SIMPLE MEASURES OF CONVERGENCE IN *PER CAPITA* GDP: A NOTE ON SOME FURTHER INTERNATIONAL EVIDENCE

by

G.E. Boyle[*] and T.G. McCarthy[**],

Department of Economics,

National University of Ireland, Maynooth,

Co. Kildare,

Ireland.

ABSTRACT

We apply simple measures of convergence in *per capita* GDP, namely, the trends in the coefficient of variation (s-convergence) and rank concordance (g-convergence), for the period 1960-1992 to a wide group of countries which are classified using the World Bank typology. The findings indicate s-convergence, albeit at a slow rate, for "High Income" and "Upper Middle Income" countries, very slow to negligible convergence for "Lower Middle Income" countries and divergence for "Low Income" countries. Our results also suggest several periods for all country categories when s-convergence is constant. However, since we do not find g-convergence during these episodes, we conclude that b-convergence is not demonstrated. The rank concordance measure emerges as significant only from about the late 1980s, save in the case of "Low Income" countries where "leap frogging" is observed from about 1981. The implications of these results for the neoclassical growth model are discussed.

JEL classification: O40, O50, O51, O52

Keywords: b-convergence, s-convergence, ranking, income distributions

[*]***Corresponding Author:***

G.E. Boyle, Department of Economics, National University of Ireland, Maynooth, Co. Kildare, Ireland.

Tel: 353-1-7083751/3728; Fax: 353-1-7083934; EMail: gboyle@.may.ie

SIMPLE MEASURES OF CONVERGENCE IN *PER CAPITA* GDP: A NOTE ON SOME FURTHER INTERNATIONAL EVIDENCE

I. Introduction

The concept of b-convergence implies that poor countries grow faster than rich countries. Typically the existence of convergence is tested by running so-called Barro (1991) regressions which involve regressing the growth in *per capita* GDP on its initial level for a given cross-section of countries (or regions within countries). Convergence in the unconditional sense is implied, according to this methodology, if the coefficient on initial *per capita* GDP is negative and statistically significant.

This methodology has been criticised by Friedman (1992) and Quah (1993) (hereafter the FQ critique) who point out that these regressions are liable to produce biased estimates of b-convergence. Friedman (1992) suggests that the simple trend in the *coefficient of variation* of *per capita* GDP provides an unbiased estimate of b-convergence. Quah (1993) suggests a methodological approach that is capable of capturing the full dynamics of evolving cross-country distributions of *per capita* GDP. In a recent paper Boyle and McCarthy (1997) advocated the use of the trend in rank concordance of *per capita* GDP, developed by Kendall (see Siegel (1956)) in another context, in conjunction with the trend in the *coefficient of variation* (or, s-convergence in Sala-i-Martin's (1995) nomenclature), as suggested by Friedman (1992), in a first pass at determining the nature and extent of the convergence process within and between countries.

Both Sala-i-Martin (1995) and Quah (1993) point out that s-convergence is sufficient but not necessary for b-convergence. The implication of this result is that the absence of s-convergence cannot be taken as implying the absence of b-convergence. Sala-i-Martin (1995) illustrates this point by setting up the example of tracking the intertemporal performance in a football league where the number of teams remains unchanged over the reference period. In this example, by construction, s-convergence

is constant but yet it is clearly possible for a substantial change in the ranking of teams to occur over time. A change in team rankings over time implies β-convergence yet, in this example, it cannot be captured by the simple measure of σ-convergence.

It is conceivable that σ-convergence could also be constant for certain distributions of *per capita* GDP. Given this possibility, the σ-convergence measure clearly lacks the merit of generality in testing for β-convergence. The potential of this circumstance is seized on by Sala-i-Martin (1995) to rehabilitate the technique of Barro-regressions, in spite of the FQ critique. One implicit justification for persisting with the technique is that, however imperfect the approach might be, it has the merit of generality in the absence of alternative measures. A second justification might be that Barro-regressions might seem to be uniquely capable of determining the extent of *conditional* convergence. In other words the growth in *per capita* GDP might be conditional on, for instance, the initial level of human capital in addition to the initial level of *per capita* GDP (see Mankiw, Romer and Weil (1992)). But it is apparent that we can also test for conditional σ-convergence. All that would be required is to track the trend in σ-convergence of the residuals from a cross-sectional regression of *per capita* GDP on human capital. The defence of Barro-regressions on this point is thus redundant[1].

But there is no need to deploy the flawed technique of Barro-regressions on grounds of its generality since there are other techniques available to test for β-convergence. Quah (1993) suggests a rich methodological approach that allows the complex dynamics of evolving cross-country income distributions to be unearthed in their entirety. The simple measure of σ-convergence is but a subset of his approach. The approach is, however, difficult to implement and it would desirable to have a simpler methodology that would be capable of setting out most of the more interesting or important stylised facts regarding convergence.

The contribution of Boyle and McCarthy (1997) was to suggest that an index of rank concordance be used in addition to σ-convergence in testing for β-convergence. For convenience we will refer to the index of rank concordance as γ-convergence. This

[1] Quah (1993) makes a similar point.

suggestion affords a number of insights. First, and perhaps most usefully, it means that in a situation where s-convergence is constant we can use the proposed measure of g-convergence to ascertain whether b-convergence exists. Second, while g-convergence clearly doesn't capture all the potentially rich features of changing income distributions, which Quah's methodology allows[2], it nonetheless provides an important additional summary indicator to s-convergence of the nature of the evolving distribution.

The purpose of this note is to extend the application given in Boyle and McCarthy (1997) for OECD countries to a broader range of countries. In this note therefore estimates of s and g-convergence are presented for four sets of countries using the World Bank typology, namely, "High Income", "Upper Middle Income", "Lower Middle Income" and "Low Income". Section II explains the data used and documents the results obtained. Section III discusses some implications of the findings.

II Data and Results

The purpose of this note is to establish what insights can be gleaned about the nature of the convergence process across a diverse group of countries using the simple measures of s and g convergence. We employed the PENN dataset (see Summers and Heston (1991)) to establish the nature of cross-country convergence of per capita GDP[3] using these measures. We decided to limit our analysis to four country blocks using the World Bank typology. We further stipulated that each of the four distributions were to have a complete distribution over the period 1960-1992. This means that we do not use the full complement of countries available from the PENN dataset. The constituent countries within each block that we employ in our analysis are given in Table 1.

[2] Quah's (1993) methodology permits us, for instance, to test for the existence of "growth clubs" or multiple nodes in the evolving cross-country income distribution.
[3] We used the real GDP (chain index) series computed at 1985 international prices.

Table 1: Countries used in the analysis of convergence, 1960-1992

HIGH INCOME	UPPER MIDDLE INCOME	LOWER MIDDLE INCOME	LOW INCOME
AUSTRALIA	ARGENTINA	ALGERIA	BANGLADESH
AUSTRIA	BOTSWANA	BOLIVIA	BURKINA FASO
BELGIUM	BRAZIL	CHILE	BURUNDI
CANADA	GABON	COLOMBIA	CHAD
DENMARK	GREECE	CONGO	CHINA
FINLAND	KOREA, REP.	COSTA RICA	EGYPT
FRANCE	MALAYSIA	DOMINICAN REP.	GHANA
GERMANY, WEST	MAURITIUS	ECUADOR	GUINEA
HONG KONG	MEXICO	GUATEMALA	HONDURAS
IRELAND	PORTUGAL	IRAN	INDIA
ISRAEL	PUERTO RICO	IVORY COAST	INDONESIA
ITALY	SAUDI ARABIA	MOROCCO	KENYA
JAPAN	SOUTH AFRICA	NAMIBIA	LESOTHO
NETHERLANDS	TRINIDAD&TOB.	PANAMA	MADAGASCAR
NEW ZEALAND	URUGUAY	PARAGUAY	MALAWI
NORWAY	VENEZUELA	PERU	MAURITANIA
SINGAPORE		PHILIPPINES	MOZAMBIQUE
SPAIN		SALVADOR	NIGERIA
SWEDEN		THAILAND	PAKISTAN
SWITZERLAND		TUNISIA	RWANDA
U.K.		TURKEY	SRI LANKA
U.S.A.			TOGO
			UGANDA
			ZIMBABWE

The indices of s- and g-convergence are derived as follows:

$$\sigma = \left(\frac{\text{var}(GDPC_{ti}) / \text{mean}(GDPC_{ti})}{\text{var}(GDPC_{t0}) / \text{mean}(GDPC_{t0})} \right)$$

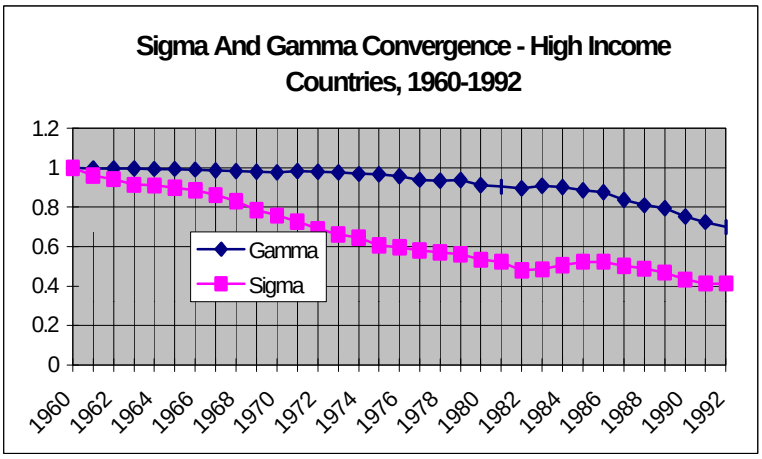
$$\gamma = \left(\frac{\text{var}(RGDPC_{ti} + RGDPC_{t0})}{\text{var}(RGDPC_{t0} * 2)} \right) \qquad \textbf{(1)}$$

where,

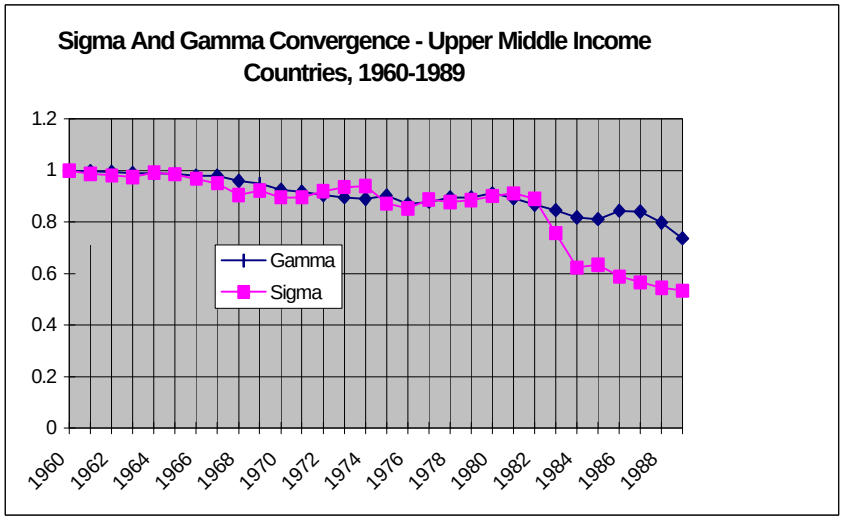
var(GDPC) refers to the variance of the absolute level of *per capita* GDP for each cross-country distribution; var(RGDPC) is the corresponding variance of the ranks of *per capita* GDP; ti refers to 1961,...,1992 and t0 is the reference year (that is 1960).

The results are documented in the following charts and tabulated values are given in Appendix 1.

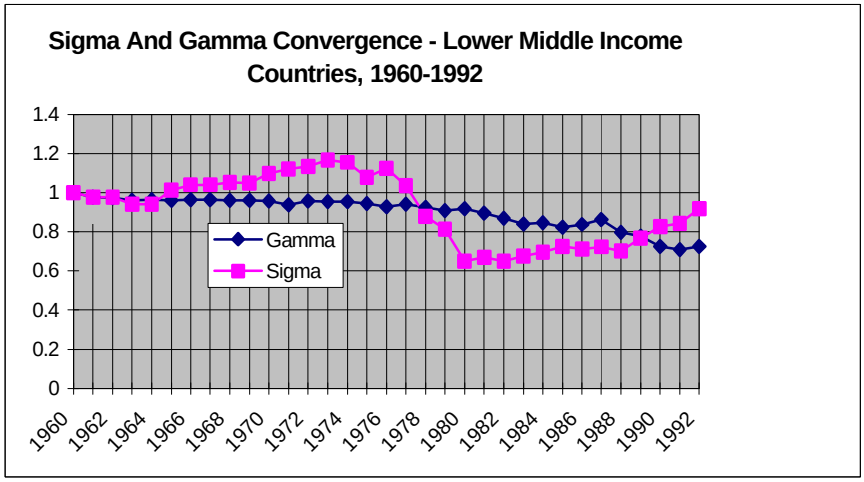
In the case of "High Income" countries we observe evidence of very strong s-convergence and hence b-convergence until about 1980/81. From this year until about 1989 we see that the coefficient of variation is more or less constant. There is no evidence of any significant g-convergence until the late 1980s onwards. It should be remembered that the test is very stringent since in the version of g-convergence used here the rank of *per capita* GDP in each year is being compared with the rank in 1960. During the period for which s-convergence is observed to be constant there is no evidence of g-convergence and hence we cannot infer b-convergence during this period.



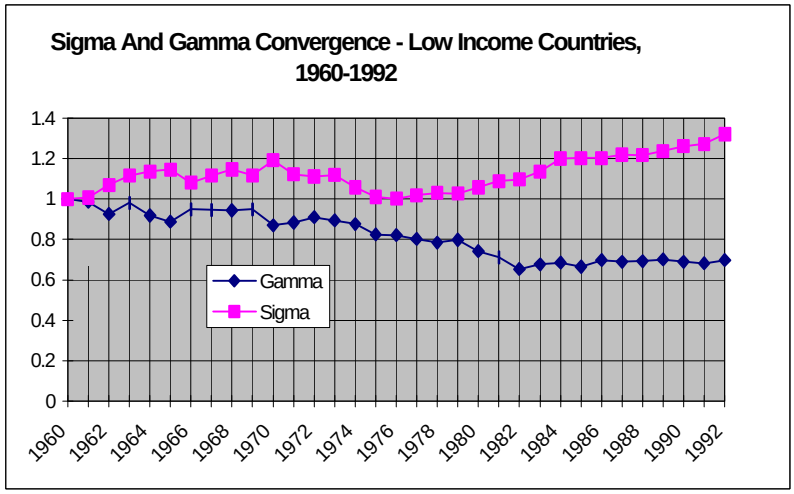
Turning to "Upper Middle-Income" countries we can see that there is a strong agreement between the trends in s- and g-convergence up to 1982. Thereafter there is a sharp decline in the index of s- convergence that implies b-convergence. This also coincides with a significant drop in our index of g-convergence. The latter finding, which we also observe though perhaps more weakly, for the "Higher Income" group of countries implies the coexistence of "leap frogging" and a narrowing of the dispersion of *per capita* income across countries. This result has some interesting implications for the Solow growth model that we take up in the final section.



The evidence for "Lower Middle Income" countries is the most curious of the four country blocks. The g-convergence index is trended downwards but a significant change in ranking only emerges from about 1988 onwards. The index of s-convergence exhibits two distinct and interesting phases. Up to the mid 1970s there is evidence of s-divergence, at least from 1971 onwards. The index sharply declines from then until the early 1980s and subsequently begins a slight upward ascent. Over the full period there is evidence of significant σ-convergence. We get an interesting crossover in the two indices in 1989.



Our final chart sets out the convergence facts for "Low Income" countries. There is little significant change in the index of s-convergence up to about 1984. Subsequently there is a significant upward shift in the intercept of this index. Over the full period of the analysis we conclude that there is evidence of a widening of the dispersion in *per capita* GDP levels. The findings for g-convergence are equally interesting. Significant g-convergence is apparent from 1978 but thereafter the trend stabilises.



0 Conclusions

This note has been concerned to set out the stylised facts about the nature of convergence in *per capita* GDP for a diverse group of countries. We employ two simple summary indicators to capture the nature and extent of convergence of the cross-country income distributions, namely, s and g-convergence. Our objectives are modest. We want, first of all, to characterise the nature of the evolving cross-country distributions in terms of our proposed indices. Second, we want to set out some pointers for further analysis.

The findings regarding s-convergence are fairly well known is so far as they are broadly consistent with the impression generated by the Barro-regression tests. The advantage of the s measure is twofold. First, it is an unbiased measure of b-convergence and second it allows one to track the evolution of the convergence process over time. Most published papers on convergence assume a constant b.

Our findings indicate an annual rate of growth of s-convergence for each of our cross-country distributions as follows:

Country Group	**Annual Average Growth in s -convergence**
High Income	-2.76%
Upper Middle Income	-2.17%
Lower Middle Income	-0.26%
Low Income	+0.87%

It would appear therefore that there is an inverse correlation between the degree of convergence and the income status of a country. These overall trends conceal some interesting sub-trends.

We have noted constant s-convergence in each of our country groupings for some sub-periods of our analysis. There is no evidence that during these episodes there is significant g-convergence. Hence, b-convergence is not demonstrated and thus the simple σ-convergence index provides robust inferences about the nature of the convergence process.

In any case our results indicate that g-convergence is only statistically significant from about the late 1980s for "High Income" and "Lower Middle Income" countries and in the case of "Upper Middle Income" countries a significant change in ranking relative to the 1960 level only emerges in 1988.

In many respects the most interesting findings emerge for the "Low Income" countries. As already noted there is clear evidence of a process of s-divergence. Yet statistically significant g-convergence is apparent from about 1981. Thereafter the process is halted.

In our view the interesting findings relate as much to the nature of the convergence process observed as to its extent. It appears to us that there are a number of results

that pose challenges for future empirical and theoretical analysis. We think it's interesting to note, for instance, that there are long periods for all country blocks where a constant s is observed. This suggests that the process of convergence or indeed divergence is not one which is smooth and incremental. Cross-country distributions adjust slowly to new s levels and subsequently remain at these lower levels for prolonged periods of time.

The process of g-convergence has been found to be painfully slow. For all our country categories, bar the "Low Income" grouping, we find that significant g-convergence is only detected after nearly 30 years. As against this finding we have the result that significant g-convergence emerges for "Low Income" countries from about 1981. It also seems interesting to us that while a significant change in ranking of *per capita* GDP occurs around this time, in the subsequent period the process of s-divergence gathers increased momentum. In other words we get "leap frogging" in terms of *per capita* GDP leading to a subsequent widening of inter-country inequality.

On a final point it is worth noting that g-convergence sits very uneasily with the neoclassical growth model. It appears to us that the existence of s-convergence does not provide unequivocal support for the Solow model since the observance of "leap frogging" behaviour is inconsistent with this framework.

Appendix 1: Tabulated values of g and s-convergence for selected cross-country distributions of per capita GDP, 1960-1992

	High Income		Upper middle Income		Lower Middle Income		Low Income	
YEAR	g	s	g	s	g	s	g	s
1960	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1961	1.00	0.96	1.00	0.99	0.98	0.98	0.98	1.01
1962	1.00	0.94	1.00	0.98	0.97	0.98	0.93	1.07
1963	1.00	0.91	0.99	0.98	0.96	0.94	0.98	1.12*
1964	0.99	0.91	0.99	0.99	0.96	0.94	0.92	1.14*
1965	0.99	0.90*	0.99	0.99	0.96	1.01	0.89	1.14*
1966	0.99	0.89*	0.98	0.97	0.96	1.04	0.95	1.08
1967	0.99	0.86*	0.98	0.95	0.96	1.04	0.95	1.12*
1968	0.98	0.83*	0.96	0.91	0.96	1.05	0.94	1.15*
1969	0.98	0.79*	0.95	0.92	0.96	1.05	0.95	1.12*
1970	0.98	0.76*	0.93	0.90	0.96	1.10	0.87	1.19*
1971	0.98	0.73*	0.92	0.90	0.94	1.12*	0.88	1.12*
1972	0.98	0.69*	0.91	0.92	0.96	1.13*	0.91	1.11*
1973	0.98	0.66*	0.90	0.94	0.96	1.17*	0.89	1.12*
1974	0.97	0.65*	0.89	0.94	0.95	1.16*	0.88	1.06
1975	0.97	0.61*	0.90	0.87*	0.94	1.08	0.82	1.01
1976	0.96	0.60*	0.87	0.85*	0.93	1.12*	0.82	1.00
1977	0.94	0.58*	0.88	0.89*	0.94	1.04	0.80	1.02
1978	0.93	0.57*	0.90	0.88*	0.92	0.88*	0.78	1.03
1979	0.94	0.56*	0.90	0.89*	0.91	0.81*	0.80	1.03
1980	0.91	0.53*	0.91	0.90*	0.92	0.65*	0.74	1.06
1981	0.90	0.52*	0.89	0.91*	0.90	0.67*	0.71*	1.09
1982	0.89	0.48*	0.87	0.89	0.87	0.65*	0.65*	1.10
1983	0.91	0.49*	0.85	0.76*	0.84	0.68*	0.68*	1.14*
1984	0.90	0.51*	0.82	0.62*	0.85	0.70*	0.69*	1.20*
1985	0.89	0.52*	0.81*	0.64*	0.82	0.73*	0.66*	1.20*
1986	0.88	0.52*	0.84	0.59*	0.84	0.71*	0.70*	1.20*
1987	0.84	0.50*	0.84	0.57*	0.86	0.72*	0.69*	1.22*
1988	0.81	0.49*	0.80*	0.55*	0.80	0.70*	0.69*	1.22*
1989	0.80	0.47*	0.74*	0.53*	0.78	0.77*	0.70*	1.24*
1990	0.75	0.43*	…	…	0.73*	0.83*	0.69*	1.26*
1991	0.72*	0.41*	…	…	0.71*	0.84*	0.68*	1.27*
1992	0.70*	0.41*	…	…	0.73*	0.92	0.70*	1.32*
%Δp.a.	**-1.12**	**-2.76**	**-1.05**	**-2.17**	**-1.00**	**-0.26**	**-1.12**	**0.87**

A '*' denotes that the particular value of the index is statistically different from its value in 1960. The test for the statistical significance of the g-convergence measure is given in Siegel (1956) and the comparable test for s-convergence is a simple t-test with the variance of the *coefficient of variation* obtained from Weatherburn (1968).

References

Barro, R.J. (1991). 'Economic Growth in a Cross-Section of Countries', *Quarterly Journal of Economics*, Vol. 106, pp. 407-43.

Boyle, G.E. and McCarthy, T.G. (1997). 'A Simple Measure of b-Convergence', *Oxford Bulletin of Economics and Statistics*, Vol. 59, No. 2, pp. 257-264.

Friedman, M.J. (1992), 'Do Old Fallacies Ever Die?'. *Journal of Economic Literature*, Vol. 30, pp. 2129-32.

Mankiw, G. Romer, P. and weil, D.N. (1992). 'A Contribution to the Empirics of Growth', *Quarterly Journal of Economics*, Vol. 107, pp. 407-37.

Quah, D.T. (1993). 'Galton's fallacy and Tests of the Convergence Hypothesis', *The Scandinavian Journal of Economics*, Vol. 95, pp. 427-43.

Sala-i-Martin (1995). 'Regional Cohesion: Evidence and Theories of Regional Growth and Convergence', Discussion paper No. 1075, Centre for Economic Policy Research, November.

Siegel, S. (1956). *Nonparametric Statistics for the Behavioural Sciences*, McGraw-Hill, New York, pp. 229-39.

Summers, R. and Heston, A. (1991). 'The PENN World Trade Table (Mark 5): An Expanded set of International Comparisons, 1950-1988', *Quarterly Journal of Economics*, Vol. 106, pp. 327-68.

Weathernburn, C.E. (1968). *A First Course in Mathematical Statistics*. Cambridge University Press.