelli. (2006). "Trends in Income Distribution in Italy: A Non-Parametric 90 And A Semi-Parametric Analysis," *Journal of Income Distribution*, 15, 90-118.

[228] Pittau, M.G. (2005). "Fitting Regional Income Distributions in the European Union," *Oxford Bulletin of Economics and Statistics*, 67, 135-61.

[229] Pittau, M.G. and R. Zelli. (2006). "Empirical Evidence of Income Dynamics Across EU Regions," *Journal of Applied Econometrics*, 21, 605-628.

[230] Pittau, M.G., R. Zelli and P.A. Johnson, P. A. (2010). Mixture Models, Convergence Clubs, and Polarization," *Review of Income and Wealth*, 56, 102-122.

[231] Pittau, M.G., R. Zelli and R. Massari, R. (2016). Evidence of Convergence Clubs using Mixture Models. Econometric Reviews, 35, 1317-1342.

[232] Pritchett, L. (1997). "Divergence, Big Time," *Journal of Economic Perspectives*, 11, 3-17.

[233] Pritchett, L. (2000). "Understanding Patterns of Economic Growth: Searching for Hills among Plateaus, Mountains, and Plains," *World Bank Economic Review*, 14, 221-225.

[234] Quah, D. (1993a). "Empirical Cross-Section Dynamics in Economic Growth," *European Economic Review*, 37, 426-434.

[235] Quah, D. (1993b). "Galton's Fallacy and Tests of the Convergence Hypothesis," *Scandinavian Journal of Economics*, 95, 427-443.

[236] Quah, D. (1994). "Exploiting Cross Section Variation for Unit Root Inference in Dynamic Data," *Economics Letters*, 44, 9-19.

[237] Quah, D. (1996a). “Empirics for Economic Growth and Convergence,” *European Economic Review*, 40, 1353-1375.

[238] Quah, D. (1996b). “Twin Peaks: Growth and Convergence in Models of Distribution Dynamics,” *Economic Journal*, 106, 1045-1055.

[239] Quah, D. (1996c). “Regional Convergence Clusters Across Europe,” *CEPR Discussion Papers 1286*, C.E.P.R. Discussion Papers.

[240] Quah, D. (1997). “Empirics for Growth and Distribution: Polarization, Stratification, and Convergence Clubs,” *Journal of Economic Growth*, 2, 27-59.

[241] Quah, D. (2001). “Searching for Prosperity: A Comment,” *Carnegie-Rochester Conference Series on Public Policy*, 55, 305-319.

[242] Racine, J.S and L. Liu. (2007). “A Partially Linear Kernel Estimator for Categorical Data,” *Econometric Reviews*, 34, 959-978.

[243] Radelet, S. (2010). *Emerging Africa: How 17 Countries Are Leading the Way*, Brookings Institution Press, Washington, DC.

[244] Raftery, A.E. (1995). “Bayesian Model Selection for Social Research,” *Sociological Methodology*, 25, 111-163.

[245] Ramsey, F.P. (1928). “A Mathematical Theory of Saving,” The Economic Journal, 38, 543-559.

[246] Reichlin, L. (2009). “Comment on ‘How Has the Euro Changed the Monetary Transmission Mechanism?’ ” *NBER Macroeconomics Annual* 2009, 23, 127-139.

[247] Rioja, F. and N. Valev. (2004). “Finance and The Sources of Growth at Various Stages of Economic Development,” *Economic Inquiry*, 42, 127-140.

[248] Rioja, F., and N. Valev. (2004). “Does One Size Fit All?: A Re-examination of the Finance and Growth Relationship,” *Journal of Development Economics*, 74, 429-447.

[249] Rodrik, D. (2011). “The Future of Economic Convergence,” NBER Working Paper No. 17400.

[250] Rodrik, D. (2012). “Why We Learn Nothing from Regressing Economic Growth on Policies,” *Seoul Journal of Economics*, 25, 137-151.

[251] Rodrik, D. (2013). “Unconditional Convergence in Manufacturing,” *Quarterly Journal of Economics*, 128, 165-204.

[252] Rodrik, D. (2014). “The Past, Present, and Future of Economic Growth,” *Challenge*, 57, 5-39.

[253] Rodrik, D. (2015). “Premature Deindustrialization,” IAS Social Science, Economics Working Papers, Princeton University.

[254] Romer, P.M. (2001). “Should the Government Subsidize Supply or Demand in the Market for Scientists and Engineers?” NBER Chapters, In: Innovation Policy and the Economy, 1, 221-252.

[255] Sala-i-Martin, X. (1996). “The Classical Approach to Convergence Analysis,” *Economic Journal*, 106, 1019-1036.

[256] Sala-i-Martin, X. (1997a). “I Just Ran 2 Million Regressions”, *American Economic Review*, 87, 178-183.

[257] Sala-i-Martin, X. (1997b). “Transfers, Social Safety Nets, and Growth,” *IMF Staff Papers*, 44, 81-102.

[258] Scarpetta, S. and T. Tressel. (2002). "Productivity and Convergence in a Panel of OECD Industries: Do Regulations and Institutions Matter?" OECD Economics Department Working Papers No. 342.

[259] Schumpeter, J.A. (1950). *Capitalism, Socialism, and Democracy*, New York: Harper and Row.

[260] Silverberg, G. and B. Verspagen. (1999). "Long Memory in Time Series of Economic Growth and Convergence," Maastricht University

[261] Silverberg, G. and B. Verspagen. (2003). "Long Memory and Economic Growth in the World Economy Since the 19th Century," Retrieved from Processes with Long Range Correlations: Theory and Applications, 270-285.

[262] Sirimaneetham, V. and J.R.W. Temple. (2009). "Macroeconomic Stability and the Distribution of Growth Rates," *World Bank Economic Review*, 23, 443-479.

[263] Slaughter, M.J. (1997). "International Trade and Per Capita Income Convergence: A Difference-In-Difference Analysis," *Journal of International Economics,* 55, 203-228.

[264] Spence, M. (2011). *The Next Convergence: The Future of Economic Growth in a Multispeed World*, Imprint New York.

[265] Solow, R.M. (1956). "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70, 65-94.

[266] Spence, M. (2012). *The Next Convergence: The Future of Economic Growth in a Multispeed World*, Imprint New York.

[267] Stengos, T. and M.E. Yazgan. (2014). "Persistence in Convergence," *Macroeconomic Dynamics*, 18, 753-782.

[268] Stock, J.H. (1994). "Unit Roots and Trend Breaks," Engle, R.F. and D. McFadden eds. Vol. IV, North-Holland, Amsterdam.

[269] Strazicich, M., J. Lee, and E. Day. (2004). "Are incomes converging among OECD countries? Time series evidence with two structural breaks," *Journal of Macroeconomics*, 26, 131-145.

[270] Subramanian, A. (2011). *Eclipse: Living in the Shadow of China's Economic Dominance*, Peterson Institute.

[271] Summers, R. and A. Heston. (1980). "A New Set of International Comparisons of Real Product and Price Levels Estimates for 130 Countries: 1950-1985," *Review of Income and Wealth*, 26, 19-66.

[272] Swan, T. W. (1956). "Economic Growth and Capital Accumulation," *Economic Record*, 32, 334-361.

[273] Tan, C.M. (2010). "No One True Path to Development: Uncovering The Interplay Between Geography, Institutions and Ethnic Fractionalization in Economic Development," *Journal of Applied Econometrics*, 25, 1100-1127.

[274] Temple, J.R.W. (1999). "The New Growth Evidence," *Journal of Economic Literature*, 37, 112-156.

[275] Tian, X., X. Zhang, Y. Zhou, and X. Yu. (2016). "Regional Income Inequality in China Revisited: A Perspective from Club Convergence," *Economic Modelling*, 56, 50-58.

[276] Tsionas, E.G. (2000) "Regional Growth and Convergence: Evidence from the United States," *Regional Studies*, 34, 231-238.

[277] Ventura, J. (1997). “Growth and Interdependence,” *Quarterly Journal of Economics*, 112, 57-84.

[278] Vollmer, S., H. Holzmann, and F. Schwaiger. (2013a). “Peaks vs Components,” *Review of Development Economics*, 17, 352–364.

[279] Vollmer, S., H. Holzmann, F. Ketterer, S. Klasen, and D. Canning. (2013b). “The Emergence of Three Human Development Clubs,” *PLoS ONE* 8(3): e57624. https://doi.org/10.1371/journal.pone.0057624.

[280] World Economic Outlook. (2017). “Roads Less Traveled: Growth in Emerging Market and Developing Economies in A Complicated External Environment,” Chapter 2, April 2017, International Monetary Fund, Washington DC.

[281] Wu (2009). “Income Inequality and Distributive Justice: A Comparative Analysis of Mainland China and Hong Kong,” *The China Quarterly*, 200, 1033–1052.

[282] Young, A., M. Higgins, and D. Levy. (2008). “Sigma Convergence Versus Beta Convergence: Evidence from U.S. County-Level Data,” *Journal of Money, Credit and Banking*, 40, 1083-1093.

[283] Zeira, Joseph. (1998). “Workers, Machines, and Economic Growth,” *Quarterly Journal of Economics*, 113, 1091-1117.\

Appendix Tables

Table A.1: Country classifications - by income groups

High Income Countries (29 countries)	Middle Income Countries (68 countries)		Low Income Countries (51 countries)	
Australia	Albania	Lebanon	Afghanistan	Nepal
Austria	Algeria	Libya	Armenia	Nicaragua
Belgium	Angola	Lithuania	Bangladesh	Niger
Canada	Argentina	Macedonia	Benin	Nigeria
Cyprus	Azerbaijan	Malaysia	Bolivia	Papua New Guinea
Czech Republic	Bahrain	Mauritius	Burkina Faso	Rwanda
Denmark	Belarus	Mexico	Burundi	Senegal
Finland	Botswana	Morocco	Cambodia	Sierra Leone
France	Brazil	Namibia	Cameroon	Sudan
Germany	Bulgaria	Oman	Central African Republic	Tajikistan
Greece	Chile	Pakistan	Chad	Tanzania
Hong Kong	China	Panama	Congo, Dem. Rep.	Timor-Leste
Ireland	Colombia	Paraguay	Congo, Republic of	Togo
Israel	Costa Rica	Peru	Cote d`Ivoire	Uganda
Italy	Croatia	Philippines	Eritrea	Vietnam
Japan	Dominican Republic	Poland	Gambia, The	Zambia
Korea, Republic of	Ecuador	Romania	Georgia	Zimbabwe
Netherlands	Egypt	Russia	Ghana	
New Zealand	El Salvador	Saudi Arabia	Guinea	
Norway	Estonia	Serbia	Guinea-Bissau	
Portugal	Ethiopia	South Africa	Haiti	
Singapore	Gabon	Sri Lanka	Honduras	
Slovak Republic	Guatemala	Swaziland	Kenya	
Slovenia	Hungary	Syria	Kyrgyzstan	
Spain	India	Thailand	Lao	
Sweden	Indonesia	Trinidad &Tobago	Lesotho	
Switzerland	Iran	Tunisia	Liberia	
United Kingdom	Iraq	Turkey	Madagascar	
United States	Jamaica	Turkmenistan	Malawi	
	Jordan	Ukraine	Mali	
	Kazakhstan	United Arab Emirates	Mauritania	
	Kuwait	Uruguay	Moldova	
	Latvia	Uzbekistan	Mongolia	
		Venezuela	Mozambique	

Table A1: Country classifications - by geographical regions (continued)

Sub-Saharan Africa (41 countries)	South Asia (6 Countries)	Latin America & Caribbean (21 countries)	Europe & Central Asia (44 countries)
Angola	Afghanistan	Argentina	Albania
Benin	Bangladesh	Bolivia	Armenia
Botswana	India	Brazil	Austria
Burkina Faso	Nepal	Chile	Azerbaijan
Burundi	Pakistan	Colombia	Belarus
Cameroon	Sri Lanka	Costa Rica	Belgium
Central African Republic		Dominican Republic	Bulgaria
Chad	**North America (2 countries)**	Ecuador	Croatia
Congo, Dem. Rep. of		El Salvador	Cyprus
Congo, Rep.	Canada	Guatemala	Czech Republic
Cote d'Ivoire	United States	Haiti	Denmark
Eritrea		Honduras	Estonia
Ethiopia	**Middle East & North Africa (16 countries)**	Jamaica	Finland
Gabon		Mexico	France
Gambia, The	Algeria	Nicaragua	Georgia
Ghana	Bahrain	Panama	Germany
Guinea	Egypt, Arab Rep.	Paraguay	Greece
Guinea-Bissau	Iran, Islamic Rep.	Peru	Hungary
Kenya	Iraq	Trinidad and Tobago	Ireland
Lesotho	Israel	Uruguay	Italy
Liberia	Jordan	Venezuela, RB	Kazakhstan
Madagascar	Kuwait		Kyrgyzstan
Malawi	Lebanon		Latvia
Mali	Libya	**East Asia & Pacific (17 countries)**	Lithuania
Mauritania	Morocco		Macedonia, FYR
Mauritius	Oman	Australia	Moldova
Mozambique	Saudi Arabia	Cambodia	Netherlands
Namibia	Syrian Arab Republic	China	Norway
Niger	Tunisia	Hong Kong, China	Poland
Nigeria	United Arab Emirates	Indonesia	Portugal
Rwanda		Japan	Romania
Senegal		Korea, Rep.	Russian Federation
Sierra Leone		Lao PDR	Serbia
South Africa		Malaysia	Slovak Republic
Sudan		Mongolia	Slovenia
Swaziland		New Zealand	Spain
Tanzania		Papua New Guinea	Sweden
Togo		Philippines	Switzerland
Uganda		Singapore	Tajikistan
Zambia		Thailand	Turkey
Zimbabwe		Vietnam	Turkmenistan
		Timor Leste	Ukraine
			United Kingdom
			Uzbekistan

Table A.1: Country classifications (continued)

Fragile States (30 countries)		Commodity Exporters (40 countries)	
Afghanistan	Kenya	Algeria	Mali
Angola	Liberia	Angola	Mauritania
Burundi	Mauritania	Azerbaijan	Mongolia
Cameroon	Nepal	Bahrain	Mozambique
Central African Republic	Niger	Burkina Faso	Namibia
Chad	Nigeria	Burundi	Nigeria
Congo, Dem. Rep.	Pakistan	Chad	Oman
Congo, Republic of	Papua New Guinea	Chile	Papua New Guinea
Cote d`Ivoire	Rwanda	Congo, Dem. Rep.	Russia
Eritrea	Sierra Leone	Congo, Republic of	Saudi Arabia
Gambia, The	Sudan	Ecuador	Sierra Leone
Guinea	Timor-Leste	Gabon	Sudan
Guinea-Bissau	Togo	Guinea	Timor-Leste
Haiti	Uganda	Guinea-Bissau	Trinidad &Tobago
Iraq	Zimbabwe	Iran	Turkmenistan
		Iraq	United Arab Emirates
		Kazakhstan	Uzbekistan
		Kuwait	Venezuela
		Libya	Zambia
		Malawi	Zimbabwe