Income convergence and the catch-up index

Kant, Chander

Seton Hall University

16 August 2018

Income Convergence and the Catch-up Index

Chander Kant[a]

Abstract

Defining a catch-up index that measures rich-poor country income convergence and comparing it to within group convergence (β-convergence), defining relative convergence as decrease in rich-poor country income ratio and absolute convergence as decrease in rich-poor country income gap, we derive an equation for years for income equality to the frontier (full convergence). Focusing on relatively homogeneous countries of Sub-Saharan Africa and South Asia, we show neither region has achieved either within group convergence or significant catching-up since 1951, and 21 of the 28 countries exhibiting catching-up in the most recent 21-years period, using US as the frontier, show falling behind over the longer period. We show years for full convergence depend also on the initial conditions; the neo-classical hypothesis that poorer countries grow faster means relative convergence, relative convergence is a necessary but not sufficient condition for absolute convergence; "Iron law of convergence" does not hold; and within group convergence is consistent with poorer countries in the group diverging absolutely while richer countries converge.

[a]Department of Economics, Seton Hall University, South Orange, NJ 07078, USA, E-mail: chander.kant@shu.edu, Telephone: 973-202-5964, Fax: 973-761-9217

Income Convergence and the Catch-up Index

1. Introduction

This paper is concerned with measurement of inter-country income inequality and comparative development. Sala-i-Martin (1990, 1996) introduces the term β-convergence for empirical tests of the neo-classical hypothesis that poorer economies tend to grow faster.[1] The word "convergence" has simultaneously been given the following two meanings by neo-classical theory: a) tendency for the poorer economies to grow faster, and b) eventual equality of all countries' per capita incomes. See, Galor (1996). This hypothesis is tested by cross-section regressions of growth rates of a group of countries on initial per capita income where β is the regression coefficient. If the regression coefficient is significant and negative, it indicates, on average, the poorer countries in the group are growing faster. Both unconditional and conditional convergence are defined. The latter depends on similarity of the countries' structural characteristics; when they are similar, one need not distinguish between unconditional and conditional convergence.

A seemingly alternative approach to comparative incomes is to examine income ratios over time. The income ratio may either be of the richest to the poorest country, or of a group of rich countries to that of all other countries, or of a select group of rich countries to a select group of poor countries; etc. This literature takes "convergence" to mean reduction of income ratios, is a-theoretical, and has no hypothesis of eventual equality of countries' per capita incomes. See,

---

[1]In what follows, we do not use the term β-convergence for the neo-classical hypothesis itself that poorer economies tend to grow faster; we restrict its use to the empirical tests of the said hypothesis.

Pritchett (1997), Jones (1997), and Cuberes and Jerzmanowski (2009).

Barro (2015) finds unconditional β-divergence at the 0.24% rate for his Case 1, viz. 151 countries from 1960-65 to 2005-10, conditional convergence for a sample of 89 countries for the 1970-75 to 2005-10 period – conditional on variables to be discussed below, and defines what he names to be "iron law of convergence," discussed below. Ho (2006) finds β-convergence for 121 countries at 1.28% annual rate. Lim and Mcleer (2004) interpret β-convergence to mean in a time series context that differences in per capita incomes among a cross section of economies are transitory. Using this frame-work, they do not find income convergence between pairs of ASEAN-5 countries for 1960-92. Peron and Rey (2012) also use time series analysis and examine convergence of Indian Ocean Zone (IOZ) countries' incomes to the IOZ average, and catch-up to the world mean income. They find neither such convergence nor catching-up for the 1950-2008 period. Pritchett (1997) considers the 1870 to 1990 period for which no historical data for most developing countries exists. By placing a lower bound on what the 1870 income would have been, and extrapolating backwards from the 1990 levels, he concludes developing countries' fell behind rich countries' Big Time between 1870 to 1990 both proportionately and absolutely.

For 17 presently high-income countries, Maddison (1995) has collected nearly complete historical national income accounts data since 1870 that are comparable across countries. Pritchett (1997) bemoans lack of similar reliable historical data for developing countries. Nevertheless, we now have reliable data for most developing countries since 1950 in PWT. This paper uses countries in South Asia and Sub-Saharan Africa to examine income convergence with this data. Most of these countries became independent after 1946 - only three existed as independent countries before 1947 (Nepal, Liberia, and Bhutan since 1768, 1847, and 1907, respectively, per the CIA's The World Fact Book); the structural factors emphasized in the conditional convergence

literature are likely to be relatively homogeneous within each of these two regions; and most of these countries, being in the lower-end in the 1950s, had greater "advantage of backwardness" in the sense of either higher marginal product of capital (as in the neoclassical theory) or of technological imitation (as in endogenous growth model) for narrowing the income gap.

We empirically examine comparative incomes overtime with a different orientation. Rather than examine whether poorer countries tend to grow faster in general, we use a bench-mark country (the frontier) and examine the extent to which countries are succeeding in their effort to catch-up to the frontier. One can compare the catch-up rates of different countries to infer within group convergence. At the same time, as we show below, the catch-up analysis directly examines poor-rich country income convergence that within group convergence does not.

We do not examine absolute or relative personal poverty or inter-personal distribution of income; but examine relative poverty of a country, i.e., its distance from the frontier, instead. Empirically, personal income depends greatly on social and economic infra-structure, and the policies of a country where individuals live. For example, Milanovic (2015) demonstrates that where individuals live, rather than individual effort or luck, is behind a greater part of world income differences; and Sala-i-Martin (2006) shows that about two-thirds of individual income inequality in the world is due to cross-country income differences. This paper's focus is on inter-country income inequality rather than income inequality within a country.

Section 2 below defines a catch-up index and relative and absolute convergence. Section 3 examines the relationship between relative and absolute convergence, and derives an equation for number of years for income equality to the frontier. It compares the catch-up index to income ratios and within group convergence (β-convergence) and shows the neo-classical hypothesis (poorer countries grow faster) measures relative convergence, not absolute. Section 4 computes

3

the catch-up index using PWT 9.0 for countries in the sample from 1951 or later (if their PWT data availability year is after 1951) to 2013. It uses 1971 and 1992 as alternative base years and examines catching-up of the two regions and within-region convergence. Section 5 concludes.

2. Catch-up Index, and Relative and Absolute Convergence

The catch-up index and relative and absolute convergence are defined as follows. Let y_{J0} and y_{BM0} represent Country J's per-capita RGDP (defined below) for the base year and the bench-mark country's per-capita RGDP for Country J's base year, respectively, and R_{J0} Country J's base per capita RGDP ratio. Then,

$$R_{J0} = (y_{J0}/ y_{BM0}) \tag{1}$$

For each subsequent year, similar ratios of a country's annual per-capita RGDP to that of the bench-mark country are computed. Thus, for year t,

$$R_{Jt} = (y_{Jt}/ y_{BMt}) \tag{1\'}$$

We assume the bench-mark country is the richer country for all t. Then,

$$R_{Jt} = (y_{Jt}/ y_{BMt}) < 1, \text{ for all } t. \tag{2}^2$$

Country J's catch-up index for year t is the ratio of its per capita RGDP ratio for year t to its base per capita RGDP ratio. Let I_{Jt} represent this index. Then,

$$I_{Jt} = (R_{Jt}/ R_{J0}) \tag{3}$$

If the value of the catch-up index is greater than 100, or it increases, it indicates catching-

---

[2]Generally, US is taken as the bench-mark or frontier country. This is not necessary. The bench-mark or frontier can be any rich country, and one can also use total RGDP and total population of group of rich countries and call these totals as belonging to one country named, say, Frontier; as long as the bench-mark or frontier country satisfies (2).

up, i.e., an increase in Country J's (poorer country's) income ratio to the frontier's. If it is less, or it decreases, it indicates falling behind or a decrease in Country J's income ratio to the frontier's. When a poorer country's income ratio increases/decreases, we call it relative convergence/divergence. Of the two terms, catching-up/falling behind or relative convergence/relative divergence, we prefer catching-up. Its focus is on income inequality and it fits in with neo-classical and endogenous growth models' "advantage of backwardness."

In contrast to relative convergence/divergence, absolute convergence/divergence is a reduction/increase in richer-poorer country income-levels gap. As far as I can make out, the phrase relative convergence/divergence has not been used in the context of income levels. Absolute divergence has been used with the same meaning as here – an increase in rich-poor country income gap. On the other hand, absolute convergence has been used to mean convergence to the same income level unconditional on structural characteristics. We call it (absolute unconditional) full convergence; and discuss this literature below.

Let y_{Jt} and y_{Kt} and y_{Jt+1} and y_{Kt+1} represent the per capita income levels, of countries J and K, ρ_{Kt} and ρ_{Kt+1} the ratios of Country K's per-capita income to that of Country J, and Δ_{Kt} and Δ_{Kt+1} the difference between Country K's and Country J's, per-capita incomes for year t and $(t+1)$. Assume Country K's per-capita income in period t is higher than Country J's.[3] Then, the income-difference, Δ_{Kt}, is positive, and income ratio, ρ_{Kt}, is greater than one. Let the (initial) income ratio be h. In symbols,

$$\rho_{Kt} = (y_{Kt}/\, y_{Jt}) = h > 1 \text{ and } \Delta_{Kt} = (y_{Kt} - y_{Jt}) = y_{Jt}(h - 1) > 0. \qquad (4)$$

---

[3]Difference of ρ_{Kt} from R_{Jt} may be noted. In the former (latter) income ratio, we take the richer (poorer) country's income in the numerator.

Subtracting the income ratio for year t from that for year $t + 1$, we have

$$(\rho_{Kt+1} - \rho_{Kt}) = (y_{Kt+1}\, y_{Jt} - y_{Jt+1}\, y_{Kt})/\, y_{Jt+1}\, y_{Jt} \tag{5},$$

$$\text{sign } (\rho_{Kt+1} - \rho_{Kt}) = \text{sign } (y_{Kt+1}\, y_{Jt} - y_{Jt+1}\, y_{Kt}). \tag{6}$$

The sign of (6) indicates relative divergence or relative convergence. When it is positive (negative), the richer-poorer country income ratio is increasing (decreasing), and we have relative divergence (relative convergence).

Let δy_J and δy_K be the change in the two countries income from year t to $t + 1$. That is,

$$y_{Jt+1} = y_{Jt} + \delta y_J \text{ and } y_{Kt+1} = y_{Kt} + \delta y_K, \tag{7}$$

Then, Country K's income excess over that for Country J in year $t + 1$, is

$$\Delta_{Kt+1} = y_{Kt+1} - y_{Jt+1} = \Delta_{Kt} + \delta y_K - \delta y_J$$

Consider now absolute convergence/divergence. Subtracting the income gap for year t from that for year $t + 1$, we have

$$(\Delta_{Kt+1} - \Delta_{Kt}) = (\delta y_K - \delta y_J), \tag{8}.$$

The sign of (8) indicates absolute divergence or absolute convergence. When it is positive (negative), the richer-poorer country income gap is increasing (decreasing), and we have absolute divergence (absolute convergence).

Substituting (7) and (4) on the right-hand side of (6) and simplifying, we get

$$\text{sign } (y_{Kt+1}\, y_{Jt} - y_{Jt+1}\, y_{Kt}) = \text{sign } y_{Jt}\, (\delta y_K - h\, \delta y_J) = \text{sign } (\delta y_K - h\, \delta y_J) \tag{9}$$

We can re-state the condition for relative divergence/convergence in terms of the sign of the last term on the right-hand side of (9), $(\delta y_K - h\, \delta y_J)$. When it is positive (negative), the richer-poorer country income ratio is increasing (decreasing), and we have relative divergence (relative convergence).

3. Relationship Between Different Convergence Concepts

Relative convergence occurs when the income of the poor country (Country J) weighted by the ratio, h, between the income of the rich country (Country K) and that of the poor country increases more than that of the rich country. In symbols, the condition of relative convergence can be written as:

$$h \, \delta y_J > \delta y_K \qquad (10).$$

The above condition is equivalent to

$$(\delta y_J/y_J) > (\delta y_K/y_K), \text{ or } r_J > r_K \qquad (10'),$$

where r_J and r_K are the (proportionate) growth rates in per capita income of Country J and K, respectively. That is, relative convergence is equivalent to considering that the income growth rate of the poor country is higher than the growth rate of the rich country.

Absolute convergence requires more simply that the income of the poor country increases more than that of the rich country, that is:

$$\delta y_J > \delta y_K \qquad (11).$$

We now derive the relationships between relative and absolute convergence. This relationship is given by relationship between the right-hand sides of (8) and (9). We discuss the two situations below:

A. <u>Relative convergence, $(\delta y_K - h \, \delta y_J) < 0$, and absolute convergence: $(\delta y_K - \delta y_J) < 0$</u>:

Start with relative convergence, i.e., assume $(\delta y_K - h \, \delta y_J) < 0$. Given that $h > 1$, the relative convergence condition can be met irrespective of whether δy_J is greater, equal or smaller than δy_K, i.e., irrespective of whether we have absolute convergence, absolute divergence, and neither absolute convergence nor absolute divergence. Relative convergence is not a sufficient condition for absolute convergence.

Now, examine the necessary condition for absolute convergence. Consider the sign of (δy_K – $h \, \delta y_J$) as unknown. Start with assuming it to be zero. Given that $h > 1$, ($\delta y_K – h \, \delta y_J$) = 0 means δy_J is smaller than δy_K and we have absolute divergence. Similarly, ($\delta y_K – h \, \delta y_J$) > 0 means δy_J is smaller than δy_K and absolute divergence. Only if ($\delta y_K – h \, \delta y_J$) < 0 can δy_J is greater than δy_K and we can have absolute convergence. Thus, relative convergence is a necessary condition for absolute convergence. Higher growth rate of the poorer country (i.e., relative convergence) is necessary to ensure absolute convergence, but not sufficient especially when the gap between the gap between rich and poor countries is initially high.

B. <u>Relative divergence, ($\delta y_K – h \, \delta y_J$) > 0, and absolute divergence: ($\delta y_K - \delta y_J$) > 0</u>:

Relative divergence clearly implies absolute divergence (since h > 1). That is, relative divergence is a sufficient condition for absolute divergence. For the necessary part, let the sign of ($\delta y_K – h \, \delta y_J$) again be unknown. As shown above, if it is zero or positive, δy_J is smaller than δy_K and we have absolute divergence. For the third case of a negative ($\delta y_K – h \, \delta y_J$) (i.e., relative convergence), the relative magnitudes of δy_J and δy_K are unknown. Then, we can have $\delta y_J < \delta y_K$, i.e., we can have absolute divergence. We have absolute divergence when there is no relative convergence/divergence (and ($\delta y_K – h \, \delta y_J$) = 0); and we can have absolute divergence when there is relative convergence. Thus, relative divergence (although sufficient) is not necessary for absolute divergence.

When there is no relative convergence/divergence, $\delta y_K = h \, \delta y_J$ and δy_J is smaller than δy_K. That is, when the income ratio is unchanged, income gap increases and we have absolute divergence. On the other hand, when there is no absolute convergence/divergence, $\delta y_J = \delta y_K$, and ($\delta y_K – h \, \delta y_J$) < 0. Thus, when income gap remains the same, the poorer country grows faster, and we have relative convergence.

We summarize these results as

Proposition 1: Relative convergence is a necessary but not a sufficient condition for absolute convergence, and relative divergence is a sufficient but not a necessary condition for absolute divergence.

Now, we compare the catch-up index to income ratios and β-convergence.

The catch-up index is not a country's income ratio to the frontier's – it is the ratio of the said ratio for a year to a similar ratio for the base year. Income ratios between rich and poor countries have the problem of income transitions, viz. a country moving from one group to the other, or even the richest and the poorest country changing, over time. When select groups of countries are used, one rich and the other poor, the income ratios will be sensitive to how the country-groups are delineated. By calculating it for each country with reference to one bench-mark country, the catch-up index avoids these problems. It also absorbs shocks to the entire region or to the whole world. By expressing change in each country's income ratios as an index, the indices for different countries can be combined to get a region's catch-up. Income ratios cannot be so combined.

β-convergence is theory-based. Neo-classical theory predicts per capita incomes become equal to one another in the long-run, independent of their initial conditions; but gives no guidance for determining the years to achieve income equality. See, Galor (1996). The catch-up index shows what the historical facts reveal. Using it, we can derive an equation to determine years for income equality or years for full convergence.

Let r_I represent the annual (proportionate) catching-up rate, i.e., growth rate of the catch-up index (defined by (3)) of Country J to the bench-mark country since the base year 0, and r_{BM}

the corresponding (proportionate) growth rates in per capita income of the bench-mark country.

Then, it can be shown that

$$r_I = r_J - r_{BM.} \tag{12}$$

(12) shows the catching-up rate depends on our choice of the bench-mark country: Higher is the growth rate of the selected bench-mark country, lower is the catching-up rate. Let n be the year Country J's income becomes equal to the frontier's. From (Í) and (3),

$$R_{J,n} = 1 \tag{1'}$$

$$I_{J,n} = (1/R_{J,0}) \tag{3}.$$

Using the compound growth expression and solving for n,

$$I_{J,n} = I_{J,0}(1 + r_I)^n = (1 + r_I)^n$$

$$n = \log(1/R_{J,0}) / \log(1 + r_I) \tag{13}$$

(13) shows that a) the number of years for full convergence (for income to equal the frontier's) depends not only on the catching-up (relative growth) rate but also on the initial conditions; and b) higher is the catching-up rate and/or higher is the initial income ratio, smaller is the number of years for full convergence.[4] These results are stated in the following proposition:

Proposition 2: a) The number of years for full convergence (for income to equal the frontier's) depends not only on the catching-up (relative growth) rate but also on the initial conditions - in contrast from the neo-classical theory's prediction of eventual equality of incomes across countries that is independent of initial conditions; and b) higher is the catching-up rate and/or higher is the initial income ratio, smaller is the number of years for full convergence.

---

[4]Of the two factors, higher catching-up rate is more important since its effect cumulates over the years.

Barro (2015, p. 911) uses the phrase "iron law of convergence," under which "countries eliminate gaps in levels of real *per capita* GDP at a rate around 2% per year. Convergence at a 2% rate implies that it takes 35 years for half of an initial gap to vanish and 115 years for 90% to disappear." Nevertheless, a 2% higher **growth rate** does not mean **income gap** is decreasing by 2% each year: it may take generations of growth at the higher rate before income gaps start decreasing. Rather than a "law of convergence," Barro's iron law is simply an arithmetic fact that **any** real-valued number that decreases by 2% each year will become about 50% of its initial value in 35 years and 10% of its initial value in 115 years.

We next show neo-classical convergence gives relative convergence, not absolute. Irrespective of whether it is unconditional or conditional, neo-classical convergence states a poorer country tends to grow faster. Using our notation and (4), neo-classical convergence can be stated as

$$(\delta y_K / y_{K,t}) < (\delta y_J / y_{J,t}) \qquad\qquad (14)$$

$$(y_{J,t}\, \delta y_K - y_{K,t}\, \delta y_J) = y_{Jt}\, (\delta y_K - h\, \delta y_J) < 0 \qquad\qquad (1\acute{4})$$

The algebraic expression on the left of the inequality sign in $(1\acute{4})$ is the same as that on the right hand side of (9). We have seen above that when (9) is negative, we have relative convergence. That is, neo-classical convergence and relative convergence are equivalent statements. Similarly, neo-classical divergence and relative divergence are equivalent statements. Using Proposition 1, neo-classical convergence only indicates richer-poorer country income ratio is decreasing; it has no implication for whether or not richer-poorer country income gap is decreasing (i.e., whether $(\delta y_K - \delta y_J) < 0$).

No simple algebraic expression (like we have derived for years for full convergence) can be derived for the number of years of relative convergence it would take for absolute income gap

11

to starts decreasing. A heuristic exercise (with numbers based on what we calculate below) shows if the US is the bench-mark country and its initial income is $24,000, Country J's $300, and the catch-up rate is 1%, it will take 409 years of relative convergence (at 1% annual rate) for absolute convergence to start. On the other hand, if Country J's initial income is $4,800 and the catch-up rate is 5%, it will take 9 years of relative convergence (at 5% annual rate) for absolute convergence to start. Clearly, even if we know the relative convergence rate, no statement about absolute convergence, e.g., for the income gap to even **start** decreasing, can be made without knowing the initial income difference.

Sala-i-Martin (2002, p. 36) states "As China and India grew (at a faster rate than the rich world), the incomes of their numerous citizens tended to converge to those of the citizens of the rich world." Suppose China or India's initial income was $1,200 and that of the US $24,000. (In 1971, US PPP PCY was $24,185, and that of China and India were $1,342 and $1,299, respectively). Then, if they were growing at a consistently faster 5 % rate, their incomes will diverge from the US for 37 years. On the other hand, if they were growing at a consistently faster 1 % rate only, their incomes will diverge from the US for 266 years, etc. Faster growth is consistent with absolute divergence.

In the β-convergence literature, Artadi and Sala-i-Martin (2003), use the phrase absolute divergence with the same meaning given above (i.e., an increase in rich-poor income gap). Barro (2015), Galor (1996), Sala-i-Martin (1996) and Barro and Sala-i-Martin, (1992) use absolute convergence to mean unconditional (full) convergence of per capita incomes of countries to one another in the long-run independent of their initial conditions. For example, Barro (2015, 911) states "This convergence [at 2% rate for US states] was absolute in the sense of not having to be conditioned on a set of variables that capture differences in long-run positions."

Following this definition and imperative, β-convergence regressions (irrespective of whether they are unconditional or conditional) have interpreted the convergence shown by such regressions to be absolute convergence (see, Sala-i-Martin, 1996, for example)

Other differences between the catch-up index and β-convergence may be noted. The catch-up index measures rich-poor convergence; β-convergence measures within-group convergence. Since regression analysis measures the average relationship between the regressand and the regressors, even if the β-regression coefficient has the right sign, it only means average relative convergence for a group of countries. It does not mean every poorer country's income ratio with the richer country is increasing; and at the same rate. Relative convergence shown by it may be due to richer countries in the sample increasing their income ratio with still richer countries while lower-level poorer countries are falling behind both relatively and absolutely (since relative divergence is sufficient for absolute divergence).[5] In contrast, an increasing catch-up index ensures the necessary condition for absolute income gap to decrease is met. β-convergence is not directly helpful for examining poor-rich country income gaps; even though, many works on it motivate their contributions by highlighting as if their focus is on poor-rich country income gaps. For example, the first paragraph of Sala-i-Martin (1996) is wholly on this question.

Some other advantages of the catch-up index are: Being an index, individual unique indices can be combined to yield information on a group or a region's catch-up to the frontier. Growth rates (and income ratios) cannot be similarly combined since the base values will be different.

---

[5]Quah (1996) makes the related point that average shown by β-convergence regression hides that the long-run economic development process in poorer countries may occur differently than in the richer ones.

Pritchett (2000), Hausmann et al. (2005), Jerzmanowski, (2006), and Jones and Olken (2008) highlight turning points, ubiquitous "miracles" and "failures" of growth experience, within-country regime changes, and variety of "states" of developing countries and note β-convergence regressions have limited usefulness to illuminate any of these phenomenon. The catch-up index is calculated year by year and so it helps in understanding within country/region variation over time. Catch-up index (or its growth rate) regressions can be run with it as the dependent variable and variables found to be useful explaining catching-up over the long period (more than twenty years). For example, Jerzmanowski, (2006) finds such factors to be institutions, education, development of financial institutions, and geography, and Summers (2003) openness, sound money, and property rights.

4. Catch-up Index for South Asia and Sub-Saharan Africa

Index by Countries

We now construct the catch-up index for South Asia and Sub-Saharan Africa; first by countries. The index is based on PWT 9.0 (available at http://www.rug.nl/ggdc/productivity/pwt). Starting with version 8.0 (the new generation), PWT gives two versions of real GDP: using prices that are constant across countries but depend on the *current year,* CGDP; and using prices that are constant across countries and are also *constant over time,* RGDP. The R variables are well-suited for comparisons across countries and over time (see, Feenstra, et al. (2015)), and we use them.

We first take US as the frontier (and explain this choice and use an alternative bench-mark country below). RGDP data for six countries in South Asia and 40 in Sub-Saharan Africa[6] since

---

[6]RGDP data for six countries in the two regions with 1990 population of less than 0.50 m. are considered too sensitive to exceptional factors, and is not used. These are, with 1990

the earliest year it is available are used. PWT 9.0 computes RGDP from 1950 (earliest) to 2014; for 10 of these 46 countries it is available since 1950.   Annual catch-up index shows sharp changes in some years/countries.   These swings are explained by a country's business cycle not synchronizing with the US, fluctuations in GDP caused by fluctuations in FDI and capital flows to some countries, sudden resource discoveries and primary products' price changes, political upheavals and civil-wars in a country/group of countries in a year. For example, Kant (2016) reports FDI as a proportion of GDP varies from -5.89 to 22.82 for developing countries even when averaged over four years. A three-year average of a country's per-capita RGDP centered on base year, and of US per-capita RGDP centered on each country's base year, are used. The ratio of the two gives us the base per capita RGDP ratio for a country. The index was computed to 2014; its three-year 2013- centered average is used as the final value.

Table 1US gives the computed catch-up index for 2013 by country (and related results) with the first year data are available for a country as the base year - in two panels; A. for South Asia and B. for Sub-Saharan Africa. One can interpret the first row of its Panel A. is as follows. During the 53 years since 1960, Bangladesh's PPP per capita income relative to the frontier fell from 100 to 66, or by 0.78% per year, and frontier/Bangladesh income ratio rose from about 12 to 18.5 times. For countries with base years between 1951 to 1961, the worst case of falling behind in South Asia is Bangladesh; and the worst three in Sub-Saharan Africa are Central African Republic, Niger, and Democratic Republic of Congo. The five such countries in the two regions with non-negligible catching-up are (with rates in parenthesis), Botswana (4.78%), Congo

---

population in the parenthesis, Cabo Verde (0.34m.), Comoros (0.42m.), Equatorial Guinea, (0.38m), Maldives (0.22m.), Sao Tome and Principe (0.11m.), and Seychelles (0.07m.).

(0.90%), Gabon (1.14%), India (0.88%), and Lesotho (0.65%).

<Insert Table 1US here.>

Table 1US gives catching-up rates over a long period - a maximum of 62 years. We next inquire whether the catching-up performance is different over more recent periods. We consider two sub-periods: 1971 to 2013 (42 years or about two-thirds of 62), and 1992 to 2013 (21 years or about one-third of 62). Both 1971 and 1992 were normal years and qualify as base year - in neither year the US experienced a recession. Figures 1a, 1b, 2a, and 2b give similar information as Table 1US but with 1971 and 1992 as the base years, respectively.[7] (Results behind the figures is in the online Appendix Tables 1US and 2US). Vertical axis in the figures measures the income ratio, and the horizontal axis the catch-up rate. Since the income ratios are with respect to the same bench-mark country (the US), comparison of data points for a year vertically in a figure shows relative income levels of countries in that year. For example, measuring the diamonds along the vertical axis, Figure 1a shows the South Asian countries were arranged in the following order in 1971 when ranked from the poorest to the richest: Nepal, India, Bangladesh, Bhutan, Pakistan, and Sri Lanka. At the same time, comparison of different catch-up rates shows the relative growth rates, since the reference country (the US) is the same for all countries. Then, β-convergence as applied to these figures means lower is the diamond (i.e., lower the 1992 income level), further to the right should a country be positioned. Similar inference is obtained by comparing countries in either region in the two tables.

<Insert Figures 1a, 1b, 2a, and 2b here.>

---

[7]To make Figure 1b easier to read, results for Botswana are not shown in it. Botswana's 1971-2013 catch-up rate is 4.79 and US/Botswana income ratios are 2502 (1971) and 351 (2013)

None of the tables/figures meet the expectations of β-convergence. We can also run β-convergence regressions for either region. They can either be of the catching-up rates on income ratios or of PCY growth rates (obtained by subtracting the US PCY growth rate from the catching-up rates) on the initial PCY levels. None of these regression equations are statistically significant. Table 1US, figures, and β-convergence regressions do not support within region convergence in either region.

At the same time, our analysis gives meaningful results about catching-up/falling-behind the frontier. Since the initial base year (see, Table 1US), four of the six South Asian countries have either fallen behind or caught-up at miniscule rates giving 2729 to 5184 years for full convergence or income equality with the US; so have 33 of the 40 countries in Sub-Saharan Africa. In Figures 1a and 1b (i.e., since 1971, see also Results behind Figure 1 - Appendix Table 1US), countries with the worst performance (i.e., worst falling behind) in South Asia/worst three in Sub-Saharan Africa are almost the same (as in Table 1US) with Liberia, that has 1965 as the base year, replacing Niger. In South Asia, although the worst performer (Bangladesh) is the same, its falling-back rate is about one-half point lower and other countries' catching-up rates are about one-half point higher since 1971 than they were in Table 1US. The additional Sub-Saharan countries showing catching-up are, with the rate in the parenthesis, Mauritius (1.46%), Swaziland (1.14%), Sudan (0.53%), and Mali (0.51%). Of these, data is available for Swaziland and Sudan only since 1971 while Mali fell-behind from 1961 to 2013.[8] The other 32 (of the 40) Sub-Saharan countries have fallen behind from 1971 to 2013 too; and more than one-half of 37 countries with data start

---

[8]It may be noted although both Mali and Sudan exhibit about the same catching up rate since 1971, at these rates it will take Sudan 543 years to reach US income and Mali 744. The

years from 1951 to 1961 fall-behind at a higher rate (and, in one case - Gabon - catch up at a lower rate) during 1971-2013 than during 1951 to 1961 to 2013.

All six South Asian countries show catching-up since 1992 (see, Figures 2a and 2b and Results behind Figure 2 - Appendix Table 2US), i.e., Bangladesh changes from falling-behind in the earlier two periods to catching-up. The catching-up rate for all increases significantly (by about one point or more) from the 1971-2013 rate. In Sub- Saharan Africa, one country (Swaziland) changes from catching-up for the 1971-2013 period to falling-behind for 1992-2013 and 14 from falling-behind to catching-up. Two countries' (Botswana and Mauritius) catching-up rate decreases significantly and four countries' falling-behind rate increases - for two significantly. The three countries with the worst falling behind since 1992, Zimbabwe (-5.26%), Central African Republic (-3.01%), and Guinea (-3.28%) are partly the same. The best three performers are Nigeria, Zambia, and Angola; all three of them fell behind over the longer period (since either 1971 or 1951).

The above analysis shows that depending on the choice of the base year, the conclusions regarding convergence/divergence may be contradictory. The catch-up rate is the excess (or short fall) of a country's income's growth rate over the bench mark country. US as the bench mark is attractive because it is getting steadily richer at about 2% yearly since 1951. Then the same country that is catching-up from one base year, may be falling-behind from another base year because it gets richer at more than 2% from one base year and at less than 2% (or even gets poorer) from another base year.

---

reason for the difference is Mali was much poorer to start with: In 1971, US income was about 45 times Mali's while "only" about 18 times Sudan's.

The catching-up rates are also different from different base years. Generally, catching-up rates since 1992 are higher than those since either 1951-1961 or 1971. The median years for full convergence of the 28 countries catching-up since 1992 is 187 years. We do not consider it advisable to project for the next 187 years what a country has been able to achieve over the 21 years (1992-2013) period - we ought to consider its experience over the past 187 years to project 187 years in the future. Since we have reliable data for these countries for a maximum of 62 years, we ought to use at least this performance for projecting into the future. Comparison of Table 1US and Figures 1a, 1b, 2a and 2b (and Appendix Tables 1US and 2US) shows that of the 28 countries showing catching-up since 1992, 21 fell behind since 1951/their earliest base year (or caught up at miniscule rates). The seven countries that show non-minuscule catching up since the earliest base year, with the time for income equality with the US in parenthesis, are Bhutan (158 years), Botswana (79 years), Congo (317 years), Gabon (161 years), India (329 years), Lesotho (529 years), and Sudan (543 years). Their catching-up rates over the longer period is, in five out of seven countries, one-fifth (India) to about one-half (Bhutan and Lesotho) of that for 1992-2013. The caching-up of these countries is by no means steady at the 1992-2013 rates since the earlier base years also. The catching-up achieved in the 1992-2013 period is fragile.

We show income growth acceleration or "miracle" even over 21 years does not mean catching-up over a longer period. Jones and Olken (2008) show growth "miracles" and "failures" are ubiquitous at ten- and fifteen-year periods. Hausmann et al. (2005) classify growth acceleration-episodes (above average growth for eight years) by whether they had negative, poor, or above average growth in the preceding eight and the following 10 years. Easterly et al. (1993) find poor correlations between growth rates across decades. Our results add to this literature that

19

to examine long term economic development and catching-up, we should study countries' experience over periods longer than 21 years, and maybe at least thirty years.

We next consider whether the full convergence time could be shorter with some other rich country as the bench mark. Of the OECD-24 (original OECD-21 plus Japan, Australia, and New Zealand), PWT data since 1950 is available for 23; but many do not satisfy (2).[9] Of those that do, three countries with the lowest PCY growth rate are New Zealand, Australia, and US (in that order). We select New Zealand as the alternative bench mark country so that our sample countries' catching-up rates are the highest and full convergence time the shortest. New Zealand also did not suffer recession in either 1971 or in 1992 - these years can be used as alternative base years for it too.

Tables 1NZ and Appendix Tables 1NZ and 2NZ, give results similar to Tables 1US and Appendix Tables 1US and 2US, respectively; but with New Zealand as the bench mark country. Comparing Table 1NZ to 1US and Appendix Table 1NZ to Appendix Table 1US, with New Zealand as the bench mark country, the catching-up rate is uniformly higher, the falling-back rate is uniformly lower, and the time for full convergence uniformly shorter.[10] For countries with an year from 1951-1961 as the initial base-year, the median full convergence time (for all countries

---

[9]Data since 1950 is not available for Greece. Among the countries that do not meet (2) are Italy, Japan, Portugal, and Spain - their incomes are lower than those of Mauritius and South Africa in 1950s.

[10]The convergence/divergence countries since 1971 are the same as with US as the bench-mark country. With a base year from 1951-1961, one additional country, Mauritania, shows non-minuscule catching-up.

in the two regions that converge) decreases from 689 to 491 years; and with 1971 as the base year, from 276 to 176 years.

<div align="center"><Insert Table 1NZ here.></div>

Comparison is different with 1992 as the base year. Comparing Appendix Table 2NZ to Appendix Table 2US, when New Zealand is used as the bench mark country instead of the US, the catching-up rate since 1992 is everywhere lower and the full convergence time generally longer; and the median full convergence time (for countries catching up) increases from 187 to 218 years. Six countries (Benin, Burkina Faso, Côte d'Ivoire, Mauritius, Rwanda, and South Africa) fall-behind New Zealand since 1992 even though they catch-up to the US for this period. The reason for these different results is New Zealand's faster income growth than the US since 1992: US suffered Great Recession in 2008-2009 from which it recovered its 2007 income level only in 2013; New Zealand's 2008 recession was so mild that the three year moving average of its income did not decline in any year, and its 2013 income was about 112% of the 2007 level. These differing results since 1992 when the bench-mark country changes reinforce that to examine catching up to any bench mark country, we should examine a country's performance over at least 30 years.

Region's Catch-Up Index

The region-wide averages and dispersion for the country performance when US (New Zealand) is the bench-mark country are presented in the six panels of Table 2US (Table 2NZ). Geometric mean (GM) is preferred[11] as the average since it is not affected by extreme values (e.g.,

---

[11]GM has an additional advantage in this paper, since (GM of I_{Jt}) = (GM of R_{Jt}) ÷ (GM of R_{J0}), J = 1, . . N, where N is the number of countries. Similar relationships between the index and the two income ratios do not exist for their either median or arithmetic mean.

GM of 8, 27, and 125 is 30) while the median does not incorporate values of other observations in it and can be significantly affected by the inclusion/exclusion of an observation. As discussed above, this paper's focus is on inter-country income inequality. Nevertheless, we discuss the population weighted GM of the catch-up index and the region/frontier income ratios and the time for full convergence with the bench mark country towards the end of this section.[12]

<Insert Tables 2US and 2NZ here.>

Emphasizing the historical experience since the initial base year (due to fragility shown above), the average catch-up index in 2013 is 118 - with US as the bench-mark (135 - with New Zealand as the bench-mark) for South Asia giving 0.30% (0.55%) as the annual catching-up rate and 865 (425) years for full convergence or equality with the frontier's income; that for Sub-Saharan Africa is 60 (70) with falling-behind annual rate of 0.96% (0.67%) and no possibility of income-equality with the frontier. When median is used instead of the GM, the catching-up rate for South Asia since 1951 decreases, and the falling back rate for Sub-Saharan Africa increases. For South Asia, with US as the bench-mark, it decreases to 0.08; and this mere 0.22 points decrease in the catch-up rate increases the years for income equality with US (full convergence) from 865 to 3152. With 1971 as the base year, the annual catching-up is about as negative for Sub-Saharan Africa as it is since 1951 with either country as the bench-mark, but is more positive for South Asia. The catching-up for the period since 1992 is quite different when New Zealand is used as the bench mark country instead of the US. The rate decreases for both the regions. For South

---

[12]Extreme values affect the weighted arithmetic mean even more strongly by since the weights may also be extreme. For example, the population-weights of India and Nigeria are about 77% in the two regions, respectively.

Asia, the full convergence time increases from 115 to 125 years. Sub-Saharan Africa changes from catching-up – the only period it shows catching-up to the US - to falling behind. Since 1992, it catches-up to the US at 0.41% rate annually; but falls behind New Zealand at 0.24% rate.

.   Sala-i-Martin (1990, 1996) defines σ–convergence/divergence as a decrease/increase in dispersion of real per capita incomes over time. The dispersion of country PPP PC incomes in a region is given in Tables 2US (and 2NZ) by the standard deviation (scaled by geometric mean) of the income ratios in the three base-years and in 2013. For South Asia, it was almost the same from 1951 to 1971, fell slightly from 1971 to 1992 and increased sharply from 1992 to 2013 - in 2013 it was 25% (= 63.0/50.4) higher than in 1951. A generally similar picture is presented by Sub-Saharan Africa – in 2013, it was about 15% (= 90.7/78.7) higher than in 1951. These regions not only failed to catch-up to the frontier in a meaningful way or fell behind the frontier sharply, their intra-regional incomes also became more dispersed. Barro (2015) clarifies the iron law takes the form of unconditional absolute convergence for a group of countries that are reasonably homogeneous. Countries in either of these two regions are reasonably homogeneous. Yet, they do not exhibit unconditional absolute convergence.

Barro (2015) shows conditional convergence for a sample of 89 countries for the 1970-75 to 2005-10 period – conditional on eleven variables described there-in while not including either labor/population growth rate or technology. As explained above, the convergence shown by such a regression is within group relative convergence rather than absolute convergence. He includes high income countries that Pritchet (1997) shows exhibit absolute convergence and considerable movement towards income-equality with the US and excludes 19 countries from Sub-Saharan Africa and South Asia – included here - for which data are available in PWT 8/8.1 and 7.0. Conditional (relative) convergence shown by him may be due to the country-sample used and the

23

specific (eleven) controls included. As noted above, β-convergence does not mean every poorer

country in the sample has experienced relative convergence; or at the same rate. Further, as noted

by Quah (1996, p. 1048) "[A]s for conditional convergence, even in the best of all possible

scenarios, all it could show is whether each country converges to its own steady state, different

from that of other countries. It is a complete puzzle how this can be interesting for whether the

poor are catching up with the rich."

The above analyzes unweighted regional catching-up/falling-behind. It examines whether

per capita incomes of countries in a region on average, unweighted by anything, are catching-up

or falling-behind the bench mark country. The emphasis is on countries rather than on the number

of persons resident in each one of them. Weighted regional catching-up, when weights are

populations, takes account of the number of people living in each country. Let w_{it} represent the

regional population-weight of Country i, $i = 1, 2, \ldots . N$, at time t, $t = 0, 1, \ldots . T$, where N is the

number of countries in the region. The population-weighted geometric mean is

$$\text{Weighted GM} = \Pi \, I_{it}{}^{wit} = \; \Pi \, R_{it}{}^{wit} \, / \Pi \, R_{i0}{}^{wit} \tag{15}$$

where each product is taken with respect to i. That is, the population weighted geometric mean of

the catch-up index of a region for year t is the ratio of the weighted GM of each country's income-

ratios to the bench-mark country's income for year t to similar weighted GM for the base year.

Unweighted regional catch-up index and full convergence time computed earlier gives the

same weight to each country's catching-up. In population weighted GM, a more populous

country's catching-up is given more importance in the regional average - the regional average is

more influenced by the more populous country. Whether population weighted GM or unweighted

GM is used makes for a substantial difference in the results; the year whose population-weights

are used does not - since a country's share of a region's population does not change much over the

years. We choose 1990 for the population-weights since it is almost in the middle of 1971, the year from which we have data for all countries, and 2013, the final year. [13]

Compared to unweighted GMs, in both Tables 2US and 2NZ, for 1951-2013 and 1971-2013, the weighted GMs for Sub-Saharan Africa show a higher falling back rate; for South Asia they show a higher catching up rate. Those for 1992 show a sharply higher catching up rate in both the regions. These results follow from those for India and Nigeria in Tables 1US and 1NZ and in the various figures and appendix tables since their weight in the respective region's population is about 77%. India catches-up at a greater rate than the unweighted GM for South Asia for each period (and against either bench-mark country) pushing-up the weighted average; Nigeria falls back during 1971-2013 at a greater rate, and catches-up during 1992-2013 at a substantially greater rate, than the unweighted GM for Sub Saharan Africa (against either bench-mark country) pushing-up both the weighted average falling-back rate during 1971-2013 and the weighted average catching-up rate during 1992-2013.

We have explained above that we disregard the 1992-2013 performance partly because the performance over the longer period is quite different and partly because the better catching-up to the US in this period is due to its slow recovery from the 2008-2009 Great Recession. Sub-Saharan Africa shows falling back over both 1951-2013 and 1971-2013, and at a higher rate, even when we consider the population weighted GM. The better population weighted catching-up rate for South Asia for 1951-2013 does not mean South Asia is projected to reach full income convergence

---

[13]Tables US 2 and 2NZ shows the results with 1990 population weights. Those with alternative population weights, e.g. those for 2013, are almost identical, and are available from the author on request.

with the US in about 400 years and with New Zealand in 263 years. The population-weighted

projections for the two regions, or even the unweighted projections, given in Tables 2US and 2NZ

have no operational meaning - since each country follows its independent policies. The projection

given in Tables 1US and 1NZ dominate – that India is projected to reach income equality with the

US (New Zealand) in 329 (237) years, Pakistan in 5184 (780) years, etc.

4. Conclusions

The dominant method for about 25 years to test empirically the neo-classical proposition

that poorer countries tend to grow faster has been β-convergence regressions. This literature

asserts/implies the convergence shown is in income levels and go so far as to assert an "iron law

of convergence" under which a 2% faster growing poorer country eliminates 50% of income gap

in 35 years and 90% in 115 years. We point out faster growth of poorer countries only means their

income ratios with the richer countries are increasing. We call it relative convergence, show neo-

classical convergence is relative convergence, and that relative convergence is a necessary but not

a sufficient condition for income gap reduction (absolute convergence) which depends on initial

conditions also.

β-convergence regressions have limited usefulness estimating poorer-richer country

(relative) convergence – the regression result may be driven by richer countries converging with

still richer countries in the sample while the lower-level poorer countries are diverging both

relatively and absolutely (since relative divergence is sufficient for absolute divergence). The

catch-up index directly measures poor-rich convergence, can measure within-group convergence,

and unlike the β-convergence, is computed year by year and can help us understand the dynamics

and within country/region income variation and inequality over time. The neo-classical theory

predicts eventual equality of incomes that is independent of the initial conditions and gives no

26

guidance for predicting years for full convergence (eventual equality of incomes). The catch-up index is used to derive an equation for years for full convergence and shows full convergence years depend on the initial conditions too.

Using PWT 9.0 and computing catch-up index from 1951-61 to 2013, and its sub-periods, we show of the 28 (out of 46) countries in Sub-Saharan Africa and South Asia that show catching-up from 1992 to 2013 when US is the bench-mark country, 21 fell behind over the longer period (or caught up at miniscule rates). The catching-up rates in five out of rest of the seven countries since their base year, is one-fifth to about one-half of that for 1992-2013. When New Zealand is used as the bench mark country, six countries that catch-up to the US from 1992-2013 fall-behind New Zealand during this period. Countries' experience over more than 21 (maybe thirty years) should be examined to judge successful catching-up, and for projections into the future, the longest period of reliable data should be used. Sub-Saharan Africa shows no possibility of catching-up from the earliest base period; South Asia does: at 0.30% (0.55%) annual rate giving 865 (425) years for full convergence when US (New Zealand) is the bench-mark country. The sample excludes three countries (with 1990 population in parenthesis), Afghanistan (12.1m.), Eritrea (3.1m.), and Somalia (6.3m.), for which PWT data are unavailable; if they were, the two regions' falling behind/lack of catch-up and within-region divergence would most likely increase.

Sub Saharan Africa has achieved faster growth in life expectancy, of 15.6% versus 9.5% for South Asia. See, Kant (2018). Nevertheless, Jones and Klenow (2016) find higher within country inequality in developing countries' neutralizes their higher life expectancy growth; and for countries in their sample, their measure of well-being (that also considers leisure and inequality) has a correlation of .98 with real GDP per capita. Real GDP per capita remains the

primary statistic of both catching-up and well-being. Using it, we show how persistent inter-country and rich-poor income inequalities are.

References

Artadi, E.V. and X. Sala-i-Martin (2003). 'The Economic Tragedy of The XXth Century: Growth in Africa', Working Paper 9865, National Bureau of Economic Research, July

Barro, R.J. (2015). 'Convergence and Modernization'. *The Economic Journal,* 125, June, 911-942.

Barro, R. J. and X. Sala-i-Martin 1992). 'Convergence'. *Journal of Political Economy,* 100, 223–51.

Cuberes, D. and M. Jerzmanowski (2009). 'Democracy, Diversification and Growth Reversals', *Economic Journal*, 119(540), 1270-1302.

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 (3), 459 – 483.

Feenstra, R.C., R. Inklaar, and M.P. Timmer (2015). 'The Next Generation of the Penn World Table,' American Economic Review, 105(10), 3150-82.

Galor, O. (1996). 'Convergence?: Inferences from Theoretical Models', *Economic Journal*, 106 (437), 1056-1069.

Hausmann, R., L. Pritchett and D. Rodrik (2005). 'Growth Accelerations', *Journal of Economic Growth*, 10(4), 303-329.

Ho, T-W. (2006). 'Income Thresholds and Growth Convergence: A Panel Data Approach', *Manchester School*, 74(2), March, 170-89

Jerzmanowski, M., (2006). 'Empirics of Hills, Plateaus, Mountains and Plains: A Markov-Switching Approach to Growth', *Journal of Development Economics*, 81(2), 357-385.

Jones, C.I. and P.J. Klenow (2016). 'Beyond GDP? Welfare across Countries and Time', *American Economic Review,* 106(9), 2426-57.

Jones, C.I. (1997). 'On the Evolution of the World Income Distribution', *Journal of Economic Perspectives*, 11(3), Summer 1997, 19-36.

Jones, B.F., and A. Olken (2008). 'The Anatomy of Start-Stop Growth', *Review of Economics and Statistics,* 90(3), 582-587.

Kant, C. (2016). 'Are Institutions in Developing Countries Malleable?' *Journal of Policy Modelling,* 38(2), 272–289.

Kant, C. (2018). 'Stillbirth: An under-recognized health problem,' available at http://ssrn.com/abstract=2909344

Lim L.K. and M. McAleer (2004). 'Convergence and Catching up in ASEAN: a Comparative Analysis', Applied Economics, 36, 137-153.

Maddison, A. (1995). 'Monitoring the World Economy, 1820-1992'. Paris: Development Centre of the Organization for Economic Co-operation Development.

Milanovic, B (2015). 'Global Inequality of Opportunity: How Much of Our Income Is Determined by Where We Live?', *The Review of Economics and Statistics* 97 (2), 452-460.

Peron,O. and S. Rey (2012). 'Trade and Convergence of Per Capita Income in the Indian Ocean Zone, 1950-2008', *Annals of Regional Science,* 49, 657-683.

Pritchett, L. (2000). 'Understanding Patterns of Economic Growth: Searching for Hills among Plateaus, Mountains, and Plains', *World Bank Economic Review,* 14 (2), 221-250.

Pritchett, L. (1997). 'Divergence, Big Time'. *Journal of Economic Perspectives,* 11(3), 3-17.

Quah, D. (1996). 'Twin Peaks: Growth and Convergence in Models of Distribution Dynamics', *Economic Journal,* 106, 1045-1055.

Sala-i-Martin, X. (2006). 'The World Distribution of Income: Falling Poverty And... Convergence, Period', *The Quarterly Journal of Economics*, 121 (2), 351-397.

Sala-i-Martin, X. (2002). The Disturbing ''Rise'' of Global Income Inequality, NBER Work. Paper, 8904

Sala-i-Martin, X. (1996). 'The Classical Approach to Convergence Analysis', *Economic Journal* 106 (437), 1019–1036.

Sala-i-Martin, X. (1990). 'On Growth and States', PhD thesis, Harvard University, Cambridge MA

Summers, L. H. (2003). "Godkin Lectures," John F. Kennedy School of Government, Harvard University (April).

World Bank, 1978 and 2013. World Development Report. Washington, D.C.

Table 1US: Catch-up to US Index by Country

Country	Base Year	No. of Yrs.	Catch-Up Index Ind.2013	Catch-Up Index Gr. Rate	Y-Equality w. US Years	US/Country PPP PCY Base Year	US/Country PPP PCY 2013
			a. South Asia				
Bangladesh	1960	53	66	-0.78		1224	1843
Bhutan	1971	42	209	1.77	158	1612	769
India	1951	62	172	0.88	329	1777	1035
Nepal	1961	52	105	0.09	3465	2582	2458
Pakistan	1951	62	103	0.05	5184	1184	1147
Sri Lanka	1951	62	104	0.06	2729	562	539
			b. Sub Saharan Africa				
Angola	1971	42	77	-0.62		505	660
Benin	1960	53	41	-1.67		1139	2801
Botswana	1961	52	1136	4.78	79	3984	351
Burkina Faso	1960	53	78	-0.47		2691	3461
Burundi	1961	52	43	-1.61		3001	6942
Cameroon	1961	52	72	-0.63		1427	1976
Cent. Afri. Rep.	1961	52	18	-3.24		1290	7339
Chad	1961	52	32	-2.17		860	2647
Congo	1961	52	159	0.90	317	1685	1057
Côte d'Ivoire	1961	52	61	-0.95		988	1625
Congo, Dem. Rep.	1951	62	16	-2.91		755	4799
Ethiopia	1951	62	101	0.02	23239	4166	4135
Gabon	1961	52	180	1.14	161	619	344
Gambia	1961	52	34	-2.05		1136	3316
Ghana	1956	57	51	-1.17		708	1391
Guinea	1960	53	23	-2.73		904	3856
Guinea-Bissau	1961	52	47	-1.44		1961	4132
Kenya	1951	62	48	-1.18		906	1899
Lesotho	1961	52	140	0.65	529	3062	2188
Liberia	1965	48	23	-3.02		1508	6431
Madagascar	1961	52	31	-2.23		1374	4439
Malawi	1955	58	40	-1.57		2131	5372
Mali	1961	52	91	-0.18		3309	3626
Mauritania	1961	52	97	-0.06		1616	1668
Mauritius	1951	62	109	0.14	848	325	300
Mozambique	1961	52	70	-0.68		3393	4853
Namibia	1961	52	86	-0.29		435	504
Niger	1961	52	20	-3.05		1243	6092
Nigeria	1951	62	59	-0.85		548	937
Rwanda	1961	52	55	-1.14		1869	3407
Senegal	1961	52	35	-2.00		823	2370
Sierra Leone	1962	51	58	-1.06		1880	3251
South Africa	1951	62	70	-0.57		296	425
Sudan	1971	42	125	0.53	543	1788	1432
Swaziland	1971	42	166	1.21	194	1042	627
Tanzania	1961	52	58	-1.04		1413	2420
Togo	1961	52	45	-1.52		1780	3945
Uganda	1951	62	56	-0.93		1604	2853
Zambia	1956	57	45	-1.39		644	1418
Zimbabwe	1955	58	33	-1.89		970	2908

Notes: Based on PWT 9.0 and derivations in the text. Base year is 1951 or the earliest data availability year.

Table 1NZ: Catch-up to New Zealand Index by Country

Country	Base Year	No. of Yrs.	Catch-Up Index Ind.2013	Catch-Up Index Gr. Rate	Y-Equality w. NZ Years	NZ/Country PPP Base Year	PCY 2013
			A. South Asia				
Bangladesh	1960	53	78	-0.47		947	1207
Bhutan	1971	42	221	1.91	128	1112	504
India	1951	62	197	1.10	237	1335	678
Nepal	1961	52	127	0.46	656	2043	1610
Pakistan	1951	62	119	0.28	780	893	751
Sri Lanka	1951	62	120	0.29	491	424	353
			B. Sub Saharan Africa				
Angola	1971	42	81	-0.50		348	432
Benin	1960	53	48	-1.38		882	1835
Botswana	1961	52	1371	5.16	69	3151	230
Burkina Faso	1960	53	92	-0.16		2085	2267
Burundi	1961	52	52	-1.25		2373	4548
Cameroon	1961	52	87	-0.27		1129	1294
Cent. Afri. Rep.	1961	52	21	-2.96		1021	4785
Chad	1961	52	39	-1.79		680	1734
Congo	1961	52	193	1.27	205	1332	691
Côte d'Ivoire	1961	52	73	-0.60		781	1065
Congo, Dem. Rep.	1951	62	18	-2.73		564	3152
Ethiopia	1951	62	115	0.23	1526	3118	2709
Gabon	1961	52	217	1.50	107	490	225
Gambia	1961	52	41	-1.70		898	2171
Ghana	1956	57	57	-0.98		515	910
Guinea	1960	53	28	-2.37		701	2526
Guinea-Bissau	1961	52	57	-1.08		1552	2705
Kenya	1951	62	55	-0.96		680	1243
Lesotho	1961	52	169	1.01	316	2421	1433
Liberia	1965	48	28	-2.62		1185	4213
Madagascar	1961	52	37	-1.89		1087	2907
Malawi	1955	58	45	-1.37		1572	3514
Mali	1961	52	110	0.18	1781	2618	2374
Mauritania	1961	52	117	0.30	844	1278	1093
Mauritius	1951	62	125	0.36	249	245	196
Mozambique	1961	52	84	-0.33		2683	3181
Namibia	1961	52	104	0.08	1638	344	330
Niger	1961	52	25	-2.63		983	3989
Nigeria	1951	62	67	-0.64		411	613
Rwanda	1961	52	66	-0.80		1478	2232
Senegal	1961	52	42	-1.65		651	1553
Sierra Leone	1962	51	70	-0.70		1497	2129
South Africa	1951	62	80	-0.36		224	278
Sudan	1971	42	131	0.64	391	1233	939
Swaziland	1971	42	175	1.34	148	720	411
Tanzania	1961	52	71	-0.66		1118	1585
Togo	1961	52	54	-1.18		1408	2586
Uganda	1951	62	64	-0.72		1201	1868
Zambia	1956	57	50	-1.21		468	929
Zimbabwe	1955	58	38	-1.65		716	1906

Notes: as above.

Table 2US: Catch up to US Index - Averages & Dispersion

Average/Dispersion	No. of Yrs.	Catch-Up Index Ind.2013	Catch-Up Index Gr. Rate	Y-Equality w. US Years	US/Country Base Year	PPP PCY 2013
				a. South Asia		
			a.1 Base Year = 1951 or Later[a]			
Geometric Mean	55	118	0.30	865	1349	1143
Std. Dev.	8	53			680	720
StdDev/GeoMean	14.7	45			50.4	63.0
1990Pop_Wtd. Geo. Mean	55	147	0.70	399	1631	1109
			a.2 Base Year = 1971			
Geometric Mean	42	142	0.84	334	1623	1143
Std. Dev.		43			810	720
StdDev/GeoMean		30.4			49.9	63.0
1990Pop_Wtd. Geo. Mean	42	162	1.16	251	1795	1109
			a.3 Base Year = 1992			
Geometric Mean	21	172	2.62	115	1970	1143
Std. Dev.		52			930	720
StdDev/GeoMean		30			47.2	63.0
1990Pop_Wtd. Geo. Mean	21	228	4.00	82	2523	1109
				b. Sub-Saharan Africa		
			b1. Base Year = 1951 or Later[a]			
Geometric Mean	53	60	-0.96		1264	2110
Std. Dev.	5	174			994	1913
StdDev/GeoMean	9.8	290.8			78.7	90.7
1990Pop_Wtd. Geo. Mean	53	55	-1.12		1077	1959
			b2. Base Year = 1971			
Geometric Mean	42	66	-0.98		1385	2110
Std. Dev.		109			1035	1913
StdDev/GeoMean		166.3			74.8	90.7
1990Pop_Wtd. Geo. Mean	42	60	-1.21		1178	1959
			b3. Base Year = 1992			
Geometric Mean	21	109	0.41	765	2310	2110
Std. Dev.		99			2136	1913
StdDev/GeoMean		90.3			92.5	90.7
1990Pop_Wtd. Geo. Mean	21	154	2.08	166	3013	1959

Note: [a] Later means from 1951 to 1961

Table 2NZ: Catch up to New Zealand Index - Averages & Dispersion

Average/Dispersion	No. of Yrs.	Catch-Up Index Ind.2013	Gr. Rate	Y-Equality w. NZ Years	NZ/Country Base Year	PPP PCY 2013
				A. South Asia		
			A.1 Base Year = 1951 or Later[a]			
Geometric Mean	55	135	0.55	425	1014	749
Std. Dev.	8	54			541	471
StdDev/GeoMean	14.7	39.9			53.4	63.0
1990Pop_Wtd. Geo. Mean	55	169	0.96	263	1230	726
			A.2 Base Year = 1971			
Geometric Mean	42	150	0.97	250	1120	749
Std. Dev.		45			559	471
StdDev/GeoMean		30.3			49.9	63.0
1990Pop_Wtd. Geo. Mean	42	170	1.27	199	1239	726
			A.3 Base Year = 1992			
Geometric Mean	21	150	1.95	125	1125	749
Std. Dev.		45			531	471
StdDev/GeoMean		29.9			47.2	63.0
1990Pop_Wtd. Geo. Mean	21	198	3.31	82	1441	726
				B. Sub-Saharan Africa		
			B1. Base Year = 1951 or Later[a]			
Geometric Mean	53	70	-0.67		971	2110
Std. Dev.	5	210			780	1913
StdDev/GeoMean	9.8	299			80.3	90.7
1990Pop_Wtd. Geo. Mean	53	64	-0.84		815	1283
			B2. Base Year = 1971			
Geometric Mean	42	69	-0.88		956	2110
Std. Dev.		115			715	1913
StdDev/GeoMean		166.6			74.8	90.7
1990Pop_Wtd. Geo. Mean	42	63	-1.09		813	1283
			B3. Base Year = 1992			
Geometric Mean	21	95	-0.24		1318	1382
Std. Dev.		86			1217	1252
StdDev/GeoMean		90			92.3	90.6
1990Pop_Wtd. Geo. Mean	21	134	1.40	204	1719	1283

Note: [a] Later means from 1951 to 1961

FIGURE 1A: CATCHING-UP/FALLING BEHIND TO US SOUTH ASIA, 1971-2013
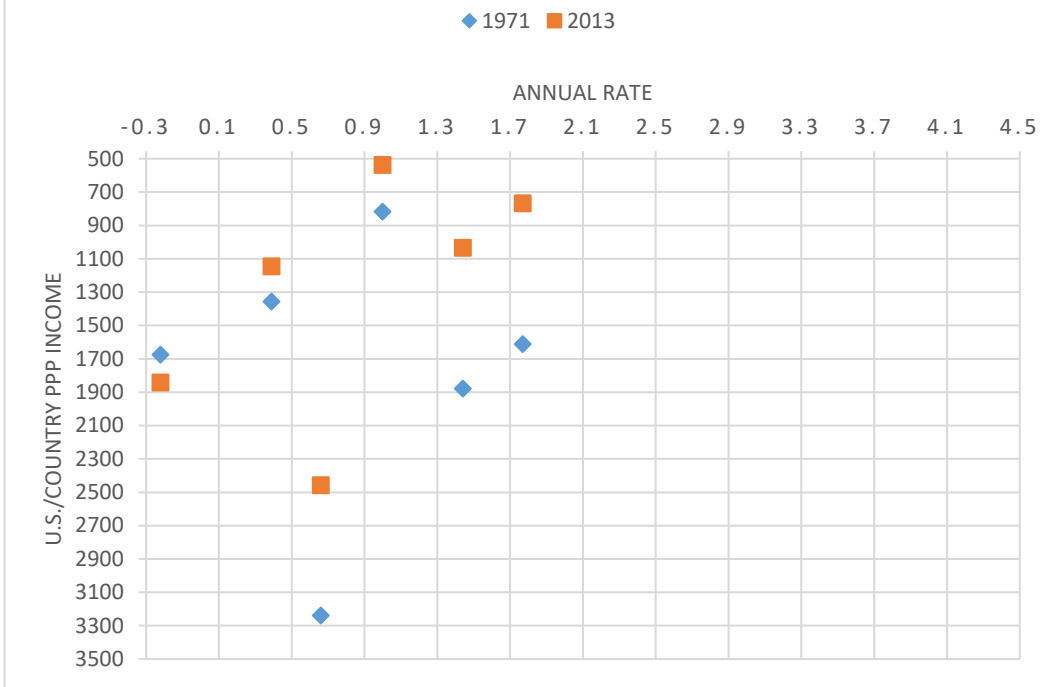
Note: Data points from left to right are for countries in the following order: Bangladesh, Pakistan, Nepal, Sri Lanka, India, and Bhutan.

FIGURE 2A: CATCHING-UP/FALLING BEHIND TO US SOUTH ASIA, 1992-2013
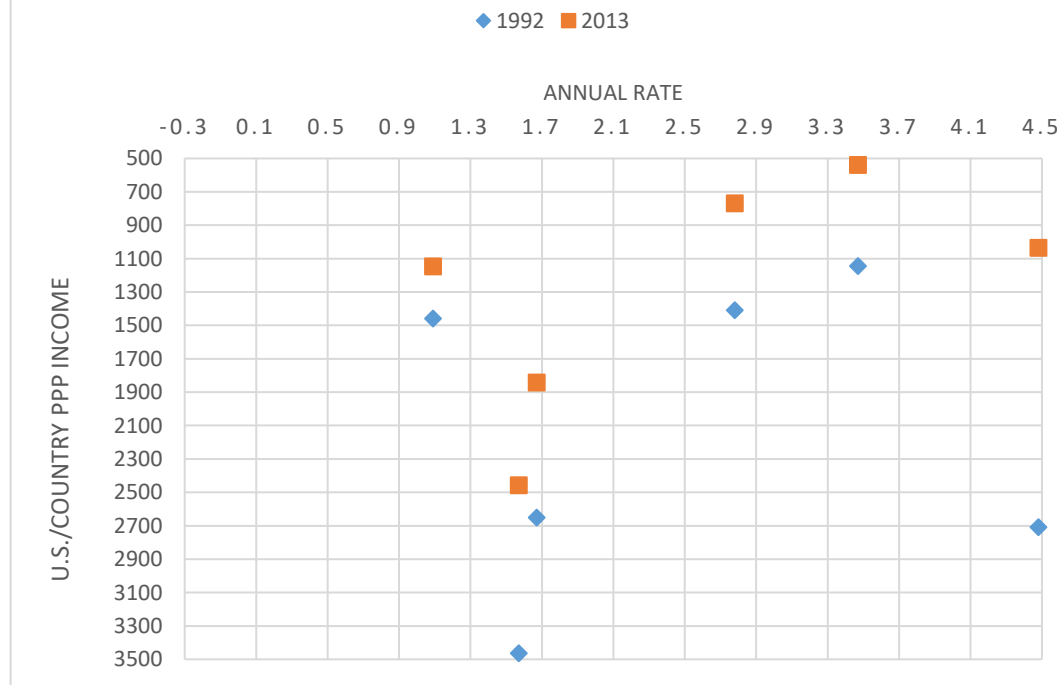
Note: Data points from left to right are for countries in the following order: Pakistan, Nepal, Bangladesh, Bhutan, Sri Lanka, and India.

FIGURE 1B: CATCHING-UP/FALLING-BEHIND TO US SUB-SAHARAN AFRICA, 1971-2013 (EXCLUDING BOTSWANA)
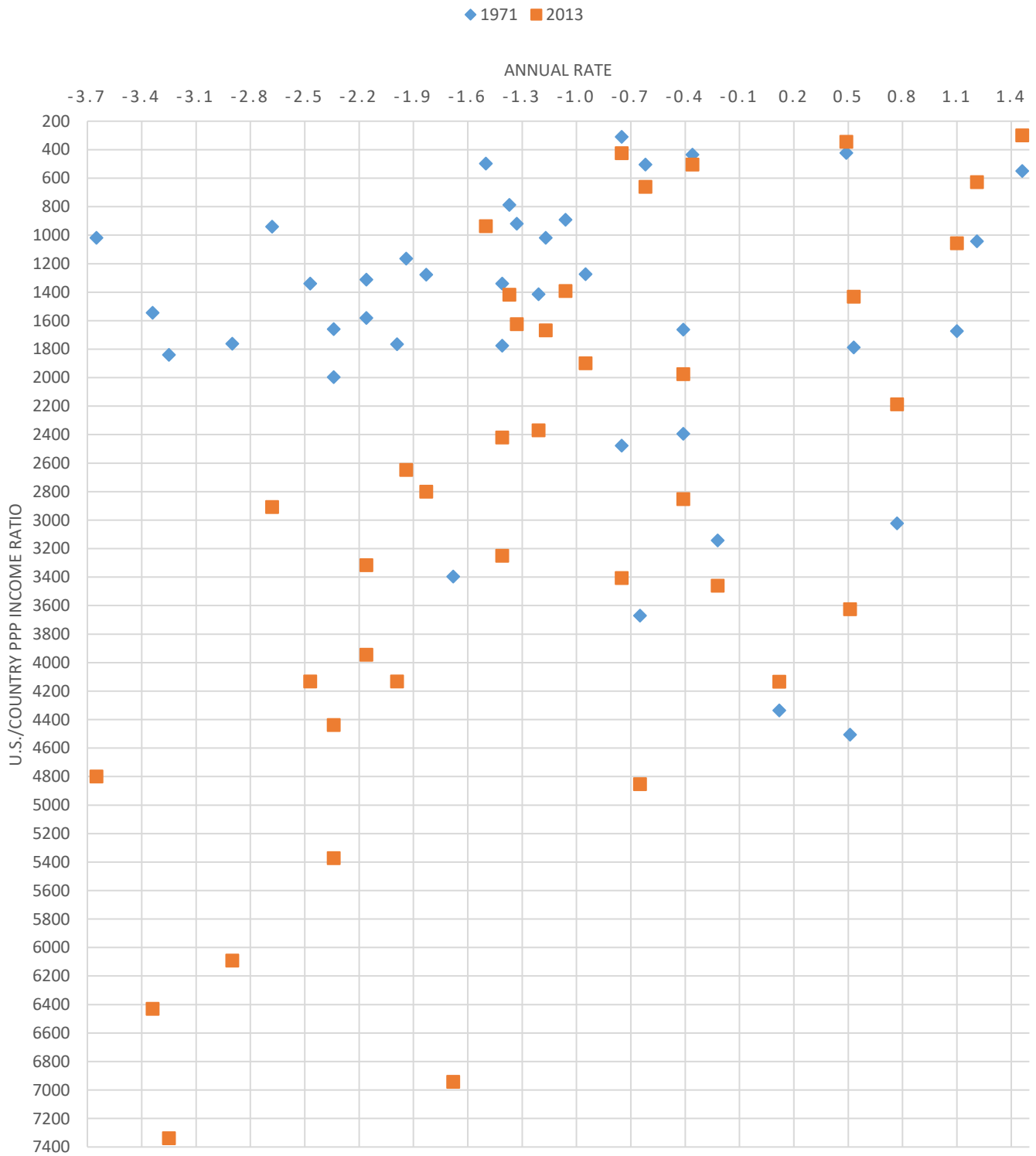
Note: Data points from left to right are for countries in the following order: Congo - DRC, Liberia, Central African Republic, Niger, Zimbabwe, Guinea, Madagascar, Malawi, Gambia, Togo, Guinea-Bissau, Chad, Benin, Burundi, Nigeria, Sierra Leone, Tanzania, Zambia, Ivory Coast, Senegal, Mauritania, Ghana, Kenya, Rwanda, South Africa, Mozambique, Angola, Cameroon, Uganda, Namibia, Burkina Faso, Ethiopia, Gabon, Mali, Sudan, Lesotho, Congo, Swaziland, and Mauritius.

FIGURE 2B: CATCHING-UP/FALLING-BEHIND TO US SUB-SAHARAN AFRICA, 1992-2013

◆ 1992   ■ 2013

ANNUAL RATE

y-axis: U.S./COUNTRY PPP INCOME RATIO
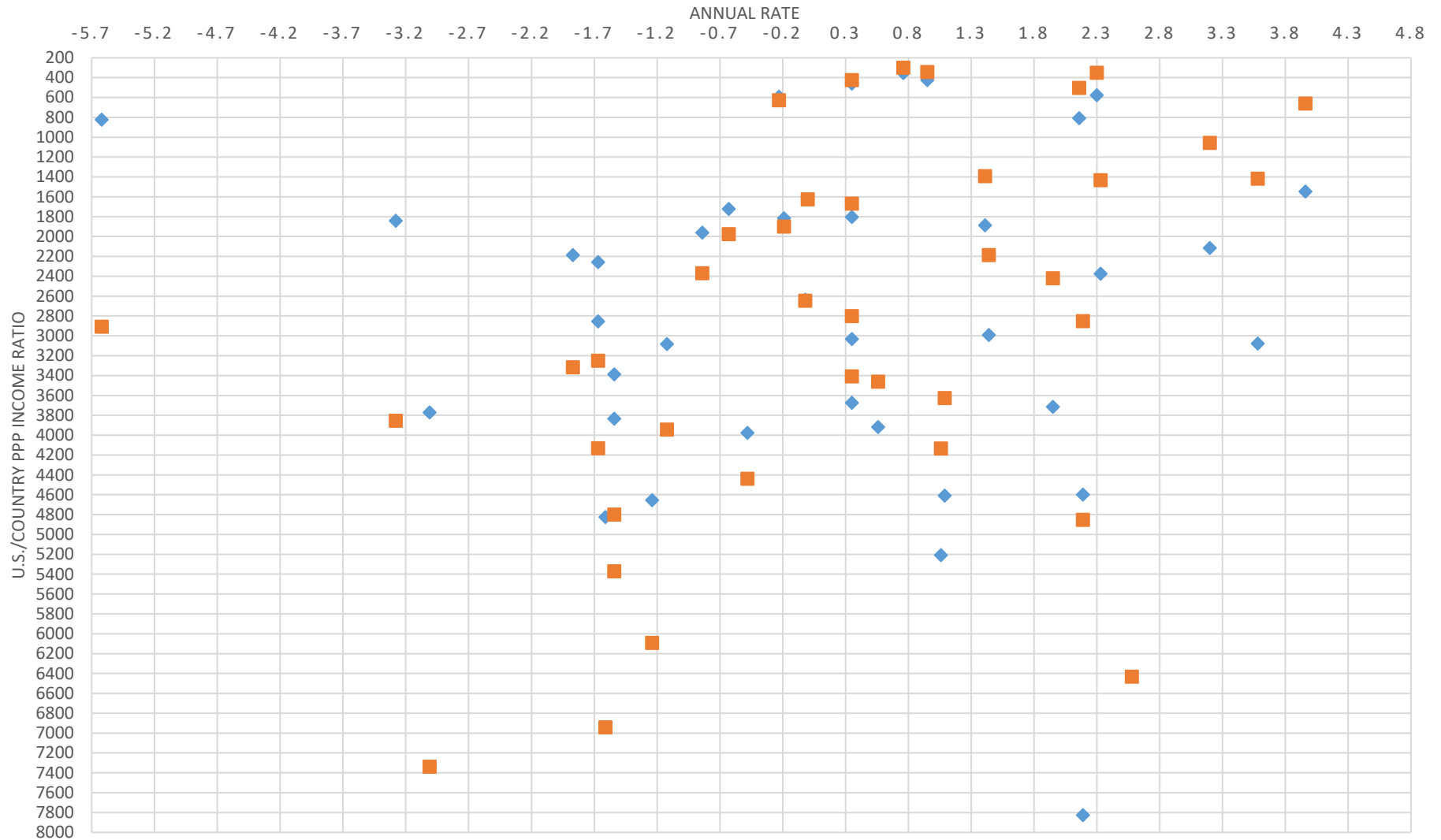
Note Data points from left to right are for countries in the following order: Zimbabwe, Guinea, Central African Republic, Gambia, Guinea-Bissau, Sierra Leone, Burundi, Congo-D.R.C., Malawi, Niger, Togo, Senegal, Cameroon, Madagascar, Swaziland, Kenya, Chad, Ivory Coast, Benin, Mauritania, Rwanda, South Africa, Burkina Faso, Mauritius, Gabon, Ethiopia, Mali, Ghana, Lesotho, Tanzania, Namibia, Mozambique, Uganda, Botswana, Sudan, Liberia, Congo, Zambia, and Angola. Data for Nigeria is not shown due to the very large value (9.0) of its catch-up rate during this period, and the 1992 U.S./Liberia income ratio of 11243 is outside the figure.

Results Behind Figure 1 - Appendix Table 1US

Country	Catch-Up Index Ind. 2013	Gr. Rate	Y-Convergence w. US Years	US/Country PPP PCY 1971	2013
a. South Asia					
Bangladesh	91	-0.22		1675	1843
Bhutan	209	1.77	158	1612	769
India	182	1.44	206	1879	1035
Nepal	132	0.66	526	3240	2458
Pakistan	118	0.39	662	1357	1147
Sri Lanka	152	1.00	211	818	539
b. Sub Saharan Africa					
Angola	77	-0.62		505	660
Benin	46	-1.83		1278	2801
Botswana	713	4.79	69	2502	351
Burkina Faso	91	-0.22		3143	3461
Burundi	49	-1.68		3396	6942
Cameroon	84	-0.41		1663	1976
Central African Republic	25	-3.25		1840	7339
Chad	44	-1.94		1165	2647
Congo	158	1.10	259	1673	1057
Côte d'Ivoire	57	-1.33		919	1625
Dem. Rep. of Congo	21	-3.65		1018	4799
Ethiopia	105	0.12	3245	4335	4135
Gabon	123	0.49	292	422	344
Gambia	40	-2.16		1312	3316
Ghana	64	-1.06		892	1391
Guinea	35	-2.47		1340	4132
Guinea-Bissau	43	-1.99		1766	4132
Kenya	67	-0.95		1274	1899
Lesotho	138	0.77	445	3023	2188
Liberia	24	-3.34		1545	6431
Madagascar	37	-2.34		1660	4439
Malawi	37	-2.34		1997	5372
Mali	124	0.51	744	4506	3626
Mauritania	61	-1.17		1019	1668
Mauritius	184	1.46	117	550	300
Mozambique	76	-0.65		3671	4853
Namibia	86	-0.36		435	504
Niger	29	-2.90		1762	6092
Nigeria	53	-1.50		498	937
Rwanda	73	-0.75		2477	3407
Senegal	60	-1.21		1415	2370
Sierra Leone	55	-1.41		1775	3251
South Africa	73	-0.75		309	425
Sudan	125	0.53	543	1788	1432
Swaziland	166	1.21	194	1042	627
Tanzania	55	-1.41		1339	2420
Togo	40	-2.16		1581	3945
Uganda	84	-0.41		2394	2853
Zambia	56	-1.37		788	1418
Zimbabwe	32	-2.68		941	2908

Note: The base year for all countries in this Table is 1971 (and the number of years is 42).

Country	Catch-Up Index Ind. 2013	Gr. Rate	Y-Convergence w. NZ Years	NZ/Country PPP PCY Base Year	2013
			a. South Asia		
Bangladesh	96	-0.10		1155	1207
Bhutan	221	1.91	128	1112	504
India	191	1.55	166	1297	678
Nepal	139	0.79	396	2235	1610
Pakistan	125	0.53	421	936	751
Sri Lanka	160	1.13	155	565	353
			b. Sub Saharan Africa		
Angola	81	-0.50		348	432
Benin	48	-1.73		882	1835
Botswana	752	4.92	59	1729	230
Burkina Faso	96	-0.10		2170	2267
Burundi	51	-1.59		2342	4548
Cameroon	89	-0.28		1148	1294
Central African Republic	27	-3.07		1269	4785
Chad	46	-1.83		804	1734
Congo	167	1.23		1155	691
Côte d'Ivoire	60	-1.21		634	1065
Dem. Rep. of Congo	22	-3.54		702	3152
Ethiopia	110	0.23	1498	2993	2709
Gabon	129	0.61	176	291	225
Gambia	42	-2.04		905	2171
Ghana	68	-0.91		615	910
Guinea	37	-2.34		925	2526
Guinea-Bissau	45	-1.88		1218	2705
Kenya	71	-0.81		880	1243
Lesotho	146	0.91	337	2087	1433
Liberia	25	-3.25		1066	4213
Madagascar	39	-2.22		1146	2907
Malawi	39	-2.22		1379	3514
Mali	131	0.64	534	3107	2374
Mauritania	64	-1.06		703	1093
Mauritius	193	1.58	85	380	196
Mozambique	80	-0.53		2533	3181
Namibia	91	-0.22		300	330
Niger	30	-2.83		1215	3989
Nigeria	56	-1.37		344	613
Rwanda	77	-0.62		1709	2232
Senegal	63	-1.09		976	1553
Sierra Leone	58	-1.29		1225	2129
South Africa	77	-0.62		213	278
Sudan	131	0.64	391	1233	939
Swaziland	175	1.34	148	720	411
Tanzania	58	-1.29		924	1585
Togo	42	-2.04		1091	2586
Uganda	88	-0.3		1652	1868
Zambia	58	-1.29		543	929
Zimbabwe	34	-2.54		650	1906

Note: The base year for all countries in this Table is 1971 (and the number of years is 42).

Results Behind Figure 2 - Appendix Table 2US

Country	Catch-Up Index Ind. 2013	Gr. Rate	Y-Convergence w. US Years	US/Country PPP PCY 1992	2013
		a. South Asia			
Bangladesh	144	1.67	198	2652	1843
Bhutan	183	2.78	96	1410	769
India	262	4.48	75	2709	1035
Nepal	141	1.57	227	3464	2458
Pakistan	127	1.09	247	1458	1147
Sri Lanka	212	3.47	71	1144	539
		b. Sub Saharan Africa			
Angola	235	3.96	71	1547	660
Benin	108	0.35	975	3032	2801
Botswana	165	2.30	77	577	351
Burkina Faso	113	0.56	660	3918	3461
Burundi	70	-1.61		4826	6942
Cameroon	87	-0.63		1723	1976
Central African Republic	51	-3.01		3771	7339
Chad	99.6	-0.02		2637	2647
Congo	200	3.20	97	2116	1057
Côte d'Ivoire	100.1	0.00	61396	1627	1625
Dem. Rep. of Congo	71	-1.54		3389	4799
Ethiopia	126	1.06	376	5208	4135
Gabon	123	0.95	154	425	344
Gambia	66	-1.87		2188	3316
Ghana	136	1.41	210	1888	1391
Guinea	48	-3.28		1842	3856
Guinea-Bissau	69	-1.67		2855	4132
Kenya	96	-0.19		1815	1899
Lesotho	137	1.44	238	2993	2188
Liberia	175	2.58	186	11243	6431
Madagascar	90	-0.48		3978	4439
Malawi	71	-1.54		3835	5372
Mali	127	1.09	353	4610	3626
Mauritania	108	0.35	827	1803	1668
Mauritius	118	0.76	168	355	300
Mozambique	161	2.19	201	7825	4853
Namibia	160	2.16	98	807	504
Niger	76	-1.24		4656	6092
Nigeria	665	8.99	48	6232	937
Rwanda	108	0.35	1030	3675	3407
Senegal	83	-0.84		1960	2370
Sierra Leone	69	-1.67		2258	3251
South Africa	108	0.35	436	460	425
Sudan	166	2.33	137	2374	1432
Swaziland	95	-0.23		593	627
Tanzania	153	1.95	187	3715	2420
Togo	78	-1.12		3084	3945
Uganda	161	2.19	177	4600	2853
Zambia	217	3.58	97	3079	1418
Zimbabwe	28	-5.62		823	2908

Note: The base year for all countries in this Table is 1992 (and the number of years is 21).

Appendix Table 2NZ

Country	Catch-Up Index		Y-Convergence	NZ/Country PPP PCY	
	Ind. 2013	Gr. Rate	w. NZ Years	1992	2013
a. South Asia					
Bangladesh	125	1.02	268	1514	1207
Bhutan	160	2.16	98	805	504
India	228	3.82	73	1547	678
Nepal	123	0.95	317	1979	1610
Pakistan	111	0.48	447	832	751
Sri Lanka	185	2.84	67	654	353
b. Sub Saharan Africa					
Angola	204	3.29	67	883	432
Benin	94	-0.28		1731	1835
Botswana	143	1.64	73	330	230
Burkina Faso	99	-0.05		2237	2267
Burundi	61	-2.22		2752	4548
Cameroon	76	-1.24		983	1294
Central African Republic	45	-3.56		2152	4785
Chad	87	-0.63		1505	1734
Congo	175	2.58	98	1208	691
Côte d'Ivoire	87	-0.63		928	1065
Dem. Rep. of Congo	61	-2.22		1930	3152
Ethiopia	110	0.43	783	2973	2709
Gabon	108	0.35	254	243	225
Gambia	58	-2.45		1249	2171
Ghana	118	0.76	316	1078	910
Guinea	42	-3.87		1051	2526
Guinea-Bissau	60	-2.30		1630	2705
Kenya	83	-0.84		1036	1243
Lesotho	119	0.79	359	1710	1433
Liberia	152	1.92	218	6397	4213
Madagascar	78	-1.12		2271	2907
Malawi	62	-2.15		2190	3514
Mali	111	0.48	690	2636	2374
Mauritania	94	-0.28		1030	1093
Mauritius	103	0.13	523	202	196
Mozambique	140	1.54	248	4467	3181
Namibia	140	1.54	100	461	330
Niger	67	-1.80		2657	3989
Nigeria	579	8.31	45	3552	613
Rwanda	94	-0.28		2098	2232
Senegal	72	-1.48		1119	1553
Sierra Leone	61	-2.22		1290	2129
South Africa	94	-0.28		263	278
Sudan	144	1.67	157	1355	939
Swaziland	83	-0.84		339	411
Tanzania	134	1.34	230	2119	1585
Togo	68	-1.74		1757	2586
Uganda	141	1.57	209	2626	1868
Zambia	189	2.94	99	1756	929
Zimbabwe	25	-6.11		470	1906

Note: The base year for all countries in this Table is 1992 (and the number of years is 21).