DIVERGENCE (UNCONDITIONAL, CONDITIONAL AND IN OECD)

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Abstract

Convergence of inter-country incomes is a widely studied subject in economics. However, faster growth does not imply income gap reduction - it only implies an increase in income ratio – and β-convergence does not imply income differences decrease, We define the convergence rate and using data from three different sources from 1950 to 2024, show there has been unconditional and conditional divergence from the smallest (OECD) to the largest group of countries; and both in general/OECD, the lower the initial income greater is the divergence rate. The reason for income divergence is the divergence in TFP from the world technological frontier.

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Divergence (Unconditional, Conditional and in OECD)

The key word "convergence" has been used in a wide variety of situations in economics literature. A search for it on econlit on December 21, 2025 yielded 50,837 hits since Carroll (1952) - who seems to have first used it. We limit ourselves to inter-country convergence of income/output per capita or per worker.[1] Section 1 reviews and synthesizes the various relevant meanings of "convergence" have been given in the literature from 1957 (Easterlin) to date them.

In the next section (Section 2), we develop the concept of relative convergence – a concept developed by Kant (2019) - and prove it does not imply income gap reduction (convergence). We point out that authors from Baumol (1986) to Kremer, et al. (2022) identify faster growth of poor countries with reduction of their income gap from the rich countries instead. We define full convergence and derive an equation for determining the number of years it takes to achieve it. We show a negative coefficient on β-convergence, does not imply income level convergence between any pair of countries; it only implies income ratio increase. We define the convergence rate and develop a test of convergence hypothesis using it.

Empirical evidence is presented in Section 3. Income data sources, and the maximum period with post-War data, are World Bank's World Development Indicators (WDI) (1960 to 2024), Maddison Project (MP) database (1950 to 2022), and Penn World Tables (PWT) (1950 to 2023). The data on conditioning variables, population growth rate and investment rate, are from U.N. World Population Prospects and WDI, respectively, and for human capital from PWT. The first sample consists of all non-major oil exporters for which data on human capital is available, the second when countries with populations of less than 1m. are excluded and the third OECD.

[1]We use income to mean per capita/worker income/output and logs to mean natural logs.

We distinguish between growth and convergence regressions and show that taking initial income in logs is not essential for either. We prove conditional divergence also for a large sample of countries from 1950 to 2024, demonstrate unconditional and conditional divergence in OECD too, and establish that the lower the initial income, the higher the divergence rate is. And this pattern is stronger for higher income countries. We show it is the divergence of TFP from the world technological frontier that explains divergence in incomes. Convergence is a rare phenomenon – even over a 60–70-year period - and differences in per capita incomes are entrenched and worsening. We cast fresh doubts on the use of neoclassical growth theory - at least as far as its use to predict convergence (unconditional or conditional) is concerned.

I. Literature Review

The work on neoclassical growth theory that has been widely used to derive implications for convergence is the Solow (1956) classic model. Under the well-known neo-classical growth theory assumptions, he expresses output per worker (that is often taken as a proxy for output per capita on the assumption that a constant proportion of population is employed) as a concave function of the capital-labor ratio, k. With a given saving proportion and a given exponential growth of labor at rate n, he defines equilibrium $k, k^*,$ such that at k^*, capital, labor and output all increase at the rate n, and per-capita output is constant. He shows the equilibrium at k^* is stable and not dependent on the initial value of k and does not hypothesize (or prove) that the country's rate of transition to the steady state is greater, the further behind its initial k is from k*. The economy achieves steady balanced growth at k^*

Solow (1956) is a one country/region/state closed economy model. He propounded it to explain growth, not convergence. The implications of Solow (1956) for convergence (or lack of it) were not drawn before the late 1980s. Easterlin (1957, 1960), who, as far as we can determine,

was the first author to examine convergence in per capita income, examined historical data for regional convergence in the US. Considering the bench-mark periods: 1880, 1990, 1919=1921, and 1949-1951, he computed weighted averages, weighted by population, of his estimates of state personal per capita incomes of nine US geographic regions; expressing them as proportions of the mean of the nine regions. The average absolute percentage deviation of regional income from the national average declined, although the income-ranks of the regions did not change.

Two major papers that have examined historical data on labor productivity and its growth compiled by Maddison (1982) for 16 industrialized countries for 1860-1979 are Abramovitz (1986) and Baumol (1986). Abramovitz (1986) uses it to show inverse rank correlation of growth in productivity to its initial level. If the followers have "social capability," technological spillovers from the leader make their catch-up growth (i.e., higher growth) feasible. He clarifies that the catch-up hypothesis does not mean a change in productivity leadership or rankings – showing both the leadership and average of 15 follower countries' productivity levels as a ratio to the leader's remained the same over 1870 - 1979. It only implies a reduction in productivity differences. Baumol (1986) gives Gerashchenkron's (1952) advantages of "relative backwardness" and Veblen's (1915) penalties of being the industrial leader theories as explanations of the negative relationship of Maddison (1982) 16 countries' productivity growth rates from 1870 to 1979 when regressed over their 1870 productivity levels. Using Summers-Heston data (Summers and Heston, 1984) for all 72 countries from 1950 to 1980, however, he finds no such relationship.

Barro and Sala i Martin (1990) derive from the neo-classical growth model for the closed economy an equation, (11), for the transition path of output per effective worker (that is, the number of workers adjusted for the effect of technological progress) of an economy at time t_0, y_{t0}, to its steady-state value, y^*, at time $t_0 + T$ (both productivity levels in logs). They call this transition

path convergence and represent the rate of transition dynamics by β.[2] Given y^*, β is higher (i.e., the more rapid the convergence to y^*) the lower the y_{t0}. Under the assumptions of the same production function, the same y^*, and the same exogenous technological progress everywhere, poorer countries have higher marginal product to k and grow and converge to y^* faster reaching the same steady state value of k, k^*, as the rich country yielding the same income level for all. They give two definitions of convergence: σ-convergence and β-convergence. σ--convergence means dispersion (measured by the standard deviation) of log per capita income or product for a group of countries that declines over time. On the other hand, they mistakably define their β-convergence as convergence in levels of per capita income.

Barro and Sala i Martin (1991 and 1992) allow y^*, and the exogenous labor-augmenting technological progress x to differ across economies and define conditional β-convergence as β-convergence conditional on the two. Empirical estimation of β now requires holding both y^* and x the same for all economies. The objective still is equality of income levels as shown by the explicit statements cited from their 1989, 1990, 1991 and 1992 papers in the Appendix with convergence in such studies meaning attaining the average of per capita income across economies. Their 1992 paper calls the β-convergence of their 1990 paper "absolute" (meaning unconditional) while their 1990 paper does not use the word "unconditional" or "absolute" anywhere.[3]

Mankiw, et al. (1992, p. 422) emphasize that the Solow (1956) model "does not predict

[2] The transition dynamics equations (1) in Barro and Sala i Martin (1991) and (10) in Barro and Sala i Martin (1992) are the same as (11) in Barro and Sala i Martin (1990) – except for the use of some different symbols on the right-hand side. The left-hand side in all three equations measures growth rate of per capita output in levels.

[3] Sala-i-Martin (1996) finds absolute β-convergence to be empirically a fallacy.

convergence (to the same income level for all countries); it predicts only that income per capita in a given country converges to that country's steady state value. In other words, the Solow model predicts convergence only after controlling for the determinants of the steady state, a phenomenon that might be called "conditional convergence."" Augmenting the Solow (1956) model with human capital, they condition convergence on physical and human capital accumulation and population growth (rather than requiring the same x and y^* as Barro and Sala i Martin (1991, 1992).

Durlauf and Johnson (1995, p. 365 and 367) accept the definition of convergence as, "the tendency for per capita output differences due to initial conditions to disappear over time," that "occurs when low per capita output economies grow more quickly than high per capita output ones." However, re-examining Summers-Heston data with regression tree methods, they find convergence for economies if grouped by their initial conditions. They suggest aggregate production functions may be regime-dependent, and different regimes attain their own steady states. Galor (1996) calls such convergence club convergence.[4] Empirical (or theoretical) rejection of absolute or unconditional convergence hypothesis (defined as a tendency for per capita output differences to disappear irrespective of country conditions) does not mean a rejection of neo-classical growth theory. Club convergence and conditional convergence are based on the neo-classical model and emerge from it.

Bernard and Durlauf (1996) give two definitions of convergence of per capita income/ output. Definition 1 means that the difference between log incomes of any pair of countries is expected to decrease. Definition 2, that they call the stronger notion of convergence, means that

[4] As far as we can make out, the phrase "club convergence" was first used by Baumol (1986) without any reference to different steady states.

the long-term forecast of the said difference is zero at a fixed time horizon. Definition 2 implies Definition 1 (that they call the weaker notion of convergence.) These definitions extend to a set of economies by requiring that every pair within the set exhibits convergence and follow from the neoclassical growth model. Nahar and Inder (2002) modify Bernard and Durlauf's (1996) Definition 2 to where the comparison of each country's income is to a benchmark (or targeted) country in the sample rather than pairwise. Durlauf, Johnson and Temple (2005, p. 583) define convergence between two economies (their Equation (21)) as Bernard and Durlauf (1996)'s Definition 2 and term Bernard and Durlauf (1996)'s Definition 1 as partial convergence.

There does not appear to be any further development[5] of the convergence concept/definition since 1996 except definitions of full convergence and relative convergence by Kant (2019) discussed below. We comment on these concepts in Section II and now review papers on this subject in the last ten years, in particular on whether country fixed effects should be included in empirical studies of convergence.

Barro (2015) estimates by the "within" panel estimator the effect of lagged initial income (ten years back) on annual growth rate of per capita income for each five-year period from 1965-2010 with or without the country fixed effects. He finds the country fixed effects lead to biased estimation and makes some of the key explanatory variables statistically insignificant. He then abandons country fixed effects and re-estimates his smaller stacked sample (with about ten observations for each country) first by 2SLS, and then by OLS alternately with each observation for ten years, two sets of time fixed effects, and a polity variable. He finds the most reliable

[5]A review of recent literature on this subject confirms it. See, Johnson and Papageorgiou (2020), Patel, et al. (2021), and Kremer, et al. (2022).

estimation is a model without country fixed effects or with a more limited set of countries.

Kremer et al. (2022) examining growth rate regressions on initial income over successive ten-year periods with year-fixed effects starting from each year from 1960, find the unconditional coefficient becomes negative starting in late 1990s. They compare conditional coefficient with a sample of 73 countries for 1985-1995 to one for 113 countries for 2005-2015, finding that the coefficient on initial income was not significant for 1985-1995 but became significant for the 2005-2015 period. Acemoglu and Molina (2022) criticize Kremer, et al. (2022)'s for not considering i) yearly increase of per capita income and ii) country fixed effects. They present a dynamic lagged dependent panel model (their equations (1) and (2)) in which the estimated coefficient is on previous period's income (not on the initial period's income). Using country fixed effects reduces omitted variable bias (see, Islam, 1995) but, by estimating the coefficients by only "within" variations, also reduces efficiency (by ignoring "between" variations, see, Durlauf, Johnson and Temple, 2005), is both highly biased for small yearly observations (see, Nickell, 1981), and is inconsistent for a finite number of observations (Woodbridge, 2010).[6] More importantly, their formulation changes the economic hypotheses under study from income level convergence to growth convergence. Islam (1995), one of the main papers on which they rely, bemoans that while his formulation studies growth convergence ("A panel data approach is advocated and implemented for studying growth convergence," p. 1127), it says nothing about

[6] Durlauf, Johnson, and Temple (2005) note that if country fixed effects are present, incomes will not converge even in the steady state irrespective of the conditioning variables and convergence by their definition (that is the same as Definition 2 of Bernard and Durlauf (1996)), will never be achieved.

income level convergence:

> "By being more successful (through the panel framework) in controlling for further sources of difference in the steady state levels of income, we have, at the same time, made the obtained convergence hollower. This is because convergence is more commonly understood as different countries of the world approaching the same or similar levels of income (i.e., in the "absolute" sense). There is probably little solace to be derived from finding that countries in the world are converging at a faster rate, when the points to which they are converging remain very different." p. 1162.

Convergence is properly studied by regressing the convergence rate (over several periods) on the initial level of income. Kremer, et al. (2022) take the (growth) rate over ten-year periods as the dependent variable. They disagree with Acemoglu and Molina (2022)'s different exercise and formulation holding that it is not economically meaningful for the question of convergence of income levels since "the country fixed effects absorb exactly the variation relevant for studying convergence" (in per capita income levels). p. 343.

Most studies on convergence ignore that incomes rarely grow on a linear path over more than a decade (Easterly et al., [1993]), few countries experience consistently high growth over several decades (Hausmann, Pritchett and Rodrik [2005]), growth miracles (faster than US growth over ten-to-fifteen-year period) and failures (slower than US growth over ten to fifteen year period) are common across countries (Jones and Olken, 2008) and most countries experience trend volatility - exceptionally high growths followed by low or even negative growth and vice versa - over the medium-term (Cuberes and Jerzmanowski, [2009]). Casual observation of WDI, MP and PWT data shows that growth miracles and failures have continued in the last twenty years too.[7] With this oscillatory path of income, now that we have usable data from three sources starting from 1950/1960 for hundreds of countries, to make a credible argument for convergence/ divergence, it ought to be examined over the entire period since 1950/1960.

[7] See Kant (2025b) for the recent data for Sub-Saharan Africa.

II. Relative Convergence, Convergence Rate, And More

A. Relative Convergence, Convergence, and Full Convergence.

Consider any two closed countries, Rich and Poor, *R* and *P*, characterized by neo-classical assumptions, particularly a concave production function. Let $y_{R\mathrm{u}}$ and $y_{P\mathrm{u}}$ represent their per-capita incomes/outputs at initial year/time *u*, where $y_{R\mathrm{u}} > y_{\mathrm{Pu}}$, and $y_{R\mathrm{v}}$ and $y_{P\mathrm{v}}$ at a later year/date *v*. Let φ_{Pu} represent the poor country's income ratio and Δ_{Pu} the poor country's income difference from the rich country in year *u*. Then

$$\varphi_{Pu} = y_{Pu}/y_{Ru} < 1 \qquad \text{and} \qquad \Delta_{\mathrm{Pu}} = (y_{Pu} - y_{\mathrm{Ru}}) < 0 \tag{1}$$

Following Kant (2019), relative convergence, relative divergence or neither to time *v* means[8]

$$\varphi_{Pv} > < = \varphi_{Pu} \text{ (relative convergence, relative divergence, neither)} \tag{2}$$

For continuous changes, we have

$$\text{sign } (d\varphi_P/dt) > < = 0 \text{ (relative convergence, relative divergence, neither).} \tag{2'}$$

Similarly, convergence, divergence or neither to time *v* means

$$\Delta_{Pv} > < = \Delta_{Pu} \text{ (convergence, divergence, neither).} \tag{3}$$

For continuous changes, we have

$$\text{sign } (d\Delta_P/dt) = (dy_P/dt) - (dy_R/dt) > < = 0 \text{ (convergence, divergence, neither)} \tag{3'}$$

(3) is the most used meaning of convergence. For example, Bernard and Durlauf (1996)

[8] In addition, Kant (2019) proves a slightly differently stated Proposition 1 below for discrete changes and without considering log incomes and derives an equation for years for full convergence using the catch-up index. An equation for years for full convergence using income ratios is derived in the Appendix.

state (on p.167) ". . . the cross-section β tests consequently examine whether the average change in the per capita output of an initially poorer country exceeds that of an initially richer country;" and (on p. 171), stating almost the full convergence definition below, "The new growth theory has led to many empirical efforts to identify whether per capita output is equalizing across economies with equivalent microeconomic structures." Further, the passages from Baumol (1986) to Mankiw, et al. (1992) cited in Appendix all ultimately define convergence either as reduction in income differences in levels or equality of incomes in levels (which, as discussed below, implies reduction in income differences in levels).

Full convergence means income differences vanish over some finite time-period, T, or

$$(y_{PT} - y_{RT}) = 0 \text{ for finite T.} \qquad (4)$$

(4) implies

$$(\log y_{PT} - \log y_{RT}) = 0 \text{ for finite T.} \qquad (4')$$

As an example of the use of this definition, Durlauf, Johnson and Temple (2005, p. 583) state that "Growth economists are generally interested in average income levels; Equation (21) [that, as noted above, is similar to Definition 2 of Bernard and Durlauf (1996)] implies that countries *i* and *j* exhibit convergence in average income levels . . . .".

There is nothing unique about countries *P* and *R*. The above definitions are extended to any pair of countries.

A search on Econlit on March 30, 2024 and on November 1, 2025 reveals that although the phrases "relative convergence" and "full convergence" have been used in a variety of situations, (as far as one can determine) they have not been given the above meanings by any other author.[9]

[9] Convergence rate (defined below) has also not been so defined in any other work.

However, equality of incomes in steady state, whether unconditional or conditional and whether regime-specific or not, as predicted theoretically by Barro and Sala i Martin (1990, 1991, 1992), Mankiw, et al. (1992), Durlauf and Johnson (1995), and Galor (1996, p. 1056 "countries converge to one another"), or defined empirically by Definition 2 of Bernard and Durlauf (1996) and Durlauf, Johnson and Temple (2005) mean full convergence as defined above (since equality of log incomes must mean equality of incomes in levels) – although none of the authors who predict income equality include the word "full" in describing the said convergence.. Like Bernard and Durlauf (1996)'s two definitions, full convergence implies convergence. Specifically, (4) and (4') imply that any shocks have transitory effects and convergence by (3) is a non-oscillatory process.

B. **Relationship between Relative Convergence and Convergence**

The following Proposition states the relationship between relative convergence/relative divergence and convergence/divergence.

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

Let g_P and g_R represent the income growth rates, $(1/y_P)(dy_P/dt) = (d\log y_P/dt)$ and $(1/y_R)(dy_R/dt) - (d\log y_R/dt)$, of the two countries. Then,

$$(d\varphi_P/dt) = \varphi_P\,[(1/y_P)(dy_P/dt) - (1/y_R)(dy_R/dt)] = \varphi_P\,[(d\log y_P/dt) - (d\log y_R/dt)] \qquad (5)$$

and

$$\text{sign}\,(d\varphi_P/dt) = \text{sign}\,(g_P - g_R) = \text{sign}\,[(d\log y_P/dt) - (d\log y_R/dt)] \qquad (5\hat{})$$

We combine (2), (2'), and (5') in the following Lemma:

Lemma 1: Relative convergence, relative divergence and neither is synonymous with a poorer country's income growing faster, slower or equal to a richer country's income and/or its income ratio to the richer country increasing, decreasing or remaining unchanged.

From (3'), convergence, divergence and neither mean

$[(dy_P/dt)/(dy_R/dt)] > 1$ (convergence); < 1 (divergence); $= 1$ (neither). (6).

When the two countries are growing at the same rate, we get from (5)

$[(dy_P/dt)/(dy_R/dt)] = (y_P/y_R) < 1;$ (7)

and from (6), the poorer country's income diverges from the richer country's income. That is, the poorer country's income gap from the richer country increases even though its income ratio remains unchanged - proving that relative divergence is not a necessary condition for divergence.

Now consider that the poorer country is growing slower (relative divergence). Then

$[(dy_P/dt)/(dy_R/dt)] < (y_P/y_R) < 1$ (8)

proving that relative divergence is a sufficient condition for divergence.

Lastly, consider that the poorer country is growing faster, i.e., relative convergence. Then

$[(dy_P/dt)/(dy_R/dt)] > (y_P/y_R)$ (9)

(9) has no implication for whether the magnitude of $[(dy_P/dt)/(dy_R/dt)]$ is greater than one, less than one, or equal to one. That is, relative convergence is not sufficient for convergence and does not imply convergence. If the magnitude of $[(dy_P/dt)/(dy_R/dt)]$ is greater than one, then the poorer country's income gap from the richer country decreases, and it experiences convergence. Since the magnitude of $[(dy_P/dt)/(dy_R/dt)]$ can be greater than one **only if** the poorer country grows faster, relative convergence is a necessary (but not sufficient) condition for convergence, proving the above proposition.

Bernard and Durlauf (1996) is the only paper that defines "convergence" as a decrease in the difference in log incomes. The deterministic statement of their definition (1) is

$(\log y_{Rv} - \log y_{Pv}) < (\log y_{Ru} - \log y_{Pu})$ (10)

or $\log (y_{Rv}/y_{Pv}) < \log (y_{Ru}/y_{Pu})$ (10')

(10') implies

$$(y_{Rv}/y_{Pv}) < (y_{Ru}/y_{Pu}) \qquad (11),$$

or a decrease in the rich country's income ratio. That is, relative convergence. We know that $y_{Ru} > y_{Pu}$. But that knowledge, and (11), carry no implication for the relationship between the two sides of (3). Difference in incomes in levels can increase even if it decreases in log incomes.[10]

Since relative divergence is a sufficient condition for divergence, i.e., a fall in the poorer country's income ratio unambiguously means an increase in its income gap, we can call relative divergence simply as divergence. On the other hand, since relative convergence is a necessary (but not a sufficient) condition for convergence: we will have to distinguish between relative convergence and convergence. For convenience, we may use r-convergence as an abbreviation for relative convergence.

C. Convergence Rate, Higher Growth Rate and Convergence or Relative Convergence?

(3) defines convergence between any single pair of countries. To compare convergence between two or hundreds of pairs of countries, it makes sense to keep one of the countries in hundreds of pairs the same. That is, to compare convergence of each country to the same reference or benchmark country. Further, to prevent scores of crossovers, the benchmark country should be the highest income country in the initial year and, if possible, for half or more years of the sample period. Let $\Delta_{\text{bmit}} = (y_{\text{bmt}} - y_{\text{it}})$ be the excess of the income of the Benchmark Country, *bm*, from Country *i*'s, in year *t,* where *t* can take values 0, *u, v*, and *T*, and $i = 1, 2, \ldots I$. Then, the convergence between periods 0 and *T* is:

[10] The last statement can be seen by constructing a simple numerical example where y_{Pu} = \$10, y_{Ru} \$1,000, y_{Pv} = \$1,000, and y_{Rv} = \$10,000. Then, (10) and (11) are satisfied but not (3).

$$(\Delta_{bmiT} - \Delta_{bmi0}) < 0 \qquad (12)$$

For ease of interpretation, we redefine convergence, divergence or neither as:

$$(\Delta_{bmi0} - \Delta_{bmiT}) > < = 0 \text{ (convergence, divergence, or neither)} \qquad (12').$$

The convergence rate for Country i between year 0 and T, cr_{iT}, is defined as

$$cr_{iT} = T^{-1}(\log \Delta_{bmi0} - \log \Delta_{bmiT}) \qquad (13)$$

If $cr_{iT} > 0$, (13) gives the convergence rate, and if it is < 0, it gives the divergence rate. This definition of the convergence rate follows from the definition of convergence, equation (3) – a reduction of income difference in levels - that is ultimately followed by almost every author who has written on this subject (as discussed above on pages 12 – 13 above.

Neoclassical growth theory uses the term "convergence rate" for the rate of transition dynamics, i.e., the growth rate of income during transition from the current level the to the steady-state level. For example, in their equation (13) given below:

$$(d\log y_t / dt) = \lambda [\log y^* - \log y_t] \qquad (14)$$

where y_t is current per capita income and y^* is the steady state income, Mankiw, et al. (1992), call λ the convergence rate. Similar statements about the transition dynamics equations are made for equations (11) in Barro and Sala i Martin (1990), (1) in Barro and Sala i Martin (1991), (10) in Barro and Sala i Martin (1992), and (2) in Durlauf and Johnson (1995). All these equations, like (14) above, have the growth rate of income in levels as the dependent variable. They derive the neo-classical growth theory result (under differing situations, e.g. whether conditioning variables are used, if yes, which ones, and whether the convergence is regime dependent) that lower is the current income, higher is the "convergence rate" meaning the growth rate of income during transition from the current level the to the steady-state level. We have cited in the Appendix passages from Abramovitz (1986), Baumol (1986), Barro (1989), Barro and Sala-I-Martin (1990,

1991, and 1992), Mankiw, et al. (1992) and from Durlauf and Johnson (1995) on p. 7 above, that state that higher growth rate of productivity/incomes mean productivity/income differences decrease. Galor (1996), Barro (2015), Johnson and Papageorgiou (2020), Patel, et al. (2021), and Kremer, et al. (2022) also make similar statements. However, as proved above, higher growth rate of income implies relative convergence (increase in income ratio); not convergence (decrease in income gap) - what to say of higher rate of convergence.

Further, Bernard and Durlauf (1996) state (in footnote 3) that they define convergence in log incomes "as the empirical literature has generally focused on logs rather than levels." It is the other way round. It is theoretical literature that focuses on logs when it derives the rate of transition dynamics (that it also calls "rate of convergence") from the current income (in logs) to the steady state income (also in logs). It is only to conclude that the lower the current income, the higher the rate of transition dynamics or the higher the rate of growth to the steady state income. See equation (14) above and the discussion following it. It is not even necessary to take initial income in logs in growth and/or convergence empirics - empirical literature takes it so only for convenience - it so takes all conditioning variables too.[11] See, Tables (4) and (5) in Mankiw, et al. (1992), and equation (7) in Durlauf and Johnson (1995). The interest in empirics is always in convergence to

[11] Taking the right-hand side variables in logs in regressions – while changing the coefficients' magnitudes, neither changes their sign nor their significance levels. For example, regressing 100 randomly generated growth rates between -1% and 5% on randomly generated incomes between $10,000 and $20,000 gives a coefficient of -0.0001407 with p-value 0.037, and on logs of the same incomes a coefficient of -2.028739 with p-value 0.041, Taking initial income in logs is essential only for fitting the income-range on the x-axis in figures.

income in levels, e.g., to income of, say, $20,000 rather than income of $9.9. See also passages from Bernard and Durlauf (1996) and Durlauf, Johnson and Temple (2005) and from the convergence literature cited on pages 12 and 13 above and the Appendix.

This paper emphasizes that convergence rate given by (13), rather than the income growth rate, should be used to examine convergence; and demonstrates that using it leads to starkly different results about convergence and their implications for growth theory.

D. β-"Convergence" Does Not Imply Convergence, Convergence Hypothesis & Test

Now, we examine the implications for income convergence of a negative coefficient of regressing income growth rates over the initial income levels.

Let g_i now represent the average annual growth rate of income/productivity of country *i, i* = 1 . . . *I*, from time 0 to time *T* and consider the regression equation

$$g_i = \alpha + \beta \log y_{i0} + \epsilon_i \qquad (15)^{12}$$

where $E(\epsilon_i) = 0$. A negative statistically significant OLS estimated value, β^h of the coefficient β is then taken to mean convergence. We examine below whether it implies that the income difference between any two countries in the regression decreases.

Let $\overline{y_{i0}}$ represent the mean of y_{i0} and $\overline{g_i}$ represent the mean of g_i. Then,

$$\beta^h = \Sigma(\log y_{i0} - \log \overline{y_{i,0}})(g_i - \overline{g_i})/ \Sigma(\log y_{i0} - \log \overline{y_{i0}})^2 \qquad (16)$$

The above can be expressed as

$$\beta^h = \Sigma[\{(\log y_{i,0} - \log \overline{y_{i,0}})^2//\Sigma(\log y_{i,0} - \log \overline{y_{i,0}})^2\} \{(g_i - \overline{g_i})/(\log y_{i,0} - \log \overline{y_{i,0}})\}] \qquad (16')$$

That is, β^h equals the weighted average of ratio of differences of growth rates from their mean to

[12] As stated in FN 11 above, taking initial income in levels will give the same sign and p-value of the estimated coefficient β^h.

that of initial incomes from their mean. A negative regression coefficient implies that (g_i - $\bar{g}_i$) and ($y_{i,0}$ - $\bar{y}_{i,0}$) must have opposite signs. However, it does not imply that income/output differences between **any** pair of countries have decreased. [13]

Convergence Hypothesis and Test

The unconditional convergence hypothesis states a poorer country reduces its income gap from the richer country and eventually eliminates its income gap. It involves the following steps:

1. Poorer countries' incomes grow faster.
2. Growing faster decreases their income gap from the richer countries.
3. Incomes of poorer countries converge to those of richer countries.

We have shown above that faster growth of the poor country's income does not imply a reduction of its income gap from the rich country. With 2. not true (and its antecedent 1. therefore irrelevant), the convergence hypothesis simply devolves to 3. and its test must be direct. We use the following regression to test for unconditional convergence:

$$T^{-1}(\log \Delta_{bmi0}) - \log \Delta_{bmiT}) = \gamma + \delta\, y_{i0} + \epsilon_i \qquad (17)^{14}$$

where $E(\epsilon_i) = 0$. Our hypothesis (assuming that the convergence rate is positive), is that lower is the initial income, the higher the convergence rate (given by (11)). That is, a negative significant estimated value, δ^h of the coefficient δ means convergence. This can be seen as: follows:

Let $\bar{y}_{i0I}$ represent the mean of y_{i0} and $\bar{cr}_{iT}$ represent the mean of cr_{iT}. Then,

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[13] Such convergence, termed unconditional convergence, is distinguished from conditional convergence where the negative coefficient holds conditional on a set of exogenous variables. It is not necessary to consider control variables for our argument here.

[14] As noted in FN 11 above, although not required, in estimation we will find it more convenient to use $\log y_{i0}$.

$$\delta^{h} = \Sigma(y_{i0} - \bar{y}_{i0})(cr_{iT} - \bar{cr}_{iT}) / \Sigma(y_{i0} - \bar{y}_{i0})^2 \quad (18)$$

which can be expressed as

$$\delta^{h} = \Sigma[\{(y_{i0} - \bar{y}_{i0})^2 / \Sigma(y_{i0} - \bar{y}_{i0})^2\} \{(cr_{iT} - \bar{cr}_{iT}) / (y_{i0} - \bar{y}_{i0})\}] \quad (18')$$

(18') states that δ^{h} equals weighted average of ratio of differences of convergence rates from their mean to that of initial incomes from their mean. Lower is Country i's initial income, greater must be Country i's convergence rate. That is, $(cr_{iT} - \bar{cr}_{iT})$ and $(y_{i0} - \bar{y}_{i0})$ must have opposite signs, and δ^{h} must be negative, to have convergence.

If the convergence rate is negative (as we find for most countries), the scatter plot between income and the convergence rate will be in the fourth quadrant and country i's income gap from the benchmark country increases. If we find the relationship between the two to be statistically significant and positive, it means the lower the initial income is the lower (algebraically or higher in absolute number) the divergence rate –the country diverges at a higher rate,

For conditional convergence/divergence, we estimate

$$T^{-1}(\log \Delta_{bmi0)} - \log \Delta_{bmiT}) = \gamma + \delta\, y_{i0} + \boldsymbol{X\Gamma} + \epsilon_i \quad (20)$$

where $\boldsymbol{X}$ is a I x k matrix of control or conditioning variables and $\boldsymbol{\Gamma}$ is a k x 1 vector of parameters.

IV Empirical Evidence

A. Data

We use three data sources for per capita income to examine the evidence for convergence. These are the World Bank's World Development Indicators (WDI), the Maddison Project Database (MPD), and Penn World Tables (PWT) version 11. WDI and PWT give data for 1960 - 2024 and 1950 - 2023, respectively, and we use data for 1950 - 2022 (its last year) from MPD. The data are available at https://data.worldbank.org/indicator/NY.GDP.PCAP.KD (WDI), https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-

2023 (MPD), and http://www.rug.nl/ggdc/productivity/pwt, (PWT), the first two accessed on 17 April 2025 and the third on November 17, 2025.

We use three conditioning variables. These are the average annual growth rate of population, share of real investment (including government investment) in real GDP and human capital. The latter two variables are also averages for a country for the sample period. Population growth data is obtained from U.N. Population Division, World Population Prospects 2024, Online Edition and investment rate from WDI (Gross Fixed Capital Formation as a % of GDP), both downloaded on April 27, 2025. Human capital in PWT (since version 8.0), like in Klenow & Rodriguez-Clare (1997), combines results of Mincer (1974) of regressing worker log wages on years of schooling and experience with average years of schooling to obtain its estimates of human capital around the world. We use this human capital data and extrapolate it from 2023 to 2024 (since no other source gives similar data).

The sample of countries is governed by availability of data on human capital from PWT. Excluding the large oil exporters, there are 137 such countries. WDI does not have data on Taiwan and Venezuela; and MPD on six (Belize, Fiji, Guyana, Macao, China SAR, Maldives, and Morocco) of the 137 countries. Excluding them, our first sample consists of 135 countries for WDI, 131 for MPD, and 137 for PWT. The second sample excludes countries with populations of less than 1m also, leaving 125 countries for WDI, and 127 for the other two. The data of these countries is likely to be more unreliable and their output dependent on unique factors. The third consists of OECD24. That is, excluding countries admitted to OECD in 1996 or later.

WDI has Switzerland with the highest income in 1960 and higher than USA for all years, and we use it as the benchmark country for this database. The convergence rates of per capita income of 125 countries to Switzerland's, and other data, from this database are stated in Appendix

Table A.1. MPD has the USA with the highest income in the start year (1950) and 44 of the 73 years, and we use it as the benchmark country for this database. In PWT data, per capita income of Switzerland is the highest in the initial year, 1950, and is higher than that of USA for 57 out of 74 years. We use them as the respective benchmark countries.

Before presenting the results, we note the caveat of Mankiw, et al. (1992, p. 424) that any empirical tests of convergence implications of Solow (1956) model are valid only if countries are in their steady state or if deviations from steady state are random.

B. Estimation Results

We report results from using the WDI data here.[15] Table A.1 shows that almost all countries' income diverges from Switzerland from their start years to 2024 except for five – Ireland, Luxembourg, Macao (China), Norway, and Singapore. Table 1 reports the results from regressing the convergence rate on the log income per capita in the initial year without considering any control variables. We find strong unconditional divergence for the two larger samples. The estimated coefficient is slightly lower when we exclude the low population countries but is double for the OECD (excluding Ireland).[16] Figure 1 is a scatter plot of convergence rates of the middle sample (124 countries – excluding Ireland) against their initial log income). The only two points with positive convergence rates are for Singapore and Norway. What is remarkable is that the poorer the country is initially, the greater its divergence rate is. And this pattern is stronger for higher income countries.

< Insert Table 1 and Figure 1 here >

[15] Those using MPD and PWT are similar and are available from author.

[16] Regressions for this sample, with or without the conditioning variables, run with Ireland included are not statistically significant but with Ireland excluded they are.

There is no OECD convergence – instead there is OECD divergence. Incomes of 19 of the remaining 20 (after excluding Ireland and the low population Iceland, and Luxembourg) OECD countries diverge from Switzerland. And, again, the poorer the OECD country is initially, the greater its divergence rate is. See, Figure 2. For both in general and for the OECD, there is a strong tendency for poor countries' income to diverge from the income leader, and especially for the higher income countries, the poorer the country, the greater its divergence rate.

< Insert Figure 2 here >

Tables 2 and 3 report the results for conditional convergence/divergence. Table 2 reports the results when population growth rates and the investment to GDP ratio are added as the righthand side variables, Table 3 when human capital is also added. To make our results comparable to the augmented Solow (1956) model given by Mankiw, et al. (1992), we use the same conditioning variables and add the same 0.05 to the population growth rate to reflect the labor-augmenting technical progress and depreciation of capital. The conditioning variables reduce the magnitude of the estimated coefficient for initial income – except for the OECD sample when it increases. For the OECD sample, where the investment ratio has the expected statistically significant positive effect, when human capital is also added, the coefficient on initial income doubles in value. Fit of the model improves with the addition of conditioning variables, and the divergence rate remains positively (algebraically) and strongly linked to initial income.

< Insert Tables 2 and 3 here >

The results of Table 3 are striking. Considering that *I*/GDP is a proxy for *K/L*, even with the same *K/L* and human capital, we find divergence. This means that the implication of Solow (1956) that *A* or TFP was a public good, was "in the air" and will easily diffuse across the world has not been realized. It is the entrenchment of TFP around the world that explains entrenchment of income differences. Not just entrenchment but accentuation of TFP differences. The world

technological frontier (WTF) is advancing, and countries are lagging in keeping pace with it – the gaps between WTF and country-TFPs are increasing. This is also shown by the following:

Since its version 8.0, PWT has been providing estimates of TFP for most countries that are comparable across countries relative to the WTF (US) taken as 1 each year. See, Inklaar and Timmer (2013). Two series of TFP are presented: *ctfp* and *cwtfp*. Feenstra, Inklaar, and Timmer (2015) explain that *ctfp* is useful in comparing productivity levels across countries with the US value taken as 1 (as the WTF) for all years. Growth rates of *ctfp* from the initial year to 2023 (the last year for which the said data is available in PWT 11*)*, that measure whether a country's TFP is getting closer to the WTF (if positive) or further behind WTF (if negative) are presented in Table A.2 and regressed on initial income. The regression results are presented in Table 4, and a scatter plot for the middle sample is presented in Figure 3. The coefficient of initial income is positive for all three samples and is highly significant for the larger samples. For 111 countries (the largest sample available) the lower is a country's initial income, the lower is the rate at which its relative TFP converges to the WTF. It is divergence of TFP from WTF that explains income divergence.

< Insert Table 4 and Figure 3 here >

We do not find any evidence that countries "at the bottom of the ranking tend to rebound toward the middle or . . . . champions tend to revert to mediocrity." Barro and Sala-I-Martin (1991, p 112). Differences in per capita output of countries even with the same human capital and savings and population growth rates are not transitory. They are entrenched and worsening. Convergence, whether unconditional or conditional, is a rare phenomenon – even over a 60–70-year period.

C. Discussion

Most of the (theoretical and) empirical analysis of convergence since Baumol (1986), whether linked to neoclassical growth theory or not, has searched for β-"convergence", i.e., initially poorer country grows faster. As proved above, β-"convergence" does not imply

convergence (income differences decrease) – faster growth only implies income ratio increases and β-"convergence" means income ratio convergence. Temple (1999) observes that same TFP growth across countries over 20-30 years is implausible. We show that assuming the same TFP growth over 60-65 years is also counter-factual and find support in Easterly and Levine (2001, p. 177) who state that "[t]he 'residual' (total factor productivity, TFP) rather than factor accumulation accounts for most of the income and growth differences across countries".

We compare our results in detail to Mankiw, et al. (1992) since as far as we know, it is one of the few papers that does all of the following: a) it examines both unconditional and conditional convergence for the largest sample (for which data for all variables is available) to the smallest (OECD), b) it examines the convergence hypothesis using the rate (it uses growth rate) over the entire post-War period for which data was available to them, c) it derives the conditioning variables theoretically – from the augmented Solow (1956) model they develop, d) it demonstrates that adding the conditioning variables makes the statistically insignificant β-(income ratio) convergence result (for the larger sample of countries) significant.

For their intermediate sample, Mankiw, et al. (1992) find the unconditional scatter plot of growth rates against initial incomes in the first quadrant and not statistically significant. We find the unconditional plot of convergence rate against initial incomes in the fourth quadrant and highly significant with a positive slope. When control variables are added, both papers report a decrease in the estimated coefficient of the log initial per capita income. With population growth and investment ratio, they find the said coefficient for their intermediate sample becomes statistically significant with R^2 of 0.35 and is negative; we find the said coefficient for our intermediate (and largest) samples remains positive and statistically significant with R^2 of 0.24. For the OECD, they find significant negative coefficient both unconditionally and conditionally on population growth

and investment ratio; we find significant divergence for OECD both unconditionally and conditionally on population growth and investment ratio

Our results differ from Mankiw, et al. (1992) because i) they, like other authors on this subject, identify faster growth with income level convergence. We have shown above that faster growth has no such implication; ii) they examine convergence for the 1960-85 period – the longest period with comparable post-War income data that was apparently available to them. We do it for the 1960-2024 period (and highlight studies since 1993 documenting oscillatory path of income).

There are some faint echoes of our empirical findings in literature. First, as noted above, some authors have found that income-ranks of countries/regions do not change over long periods - Easterlin (1957 and 1960) for US regions over 1880 - 1950; Abramowitz (1986) for average of 15 follower countries' productivity levels as a ratio to the leader's (that remained the same) over 1870 - 1979. Easterly et al. (1993) report that for 28 Madison (1989) countries, the rank correlation of 1988 income with that in 1870 is 0.82. Roberts (1979) shows that once per capita incomes are adjusted for urban and rural-urban price differences in Easterlin's (1957, 1960) data, no significant difference in the level of regional incomes occurred. Arias & Wen (2016) find the per capita income gap of most countries from the US remained constant in the post-War period. Dowrick (1992) finds income disparities between countries increased from 1960-1988. Pittau, Zelli, and Johnson (2010) present evidence supporting that the gaps between both upper middle and high-income and between poor and high-income countries has widened since the early 1970s.

However, as far as we know, there is no paper that has shown that taking income in logs is not essential for convergence regressions, defined the convergence rate, given a test for convergence using it, proved conditional divergence for a large sample of countries, demonstrated unconditional and conditional divergence in OECD too, and shown both in general and for the

OECD that the lower the initial income, the higher is the divergence rate – a result especially true for high income countries. We show it is the divergence of TFP from the world technological frontier that explains divergence in incomes. This paper casts fresh doubts on the neoclassical growth theory as far as its prediction of convergence in income levels is concerned. It also presents evidence against the scale economies-based prediction of the endogenous growth theory, Romer (1986). We show that only a few small economies' income has converged to the initial leader (Switzerland - which itself is a small country), while the income gap of the largest economy (the US) from Switzerland has increased for 64 years (although at the low annual rate of 0.14%).

We note some of the limitations of our analysis. We have not examined the fundamental factors behind divergence. Durlauf, Johnson and Temple (2005), in their Appendix B, list hundreds of right-hand variables that have been found statistically significant in cross-country growth (not convergence) regressions. Which of these explain divergence since 1950 is beyond the scope of this paper. We have not discussed σ-convergence – we are unable to relate a decline in average squared deviation of log income from geometric mean of incomes to our definition of convergence given by (3). We cannot use observations after a country's income exceeds the benchmark country's income (because its log will be undefined). However, for our data, there are only 38 such observations - four for Ireland and 34 for Luxembourg - out of a total of about 8,000. A synthetic benchmark country can be created, or a country outside the group can be used to overcome the limitation that the benchmark country should have the highest income in the initial year and in more than half of the years for convergence. [17]

[17] Recently, for event studies, synthetic control (SC) country has been proposed and used to match exactly the pre-treatment behavior of a treatment country. See, Kant (2025a) for

5. **Conclusions**

We add the following to the existing literature on this subject. We synthesize various convergence concepts in literature since the first (in 1957). We develop the concept of relative convergence– a concept first used by Kant (2019) - and prove it does not imply income gap reduction (convergence). We point out that authors from Baumol (1986) to Kremer, et al. (2022) mistakably identify faster growth of poor countries with reduction of their income gap from the rich countries. We define full convergence and derive an equation for determining the number of years it takes to achieve it. We show a negative coefficient on β-convergence, does not imply income convergence between any pair of countries; it only implies an increase in income ratio. We define the convergence rate and develop a test of convergence hypothesis using it.

Empirically, we add the following to literature. We distinguish between growth and convergence regressions and show that taking income in logs is not essential for either. Using three sets of data from 1950 to 2024, and the newly defined convergence rate, we prove conditional divergence also for a large sample of countries from 1950 to 2024, demonstrate unconditional and conditional divergence in OECD too, and establish that both in general and for the OECD the lower the initial income, the higher the divergence rate is. And this pattern is stronger for higher income countries. We show it is the divergence of TFP from the world technological frontier that explains divergence in incomes. The world technological frontier (WTF) is advancing, but countries are lagging in keeping pace with it. Convergence is a rare phenomenon – even over a 60–70-year period - and differences in per capita incomes are entrenched and worsening. We cast

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comparison of the SC method with the traditional TWFE DID estimation. The synthetic benchmark country for estimating convergence will not require such exact matching.

fresh doubts on the neoclassical growth theory - at least as far as its use to predict convergence (unconditional or conditional) is concerned.

The interest in the convergence hypothesis is astounding. No doubt, it is due to its potential to make the search for growth less elusive. Johnson and Papageorgiou (2021, p. 165) observe, "Ultimately, understanding convergence would get us closer to understanding the process of economic growth—a truly humbling endeavor." What this paper shows is that the vision of Lucas (2000) that Divergence, Big time (Pritchett, 1997) of the last two centuries may be replaced by great convergence of the 21st century is unlikely to be realized.[18] During the last seventy years, the Great Depression, and the two World Wars of the 1910-1950 period were replaced by the end of colonialism, great expansion of trade, and spread of capitalism often accompanied by democracy. Yet, great divergence has continued; and is likely to continue with prospects of trade wars, climate change, and the leaders developing new technologies at a furious pace.

At the same time, the paper shows that Ireland, Luxembourg, Macao (China), Norway, and Singapore, all with current population of less than 6m., are the only ones that have converged in per capita income and Switzerland (population about 9m.) has maintained its leadership. That suggests country studies to learn from their experience may be warranted. Yet, that is unlikely to be enough. The plan for future work must be to learn broadly why we had divergence of incomes for the last seventy years and why the poorer a country is initially, the greater is its divergence rate.

[18] Johnson, P. and C. Papageorgiou (2020) also observe that huge inter-country income differences are unlikely to be mitigated easily.

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Table 1
Tests for Unconditional Convergence

Dependent variable: Convergence rate from the initial year to 2024 to Switzerland's per capita income

Sample	Ex. Oil	Ex. (Oil & Low Pop)	OECD
Observations	135	125	20
Constant	-3.0217[a]	-2.5519[a]	-4.5763[b]
	(0.3276)	(0.2826)	(1.6530)
lnPCY (initial year)	0.2764[a]	0.2094[a]	0.4187[b]
	(0.0421)	(0.0367)	(0.1775)
R-sq	0.2441	0.2089	0.2360
Root MSE	0.6039	0.4991	0.4495

Note :Standard errors are in parntheses. For initial years, see Appendix Table 1. Super-scripts a and b indicate 1% and 5% significance levels. The OECD sample excludes Ireland.

Table 2
Tests for Conditional Convergence

Dependent variable: Convergence rate from the initial year to 2024 to Switzerland's per capita income.

Sample	Ex. Oil	Ex. (Oil & Low Pop)	OECD
Observations	135	125	20
Constant	-2.6813[a]	-2.9299.[a]	-0.6266
	(0.9265)	(0.7766)	(4.7227)
lnPCY (initial year)	0.2437[a]	0.1483[a]	0.4350[b]
	(0.0533)	(0.0464)	(0.1663)
ln Pop. Growth Rate	-0.0965	-0.4415	0.3843
	(0.3435)	(0.2910)	(1.3533)
ln Inv./GDP	0.2170	0.2294	2.2593[b]
	(0.1745)	(0.1472)	(1.0628)
R-sq	0.2533	0.2376	0.4059
Root MSE	0.6048	0.494	0.4204

Note :Standard errors are in parntheses. For initial years, see Appendix Table 1. Super-scripts a and b indicate 1% and 5% significance levels. 0.05 is added to the population growth rates for labor-augmenting technical progress and depreciation. The OECD sample excludes Ireland.

Table 3
Tests for Conditional Convergence With Human Capital

Dependent variable: Convergence rate from the initial year to 2024 to Switzerland's per capita income.

Sample	Ex. Oil	Ex. (Oil & Low Pop)	OECD
Observations	135	125	20
Constant	-2.6188[b]	-2.5545[b]	-2.4673
	(1.1915)	(1.0068)	(4.9520)
ln PCY (initial year)	0.2410[a]	0.1314[b]	0.8270[b]
	(0.0628)	(0.0547)	(0.3820)
ln Pop. Growth Rate	-0.0728	-0.2998	0.2544
	(0.4457)	(0.3783)	(1.3459)
ln Inv./GDP	0.2143	0.2052	2.7184[b]
	(0.1782)	(0.1506)	(1.1279)
ln Human Capital	0.0259	0.1535	-1.4817
	(0.3088)	(0.2610)	(1.3031)
R-sq	0.2534	0.2398	0.4531
Root MSE	0.6071	0.4953	0.4166

Note :Standard errors are in parntheses. For initial years, see Appendix Table 1. Super-scripts a and b indicate 1% and 5% significance levels. 0.05 is added to the population growth rates for labor-augmenting technical progress and depreciation. Human capital is as given in PWT. The OECD sample excludes Ireland.

Table 4
Tests for TFP Convergence

Dependent variable: Growth rate from initial year to 2023 of relative TFP (US = 1)

Sample	Ex. Oil	Ex. (Oil & Low Pop)	OECD
Observations	111	105	19
Constant	-1.7948[a]	-2.0858[a]	-0.4319
	(0.6145)	(0.6281)	1.2368)
lnPCY (initial year)	0.2106[a]	0.2517[a]	0.0759
	(0.0772)	(0.0798)	(0.1332)
R-sq	0.0638	0.0881	0.0187
Root MSE	0.9671	0.9476	0.3288

Note :Standard errors are ın parntheses. All three samples exclude Switzerland and the US; the OECD sample excludes Ireland too. The 111 countries are those for which relative TFP data are available.The countries, their initial years and growth rates of relative TFP are listed in Appendix Table 2. Super-scripts a indicates 1% significance level.

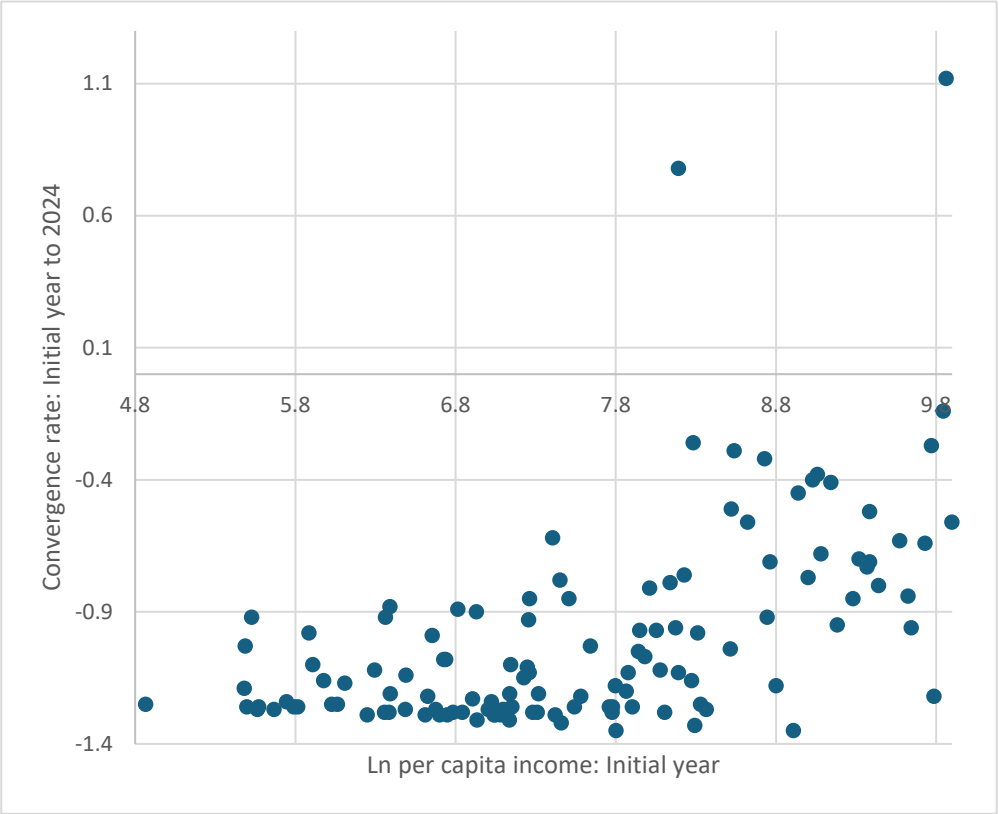


Figure 1

Unconditional Divergence: 125 countries

Note: Convergence rate, if positive, means the annual rate at which a country's income level difference from the bench-mark country's (Switzerland here) income level decreases; and if negative, means the annual rate at which a country's income level difference from the bench-mark country's income level increases. The initial year varies from 1960 for 86 countries to 1990 for 12 (all ex-socialist) countries and the rest between these two years.

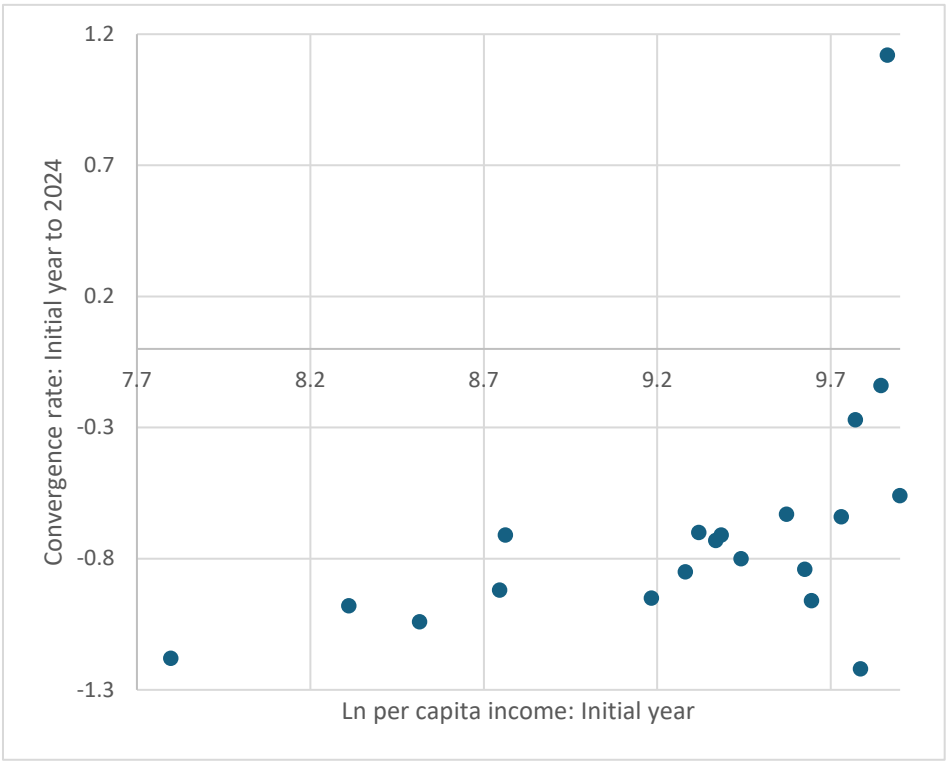


Figure 2

Unconditional Divergence: OECD except Ireland

Note: Convergence rate, if positive, means the annual rate at which a country's income level difference from the bench-mark country's (Switzerland here) income level decreases; and if negative, means the annual rate at which a country's income level difference from the bench-mark country's income level increases. The initial year is 1960 for all OECD24 countries.

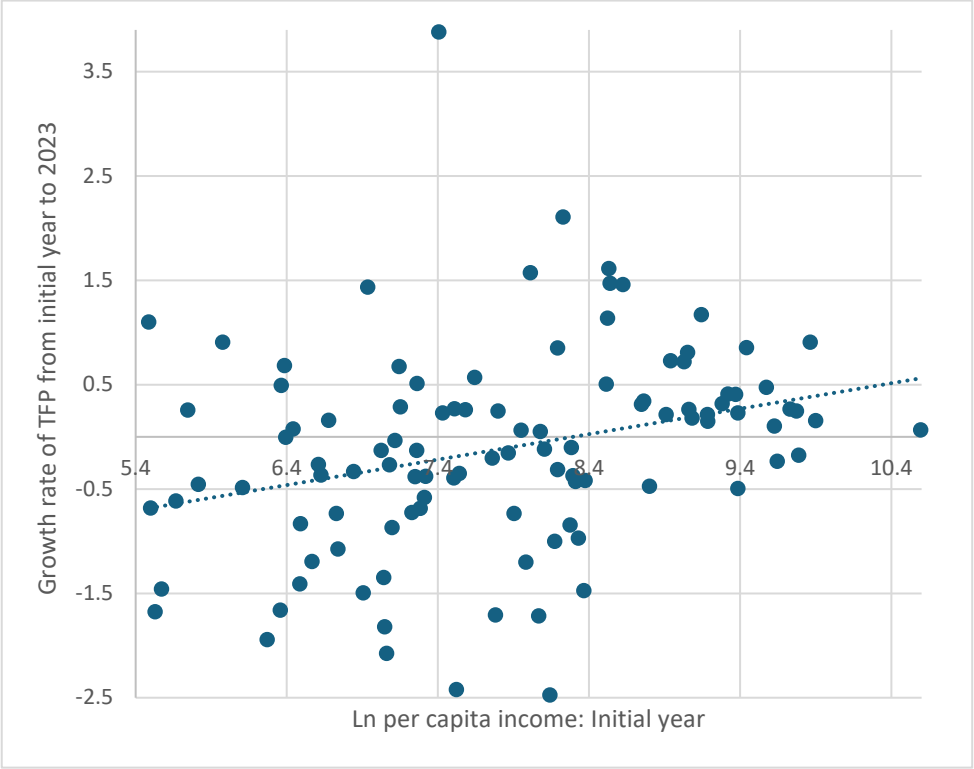


Figure 3

Divergence of TFP From the World Frontier (US = 1), 105 Countries

Note: TFP is productivity level across countries each year with US value = 1 in all years. Its growth rate, if positive, shows TFP became closer to the US level since the initial year, and if negative, shows it became further behind the US level.

Appendix
Divergence (Unconditional, Conditional and in OECD)

Definitions and Historical Usage of "Convergence."

We assemble below some of the passages from literature defining or giving meaning to "convergence.".

Abramovitz (1986, p. 396), states "The catch-up hypothesis in its simple form does not anticipate changes in leadership nor, indeed, any changes in the ranks of countries in their relative levels of productivity. It contemplates only a reduction among countries in productivity differentials."

Baumol (1986, p. 1073) states "Among the main observations that will emerge here is the remarkable convergence of output per labor hour among industrialized nations."

Barro and Sala i Martin (1990) state on p.1," . . . are there automatic forces that lead to convergence over time in the levels of per capita income and product;" and on p. 11, " . . . convergence applies if a poor country tends to grow faster than a rich one, so that---other things equal-the poor country tends to catch up with the rich one in terms of the level of per capita income or product." Barro (1989, p 1) also states, "Therefore, in the absence of shocks, poor and rich countries would tend to converge in terms of levels of per capita income."

Barro and Sala i Martin (1991, p. 107) state,

> "An important economic question is whether poor countries or regions tend to converge toward rich ones. We want to know, for example, . . , whether the south of Italy will become like its north, whether and how fast the eastern regions of Germany will attain the prosperity of the western regions, and-in a historical context-how the American South became nearly as well off as the North;"

Barro and Sala i Martin (1992, p. 223) observe, "A key economic issue is whether poor countries or regions tend to grow faster than rich ones: are there automatic forces that lead to convergence over time in the levels of per capita income and product?"

Mankiw, Romer, and Weil (1992) state on p. 407, "The paper also examines the implications of the Solow model for convergence in standards of living, that is, for whether poor countries tend to grow faster than rich countries" and mean that convergence in levels of standards of living and whether poor countries grow faster than rich countries are equivalent statements.

Years for Full Convergence

We now derive an equation giving the years for full convergence using income ratios,

Neo-classical theory predicts per capita incomes become equal in the long run but gives no guidance for determining the years to achieve income equality. See, Galor (1996). We do it below: Consider full convergence to a benchmark country by country *i*. Let φ_{it} represent the ratio of country *i*'s income to the bench-mark country's income in year *t* and let *T* be the year the two incomes become equal. Then,

$\varphi_{it} = (y_{it}/y_{BMt}) < 1$, $\varphi_{iT} = (y_{iT}/y_{BMT}) = 1$, and

$$\varphi_{iT} = \varphi_{it}\,(1 + g_{\varphi ii})^n \qquad \text{(A.1).}$$

where $g_{\varphi ii,}$ is the annual compound growth rate of φ_{it} and *n* the number of years it takes for the two incomes to become equal. (A.1) can be expressed as

$$(1/\varphi_{it}) = (1 + g_{\varphi it})^n \qquad \text{(A.1')}$$

Solving (A.1') for *n*, we get

$$n = \log (1/\varphi_{it}) / \log (1 + g_{\varphi ii}) \qquad \text{where} \qquad \text{(A.2).}$$

$$g_{\varphi ii} = (y_{BMt}/y_{it})\,(d\varphi_{it}/dt) = [(1/y_i)(dy_i/dt) - (1/y_{BM})(dy_{BM}/dt)] =$$

$$(g_i - g_{BM}) = [(d\log y_i/dt) - (d\log y_{BM}/dt)] \qquad \text{(A.3)}$$

(A.2) shows that the number of years for full convergence depends not only on the relative growth rates but also on the initial conditions or initial income ratio.

Table A.1 and A.2

Table A.1 lists the convergence rates of per capita income of 135 countries to Switzerland's, and other data, from the WDI and other sources as described in the text. In Table A.2, we list (for the 111 countries with relative TFP data), the start year of this data and its growth rate to 2023.

Table A.1

Number	Country	Initial Year	Sample N	NN	O	PCY Difference (in 000's) Switzerland-Country Initial Year	2024	Converg Rate	Pop. Growth Rate	I/GDP	HC
1	Albania	1980	1	1	0	57.9	84.1	-0.85	0.4	19.8	2.5
2	Algeria	1960	1	1	0	37.5	85.0	-1.28	2.2	36.7	1.7
3	Angola	1980	1	1	0	56.9	87.4	-0.97	3.1	33.8	1.3
4	Argentina	1960	1	1	0	32.5	77.1	-1.35	1.2	15.0	2.5
5	Armenia	1990	1	1	0	68.4	84.4	-0.62	-0.4	15.5	3.1
6	Australia	1960	1	1	1	20.0	28.6	-0.56	1.5	28.4	3.3
7	Austria	1960	1	1	1	28.0	44.2	-0.71	0.4	26.2	3.0
8	Bangladesh	1960	1	1	0	39.5	87.8	-1.25	1.9	15.2	1.5
9	Barbados	1960	1	0	0	32.5	69.3	-1.18	0.3	12.3	2.5
10	Belgium	1960	1	1	1	28.2	44.9	-0.73	0.4	27.7	2.8
11	Belize	1960	1	0	0	38.4	83.2	-1.21	2.4	14.8	2.7
12	Benin	1960	1	1	0	39.3	88.5	-1.27	2.8	13.6	1.4
13	Bolivia	1960	1	1	0	38.6	86.6	-1.26	1.9	14.4	2.2
14	Botswana	1960	1	1	0	39.5	82.8	-1.16	2.4	29.0	2.0
15	Brazil	1960	1	1	0	37.3	80.2	-1.20	1.7	19.9	2.0
16	Bulgaria	1980	1	1	0	56.3	79.7	-0.79	-0.2	14.6	2.9
17	Burkina Faso	1960	1	1	0	39.7	89.0	-1.26	2.3	13.7	1.1
18	Burundi	1960	1	1	0	39.6	89.5	-1.27	2.4	10.7	1.2
19	Cambodia	1975	1	1	0	54.0	87.6	-0.99	1.7	14.9	1.5
20	Cameroon	1960	1	1	0	39.0	88.3	-1.28	2.6	17.1	1.5
21	Canada	1960	1	1	1	24.5	45.4	-0.96	1.2	24.9	3.3
22	Cent. African Rep.	1960	1	1	0	39.3	89.4	-1.28	2.0	15.8	1.3
23	Chile	1960	1	1	0	36.7	75.2	-1.12	1.4	18.3	2.6
24	China	1960	1	1	0	39.7	76.7	-1.03	1.2	28.6	2.0
25	Colombia	1960	1	1	0	37.9	82.9	-1.22	1.9	21.5	2.6
26	Congo	1960	1	1	0	38.7	89.2	-1.31	2.7	24.0	2.2
27	Congo, Dem. Rep.	1990	1	1	0	58.2	69.3	-0.52	3.0	17.5	2.0
28	Costa Rica	1960	1	1	0	38.7	88.1	-1.28	2.1	14.7	1.7
29	Côte d'Ivoire	1960	1	1	0	36.3	74.9	-1.13	3.4	10.4	2.2
30	Croatia	1960	1	1	0	38.4	87.4	-1.28	-0.5	21.5	1.3
31	Cyprus	1990	1	0	0	60.3	72.0	-0.52	1.1	33.3	3.2
32	Czech Republic	1975	1	1	0	48.6	56.8	-0.32	0.2	25.6	2.4
33	Denmark	1960	1	1	1	22.4	26.6	-0.27	0.6	25.7	3.6
34	Dominican Rep.	1960	1	1	0	38.5	80.6	-1.15	1.9	20.7	1.4
35	Ecuador	1960	1	1	0	37.5	83.8	-1.26	2.2	23.9	3.1
36	Egypt	1960	1	1	0	39.2	85.6	-1.22	2.1	9.0	2.0
37	El Salvador	1965	1	1	0	43.7	85.2	-1.13	1.4	12.3	2.3
38	Estonia	1990	1	1	0	60.7	69.7	-0.41	-0.4	24.5	1.8
39	Eswatini	1970	1	1	0	53.1	86.0	-0.89	1.9	12.5	1.7
40	Ethiopia	1961	1	1	0	42.1	88.9	-1.19	2.7	12.2	3.3
41	Fiji	1960	1	0	0	37.8	83.9	-1.25	1.3	22.4	1.7
42	Finland	1960	1	1	1	28.8	44.9	-0.70	0.4	31.7	1.2
43	France	1960	1	1	1	29.2	50.3	-0.85	0.6	26.1	2.2
44	Gabon	1960	1	1	0	36.6	83.2	-1.28	2.3	17.8	2.9
45	Gambia	1966	1	1	0	46.5	89.0	-1.12	3.2	12.7	2.8

46	Germany	1960	1	1	1	27.3	45.7	-0.80	0.2	27.8	1.9
47	Ghana	1960	1	1	0	38.8	87.6	-1.27	2.5	29.3	1.2
48	Greece	1960	1	1	1	34.9	68.1	-1.04	0.3	28.4	3.3
49	Guatemala	1960	1	1	0	38.0	85.2	-1.26	2.3	13.9	1.9
50	Guyana	1960	1	0	0	37.2	56.9	-0.66	0.5	21.3	2.6
51	Haiti	1960	1	1	0	38.2	88.6	-1.32	1.8	23.1	1.5
52	Honduras	1960	1	1	0	38.7	87.2	-1.27	2.7	18.5	2.4
53	Hong Kong (China)	1961	1	1	0	38.3	45.1	-0.26	1.4	24.4	1.4
54	Hungary	1960	1	1	0	37.8	73.3	-1.03	-0.1	22.6	1.8
55	Iceland	1960	1	0	0	26.4	31.8	-0.29	1.2	31.5	3.0
56	India	1960	1	1	0	39.6	87.4	-1.24	1.8	21.1	2.7
57	Indonesia	1960	1	1	0	39.3	85.4	-1.21	1.7	19.5	1.6
58	Iran	1960	1	1	0	37.6	84.0	-1.26	2.2	29.9	1.9
59	Iraq	1960	1	1	0	38.9	85.6	-1.23	2.8	17.6	1.6
60	Ireland	1960	1	1	0	31.4	3.7	3.55	1.0	26.7	1.8
61	Israel	1960	1	1	0	31.1	47.9	-0.68	2.3	26.5	2.8
62	Italy	1960	1	1	1	30.2	55.4	-0.95	0.3	25.7	3.2
63	Jamaica	1966	1	1	0	43.1	84.5	-1.16	0.9	17.8	2.6
64	Japan	1960	1	1	1	33.5	52.6	-0.71	0.4	31.4	2.3
65	Jordan	1976	1	1	0	51.4	85.8	-1.07	3.4	28.7	3.2
66	Kazakhstan	1990	1	1	0	64.5	77.9	-0.56	0.6	19.4	2.1
67	Kenya	1960	1	1	0	39.1	87.9	-1.27	3.1	12.4	3.2
68	Korea, Rep.	1960	1	1	0	38.9	89.8	-1.31	1.1	32.9	1.8
69	Kyrgyzstan	1986	1	1	0	62.7	88.4	-0.90	1.4	13.3	3.1
70	Lao People's DR	1984	1	1	0	60.4	87.1	-0.92	1.9	25.9	1.6
71	Latvia	1990	1	1	0	62.4	72.8	-0.45	-1.0	21.8	2.9
72	Lesotho	1960	1	1	0	39.6	88.8	-1.26	1.6	23.5	1.8
73	Liberia	1960	1	1	0	37.5	89.1	-1.35	2.6	18.8	1.5
74	Lithuania	1990	1	1	0	61.7	70.7	-0.40	-0.8	17.0	3.1
75	Luxembourg	1960	1	0	0	12.0	4.0	3.64	1.2	24.1	2.7
76	Macao (China)	1982	1	0	0	36.2	25.7	0.82	2.4	22.9	1.4
77	Madagascar	1960	1	1	0	39.1	89.3	-1.29	2.7	8.9	1.5
78	Malawi	1960	1	1	0	39.6	89.2	-1.27	2.8	16.7	2.3
79	Malaysia	1960	1	1	0	38.6	77.9	-1.10	2.2	25.4	1.8
80	Maldives	1970	1	0	0	52.5	77.8	-0.73	2.9	21.7	1.1
81	Mali	1967	1	1	0	47.5	88.9	-1.10	2.5	12.8	2.6
82	Malta	1970	1	0	0	50.9	56.3	-0.19	0.7	26.3	1.4
83	Mauritania	1961	1	1	0	41.0	88.1	-1.21	2.6	22.5	2.1
84	Mauritius	1960	1	1	0	38.5	78.2	-1.11	1.0	14.9	2.2
85	Mexico	1960	1	1	0	35.8	79.5	-1.25	2.0	19.7	2.4
86	Moldova	1990	1	1	0	66.3	85.9	-0.76	-0.3	15.6	1.4
87	Mongolia	1981	1	1	0	59.0	85.2	-0.85	1.6	28.1	1.1
88	Morocco	1966	1	1	0	46.2	86.3	-1.08	1.7	22.4	1.5
89	Mozambique	1980	1	1	0	59.5	89.2	-0.92	2.5	23.4	1.9
90	Myanmar	1960	1	1	0	39.8	88.6	-1.25	1.5	12.5	1.3
91	Namibia	1980	1	1	0	56.2	85.7	-0.96	2.3	20.2	3.0
92	Nepal	1960	1	1	0	39.6	88.6	-1.26	1.7	18.0	3.2
93	Netherlands	1960	1	1	1	25.5	38.3	-0.63	0.7	25.1	1.8
94	New Zealand	1960	1	1	1	22.1	48.4	-1.22	1.2	22.8	1.1

95	Nicaragua	1960	1	1	0	38.2	87.5	-1.29	2.2	21.6	1.4
96	Niger	1960	1	1	0	39.2	89.2	-1.29	3.2	17.4	3.2
97	Nigeria	1960	1	1	0	38.5	87.3	-1.28	2.6	39.4	1.5
98	Norway	1960	1	1	1	20.7	10.1	1.12	0.7	30.5	2.4
99	Pakistan	1960	1	1	0	39.5	88.1	-1.25	2.6	11.9	2.1
100	Panama	1960	1	1	0	37.1	72.6	-1.05	2.2	23.3	2.2
101	Paraguay	1960	1	1	0	38.4	83.1	-1.21	2.1	21.6	2.2
102	Peru	1960	1	1	0	37.2	83.1	-1.26	1.9	17.4	2.9
103	Philippines	1960	1	1	0	38.8	85.9	-1.24	2.3	19.5	1.9
104	Poland	1990	1	1	0	65.0	71.8	-0.29	0.0	17.9	2.8
105	Portugal	1960	1	1	1	35.8	67.3	-0.98	0.3	24.4	2.9
106	Romania	1990	1	1	0	65.0	77.3	-0.51	-0.6	20.8	2.7
107	Russia	1989	1	1	0	60.2	78.7	-0.77	-0.1	19.5	3.2
108	Rwanda	1960	1	1	0	39.6	88.7	-1.26	2.4	8.8	1.4
109	Senegal	1960	1	1	0	38.8	88.3	-1.29	2.7	12.2	1.3
110	Serbia	1995	1	1	0	64.3	81.2	-0.81	-1.3	18.3	3.0
111	Sierra Leone	1960	1	1	0	39.0	88.6	-1.28	2.0	6.6	1.3
112	Singapore	1960	1	1	0	36.3	22.1	0.78	2.1	37.6	2.3
113	Slovakia	1990	1	1	0	61.5	70.0	-0.38	0.1	21.4	3.5
114	South Africa	1960	1	1	0	35.9	84.1	-1.33	2.1	19.5	2.1
115	Spain	1960	1	1	1	33.6	60.6	-0.92	0.7	25.3	2.5
116	Sri Lanka	1961	1	1	0	41.6	85.6	-1.14	1.2	20.1	2.5
117	Sudan	1960	1	1	0	39.1	89.2	-1.29	2.9	12.7	1.3
118	Sweden	1960	1	1	1	23.1	34.9	-0.64	0.5	27.9	3.1
119	Syria	1960	1	1	0	39.4	89.8	-1.29	2.4	13.8	1.9
120	Tajikistan	1985	1	1	0	61.5	88.3	-0.93	2.0	11.9	3.1
121	Tanzania	1960	1	1	0	37.5	74.6	-1.08	2.9	22.1	2.0
122	Thailand	1960	1	1	0	39.1	88.7	-1.28	1.5	24.1	1.5
123	Togo	1960	1	1	0	39.3	83.2	-1.17	2.7	22.6	2.6
124	Trinidad & Tobago	1960	1	1	0	39.5	88.9	-1.27	0.8	14.0	1.7
125	Tunisia	1960	1	1	0	35.6	73.6	-1.13	1.7	17.3	1.8
126	Turkey	1961	1	1	1	40.9	85.8	-1.18	1.8	25.7	1.4
127	Uganda	1982	1	1	0	58.9	88.8	-0.98	3.2	16.5	1.6
128	Ukraine	1987	1	1	0	61.2	87.6	-0.97	-1.0	14.9	3.1
129	United Kingdom	1960	1	1	1	24.8	42.5	-0.84	0.4	22.9	3.3
130	United States	1960	1	1	1	21.1	23.1	-0.14	0.9	24.3	3.4
131	Uruguay	1960	1	1	0	33.3	70.8	-1.18	0.6	17.7	2.3
132	Viet Nam	1984	1	1	0	60.4	85.8	-0.88	1.3	17.7	2.0
133	Yemen	1990	1	1	0	68.3	89.0	-0.78	3.1	14.8	1.4
134	Zambia	1960	1	1	0	38.7	88.4	-1.29	2.9	14.4	1.9
135	Zimbabwe	1960	1	1	0	38.8	88.4	-1.29	2.2	15.3	1.9

Notes: The convergence rate is over the entire period, the population growth rates is annual. I-ratio is a % of GDP, HC is human capital measure as given in PWT. The last three are averages of the annual numbers. N, NN, and O refer to non-oil, non-oil & non-low-population, and OECD samples. The Switzerland-Country PCY difference for "2024" for Ireland is for 2020 and for Luxembourg for 1990 - the last years when such differences were positive.

Table A.2, Relative TFP Data

	Country	Initial Year	Gr. Rate
1	Albania	1980	0.27
2	Angola	1980	0.06
3	Argentina	1960	0.21
4	Armenia	1994	3.88
5	Australia	1960	0.16
6	Austria	1960	0.23
7	Barbados	1964	-2.49
8	Belgium	1960	0.41
9	Benin	1980	-1.41
10	Bolivia	1960	0.29
11	Botswana	1964	0.91
12	Brazil	1960	-0.15
13	Bulgaria	1980	-2.47
14	Burkina Faso	1963	-0.68
15	Burundi	1980	-0.61
16	Cameroon	1964	-0.33
17	Canada	1960	-0.23
18	Central African Republic	1980	-1.66
19	Chile	1960	0.05
20	China	1960	1.10
21	Hong Kong SAR, China	1964	-0.10
22	China, Macao SAR	1980	-0.95
23	Colombia	1960	0.26
24	Costa Rica	1960	-0.31
25	Cote d'Ivoire	1964	-0.58
26	Croatia	1994	0.15
27	Cyprus	1975	0.48
28	Czechia	1994	-0.49
29	Denmark	1960	0.25
30	Dominican Republic	1960	-0.73
31	Ecuador	1960	-1.71
32	Egypt, Arab Rep.	1960	-0.37
33	El Salvador	1975	-1.72
34	Estonia	1994	1.17
35	Eswatini	1980	-0.03
36	Fiji	1980	-0.75
37	Finland	1960	0.41
38	France	1960	0.32
39	Gabon	1964	-0.12
40	Germany	1960	0.85
41	Greece	1960	0.50
42	Guatemala	1960	-0.35
43	Honduras	1970	-0.87
44	Hungary	1974	0.57
45	Iceland	1960	0.64
46	India	1960	0.26
47	Indonesia	1964	-0.01
48	Iran, Islamic Rep.	1960	-0.20
49	Iraq	1974	-1.50
50	Ireland	1960	0.81
51	Israel	1960	0.18
52	Italy	1960	0.22
53	Jamaica	1966	-0.84
54	Japan	1960	0.34
55	Jordan	1976	-1.20
56	Kazakhstan	1994	1.46

57	Kenya	1960	0.16
58	Kyrgyz Republic	1994	0.08
59	Lao PDR	1980	0.49
60	Latvia	1994	0.73
61	Lesotho	1970	-1.46
62	Lithuania	1994	0.72
63	Luxembourg	1960	-0.18
64	Malaysia	1960	0.67
65	Malta	1970	0.41
66	Mauritania	1977	-0.39
67	Mauritius	1960	-0.38
68	Mexico	1960	-0.97
69	Mongolia	1980	0.51
70	Morocco	1966	-1.08
71	Mozambique	1980	-1.68
72	Namibia	1980	-1.00
73	Netherlands	1960	0.48
74	New Zealand	1960	-0.18
75	Nicaragua	1980	-2.42
76	Niger	1964	-0.27
77	Nigeria	1960	-0.69
78	Norway	1960	0.91
79	Panama	1969	-0.42
80	Paraguay	1960	-0.38
81	Peru	1960	-0.73
82	Philippines	1960	-0.13
83	Poland	1990	1.47
84	Portugal	1960	-0.43
85	Korea, Rep.	1960	1.43
86	Moldova	1994	2.11
87	Romania	1990	1.14
88	Russian Federation	1994	1.61
89	Rwanda	1964	-0.46
90	Senegal	1964	-1.82
91	Serbia	1994	1.57
92	Sierra Leone	1980	-2.07
93	Singapore	1964	0.85
94	Slovak Republic	1994	0.26
95	South Africa	1960	-0.37
96	Spain	1960	0.31
97	Sri Lanka	1960	-0.83
98	Sudan	1974	-1.20
99	Sweden	1960	0.27
100	Tajikistan	1994	-1.94
101	Thailand	1960	0.68
102	Togo	1980	-0.49
103	Trinidad and Tobago	1960	-1.48
104	Tunisia	1964	-0.13
105	Turkiye	1960	0.25
106	Tanzania	1964	-0.73
107	Ukraine	1994	0.23
108	United Kingdom	1960	0.11
109	Uruguay	1960	-0.47
110	Zambia	1960	-0.27
111	Zimbabwe	1960	-1.35

Notes: Relative TFP is relative to US (=1).The initial year is the later of the intial years for TFP and income data.