Convergence in the World Economy – Evidence from the Last Fifty Years

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Intuitive Notion of Convergence

We start with the intuitive notion:

Income convergence across countries is said to occur if each country contributes to world income in proportion of its population, equivalently when the share of the country in world income equals its population share.

If income and population shares are given by:

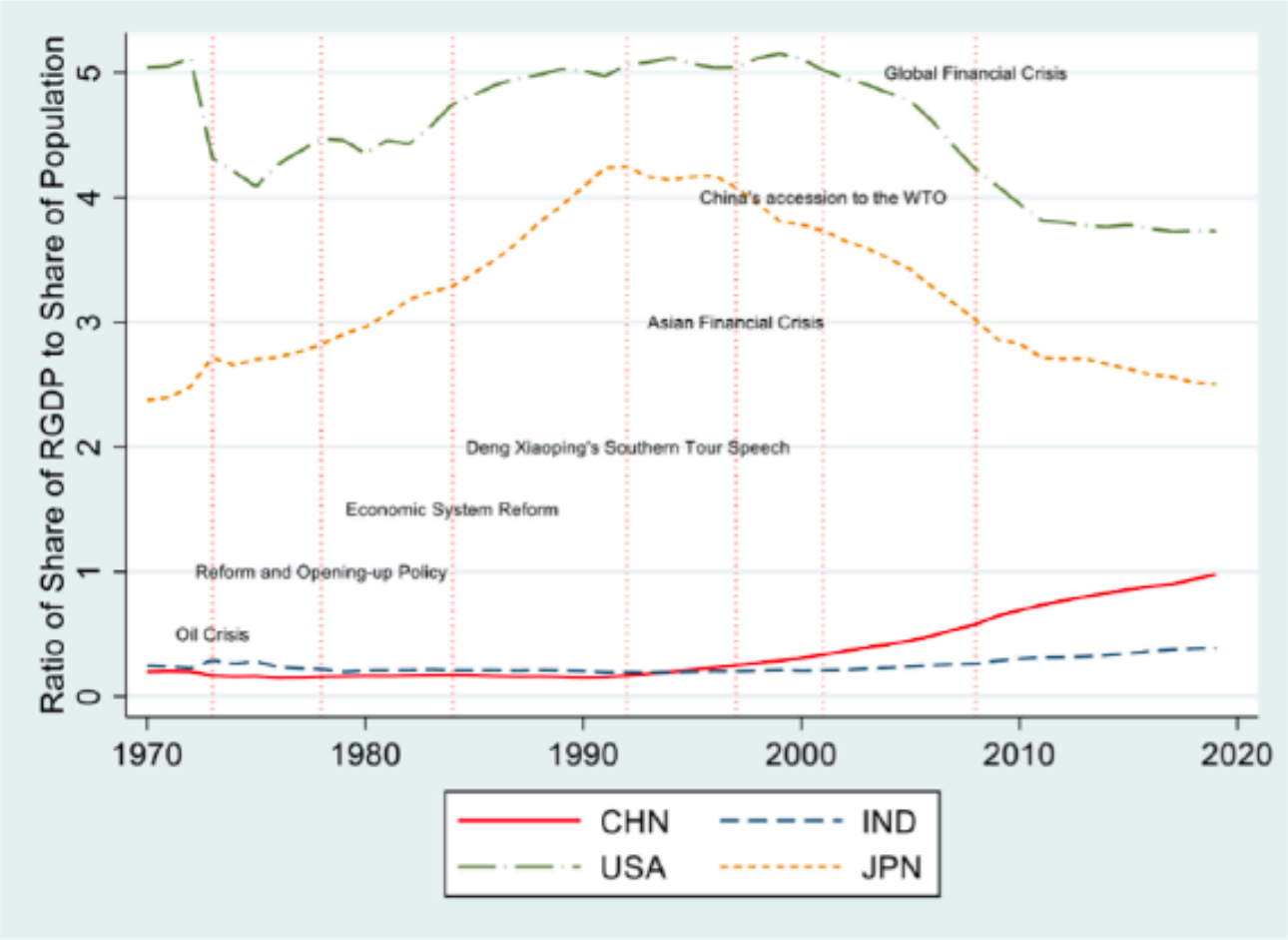
$$IS_{it} = \frac{N_{it} \cdot \bar{x}_{it}}{\sum_{j=1}^{M} N_{jt} \cdot \bar{x}_{jt}} \quad and \quad PS_{it} = \frac{N_{it}}{\sum_{j=1}^{M} N_{jt}}$$

The income-population Contribution Ratio is:

$$IPCR_{it} = \frac{IS_{it}}{PS_{it}} = \frac{\frac{N_{it} \cdot \bar{x}_{it}}{\sum_{j=1}^{M} N_{jt} \cdot \bar{x}_{jt}}}{\frac{N_{it}}{\sum_{j=1}^{M} N_{jt}}} = \frac{\bar{x}_{it}}{\sum_{j=1}^{M} N_{jt} \cdot \bar{x}_{jt} / \sum_{j=1}^{M} N_{jt}} = \frac{\bar{x}_{it}}{\sum_{j=1}^{M} PS_{jt} \cdot \bar{x}_{jt}} = \frac{\bar{x}_{it}}{\bar{x}_{Wt}}$$

Convergence occurs if: $\lim_{t \to \infty} IPCR_{it} \to 1$

Ratio of Income Share to Population Share
Selected countries 1975-2019



Source: authors' calculations based on data from UQICD V 3.0

Notion of Convergence

We start with the notion of convergence between two income streams (individuals) which is:

$$\lim_{t\to\infty}\frac{x_{it}}{x_{jt}}=1.$$

Result: Income sequence of *N* individuals is convergent as above if and only if for every individual *j*, the ratio of individual income to average income converges to 1. That is:

$$\left\{\lim_{t\to\infty}\frac{x_{it}}{x_{jt}}\to 1\ \forall pairs\ of\ individuals\ i\ and\ j\right\}\Leftrightarrow\left\{\lim_{t\to\infty}\frac{x_{jt}}{\sum_{i=1}^{N}x_{it}/N}\to 1\ \forall\ i=1,2,\ldots,N\right\}$$

An implication is that convergence in incomes according to definition above is that inequality in the distribution of incomes goes to zero.

Notion of Convergence of Incomes Between Countries

Let M represent the number of countries.

Convergence is said to occur if :

$$IPCR_{it} = \frac{\overline{x}_{it}}{(1/M)\sum_{i=1}^{M}\overline{x}_{it}} \rightarrow 1 \; as \; t \rightarrow \infty$$

This is the concept used in Phillips and Sul (2009). However, as countries vary by population size it is more appropriate to consider the following convergence:

$$IPCR_{it} = \frac{\overline{x}_{it}}{\sum_{i=1}^{M} w_{it}\overline{x}_{it}} \rightarrow 1 \; as \; t \rightarrow \infty$$

We implement both in our paper.

Objectives

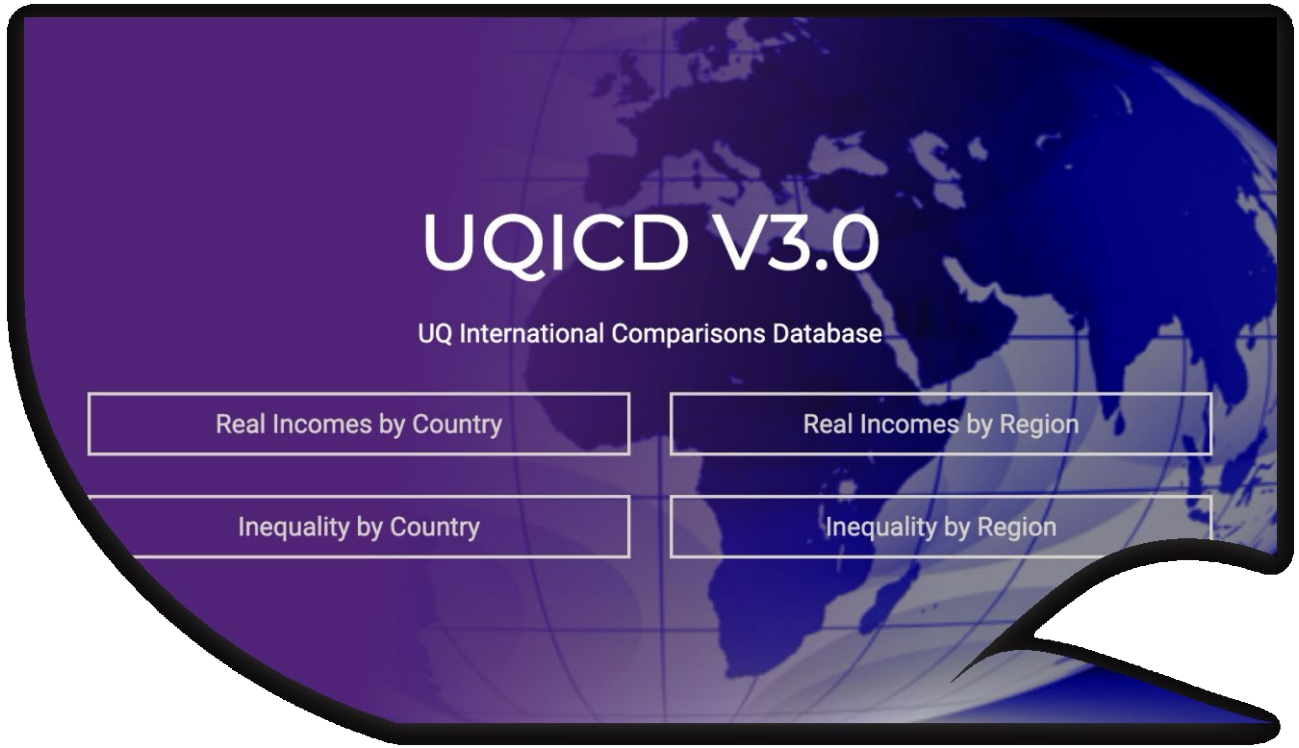
Using data from UQICD covering 185 countries and the period 1970 to 2019, we focus on these key questions:

- ***Has there been convergence in incomes of people in the world?***
- ***Has there been convergence in real per capita incomes across nations (β- and σ-convergence)?***
- ***Has there been convergence in income distributions of countries is proposed and trends over time are presented. We develop a new measure of convergence in income distributions.***

University of Queensland International Comparison Database (UQICD) Version 3.0

New series (panels) on PPPs, real incomes, inequality, regional growth and inflation

https://uqicd.economics.uq.edu.au/



Why UQICD V3.0?

Sen's (1976) framework for welfare comparisons is at the core of UQICD V3.0

A rephrased version of Theorem T.15 in the paper is:

Let ***x*** and ***x'*** are two vectors enjoyed by two communities not necessarily of the same size but with the same types of commodities. Let μ and μ' are mean (per capita) incomes adjusted for price level differences and *G* and *G'* the respective Gini coefficients of the two income distributions of the two communities.

Under a set of axioms on preferences, μ(1-*G*) > μ'(1-*G'*) implies that *x P x'*

To make welfare comparisons, we need:

- Gini measure of inequality
- For temporal comparisons, need mean incomes at constant prices – incomes adjusted using CPI or another deflator
- For spatial comparisons across countries – need *purchasing power parities of currencies or spatial price index numbers and mean incomes in PPP terms*

UQICD provides series that facilitate comparisons and analysis of welfare

Why UQICD V3.0?

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Most studies on convergence make use of data from the Penn World Table (PWT).

Real Income series from UQICD are similar to those in PWT but the main advantages are:

- **UQICD series are panels of PPPs and real incomes constructed using data available from all the benchmark comparisons from all sources;**
- **Deflator and growth data from countries; and also**
- **Incorporate additional information through Price Level Regressions**

Inequality data in the form of fitted income distributions and inequality measures are also available

UQICD V3.0 - Modules

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- **Module 1: Real Incomes by Country**

Estimates of Purchasing Power Parities (PPPs) and real per capita expenditures at the GDP level; for Consumption, Government and Gross Capital Formation along with their standard errors.

- **Module 2: Inequality and Income Distributions by Country**

Panels of income distributions constructed using methodology developed by the authors. Estimated parameters and their standard errors for: Lognormal; Pareto-lognormal; Generalized Beta Distribution of the second kind (GB2); and Mixtures of lognormal distributions. Inequality measures like Gini and Theil and shares of bottom 10, 30% and top 10 and 1% are provided.

- **Module 3: Real Incomes by Regions**

Decomposition of changes in real GDP of a region over time into three components: Domestic Growth; Domestic Inflation; PPP effects; and Price effects (domestic inflation and PPP effects combined) and real income by: geographic regions; WB income-level; OECD and EU.

- **Module 4: Inequality by Regions**

Inequality measures for the regional groupings above. Computed by constructing regional income distributions as mixtures or weighted averages of distributions of countries belonging to the region. Inequality measures and shares of selected population sub-groups are available.

World Economy over the last Fifty Years

World Economy: Last Five Decades

	WORLD				
	1970	1980	1990	2000	2019
Population (bill)	3.374	4.096	5.263	6.069	7.619
RGDP ($ trillion)	3.428	11.715	24.823	43.222	133.088
NGDP ($ trillion)	2.931	11.218	22.743	33.166	86.473
CGDP ($trillion)	20.397	30.495	45.893	61.163	118.187

We are in the process of updating series to 2024.

Decomposition of change in Real World GDP over time

Using Balk, Rambaldi and Rao (2023), UQICD provides a decomposition of change in real GDP of the world (or any group of countries) as:

$$\frac{RGDP_{W,t}}{RGDP_{W,t-1}} = \frac{\sum_{j=1}^{M} RGDP_{j,t}}{\sum_{j=1}^{M} RGDP_{j,t-1}} = \prod_{j=1}^{M}\left[\frac{CGDP_{j,t}}{CGDP_{j,t-1}}\right]^{\omega_j} \prod_{j=1}^{M}\left[\frac{Def_{j,t}}{Def_{j,t-1}}\right]^{\omega_j} \prod_{j=1}^{M}\left[\frac{PPP_{j,t-1}}{PPP_{j,t}}\right]^{\omega_j}$$

$$= \prod_{j=1}^{M}\left[Dom.GR_{j,t-1,t}\right]^{\omega_j} \prod_{j=1}^{M}\left[Dom.Inf_{j,t-1,t}\right]^{\omega_j} \prod_{j=1}^{M}\left[PPP\ effect\right]^{\omega_j}$$

$$= \text{Global growth} \times \text{Average Dom Inf} \times \text{PPP change effect}$$

$$= \text{Global growth} \times \text{Global Inflation}$$

Global Growth and Inflation 1970-2019

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We consider the change in RGDP of the world over the period 1970 to 2019

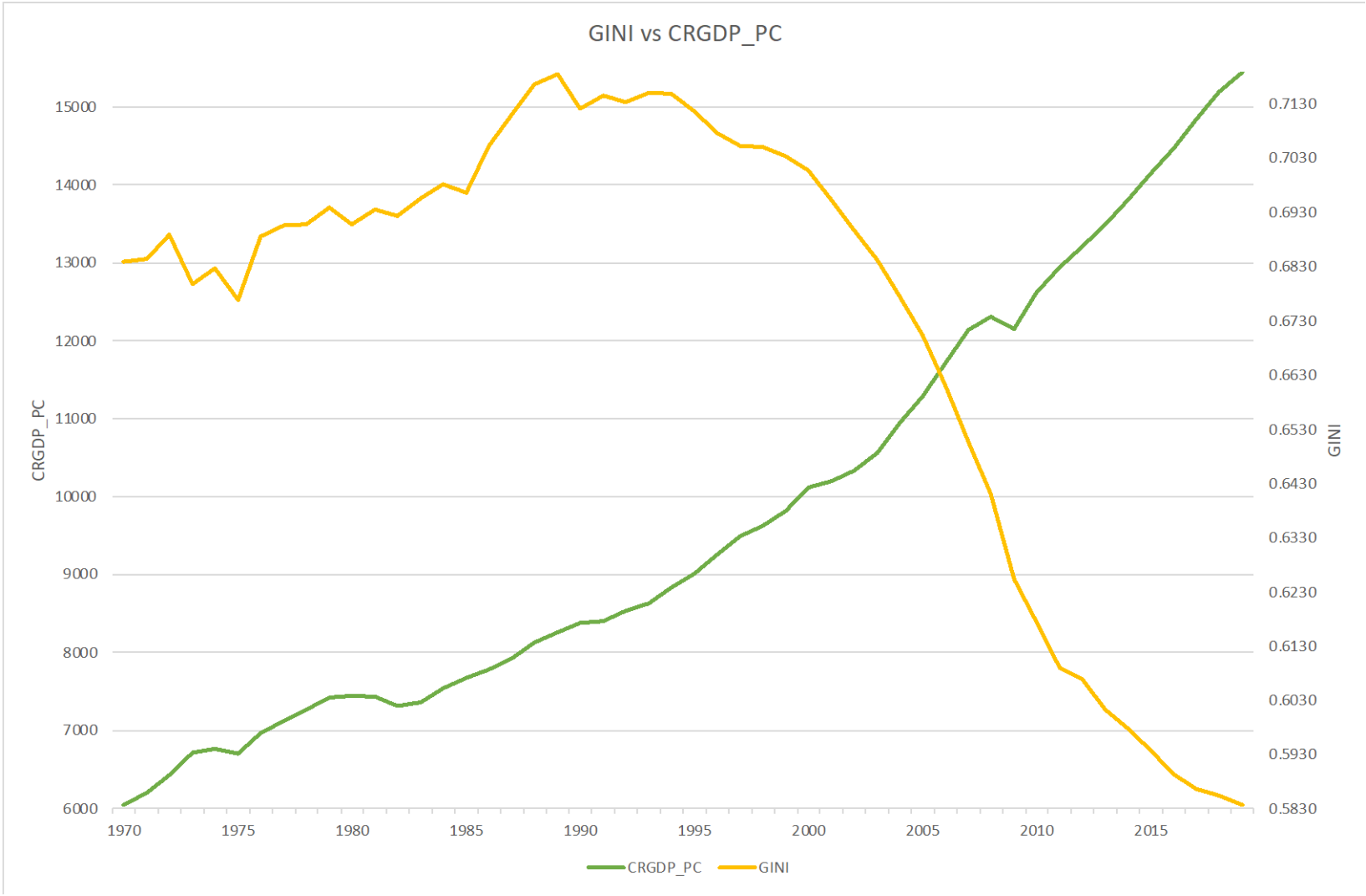
Measure	VALUE
RGDP_1970	$3.428 trillion
RGDP_2019	$125.929 trillion
RGDP_2019/RGDP_1970	36.73
DOM_GR	6.33
DOM_INF	61.64
PPP_EFFECT	0.10
PRICE_EFFECT	6.13

Ln(Growth rates)		% contribution
LN(RGDP ratio)	3.60	
LN (DOM_GR)	1.79	49.68%
Australia	0.02	0.98%
China	0.45	25.36%
Germany	0.05	2.62%
India	0.15	8.37%
Japan	0.07	3.90%
United States	0.33	18.51%

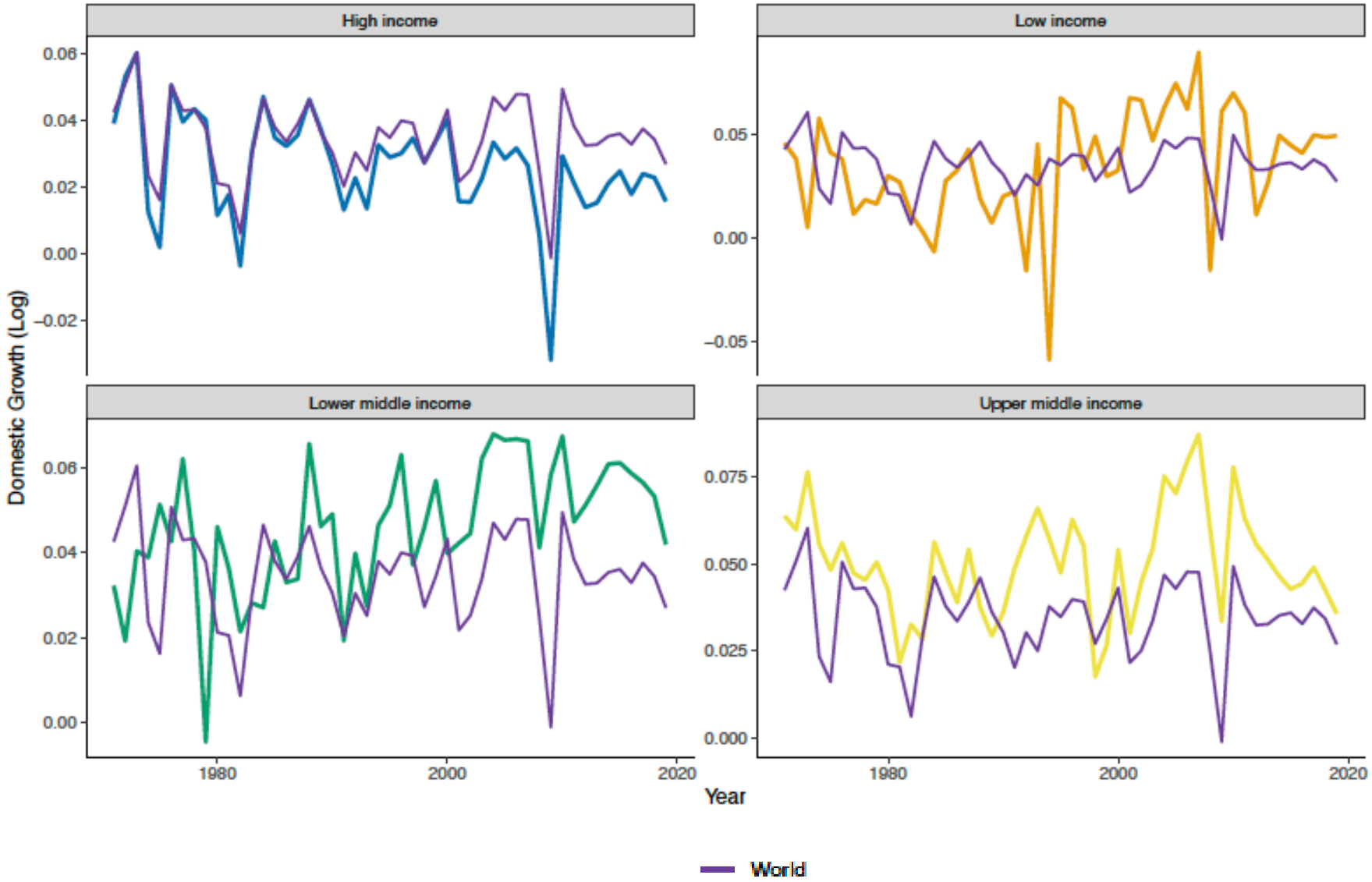
Shares in World Real GDP by Income Groups

Countries by income Groups	1970	2000	2019
Low income	1	1	1
Lower middle income	9	9	15
Upper middle income	16	21	35
High income	74	69	49

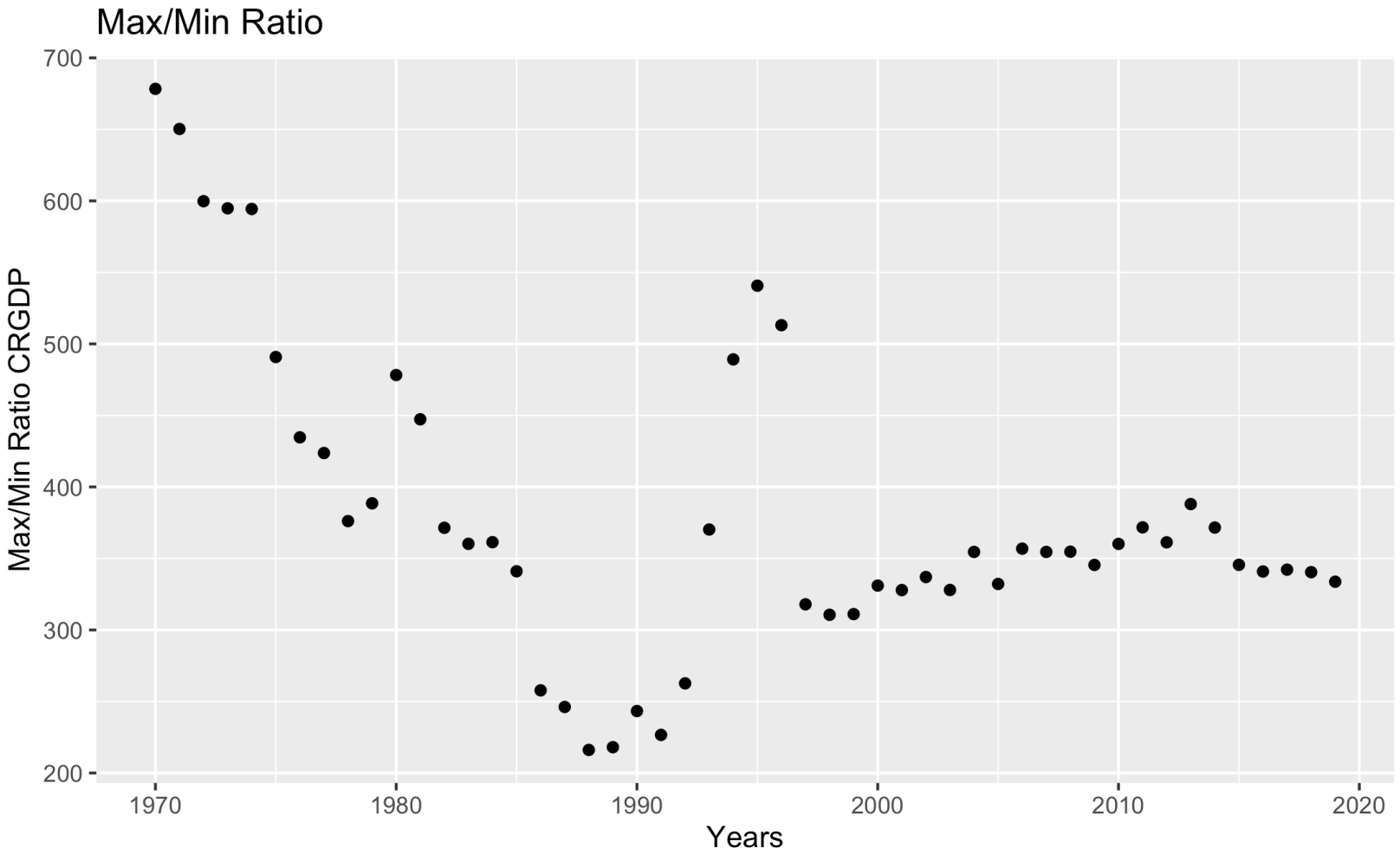
Global Growth and Inequality 1970-2019



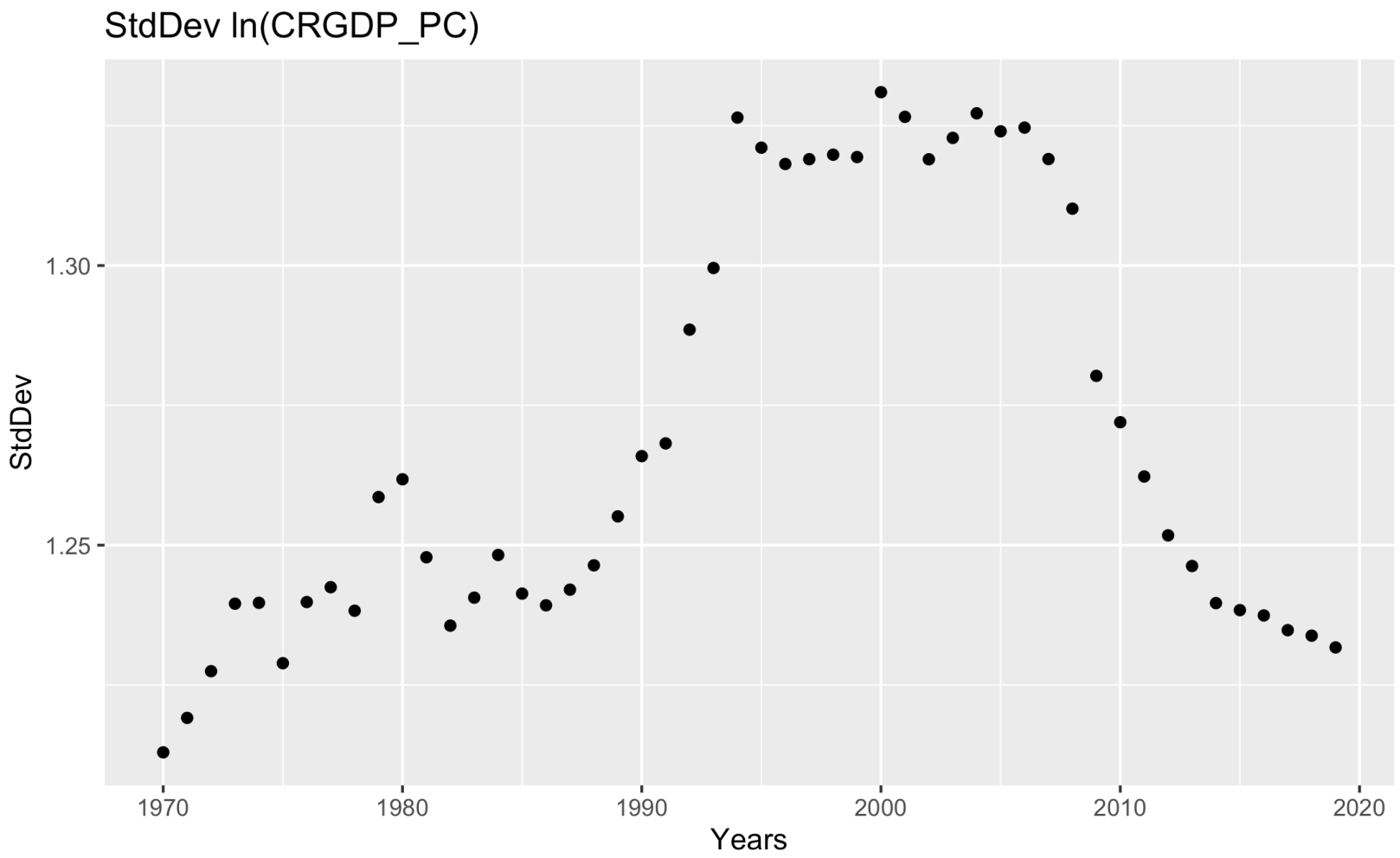
Growth: Income based groups



Ratio of Max to Min real per capita incomes



Standard deviation of log of per capita incomes



Growth Incidence Curves

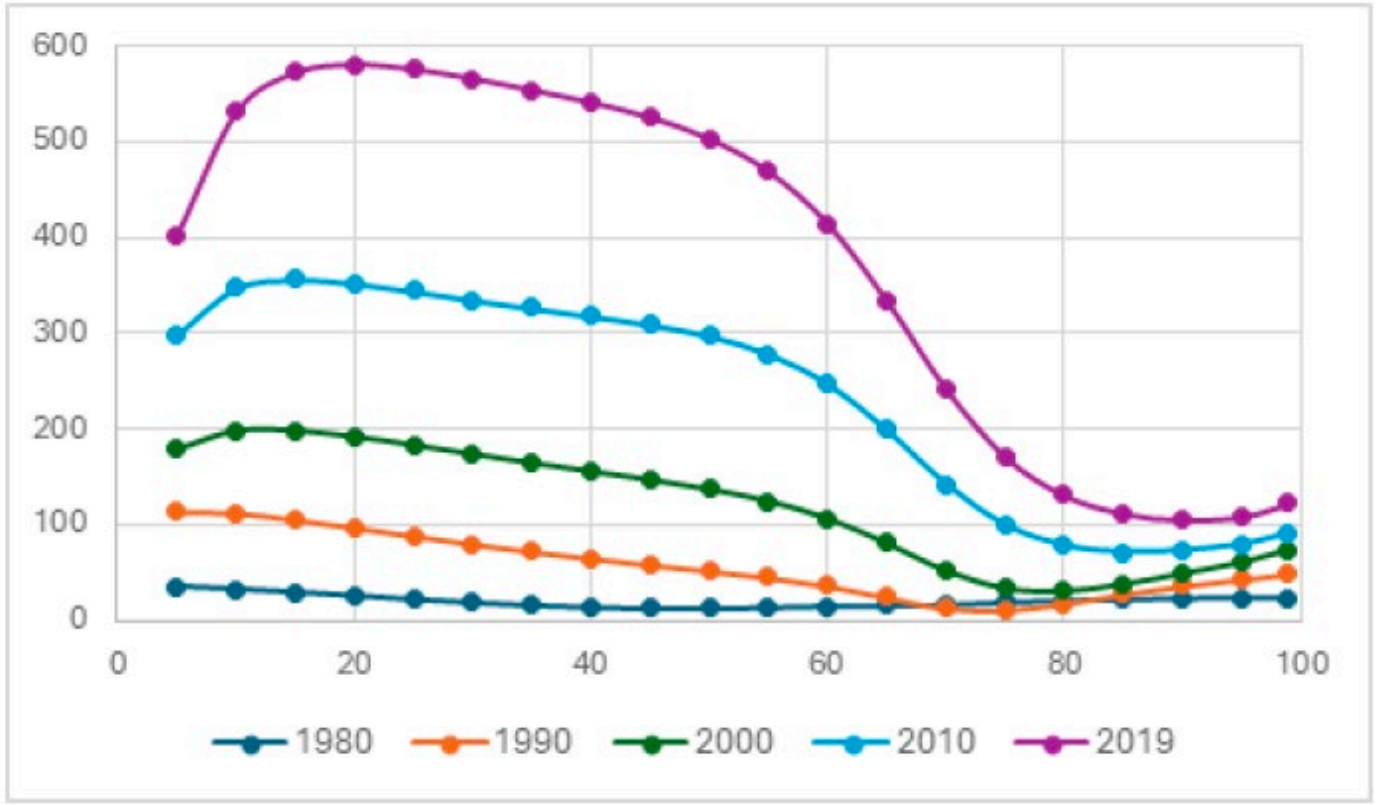
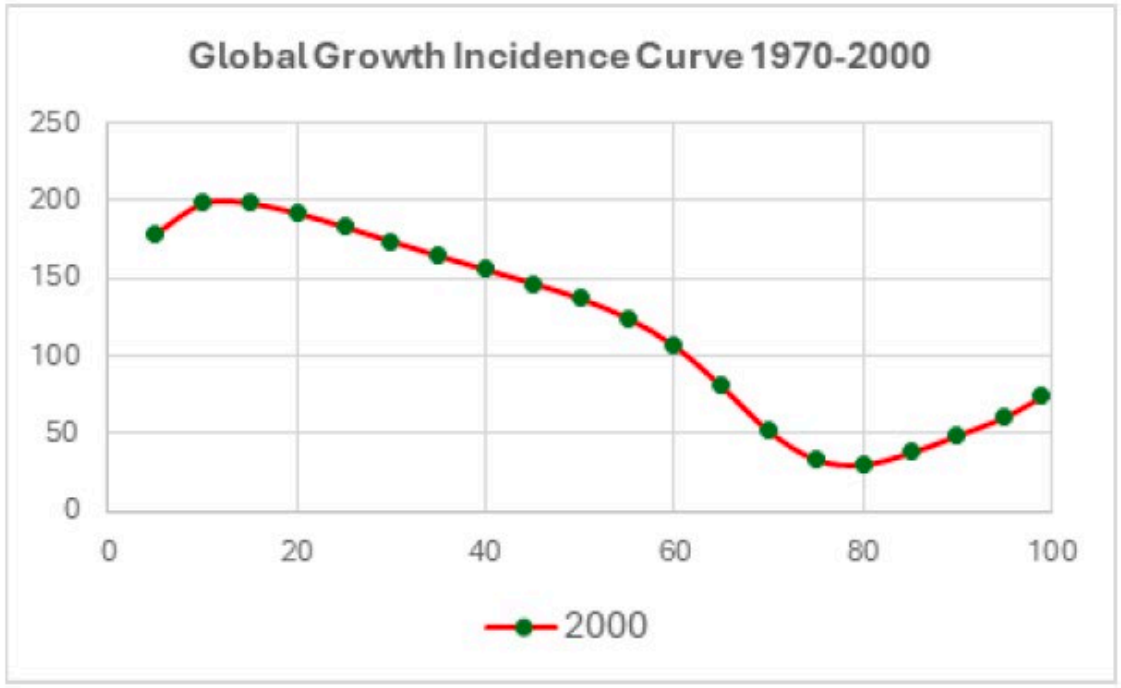


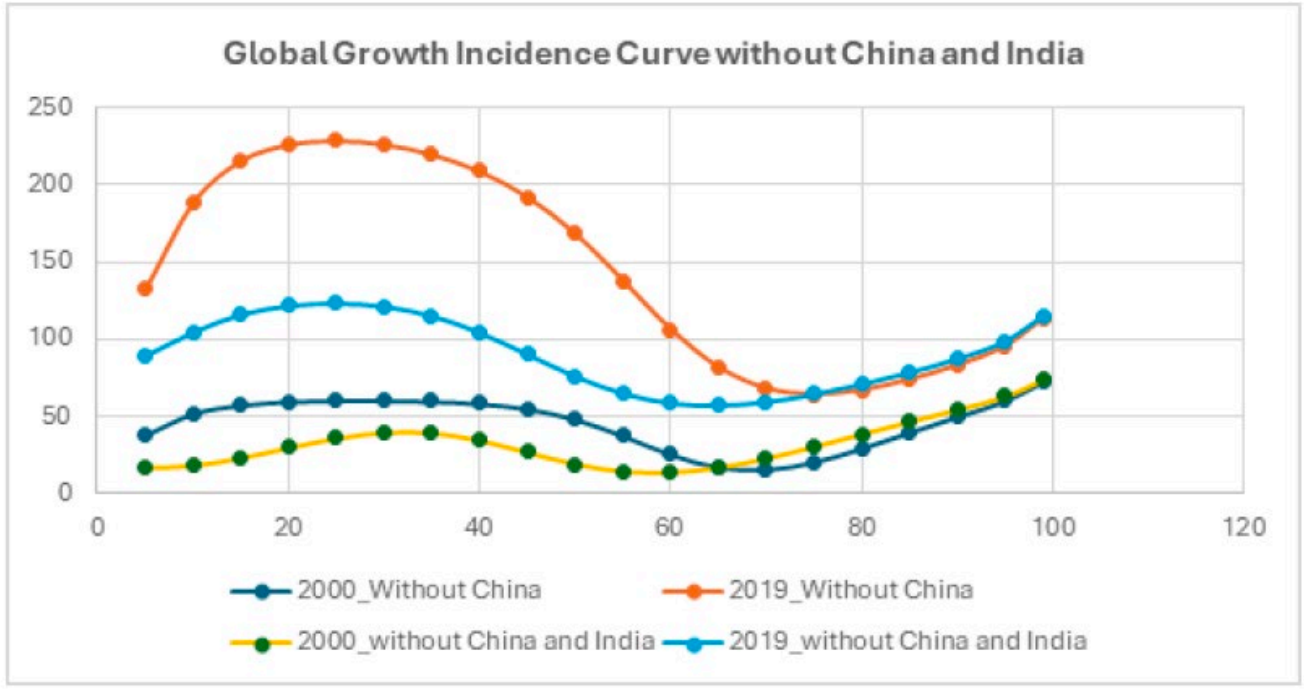
Figure 4: Growth Incidence Curves: 1980, 1990, 2000, 2010, 2019

Support the huge shift in shares from rich country-group to upper middle and lower-middle class. Poorer sections of the community had low growth rates compared to high growth rates enjoyed by upper middle and richer sections. These growth rates, especially in the graph to 2019, are largely influenced by growth performance of China and India.

Compared to Lakner and Milanovic (2013) graph, our graphs are less granular at the top end of the distribution.

Growth Incidence Curves



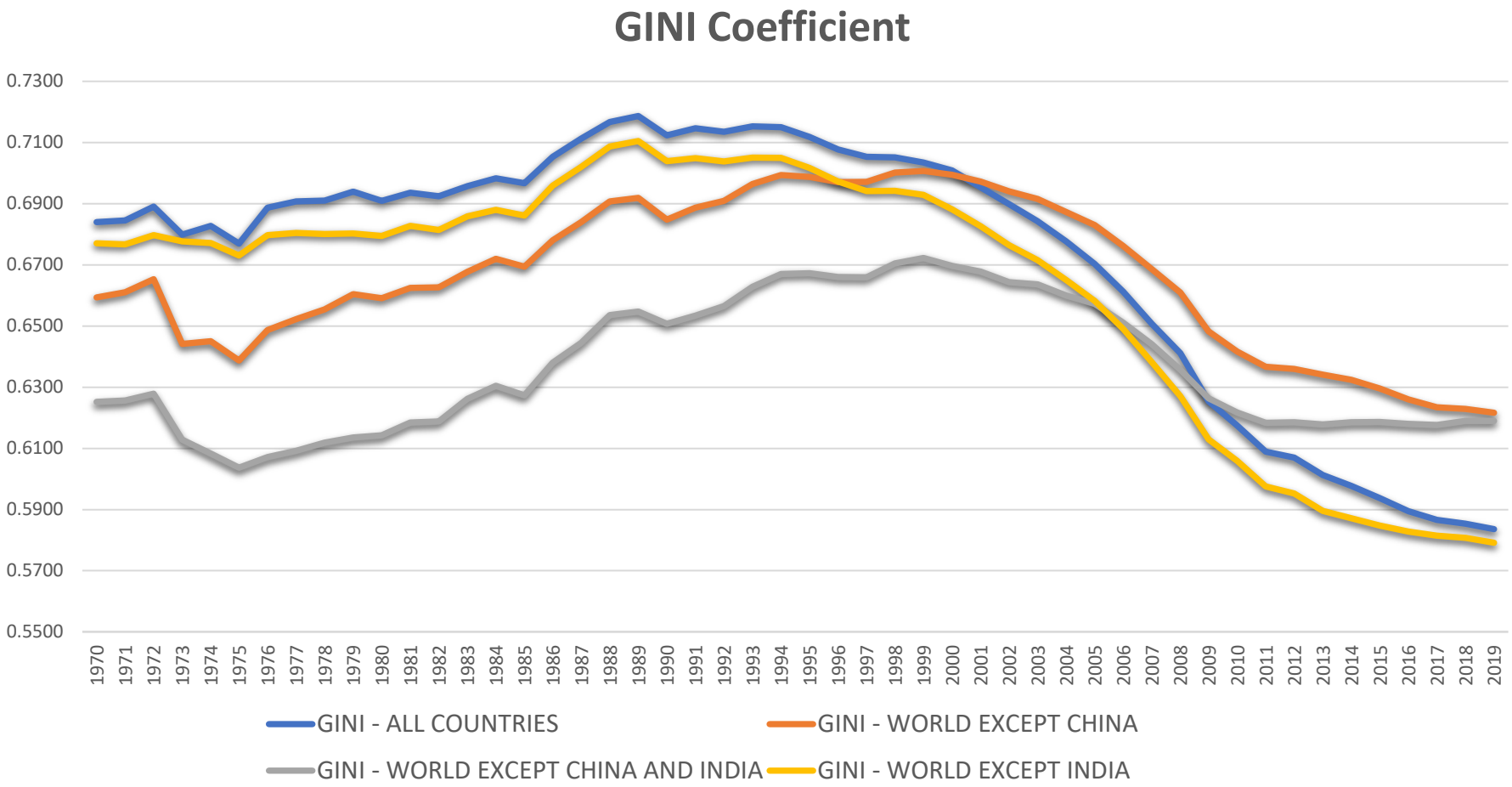


Our growth incidence curve for the period 1970 to 2000 is somewhat similar to that reported in Lakner and Milanovic (2023) where the now popularly referred to “elephant curve” emerged.

Our figures are less granular at the top end of the income scale as our data from World Bank are based on ventile shares.

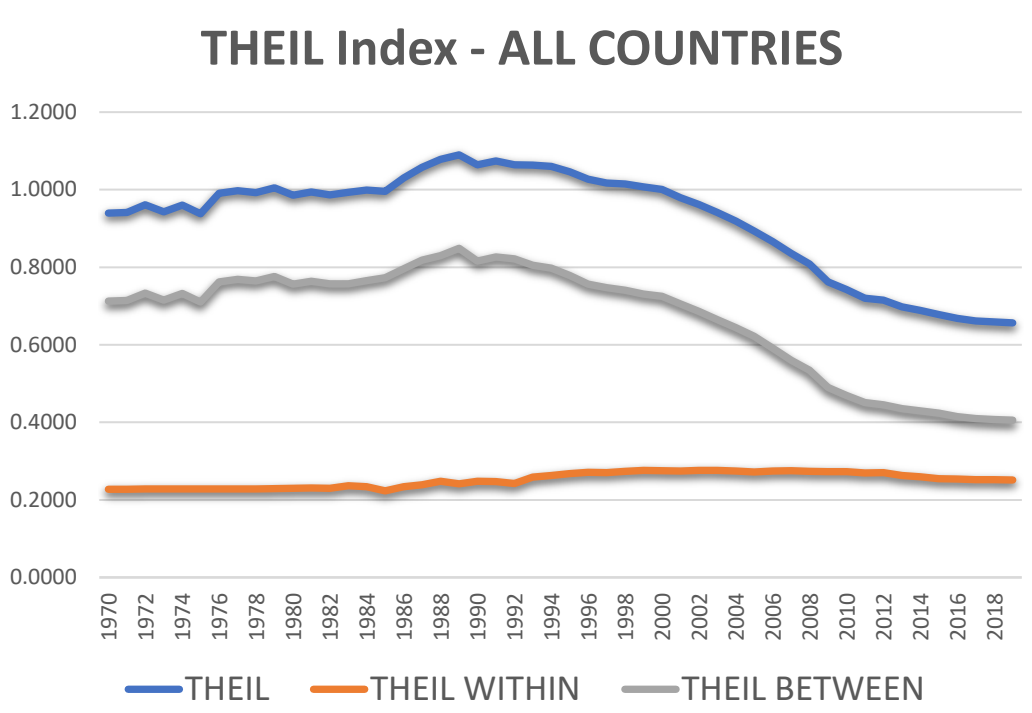
We also observe a vanishing “elephant curve” when we consider periods up to 2010 and 2019.

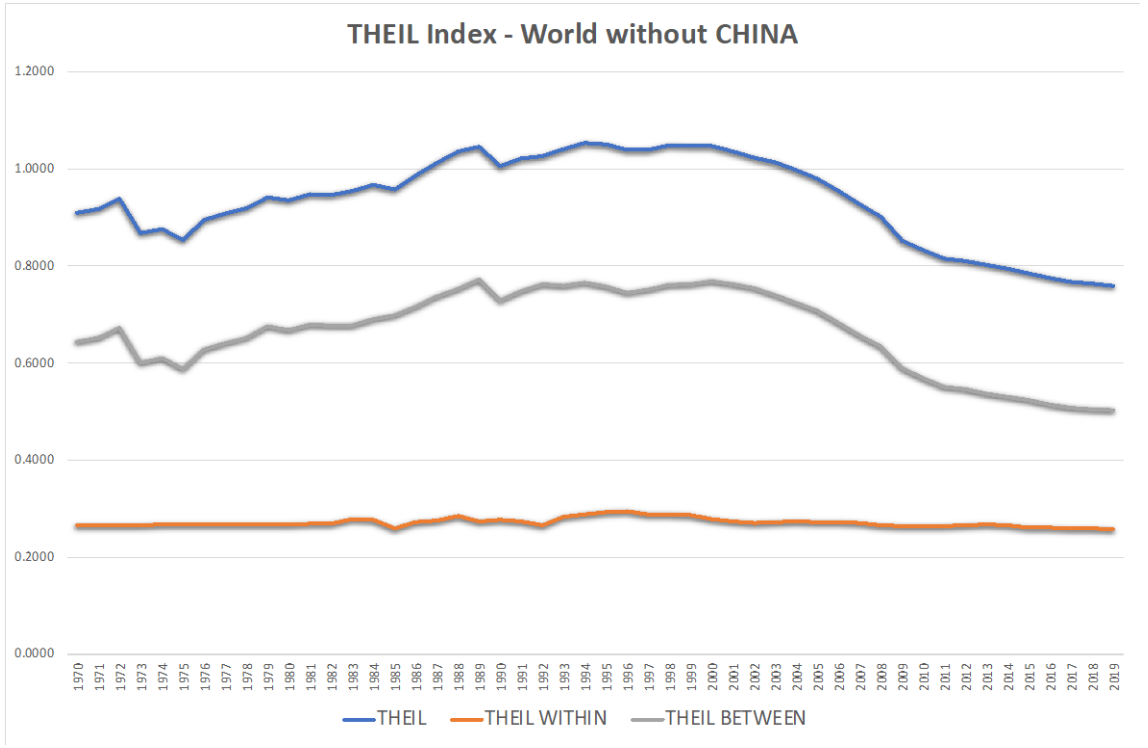
Global inequality



World inequality increased until 1990 and since then has shown a steady decline indicating a degree of convergence in incomes of people in the world. The China and India effects are shown.

Global inequality





Theil's index shows that between country inequality is a major driver of inequality in the world and that it has been decreasing since 1990's. This is indicative of convergence in real per capita incomes of countries.

Sala-i-Martin β-convergence (absolute) - 159 Countries

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Table 5: Absolute β-Convergence Regressions (World)

	1975-85	1985-1995	1995-2005	2005-19	1975-2019
Estimated β	0.025***	0.022***	0.020***	0.021***	0.019***
	(0.003)	(0.004)	(0.004)	(0.003)	(0.001)
N	159	159	159	159	159
R2	0.434	0.333	0.177	0.319	0.702
AIC	-717.9	-690.3	-723.2	-797.0	-1017.9
BIC	-699.5	-671.9	-704.8	-778.5	-999.5
Log.Lik.	364.966	351.147	367.590	404.477	514.951
F	29.508	19.193	8.272	18.021	90.774
RMSE	0.02	0.03	0.02	0.02	0.01

Regression: $y = a - \beta x + FE + noise$; if $\beta > 0$ the data exhibits absolute convergence (Sala-i-Martin, 1996, Econ Journal)

$y = (1/(T-t))*\ln(CRGDP\_PC_T/CRGDP\_PC_t)$; $x = \ln(CRGDP\_PC_t)$; WB income group fixed effects.

Sala-i-Martin β-convergence (absolute) – OECD Countries

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Table 6: Absolute β-Convergence Regressions (OECD)

	1975-85	1995-2005	2005-19
Estimated β	0.009**	0.021***	0.017***
	(0.004)	(0.004)	(0.004)
N	30	36	36
R2	0.138	0.438	0.367
AIC	-180	-210.1	-229.6
BIC	-175.8	-205.4	-224.9
Log.Lik.	92.994	108.074	117.801
F	4.501	26.549	19.751
RMSE	0.01	0.01	0.01

Regression: $y = a - \beta x$; if $\beta > 0$ the data exhibits absolute convergence (Sala-i-Martin, 1996, Econ Journal).
$y = (1/(T-t))*\ln(CRGDP\_PC_T/CRGDP\_PC_t)$; $x = \ln(CRGDP\_PC_t)$;

Relative Transition Coefficients

Phillip and Sul (2009)l introduced the notion of relative transition coefficients, which are defined for each country *i* as:

$$h_{it} = \frac{\log(CRGDP\_PC_{it})}{M^{-1}\sum_{i}^{M} log\,(CRGDP\_PC_{it})}$$

where *CRGDP_PC* is per capita real GDP (in PPP terms) at constant 2011 prices.

In our work we also consider a variant that uses population share weights:

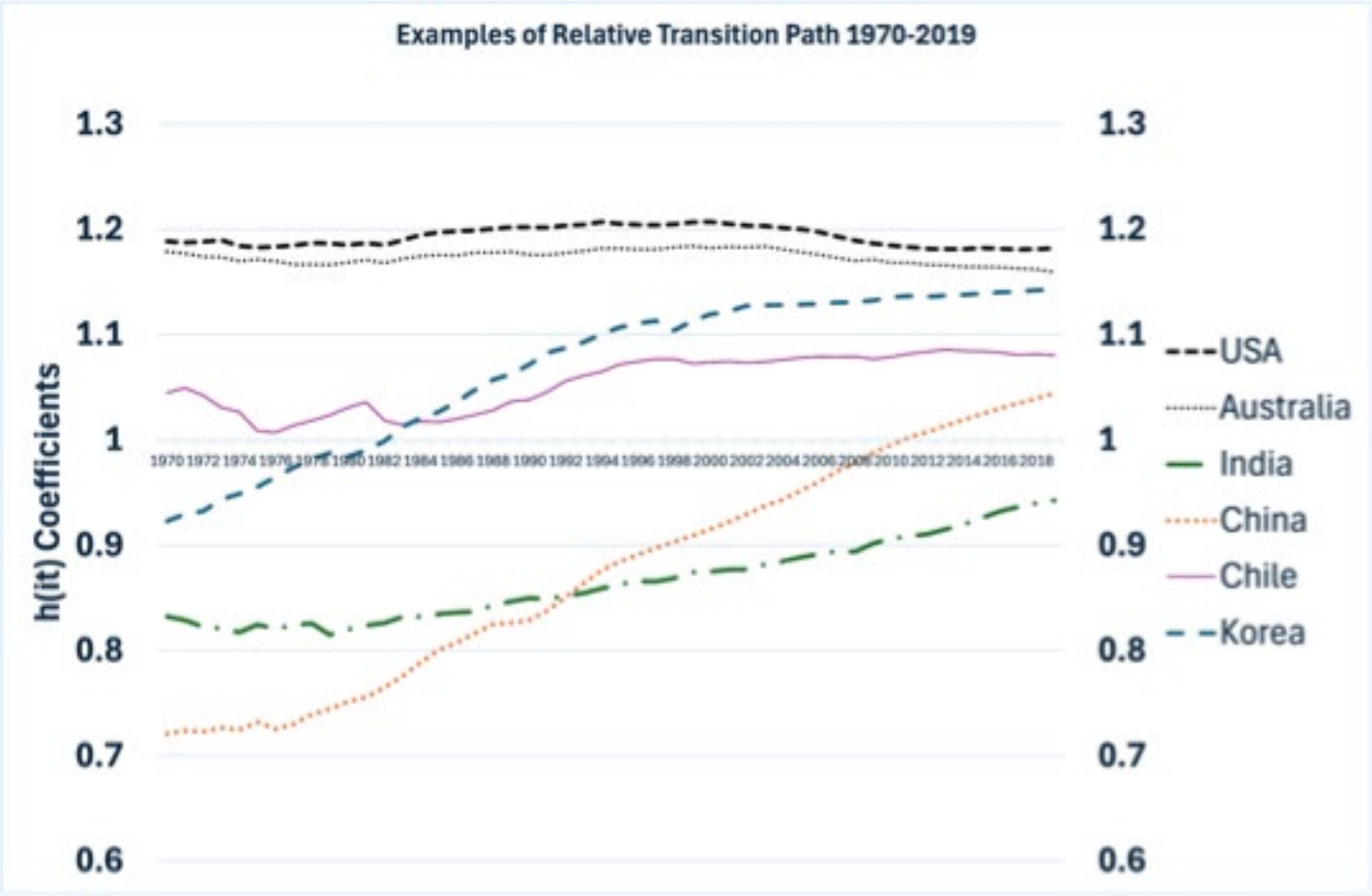
$$h_{it}^{*} = \frac{\log(CRGDP\_PC_{it})}{\sum_{i=1}^{M} w_{it}\, log\,(CRGDP\_PC_{it})}$$

There could be a common (limiting transition behaviour across economies. The transition path of these coefficients can be used to measure the extent of the divergent behaviour and to assess whether such divergence is transient.

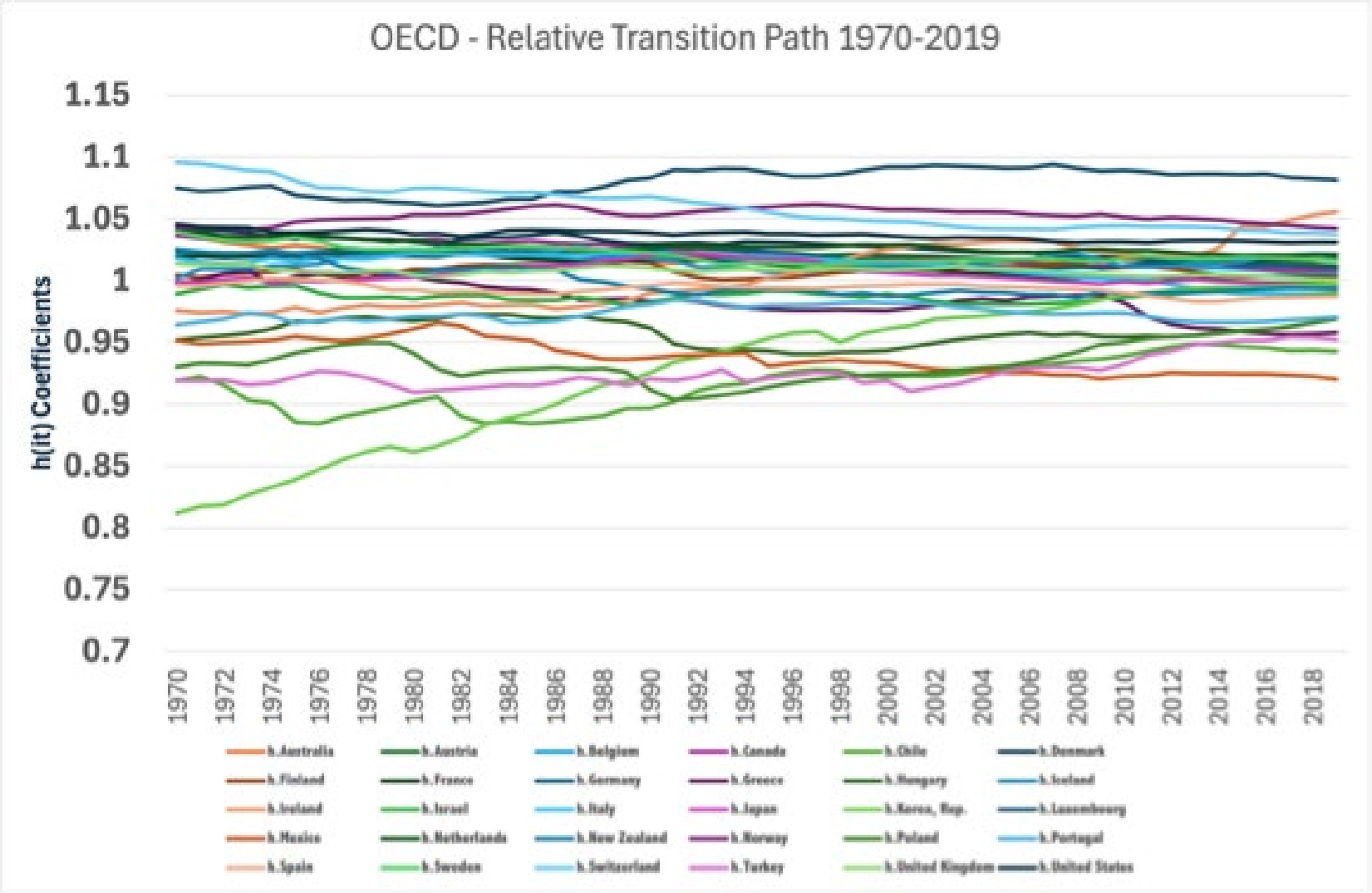
Ultimately growth convergence is given by:

$$h_{it} \rightarrow 1 \forall i, \text{ as } t \rightarrow \infty.$$

Relative Transition Coefficients (Selected countries, 1970-2019)



Relative Transition Coefficients (OECD countries, 1970-2019)



Phillips and Sul (2009) Test for Convergence

The Phillips and Sul (2009) "Log t'" test is implemented by estimating the following Regression:

$$\log \frac{H_1}{H_t} - 2\log(logt) = a + \gamma logt + u_t, \ for\ t = T_0, \ \ldots, \ T$$

where

$H_t = M^{-1}\sum_{i=1}^{M}\left(h_{it}^{v} - 1\right)^2 \quad h_{it}^{v} = h_{it}, h_{it}^{*}$ as defined

(i) If $\gamma \geq 2$ (and the growth component μ_t follows a random walk with drift or a trend stationary process), then large values of γ imply convergence in level per capita incomes.

(ii) If $2 > \gamma \geq 0$ the speed of convergence corresponds to conditional convergence, i.e. income growth rates converge over time.

(iii) If $\gamma < 0$ there is no evidence of convergence.

Phillips and Sul (2009) Test

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Table 7: Phillips and Soul (2009) Convergence Test

Transition Parameter	Estimate	World	OECD	Asia	SSF	LMI	MEA	UMI
Unweighted (h_{it})	$\hat{\gamma}$	-0.675***	-0.349***	-0.347***	-0.899***	-0.234***	-0.494***	**0.232***
Weighted (h^*_{it})	$\hat{\gamma}$	-0.420***	-0.351***	-0.076	-0.920***	**0.1195***	-0.361***	**1.321***
N		159	36	21	45	46	16	49
rT		45	45	45	45	45	45	45
Conclusion		No C	No C	No C	No C	Mixed	No C	Cond. C

*** Significant at 1% level ** Significant at 5% level, * Significant at 10% level

$0 < \hat{\gamma} \leq 2$ the speed of convergence corresponds to conditional convergence, i.e. income growth rates converge over time.

- **We find no evidence of convergence in levels or conditional convergence for the world and most regions with the exception of the Upper Middle Income Group. Our results are consistent with results reported by Phillips and Sul (2009) which uses PWT data for 1970 to 2003.**

- **We find conditional convergence for Lower Middle Income group when we use population weighted measure.**

Weak Convergence Test (Kong et al, 2099)

The third test we implement was introduced by Kong et al. (2019) building on Phillips and Sul (2007, 2009). This is a test for weak σ-convergence, whereby the cross-section variation in the panel decreases over time. The paper formalizes this concept and proposes a simple-to-implement linear trend regression test of the null of no σ-convergence.

The test is based on running the regression:

$$K_{nt} = \widehat{a_{nT}} + \widehat{\phi_{nT}}\, t + \widehat{u_t}, \quad t = 1, ..., T$$

where, K_{nt} cross-section sample variation, $n = 1, ..., M$

$\hat{u}_t$ is the fitted residual

$\widehat{\phi_{nT}}$ is the time trend slope coefficient

This is a one-sided test on the slope coefficient of time trend *t*.

Weak Convergence Test (Kong et al, 2099)

Table 8: Kong et al (2019) σ-Convergence Test

	World	OECD	Asia	SSF	LMI	MEA	UMI
t-stat	**-11.504**	370.446	89.700	266.503	127.087	**-134.582**	**-134.460**
Conclusion	Weak σ -C	No evidence of weak σ -C				Weak σ -C	Weak σ -C

Note: One sided t-test: Critical value -165. Negative implies evidence of weak σ-convergence

There is evidence of weak σ-convergence for the *World* and two subgroups (*Middle East and North Africa* group-MENA and *Upper Middle Income* Group - UMI as defined by the World Bank).

The consistent finding that the Upper Middle Income group shows evidence of conditional convergence, and weak σ- convergence is within expectation. This is the group of countries that has been driving the growth in the world economy over that last thirty to forty years.

Divergence of Income Distributions

Here we wish to examine:

- **If income distributions of countries are diverging from period to period**
- **If income distributions of the world are bunching together (convergence)**

- **We use the approach developed by Hajargasht (2022) to derive these measures for specific distributions.**

- **The approach relies on the Kullback-Leibler measure divergence between two distributions:**

Divergence in Income Distributions

Following Cowell et al (2009), we consider the following class of divergence measures between distributions:

$$D_\alpha(q_1, q_2) = \frac{1}{\alpha(1-\alpha)} \int \left(1 - q_1(x)^\alpha q_2(x)^{1-\alpha}\right) dx \quad \alpha \neq 1, 0$$

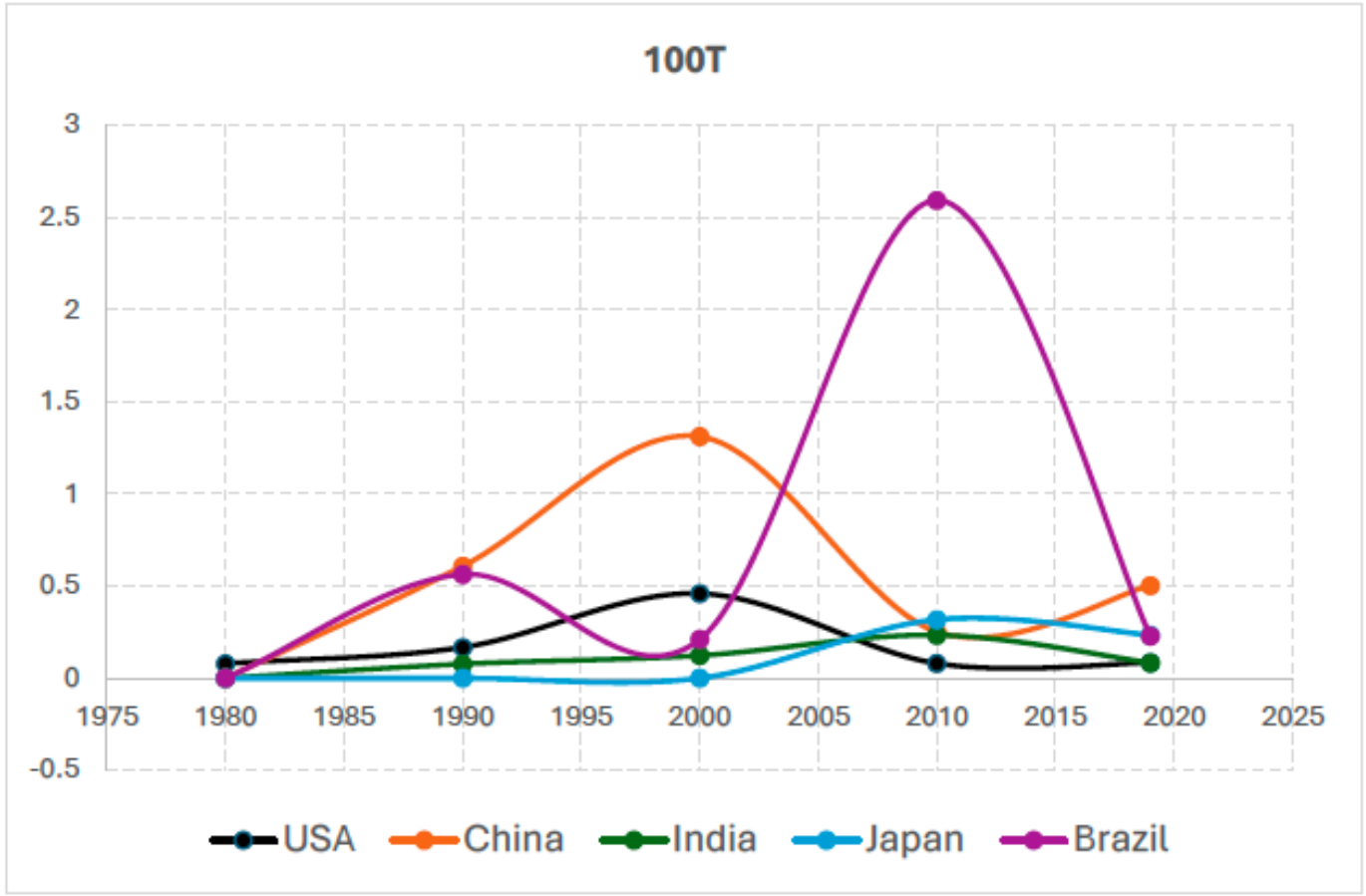
$$= K(q_1, q_2) = \int q_1(x) \ln\left[q_1(x)/q_2(x)\right] dx \quad \alpha = 1$$

where q_1 and q_2 are density functions of two income distributions. A scale-independent version based on share functions $s(\pi)$ is given by:

$$T_\alpha(q_1, q_2) = \frac{1}{\alpha(\alpha-1)} \int_0^1 \left[s_1(\pi)^\alpha s_2(\pi)^{\alpha-1} - 1\right] d\pi \quad \alpha \neq 0, 1$$

$$T_1(q_1, q_2) = \int_0^1 s_1(\pi) \ln\left[s_1(\pi)/s_2(\pi)\right] d\pi$$

Divergence of Income Distributions over time



Measuring Total Divergence among of Income Distributions of countries in the world

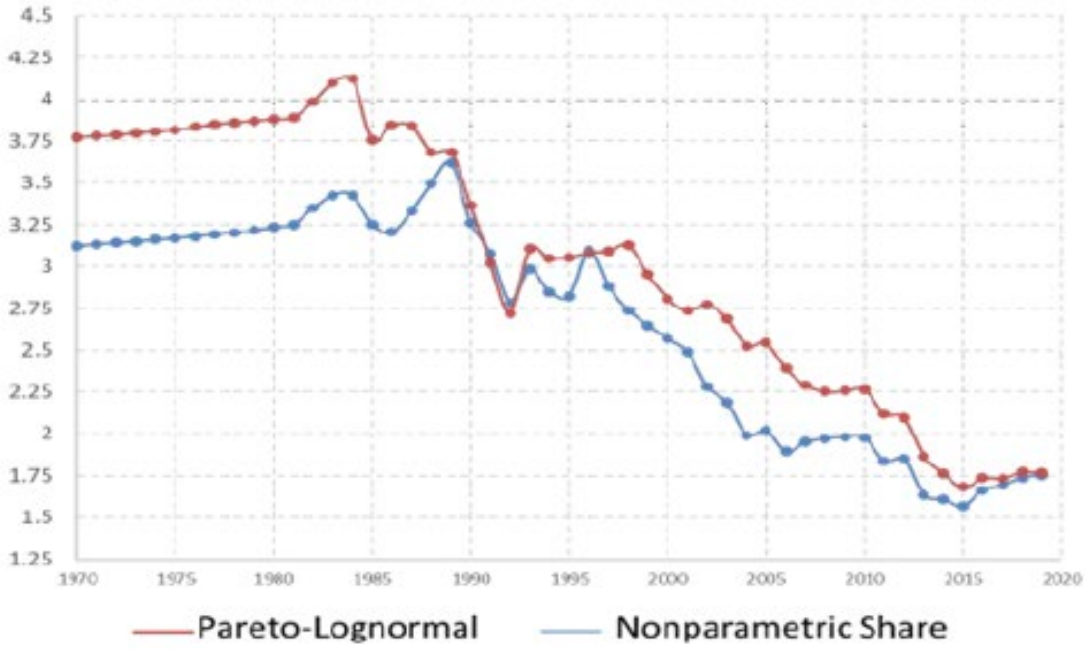
- We measure divergence between distribution of country *j* from the distribution of country *k using the T_J - measure described - for all pairs j and* k.
- We propose a measure of total divergence as the average of the divergence between income distributions of all pairs of countries. This is given by:

$$\tau_J(q_1, \ldots, q_M) = \frac{1}{1 - \sum_{i=1}^{M} w_i^2} \sum_{i=1}^{M} \sum_{j=1}^{M} w_i w_j T(q_i, q_j)$$

where w_i is the population share of the country and *M* is the number of countries. The bivariate divergence measure defined above can be computed and used in this formula.

Divergence of Income Distributions of Countries: 1970-2019

100 x T_J Measure for the World



Source: Authors' calculations using UQICD V3.0 data.

Closing Remarks

- **Real size (in PPP terms, the world economy grew from $3.5 trillion to $125.9 trillion**
  - **a 36.7 – fold increase in the size**
  - **growth accounted for 50% and price effects for another 50%**
  - **China's contribution to this growth is 25.36%, followed by USA (18.51%); India (8.37%) and Japan (3.9%)**
- **Disparities have been decreasing**
  - **Ratio of per capita incomes of the richest to poorest decreased from 680 times in 1970 to 340 times in 2019**
  - **Global inequality peaked during 1990 to 1995 with a Gini coefficient around 0.72 decreasing to 0.575 by 2029**
  - **However, if China and India are not included, global inequality has been on the rise since 2010 increasing to 0.62 in 2019.**

Closing Remarks

- **Income convergence**
  - There is strong evidence of income convergence
  - Strong reduction in max-min per capita incomes
  - Standard deviation of logarithm of incomes showed a steady increase until the 1990's and has been declining since 2005
  - Evidence of strong absolute as well as conditional convergence over the whole period but stronger evidence during 2005 to 2019
  - Strong evidence of weak-sigma convergence (test based on Kong, Phillips and Sul, 2019) in the world but not in OECD countries
  - Evidence from growth rates by income groupings and trends in Theil's between country inequality is supportive of income convergence.
  - Growth incidence curves show different patterns over different decades. GIC for the decade of 1990 to 2000 shows elephant curve pattern.

Thank you!