Accelerating Convergence in the World Income Distribution

Tim Kane*

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HOOVER INSTITUTION
434 GALVEZ MALL
STANFORD UNIVERSITY
STANFORD, CA 94305-6010

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In the 1990s, cross-country empirical data suggested that the world income distribution was diverging into two peaks, rich and relatively poor. With the passing of time, we can update that empirical analysis by calculating a Markov transition matrix for the most recent two decades. This paper presents the clearest empirical picture to date of how the world income distribution has changed every succeeding decade from 1960 to 2010. This paper also compares transition matrices for 122 countries over two periods, 1970-90 and 1990-2010 and finds that divergence in the earlier period has shifted to convergence in the latter. Further, differencing the two matrices shows how the dynamic is itself evolving. Projecting these dynamics forward suggests rapid growth across all regions over the coming century that will bring nearly all countries to within 80 percent of the per capita income frontier.

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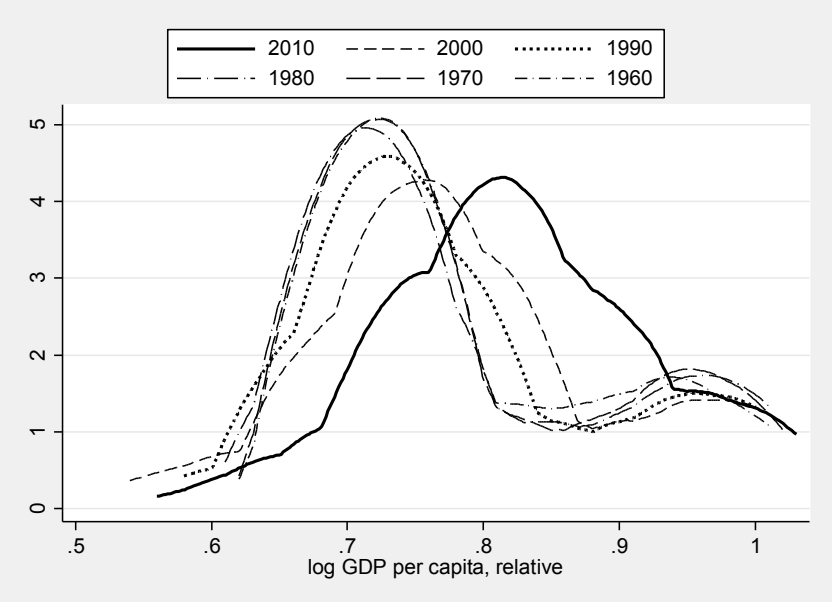
* Contact is Tim Kane (tjkane@stanford.edu), 464 Galvez Mall, Hoover Institution, Stanford University, CA 94305.

1 Introduction

Two decades ago, the world's economies seemed to be diverging into rich and poor clubs, widely described as the first world and the third world. A series of studies attempted to resolve the convergence question, notably Abramowitz (1986), Baumol (1986), and DeLong (1988). With panel data in the form of the Penn World Table (PWT), scholars were able to investigate theories of comparative growth across countries and time. Econometric studies attempted to resolve the convergence question by identifying a significantly negative coefficient on the typical country's initial income level in an equation explaining its growth rate. "Divergence, Big Time" was the provocative conclusion drawn by Lant Pritchett (1997).

In contrast, the possibility of a diverging "twin peaks" phenomenon was first identified by Quah (1993, 1996). It is possible for the median country to be converging (or diverging) despite the separation of the distribution into two income clubs, one rich, one poor. Quah was challenging researchers to look at the world income distribution's changing shape instead of econometric models. Within a decade there were empirical papers showing the divergence conclusion had been premature, notably Sala-i-Martin's (2006) aggregation of internal country income distributions.

Figure 1. Relative log incomes 1960-2010, population weight (N=106)



A novel approach to the convergence debate was Charles Jones' (1997) analysis of the evolution of the world income distribution between 1960 and 1988 using a Markov switching matrix. The matrix captured how countries moved among six income tiers relative to the leading economy (the United States). Further, Jones used the matrix to forecast a long-term equilibrium which confirmed the twin peaks dynamic. Even so, Jones concluded, "The long-run results here suggest that there is no development trap into which the poorest countries will be permanently

condemned." This long-run distribution, the result of multiplying the distribution by the transition matrix "many times," anticipates a future in which only one-fifth of countries will be in the richest tier (above the 80 percent relative level of the highest-income country). Anyone who doubted that conclusion had to wait until the PWT aged and increased its time dimension.

Have the distribution dynamics been steady? I hypothesize that the transition matrix is itself evolving, perhaps accelerating. Using data from the latest Penn World Table (Mark 8.1), figure 1 shows that the population-weighted world income distribution has evolved away from twin peaks into a single, fatter-tailed, wealthier peak. The figure shows six different distributions for each decade: 1960, 1970, 1980, 1990, 2000, and 2010 – each relative to the leading economy. Even though the leading economy is itself growing, there has been a distinct and uninterrupted rightward shift in each succeeding distribution. Moreover, the rightward shift appears stronger with each decade. In this paper, I compare the predicted 2010 distribution to the actual 2010 outcomes. I also explore whether the transition dynamics have been steady.

2 Transition Dynamics

The PWT contains population and real gross domestic product measures to allow for cross-country comparisons of income per capita over time. There are 167 countries in the table, but some have data that extends back no further than 1960, some to just 1970. Many countries have populations of 300,000 people or fewer, and those were not included here.

The first challenge in conducting this kind of study is defining the dataset. It involves a tradeoff between breadth of countries and length of years. The longest possible dataset that includes observations from 1950 can include only 53 countries. More than twice as many countries (106) are included if the dataset starts in 1960. However, the relative distribution of incomes in 1960 is nearly identical to 1970, and by limiting the time dimension to 1970, 122 countries can be included in the panel. This paper focuses on a 122 country dataset of real GDP per capita. That allows me to calculate a transition matrix for two different periods, 1970-1990 and 1990-2010. The two periods have wildly different transition dynamics.

If we calculate a single matrix based on the transition of countries from 1970-1990, similar to what Jones calculated for 1960-1988, our projected world income distribution will remain twin-peaked a century from now. If we use the 1990-2010 matrix, the projected distribution will be dramatically wealthier and single-peaked. Both approaches assume the same matrix dynamics will iterate forward. Alternatively, if we calculate a model of matrix evolution, the dynamics continuously change, which predicts that nearly every country in the world will have converged to the top tier in 100 years.

In 1970, one in five countries could be considered advanced economies. The rest had per capita incomes that averaged less than 40 percent of the United States level. Table 1 shows the distribution of relative national income per capita using the six tiers defined by Jones. The poorest countries (which I label tier 6) have average per capita incomes below 5 percent of the contemporary U.S. level. The cutoff levels between the six tiers are 5 percent, 10 percent, 20

percent, 40 percent, and 80 percent. For example, U.S. income per capita in 1970 was $20,547. Indonesia's average income was $821, which placed it in tier 6.

Table 1. World Income Distributions in 1970, 1990, and 2010

		1970	1990	2010
Tier 6	$\hat{y} \leq .05$	16	32	27
Tier 5	$.05 < \hat{y} \leq .10$	32	21	17
Tier 4	$.10 < \hat{y} \leq .20$	27	22	21
Tier 3	$.20 < \hat{y} \leq .40$	22	18	21
Tier 2	$.40 < \hat{y} \leq .80$	18	25	20
Tier 1	$\hat{y} > .80$	7	4	16

Entries in the table reflect the number of countries with relative incomes in each tier. Income per capita relative to the highest-income country is represented by the variable $\hat{y}$.

In 1990, the world income distribution looked visibly twin-peaked: the number of the relative poorest countries (tier 6) doubled from 1970, while the number of countries in the richest two tiers also increased. This 1970-1990 trend is what led many observers to the conclusion that the world was diverging rather than converging. However the most recent data for the year 2010 shows a remarkable turnaround. There was a shift of countries up the distribution tiers, with fewer in the poorest relative group and many more in the richest tier 1.

Within this overall distribution, there were dynamic shifts. The full transition pattern is shown in figure 2. It shows 39 countries dropping to lower-income tiers, 63 holding steady, and only 20 rising to higher-income tiers. Looking specifically at the poorest relative tier, there were 16 countries in tier 6 in 1970, and 32 in in 1990. This is a result of 12 countries staying in the tier, four rising (three to tier 5, one to tier 4), and 20 falling (18 from tier 5, two from tier 4).

Figure 2. Country transitions among relative income tiers, 1970-1990

		1970						
		Tier 6	Tier 5	Tier 4	Tier 3	Tier 2	Tier 1	
1990	Tier 6	12	18	2				**32**
	Tier 5	3	9	8	1			**21**
	Tier 4	1	4	13	4			**22**
	Tier 3		1	4	11	2		**18**
	Tier 2				6	15	4	**25**
	Tier 1					1	3	**4**
		16	**32**	**27**	**22**	**18**	**7**	**122**

For example, by 1990, Indonesia's average income had risen to $2730 while the U.S. had grown to $31,439. In relative terms, Indonesia had 8.7 percent of U.S. income levels, which

means it rose to tier 5. Unfortunately, that kind of fast growth experience was rare in the two decades after 1970.

The next step is to convert the numbers from figure 2 into a transition matrix M of the form

$$\hat{y}_2 = M\,\hat{y}_1$$

where $\hat{y}_i$ is a vector of relative income per capita counts at the end of period i and M is the transition matrix governing movement among the tiers. This is a simple matter of changing each column in figure 2 into fractions that sum to unity, shown in figure 3.

Figure 3. Markov transition matrix, 1970-1990

$\mathbf{M_1} =$

75%	56%	7%	0%	0%	0%
19%	28%	30%	5%	0%	0%
6%	13%	48%	18%	0%	0%
0%	3%	15%	50%	11%	0%
0%	0%	0%	27%	83%	57%
0%	0%	0%	0%	6%	43%

Is this M dynamic stable over time? In other words, is the matrix M_1 steady for all time periods, or does it evolve into some M_2 for the next 20-year period, M_3 for the next, and so on? This is easy to assess by projecting one cycle ahead ($\hat{y}_3$) using the M_1 matrix. In table 2, I compare this projected 2010 distribution to the actual 2010 distribution in the PWT. The difference is dramatic: there are ten fewer tier 6 countries and five *times* more tier 1 countries in reality than the M_1 dynamics projected.

Table 2. World Income Distributions in 2010, projected and actual

		2010 projected	2010 actual
Tier 6	$\hat{y} \leq .05$	*37*	27
Tier 5	$.05 < \hat{y} \leq .10$	*19*	17
Tier 4	$.10 < \hat{y} \leq .20$	*18*	21
Tier 3	$.20 < \hat{y} \leq .40$	*16*	21
Tier 2	$.40 < \hat{y} \leq .80$	*28*	20
Tier 1	$\hat{y} > .80$	*3*	16

In the second period from 1990 to 2010, it appears there is much more upward movement than M_1 can explain. That is, there is convergence toward the higher incomes across *all* tiers. That empirical pattern is even more compelling in the 1990-2010 dynamics in figure 4. In this latter period, there were only 7 countries dropping, compared to 45 rising. The answer to the stability question is no, the M dynamic is not stable. Rather, an important fact revealed by our analysis so far is that world income distribution dynamics are changing in manner that reflects convergence at many levels of income.

Figure 4. Country transitions among relative income tiers, 1990-2010, and associated dynamic matrix

		1990 Tier 6	Tier 5	Tier 4	Tier 3	Tier 2	Tier 1	
2010	Tier 6	23	4					**27**
	Tier 5	8	7	2				**17**
	Tier 4	1	7	12	1			**21**
	Tier 3		3	8	10			**21**
	Tier 2				6	14		**20**
	Tier 1				1	11	4	**16**
		32	**21**	**22**	**18**	**25**	**4**	**122**

$\mathbf{M_2}$ =

72%	19%	0%	0%	0%	0%
25%	33%	9%	0%	0%	0%
3%	33%	55%	6%	0%	0%
0%	14%	36%	56%	0%	0%
0%	0%	0%	33%	56%	0%
0%	0%	0%	6%	44%	100%

From this, I was able to generate a 1990-2010 Markov transition matrix, M_2 which is shown in figure 4. If this latter dynamic holds in the near future, then five to six countries will rise to the wealthiest tier every decade, and none will drop. At the same time, three or four countries from the poorest tier will rise each decade while a different 1 or 2 will fall back. This is a pattern of slow but definite convergence. But is there any point in making future projections if the dynamics are unstable? More to the point, does instability mean random, or might there be a pattern in the changing dynamics?

Historically, as Jones noted, the world's frontier economy grew reliably after about 1800, but the growth rate itself grew as well. Income growth accelerated from less than a tenth of a percent per year to 0.5 to 1.0 and ultimately to the modern norm of "2 percent per year." There's no reason to think that transition dynamics are not accelerating as well. Indeed, the pattern in figure 1 appears to show acceleration towards greater convergence every decade. Let's set that aside for discussion later, and here consider the mechanics of the evolving dynamics.

To generate an evolution matrix, *Z,* I compared changes between the transition matrices, M_1 and M_2, specifically by calculating the ratio across cells I then extrapolate the 2010-2030 transition matrix, M_3, by point multiplying M_2 with *Z,* and normalizing the cells in each column so that they sum to 100%. Evolution in the transition dynamics continues again during the next 20-year period, then again and again, iteratively. I generated transition matrices this way to forecast the world income distribution as far forward as 2110 under evolving dynamics and baseline scenarios. For tractability, I present just one of these projected matrices below, M_7 (for 2090-2110).

Figure 5. Future Markov transition matrix, 2090-2110 (M_7)

$M_7 =$

36%	0%	0%	0%	0%	0%
64%	0%	0%	0%	0%	0%
0%	14%	3%	0%	0%	0%
0%	86%	97%	51%	0%	0%
0%	0%	0%	49%	0%	0%
0%	0%	0%	0%	100%	100%

Compare what can happen to a tier 5 country in 1990 versus 2090. In 1990, the M_2 transition dynamics show what did happen—a tier 5 country had 19% chance of falling one tier, 33% chance of staying put, a 33% chance of rising one tier, and a 14% chance of rising up to tier 3. By 2090, accelerating convergence will change the dynamics so that no country in tier 5 is likely to decline or even stay steady. Instead, there will be a 14% likelihood of rising to tier 4 and an 86% likelihood of rising to tier 3 during the following two decades.

Table 3 presents a summary of the 2050 distribution under four different projection scenarios. In scenario 1, the transition patterns of 1970-1990 hold constant and the distribution evolves according to M_1. In the second scenario, the more recent patterns of 1990-2010 continue and the distribution evolves according to M_2. In the third scenario, the transition matrix does not stabilize but instead evolves as described above. In the fourth scenario, the transition matrix is an average of M_1 and M_2.

Table 3. Three Projections of the World Income Distribution in 2050

		2010	2050 Scenario 1 (M_1)	2050 Scenario 2 (M_2)	2050 Scenario 3 (evolution)	2050 Scenario 4 (avg. M_1 and M_2)
Tier 6	$\hat{y} \leq .05$	27	34	19	11	26
Tier 5	$.05 < \hat{y} \leq .10$	17	17	12	8	15
Tier 4	$.10 < \hat{y} \leq .20$	21	16	17	9	17
Tier 3	$.20 < \hat{y} \leq .40$	21	15	21	36	18
Tier 2	$.40 < \hat{y} \leq .80$	20	35	17	13	28
Tier 1	$\hat{y} > .80$	16	5	35	44	19

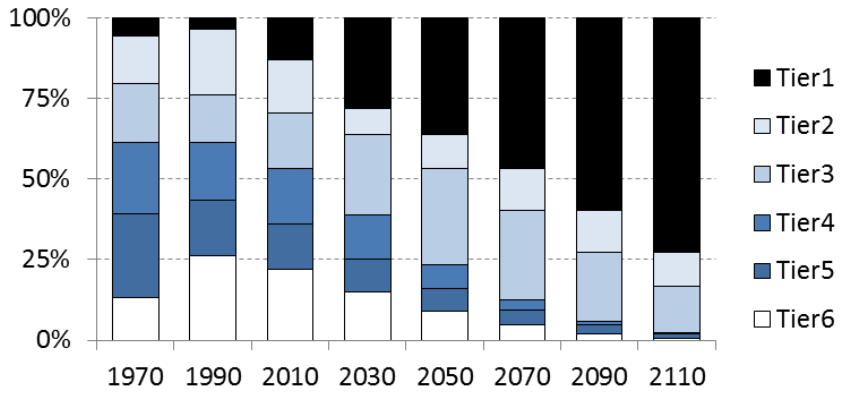
Entries in the table reflect the number of countries with relative incomes in each tier.
Income per capita relative to the highest-income country is represented by the variable $\hat{y}$.

These 2050 projections are astonishing. If the world reverts to the divergent dynamics of the 1970s and 1980s, then the number of tier 6 countries will balloon, but there will be a large cluster of relatively wealthy tier 2 countries as well. If instead the convergent dynamics of the past two decade continue, an additional twenty countries will jump into tier 1, which is the income level of Japan or higher. If my theory of an evolving dynamics bears out, then there will be even more booming prosperity and an unprecedented elimination of relatively poor countries. In this scenario (3), the number of countries in the poorest three tiers (below 20% of U.S. income

per capita) will go from 65 in 2010 to 28 in 2050. More than half of the poorest countries in the world will catch up to the world's productivity frontier (PPF) some by jumping three tiers. If your instinct is that this kind of 4-decade catch-up is impossible, you are not thinking carefully about the countries that already made such leaps from 1970 to 2010. South Korea caught up from 9 percent of the PPF to 65 percent (tier 5 to 2), similar to Singapore, Hong Kong, and Malaysia. Taiwan rose from 23 to 78 percent, while Ireland grew from 39 to 85 percent.

Projecting the world income distribution in the future to 2110 under the evolving dynamics scenario, 89 of the 122 countries will have tier 1 per capita incomes, meaning incomes higher than 80 percent of the leading economy. If we assume a global slowdown with a PPF growth rate of just 1 percent per year, then average income in 2110 in the leading economy will be $170,632. This means that average income per capita for the vast majority of countries will be above $137,000 per year. The evolution of the world income distribution under this scenario is shown in figure 5.

Figure 5. Evolving convergence dynamics across 122 countries
per capita income relative to the wealthiest economy in that year



Is this outcome realistic? There are plenty of good reasons to be skeptical, including the threats of environmental devastation, depletion of natural resources, and human conflict. However, the fastest decades of growth in the past century were marked by world wars and horrible genocides. The point is, there are always good reasons to be pessimistic, but the PWT data affirm a more optimistic outlook.

3 Discussion

If the income distribution dynamics of the past twenty years, represented by M_2, represent the new normal, then the world is in for many decades of rapid growth and convergence that will leave an impoverished minority of very few nations. This outcome makes sense even if civil war erupts at the same rate of recent decades, causing an unfortunate few countries at the cusp of

modernization to fail. However, the dynamics of the past two decades imply many more countries will converge than diverge.

Presumably most skeptics believe the world is already falling back into the pattern of increasing inequality, the diverging twin-peaks M_1 dynamics of 1970-1990. This is possible, but what are the mechanics? Are industrializing economies reverting to agrarian subsistence? Is there an erosion of human capital, either in health or education levels? There was some concern that the Asian miracle went bust in 1997, but the bust itself was the illusion.

The alternative scenario is that economic growth and diffusion of productivity accelerate in the same way they did during the two periods documented above (1970-1990 and 1990-2010). The modern acceleration is real. Whether it will continue is unknown.

The case against acceleration is that it assumes something unrealistic. Why should we assume recent decades are indicative of future performance rather than an anomaly? The 1990s were an auspicious time of relative global peace and expanded trade. It was an era of the Internet's invention and the expansion of China. It seems just as likely that transition dynamics, like history, follow a random walk. Or, as Tyler Cowen puts it, perhaps all the "low hanging fruit" has been picked.

The accelerating expansion of prosperity surely seems difficult to accept psychologically, but the growth experience of the past 200 years would have also been difficult to accept as a forecast at almost any time along the way. The actual growth from 1810 to 1910 was unbelievable in 1810, as was the actual growth from 1910 to 1960 in 1910, or from 1960 to 2010 in 1960 (certainly from the perspective of any town in Asia or Africa). If any economist today were to go back in time to 1800 or 1900 and predict the realized income levels of the year 2000, we all know how such a prediction would be received by the leading minds of the day—with derision. Psychological hang-ups with conceptualizing growth are one thing, science and data are another.

The normal living standard for almost every human in history was around two dollars a day until about 1820. A centuries-long process of accumulating innovations enabled a few countries in Europe to experience an economic revolution. We think of it now as an industrial revolution, but what it did was enable masses of people in England to escape the trap imagined by Thomas Malthus in which productive surplus was outpaced by rising birth rates. Once that threshold was broken, productivity growth began to gallop and per capita income growth began to accelerate.

In quick time, historically speaking, other Western nations adopted the technologies and institutions that sparked Britain's surging economy. The great diffusion of productivity is still underway in our era. Indeed, the pattern of diffusion shows productivity growth radiating first to Europe (Britain's neighbors) and to English-speaking nations on other continents (Britain's colonies). With few exceptions, the productivity revolution is a one-way ticket. Countries recess in the business cycle, but they do not regress in a productivity cycle.

Robert Lucas (2000) captured this process with a hazard rate model that essentially uses the divergence of economies over the initial period as a driver of convergence in the later periods.

Economists and historians documented growth and convergence clubs in the past half century, which describes how some regions such as Asia have experienced a near-simultaneous boom in growth rates while other regions such as Africa have experienced slow and now rebounding growth rates together.

One channel through which the Lucas model may be operating is the industrialization cycle. Country after country since 1950 has experienced a rapid industrialization, often fueled by foreign investment and most certainly by foreign trade, especially the export of manufactured good. Yet we also see that the industrialization phase is followed by a gradual and relative deindustrialization when the modern service economy displaces the relative (but not absolute) size of the manufacturing sector in total output. In short, the global economy is relentlessly hungry for inexpensive labor to work its manufacturing – textiles, raw materials, and Nike shoes. And it pays well, far above the Malthusian threshold. There is a human capital story that is common as well. First generation industrial workers tend to invest heavily in the human capital of the second generation, and the takeoff is complete.

These are the principal underlying forces driving the evolution of the world income distribution: industrial investment, globalization, and human capital investment. The divergence of the 1960-90 timeframe identified by Jones and others seems to be a snapshot of an incomplete diffusion of the productivity revolution. We know now that the postwar Japanese miracle was quickly mimicked by neighbors, first in northeast Asia and now in southern Asia. It did not take hold in Africa, and was arrested by populist dictatorships throughout Latin America. We also know that Soviet domination in Eastern Europe arrested economic development during the cold war era, and funded anti-market rulers in poor countries. After 1990, the productivity revolution embodied in the spread of global capitalism re-emerged as the walls, literally and figuratively, collapsed.

The downside of this story is that too many countries may be trying to grow so quickly that they tolerate what seem to be noneconomic externalities of pollution and corruption in the short term. They adopt fast-growth institutions which fall short of highest-income institutions (i.e., centrally planned industrialization versus entrepreneurism and free market financing). And in the end, national averages obscure the gross inequalities evident in many countries, which further obscures the human cost of unprecedented pollution levels in many fast-growth nations. All this might be true, but it hardly seems to support long-term pessimism.

4 Conclusion

In this paper, I expand on the analysis of the world's evolving income distribution that was imagined by Danny Quah in 1993 and first explored by Chad Jones in 1997. I use new PWT data with a longer time series that allows us to see that the first stage of dynamics in 1970-1990 did not persist in the following two decades. The predicted 2010 distribution of twin peaks was not realized. To the contrary, I show that the world's income distribution has been converging to a single peak with successively higher income levels during every decade from 1960 to 2010.

The main part of the paper compares the change in transition dynamics in the two periods, 1970-1990 versus 1990-2010. I present a model of matrix evolution and use it to project future world income distributions. Unless the dynamics fully snap back to the divergent patterns of the Cold War era, future projections are astonishingly rosy.

Finally, I discussed some of the underlying global forces that may be generating the convergent data reported in the most recent years of the PWT. I would caution pessimists to consider that while the monumental measurement effort in the PWT is fraught with challenges, the most accurate years of measurement are the most recent ones. We should have more faith in the 1990-2010 transition dynamics than any other. That too is a reason to believe the rosy projections are more likely than pessimistic assumptions.

Whether poverty and chaos will indeed be trumped by the productivity revolution, only time will tell. Or time series.

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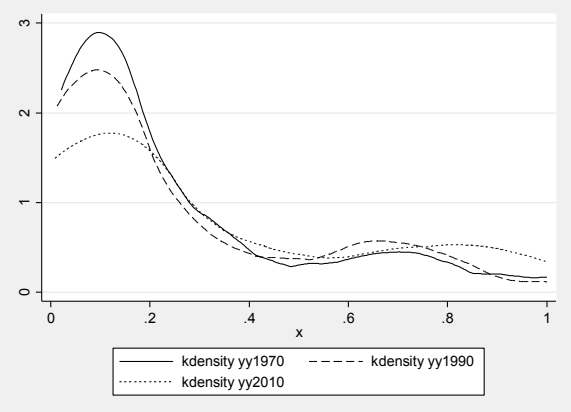
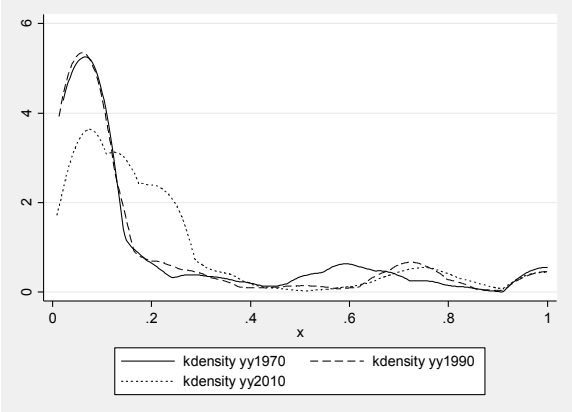
6 Additional Figures for Discussion

Figure 6. World income distribution under four treatments (with and without population weighting country observations, with and without log values of income per capita).

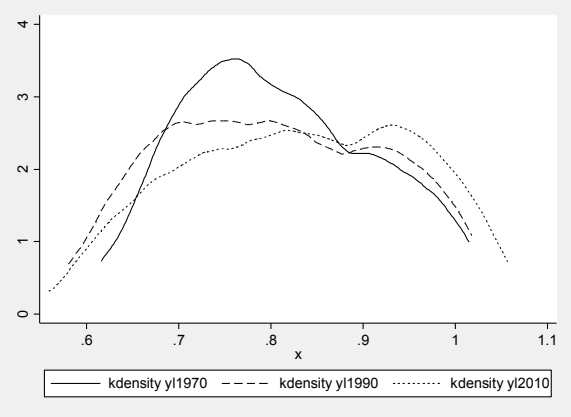
A. Relative incomes (N=122)



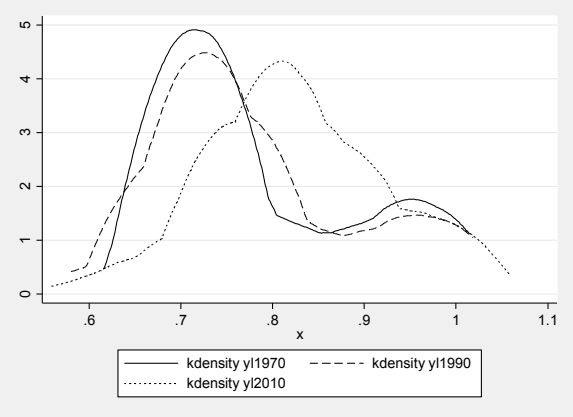
B. Relative incomes, pop. weight (N=122)



C. Relative log incomes (N=122)



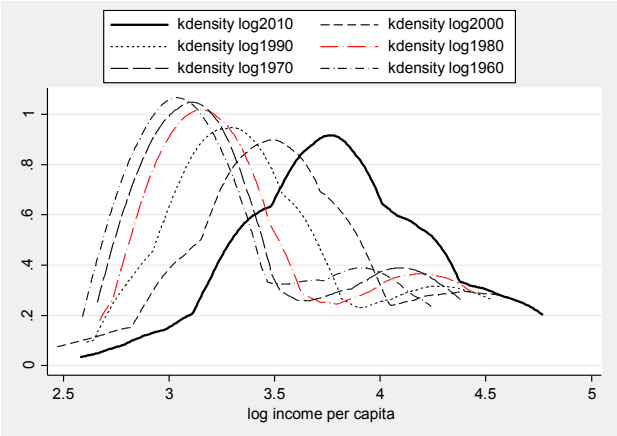
D. Relative log incomes, pop. weight (N=122)[1]



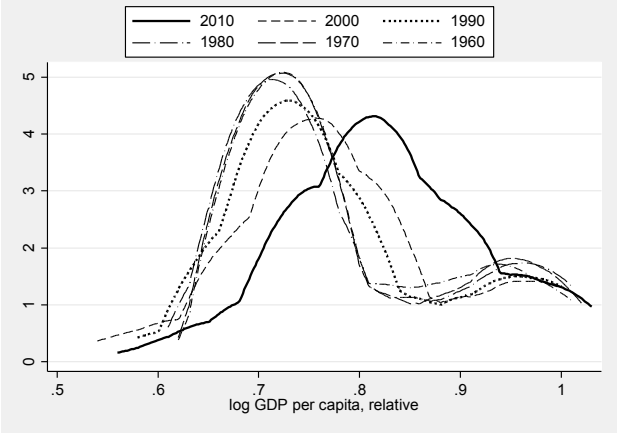
[1] STATA code is : twoway kdensity yl2010 [fweight = p2010] , bwidth(0.04) || kdensity yl1990 [fweight = p1990], bwidth(0.04) || kdensity yl1970 [fweight = p1970] , bwidth(0.04)

Figure 7. World income distribution with shorter time panels.

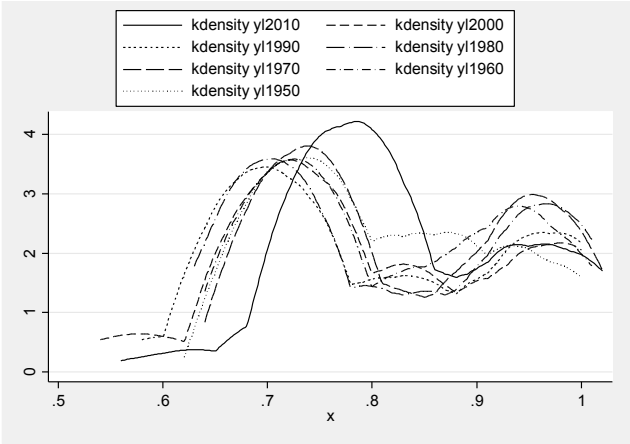
A. Log income per capita 1960-2010, population weight (N=106)[2]



B. Relative log incomes 1960-2010, population weight (N=106)



C. Relative log incomes 1950-2010, population weight (N=53)



[2] twoway kdensity log2010 [fweight = p2010] , bwidth(0.15) || kdensity log2000 [fweight = p2000] , bwidth(0.15) || kdensity log1990 [fweight = p1990], bwidth(0.15) || kdensity log1980 [fweight = p1980] , bwidth(0.15) || kdensity log1970 [fweight = p1970] , bwidth(0.15) || kdensity log1960 [fweight = p1960] , bwidth(0.15)

Figure 8. Relative income per capita shifts, two eras (1970-1990 and 1990-2010).