Global Divergence

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Abstract

I show that the evolution of cross-country incomes is characterized by global divergence. To do this, the sample of non-mainly-petroleum-exporting countries having market economies during the period 1960-1997 is divided into five clusters of countries by a regression clustering algorithm according to the levels and rates of change of income and life expectancy. The five clusters correspond to advanced countries, especially fast growing countries, and three tiers of less developed countries with qualitatively different development paths. I show that the following properties hold for these clusters. 1) Growth rates across groups of countries are globally divergent; some successive groups converge while most diverge. 2) Income inequality *between* these groups of countries has *increased* while income inequality *within* the groups has remained almost *unchanged*. 3) The five groups of countries exhibit β and σ income *divergence between groups* and *convergence within groups*. Besides, the implied steady state growth rates across groups of countries are globally divergent, the five-club convergence model is much more significant than the one-club model, and the *distributions* of country-specific convergence regression *coefficients* are significantly different across groups of countries. The convergence found within groups is consistent with the relative convergence (to steady state trajectories) found in the literature. However, relative convergence only means that there are a series of perhaps distinct, local equilibrium processes going on. Indeed, these may themselves be due to economic forces that *prevent* global convergence. The empirical facts are consistent only with theories of economic growth *explaining divergence and proposing multiple steady states* or other explanations for prolonged transitions Such models usually reflect advantages of the rich and disadvantages of the poor. A descriptive study of the five groups of countries suggests, as a stylized fact, that there are three large-scale steady states or convergence clubs, *semi-stagnation* (low income and life expectancy), *semi-development* (middle income and high life expectancy) and *development* (high income and life expectancy), according to whether countries have overcome barriers to human development and to technological innovation. Three of the five groups lie in each of these steady states and the other two transit between them.

Introduction

The discussion of convergence has occupied a prominent place in the study of economic growth across countries for over a decade. The finding of a significant, negative "convergence coefficient" has been one of the most robust in cross-country growth regressions (Barro, 1991, 1997; Barro and Sala-i-Martin, 1991, 1992a, see Levine and Renelt, 1992, for a comparative sensitivity analysis covering many studies). Evans (1995) confirms convergence in a large group of medium- to high-income countries, at least to parallel growth paths. However, empirical studies have also found evidence for divergence in the data. Cross-country per capita income differences widened dramatically during the twentieth century (Pritchett, 1997). Quah's (1993, 1996, 1997) finding of an emerging twin-peaked cross-country income distribution can be interpreted as a continuation of this divergence. Mayer-Foulkes (2001c) finds evidence for convergence-clubs in life expectancy dynamics over the period 1962-1997, with three groups of countries; those remaining in a lower peak, those changing to the higher peak, and those in the higher peak throughout. Other anomalies of "convergence" are the following. First, the presence of especially fast-growing countries, either at higher levels of income, like Singapore, Hong Kong and Korea, or at lower levels of income, like Botswana. Second, continent-wide growth slow-downs since the 80's, in the case of Latin America, which slowed from an average of 2.5% to –0.5%, and Sub-Saharan Africa, which slowed from 1.5% to –0.8%. These phenomena add to the already complex panorama of convergence and divergence. I show in this paper that these diverse empirical facts can be reconciled by examining convergence clusters of countries. I define a convergence clustering as a subdivision of countries into groups or clusters showing convergence within groups; a partial empirical counterpart of the concept of convergence clubs.[1] Using a specially defined clustering algorithm, I find a subdivision of countries which is simultaneously an income and a life expectancy convergence clustering. Between these groups, a series of tests show that there is global divergence, while within the groups there is convergence. As I show below, the presence of these convergence clusters serves as a qualitative test for the theories explaining economic growth, showing that these can only account for the empirical facts if they involve *multiple steady states and explain divergence*.

Up to the middle of the twentieth century, economic growth was viewed fundamentally as a process of capital accumulation, or industrialization (Harrod, 1939; Domar, 1946). This point of view has shifted, giving technological change a more prominent role. First, the recognition of decreasing returns to capital implied that technological change plays a fundamental role in the long run (Solow, 1956; Swan, 1956). Capital accumulation was now conceptualized as playing a transitional role encompassing at least part of the process of development, and its decreasing returns supported and came to be the focus of the convergence hypothesis. Capital flows between developed and underdeveloped countries, however, were inconsistent with the theory. This led to including human capital as an essential component of growth, both as an input complementary with physical capital and as knowledge. Knowledge could lead to endogenous growth, originated as an externality of capital accumulation, or through the purposeful application of human capital (Arrow, 1962; Uzawa, 1965; Frankel, 1962; Romer 1986; Lucas, 1988; Romer, 1990). Using an augmented Solow model, Mankiw, Romer and Weyl (1992) argued that just including the role of human capital as an input could account for an important proportion of cross-country income variation. However, evidence for the importance of productivity differences across countries has accumulated (Knight, Loayza and Villanueva, 1993; Islam, 1995; Caselli, Esquivel and Lefort, 1996; Klenow and Rodriguez Clare, 1997; Hall and Jones, 1999; Easterly and Levine, 2000). Martin and Mitra (2001) show that total factor productivity in both agriculture and manufacturing grew more rapidly in developed than in less developed countries during the period 1967-1992. Parente and Prescott (2000) show by simulation that barriers to increasing total factor productivity may result in amplified differences in income. Dollar and Wolff (1994) argue that technological convergence rather than factor accumulation was behind the catch up of the OECD countries to the U.S. Feyrer (2000) finds that although the distribution of output per capita is single-peaked, and the distribution of human capital is almost flat, the distribution of the productivity residual

[1] I take the position that showing the existence of convergence clubs includes determining the economic phenomena originating them, in correspondence with the theory. Also, the clusters represent significantly different trajectories, but not necessary different steady states, for example in the case of NIC's versus developed countries.

is increasingly twin-peaked, calling for a technological explanation of cross-country income disparities and dynamics. From the theoretical point of view, the Schumpeterian (1934) conceptualization of growth through purposeful innovation and creative destruction has been modeled by Aghion and Howitt, (1992, 1998), who distinguish clearly between knowledge and human capital inputs and describe the basic dynamics of technological change, conceptualized now as a driving force complementary to capital accumulation. Howitt's (2000) multi-country model shows that convergence and growth could be driven by the diffusion and spillover of ideas. Thus the changing theoretical perspective means that convergence is now viewed as a process that might result not only from decreasing returns to capital accumulation, but also from technological catch-up and other processes. The strong convergence that was found to hold for some specific cases, such as the U.S. states, European regions or the Japanese prefectures (Barro and Sala-i-Martin, 1995), may result from technological, institutional and other types of convergence as well as from capital accumulation.

Besides these central theoretical and empirical developments, the practical difficulties of development and economic growth, and the evidence for income divergence across countries, as well as inequality within countries, has motivated a series of models explaining these phenomena in terms of multiple steady states in income dynamics that might lead to convergence clubs, an idea originated by Baumol (1986). These are based on multiple equilibria in physical capital accumulation (such as Becker, Murphy and Tamura, 1990; Galor and Weil, 1996; Becker and Barro, 1989; Murphy, Shleifer and Vishny, 1989) and in human capital accumulation (such as Azariadis and Drazen, 1990; Benabou, 1996; Durlauf, 1993, 1996; Galor and Zeira, 1993; Galor and Tsiddon, 1997; Tsiddon, 1992). Other phenomena that may lead to persistent income differences or multiple equilibria in development have also been discussed. These include threshold externalities (Azariadis and Drazen, 1990), and the effects of nutrition and health on persistent educational inequality (Galor and Mayer-Foulkes, 2002). More recently, taking the viewpoint of endogenous technological change, Howitt and Mayer-Foulkes (2002) note that R&D is limited to just a few countries, and extend the Schumpeterian approach to include both innovation and technology implementation. They show that convergence clubs of countries carrying out innovation, or trapped in implementation or stagnation, can exist in which productivity levels can be quite different and may be influenced by a series of country-specific productivity and policy parameters. They thus give a technological explanation for the large-scale divergence of incomes that occurred through the 20th century, as well as for the convergence of middle- and high-income countries in the second half of that century. These multiple steady state dynamics also suggest explanations for the growth anomalies mentioned above. Discussing another low technology trap Acemoglu, Aghion and Zilibotti (2002) show that political economy traps can exist in which large industrial conglomerates preclude reforms promoting the selection of entrepreneurial ability that would advance strong, innovation-based growth.

Kremer, Onatski and Stock (2001) propose a modification to steady state theory in which there is a low but permanent probability of moving from a low, otherwise steady state to a high steady state, in a prolonged transition. In theories of multiple steady states, transitions between states can arise from the disappearance of an attractor. Multiple steady states are often also meant to be suggestive of barriers giving rise to long transitions. Thus, for the purpose of this paper I regard Kremer, Onatski and Stock's (2001) model of prolonged transition as one explanation (finding appropriate policies) of how such transitions may arise.

The wide panorama presented by the theory of economic growth means that different countries or groups of countries are likely to be undergoing quite different processes whose dynamical features correspond to different economic phenomena. These may include processes of physical and human capital accumulation, or technological and institutional change, perhaps affected by geography (e.g. Bloom and Sachs, 1998; Sachs and Warner, 1997; Krugman, 1991a, 1991b, 1994) or policy choice

(Kremer, Onatski and Stock, 2001), that may be confronting different problems at different stages or levels of development. In spite of this wide theoretical panorama, empirical cross-country studies are usually designed to confront only a *single* theory, describing a single economic phenomenon, with the empirical facts. Here instead I test a wide class of theories by asking whether the empirical facts, including the robust convergence coefficient, correspond to a single or to multiple convergence clubs. The conclusion favors multiple convergence clubs, something that has strong implications for both theory and policy.

Before proceeding with the discussion it is necessary to distinguish between *conditional* and *relative* convergence, which are different concepts in the context of multiple steady states. Galor (1996) defines conditional convergence to mean that countries with the same characteristics converge to the same growth path. According to this definition, if countries with identical parameters find themselves in different steady states, as in multiple steady state models, then conditional convergence does not hold. However, this distinction is not made by studies deducing conditional convergence from a negative convergence coefficient, (e.g. Barro 1991, 1997, Barro and Sala-i-Martin, 1991, 1992a). Instead, what is assumed is what I shall call relative convergence, that each country tends to its own steady state path (which may be of a certain type thus belonging to a club) and that growth slows when income increases towards the steady state levels. Two countries with identical parameters tending to different steady states would exhibit relative convergence (with a negative convergence coefficient) but not conditional convergence. A panel study with country-specific effects (e.g. Islam, 1995) includes information on the steady state type in these effects, as well as country-specific parameters. An essential implication of multiple steady states is that, under certain conditions, relatively small differences in endowments, or the application of specific policies, can result in important differences in economic performance. Countries on one side of the divide will diverge from countries on the other side.

According to the definition above, cross-country studies usually test for *relative* convergence. It is usually assumed that each country's economic trajectory tends towards some steady state trajectory. Then it is assumed, without discussion, that there is a single type of steady state or convergence club. Instead, I assume that there may be several convergence clubs. Consider a set of theories in which each country is following some dynamical system toward some type of steady state or, alternatively, a theory in which each country lies in different basins of attraction of one grand system. In such a situation the typical convergence study will find relative convergence. This *only* means that there *are* a series of *perhaps distinct* equilibrium processes going on. Indeed, it may be precisely these local equilibria that *prevent* global convergence. I subdivide a wide sample of countries into five groups that meet the criteria for convergence clusters, that is, there is convergence within groups. These also exhibit global divergence.

For these five groups of countries, *between* group income inequality has increased while *within* group income inequality has remained almost unchanged. Also, there is mean and variance divergence of income *between* groups and convergence *within* groups. In the case of life expectancy, for which global convergence can be expected, since it is closely bounded above, the result is that there is convergence within groups and convergence between groups except for Group 5 (the poorest), whose life expectancy improved much less than convergence would imply throughout the period, and stagnated in the 1990's.[2] Inequality of life expectancy between and within groups decreased until the 1980's, but then increased again in the 1990's. Thus, the divergence of income across groups of countries is confirmed in one test after another. Except for the fast-growing countries, it is found that richer groups of countries have higher average and steady-state growth rates. Besides, in several

[2] Wars and Aids in Africa are amongst the causes.

different tests, the hypothesis of a single convergence club is *rejected* when contrasted with the hypothesis of five convergence clusters, for both income and life expectancy. Each of the five clusters is found to differ significantly from the others in at least one respect: steady state levels, steady state growth and convergence coefficients, or the distribution of country-specific effects. The results can be interpreted as a qualitative test for a wide class of theories, by asking how many convergence clubs these support, and whether they explain divergence.

The empirical evidence thus supports theories involving multiple convergence clubs, rather than a single club. As reviewed above, the multiple steady state theories that have been advocated theoretically often result from advantages of the rich over the poor, as individuals, as classes of people or as countries, originating in production, education, technology, institutions or market failures.[3] To be consistent with the facts, theories must explain global divergence as well as the presence of multiple steady states or prolonged transitions.

A descriptive study of the five groups of countries suggests, consistently with Ranis, Stewart and Ramírez (2000), that there are three large-scale steady states, according to whether countries have overcome barriers to human development, as indicated by life expectancy, and to technological innovation (as indicated by high levels of income). *Developed* countries in Group 1 have overcome both barriers. *Semi-developed* countries in Group 3 have overcome only the human development barrier. *Semi-stagnant* countries in Group 5 have overcome none. Group 2 was in transit from semi-development to development, and Group 4 from semi-stagnation to semi-development.

The remainder of the paper is organized as follows. First, we summarize an antecedent study in life expectancy convergence clubs to explain why the clustering is defined in *five* groups. Next, the clustering algorithm is described. Then descriptive statistics are given for the five groups of countries. These are followed by a battery of tests on divergence and convergence. The first three tests do not depend on convergence regression models. The next tests apply convergence regressions by groups of countries, finding further evidence for divergence between and convergence within groups. These tests are further supported by tests on the distribution of country-specific convergence regression coefficients across groups of countries. The final section sets out the conclusions.

Life Expectancy Convergence Clubs

This study builds upon a previous study finding convergence clusters in the patterns of life expectancy dynamics (Mayer-Foulkes, 2001c). There it is shown that the cross-country distribution of life expectancy for 163 countries is very distinctly twin-peaked in 1962 and 1997. Approximately half the countries belonged to the lower peak in 1962, and approximately half of these migrated to the higher peak during the 35-year period. This unusually clear empirical subdivision gives rise to three groups of countries, 40 Low-Low, 42 Low-High, and 81 High-High countries. The trajectories followed by the life expectancy levels are quite distinct, and convergence in life expectancy levels is found within the groups. This broad characterization of countries according to life expectancy trajectories is informative only for the countries lying in the lower peak in 1962. Any further subdivision of the 81 High-High countries according to development paths must necessarily involve income data. In this paper we find that such a subdivision is possible. By combining income and life expectancy information the resulting

[3] These advantages often result from or are induced by nonconvavities in the models. There are a few cases in which multiple steady states may be argued to arise from phenomena not directly related to these types of advantages. These include multiple equilibria due to expectations and to political and economic institutions.

subdivision reflects both income growth and human development. The hope is that, even though categorizations into groups are often somewhat arbitrary, this subdivision can be further studied to shed some light on the actual, distinct growth process going on at different levels of income and life expectancy. The 81 High-High life expectancy cluster contains many less-developed Latin American countries, the newly industrialized countries (NIC's), and the whole developed world. Generating a subdivision of this cluster that distinguishes between these three categories thus demands a total of at least five groups of countries, namely the developed countries, the fast-growing countries and three tiers of less-developed countries corresponding to the Low-Low, Low-High and High-High life expectancy convergence clusters described before.

To this purpose, I exclude both ex-socialist block countries and mainly-petroleum-exporting countries. The reason is that these countries followed very different processes. Most theories for economic growth over the period 1960-1997 are not geared to explain growth in these countries. Socialist countries followed a non-market process that is addressed only vaguely by the theory of development for countries with market economies, and the economic interrelationship they held with market economies was very weak. Thus they naturally form a separate club that may or may not converge. The income of mainly oil exporting countries evolves according to petroleum prices, and these countries have highly distorted relationships between their per capita income and human development variables, which must be addressed in more specific terms and would introduce noise in the data if included.

It must be mentioned here that there is a very close, mutually causal micro and macro relationship between income and health that has been studied intensely (Preston, 1975; Pritchett and Summers, 1996; Anand and Ravallion, 1993; Fogel, 1994; Barro, 1991; Arora, 2001; Mayer-Foulkes, 2001a; Schultz, 1992, 1997, 1999; Thomas, Schoeni and Strauss, 1997; Strauss and Thomas, 1998; Savedoff and Schultz, 2000; Steckel, 1995, amongst many others. For a further review of this interrelationship see Mayer-Foulkes, 2001b). Life expectancy is an excellent indicator of development with a wider coverage across countries than income per capita. Thus use of income and life expectancy data as joint indicators of growth and development is quite appropriate.

As mentioned above, the five groups of countries do not necessarily correspond to different steady states. Two of them are more likely to represent accelerated transitions between steady states, respectively overcoming barriers to human development and to technological innovation. Because the trajectories are quite distinct, I nevertheless treat the five groups as convergence clusters that do indeed exhibit convergence within groups. Treating the clusters in transition distinctly brings out divergence and convergence more clearly.

The Clustering Algorithm

The choice of groups is carried out by a clustering algorithm using both income and life expectancy data. For this to work it was necessary to take both level and rate of change data into account.[4] The clustering algorithm maximizes the R^2 of four regressions describing the level and growth rate trajectories of income and life expectancy data by groups of countries in terms of time trends. These descriptive regressions take the form

$$X_{it} = \alpha_j^0 D_{ji} + \alpha_j^1 D_{ji} t + \alpha_j^2 D_{ji} t^2 + u_{it} \qquad \text{(RC)}$$

[4] In Mayer (2001c) level data for life expectancy was sufficient.

where $D_{ji} = 1$ if country *i* belongs to group *j*, so that $\alpha_j^0, \alpha_j^1, \alpha_j^2$ are coefficients of a quadratic expression describing the path of X_{it} for each group *j*. The dependent variables X_{it} are log income per capita, log life expectancy and their rates of change.[5] t ranges quinquenially over 1960-1995 for income, 1962-1997 for life expectancy, and one period less for the rates of change. The algorithm maximizes the average of the four R-squares of these estimates over joint partitions of the sample of countries into five groups. This is equivalent to maximizing their joint R-square once the four dependent variables are normalized to the same variance. See Appendix 1 for a further description of the clustering algorithm and its properties. The sample consists of all counties for which the full quinquenial data is complete for income for 1960-1995 or life expectancy for 1962-1997. The regressions for income and life expectancy were run for countries for which the full respective data is available. Thus the group definitions are shaped by all the available complete data in income and life expectancy and by all of the available complete data on their joint evolution. Once the socialist block and the mainly-petroleum-exporting countries were excluded, the algorithm produced a very reasonable subdivision that accords quite well with a commonsense appraisal of the facts. The result was a partition of the sample of 126 countries into five groups that will be shown to define a convergence clustering for both income and life expectancy simultaneously. Although any subdivision into groups may be argued to be somewhat arbitrary, the five groups of countries correspond quite closely to a common-sense classification of countries. In any case, the subdivision is neutral to the relationship between levels and rates of growth across the distribution of income and life expectancy.

The Groups of Countries: A Descriptive View

Group	West Europe and North America	East Asia Pacific	Latin America and Caribbean	Middle East, North Africa and Turkey	South Asia	Sub-Saharan Africa	Total
1	19	3	7	1	0	0	30
2	3	7	2	0	0	2	14
3	0	3	15	5	1	3	27
4	0	2	4	3	5	13	27
5	0	0	1	0	1	26	28
Total	22	15	29	9	7	44	126

Table I. The five clusters of countries by continents.

Table I shows the composition of the groups by continents.[6] Group 1 consists mainly of developed countries, with the exception of Argentina and Uruguay, characterized by high levels of

[5] The life expectancy and income (Penn World Table 5.6, real GDP at constant 1985 purchasing power parity dollars) data were obtained from the World Bank data base at http://www.worldbank.org/research/growth/GDNdata.htm collected by Easterly and Sewadeh.

[6] The membership of the groups including groups of excluded countries, is the following:
Group 1: Argentina; Australia; Austria; Bahamas; Barbados; Belgium; Bermuda; Canada; Denmark; Finland; France; Fed. Rep. of Germany (former); Italy; Japan; Luxembourg; Netherlands; Netherlands Antilles; New Zealand; Norway; Puerto Rico; Spain; Sweden; Switzerland; United Kingdom; United States; Uruguay. **Group 2**: Botswana; Cyprus; Guadeloupe; Hong Kong; Rep. of Korea; Macao; Malaysia; Malta; Martinique; Portugal; Seychelles; Singapore; Taiwan; Thailand. **Group 3**: Belize; Brazil; Chile; Colombia; Costa Rica; Dominican Republic; Ecuador; El Salvador; Fiji; Guyana; Jamaica;

income and life expectancy throughout the period, and relatively high income growth and low life expectancy growth. Group 2 consists of exceptionally fast growers at various income levels. Group 3 has many Latin American, Middle Eastern and North African middle income countries. Group 4 has South Asian, Latin American and Sub-Saharan countries with low incomes but high, transitional life expectancy growth. India accounts for about 58% of the population of this group. Group 5 consists mainly of Sub-Saharan countries whose average income declined and whose life expectancy remained very low.

Table II shows the average income and life expectancy levels and growth rates through the respective periods, together with the number of countries for which income or life expectancy data is available in each group.

	Income				Life Expectancy			
	Balanced Obs.	Levels		Growth Rate	Balanced Obs.	Levels		Growth Rate
Group		1960	1995	1960-1995		1962	1997	1962-1997
1	27	5631	13064	2.48%	28	70	77	0.27%
2	10	1409	8891	5.04%	13	62	73	0.49%
3	24	1739	3483	1.91%	25	57	71	0.62%
4	24	926	1500	1.36%	27	43	60	0.94%
5	23	693	610	-0.32%	28	39	47	0.49%

Table II. Average Income and Life Expectancy for the five groups of countries: initial and final levels and growth rates. Number of countries in each group with complete respective data also indicated.

Some of the characteristics of the countries excluded from the clustering algorithm are the following. Group 6 consists of ex-Soviet block countries, which arguably could form a convergence cluster, since these countries had close economic and political ties which mostly continue due to their geographical and historical proximity. However, the corresponding convergence coefficient was neither negative nor significant. Group 7 are the remaining socialist or ex-socialist countries, with about 80% of the population in China. Group 8 are the mainly-petroleum-exporting countries. Groups 1 to 5 contain about 63% of the world population while Groups 6 to 8 contain about 37%. The population of Groups 1 to 8 accounts for 99.9% of the world population.

Apart from Group 2, which consist of fast-growing countries, the average growth rate of Group 1 to 5 is increasing in the income levels, confirming that income has diverged between groups of countries.[7] In the case of life expectancy, for which the returns to wealth decrease very strongly (Group

Jordan; Lebanon; Mauritius; Mexico; New Caledonia; Panama; Paraguay; Peru; Philippines; Reunion; South Africa; Sri Lanka; Suriname; Syrian Arab Republic; Tunisia; Turkey. **Group 4**: Bangladesh; Benin; Bolivia; Cameroon; Cape Verde; Comoros; Egypt; Equatorial Guinea; Gambia; Ghana; Guatemala; Honduras; India; Indonesia; Lesotho; Maldives; Mauritania; Morocco; Namibia; Nepal; Nicaragua; Pakistan; Papua New Guinea; Senegal; Sudan; Swaziland; Yemen. **Group 5**: Afghanistan; Burkina Faso; Burundi; Central African Republic; Chad; Dem. Rep. of Congo; Cote d'Ivoire; Djibouti; Eritrea; Ethiopia; Guinea; Guinea-Bissau; Haiti; Kenya; Liberia; Madagascar; Malawi; Mali; Mozambique; Niger; Rwanda; Sierra Leone; Somalia; Tanzania; Togo; Uganda; Zambia; Zimbabwe. **Group 6** (Ex-Soviet block): Armenia; Azerbaijan; Belarus; Bulgaria; Czech Republic; Estonia; Georgia; Hungary; Lithuania; Poland; Romania; Slovenia; Tajikistan; Turkmenistan; Ukraine; Yugoslavia (Serbia/Montenegro). **Group 7** (Other socialist or ex-socialist): Albania; Angola; Cambodia; China; Dem. Rep. of Korea; Laos; Latvia; Mongolia; Myanmar; Vietnam. **Group 8** (Mainly petroleum exporting): Algeria; Bahrain; Brunei; Rep. of Congo; Gabon; Iran; Iraq; Kuwait; Libya; Nigeria; Oman; Qatar; Saudi Arabia; Trinidad and Tobago; United Arab Emirates; Venezuela.

[7] The significance of this finding is confirmed below.

1 had 21.4 times the average income per capita of Group 5 in 1995, but average life expectancy was only 64% higher in 1997), increases in average life expectancy were absolutely higher for groups with lower life expectancies, except for Group 5, which improved very slowly.

Figures 1.1 and 1.2 show the empirical phase diagrams plotting changes against levels in log-income for 1960-1995 and log life expectancy for 1962-1997 by groups. The life expectancy phase diagram (Figure 1.1) is clearly arch-shaped. Countries and groups begin on the left with low levels and low (even negative) changes, with a high dispersion of rates of change. Fortunate countries then move to the region of somewhat higher levels and high rates of change at the top left of the arch. Finally they transit diagonally downwards converging towards high levels and moderate but sustained improvement. The transition from low to high life expectancy levels involves, according to this cross-sectional view, an initial transitional period of rapid change. In the case of income, if we exclude Group 2, countries shift, in general terms, form the low dispersed income, low growth region, to the high income, high growth region. Group 2 is distinct in that it has faster growth. Excluding the socialist block and mainly oil exporting countries, as well as plotting the convergence clustering obtained in conjunctions with life expectancy data, clarifies this diagram, presented elsewhere as a mysterious stochastic plot (see for example, Barro, 1997, page 10).

It is notable that the transition to higher life expectancies occurs, as a rule, ahead of the transition to higher incomes, as can be corroborated by the relatively lagged positioning of the groups in the income phase diagram as compared to the life expectancy phase diagram. This pattern corroborates Ranis, Stewart and Ramírez' (2000) results, who finds that the transition to a 'virtuous cycle' in human development is both usually more stable and a propitious antecedent to the transition to a 'virtuous cycle' in income growth. It is also consistent with studies affirming the causality from health improvements to economic growth during this and other historical contexts (Fogel, 1994; Arora, 2001; Mayer-Foulkes, 2001a, 2001b).

Thus the evidence is suggestive of the three large-scale convergence clubs mentioned above. The lowest steady state (*semi-stagnation*) is almost stagnant in income but observes some life expectancy growth. The middle steady state (*semi-development*) has much higher life expectancies and a middle level of income. The highest steady state (*development*) has high levels of income and life expectancy. Group 2 transits from semi-development to development. This may explain its fast rates of growth. Group 4 transits from semi-stagnation to semi-development. These three steady states are compatible with the technological convergence club model proposed by Howitt and Mayer-Foulkes (2002). The higher steady state corresponds to he ability to perform or to imitate R&D. The middle steady state correspond to the ability only to implement technologies, with R&D imitation requiring levels of science that remain inaccessible due to low educational levels. The lower steady state corresponds to stagnation, interpreted to mean that only very low cost technologies can be implemented. These nevertheless lead to rises in life expectancy. Under such and interpretation, long term forces may lead to the disappearance of the lower steady states in a prolonged transition. What may not be explained sufficiently in the Howitt Mayer-Foulkes (2002) model is the degree and continuity of global divergence that is observed across Groups 1 to 4.

Figure 2 plots average life expectancy[8] for 1962, 1967, ...,1997 against average log income per capita for 1960, 1965, …, 1995, including all eight groups of countries. It is interesting to note that, together, the five groups of countries in the convergence clustering almost conform a functional relationship between life expectancy and income. However, each group of countries achieves a higher life expectancy at the end of the period than the next richer group obtained at some earlier time when it had and equal or higher level of income, confirming Preston's (1975) study. The following descriptive

[8] (Actually, the exponent of average logs.)

estimation for life expectancy in terms of income is a reestimation of this relation confirms this relationship (run with fixed effects and White's heteroskedasticity correction; t-statistics in parenthesis; R-squared: 0.966).

$$\log(LE_{it}) = \underset{(5.39)}{0.252} \log(y_{it}) + \underset{(13.16)}{0.073}\, t - \underset{(-5.02)}{0.015} \log(y_{it})^2 - \underset{(-4.38)}{0.04} \log(y_{it})\, t - \underset{(-4.73)}{0.002}\, t^2 + c_i + u_{it}$$

According to the regression, log life expectancy was decreasing in log per capita income and increased with time, in an effect which was stronger for lower income countries and decreasing through time.

It is notable that the ex-Soviet block countries (Group 6) and other socialist or ex-socialist countries (Group 7, mainly China) enjoyed better life expectancy at comparable income levels than their market counterparts until the 1970's and 1980's respectively. The reverse holds for the mainly-petroleum-exporting countries, which had much higher income for given life expectancy levels. This, by the way, supports their exclusion from the sample.

Figures 3.1 and 3.2 show three standard deviation corridors for the log life expectancy and log income of each group of countries at five year intervals. It is quite clear that each group of countries is following its own significantly different pattern of economic growth. The health improvement pattern followed by the less-developed Groups 3, 4, and 5 reproduces the convergence clustering found for life expectancy in the antecedent study mentioned above (Mayer-Foulkes, 2001c), with Group 4 changing from the level of Group 5 toward that of Group 3.

It is noteworthy that income also follows this pattern, with Group 4 tending to catch up on Group 3, and Group 5 staying behind, actually experiencing negative average growth after 1980. On the other hand, Group 2, the fast-growing countries, starts from levels comparable to Group 3 and almost catches up with Group 1, the developed world.

These different growth experiences are grounded in conditions originating long before 1960. Acemoglu, Johnson and Robinson (2000) give evidence that the current distribution of income has substantive long-term determinants, being correlated with mortality data from the colonial era. Howitt and Mayer-Foulkes (2002) point out that their econometric results are consistent with long-term technologically-caused convergence clubs giving rise to persistence in the cross-country distribution of income. The correlation that exists between group membership and geographical location by continents (see Table II) also underlines the long-term antecedents of group membership, independently of whether the main transmission channels are historical, institutional, technological or geographical, or whether the transmission mechanisms have changed over time. These proposed mechanisms explaining the persistence of the income distribution across countries could in any case work in succession, because they each deliver the appropriate initial conditions for the succeeding mechanism in a new historical period dominated by different economic forces.

Convergence and Divergence Across Groups of Countries

It is not difficult to obtain a first tests of the convergence and divergence properties across the five groups of countries that is independent of regression models. This consists of testing for a trend across ordered groups, by applying Cuzick's (1985) non parametric test. The results are shown in Table III. When the test is applied to the full subdivision into five groups, a highly significant divergence trend is found (represented by a negative sign because higher income groups have a lower index number). This trend is independent of the inclusion of Group 2, as is shown by excluding this Group from the sample. In the case of life expectancy, the overall pattern is one of convergence, independently of the inclusion of Group 2. Next, we examine neighboring groups in succession. Groups 1 and 2 converge in income and life expectancy. Groups 2 and 3 diverge in income and exhibit a somewhat significant life expectancy convergence. Groups 3 and 4 converge in life expectancy and exhibit a somewhat significant income divergence. Groups 4 and 5 diverge in income and life expectancy. This pattern of convergence and divergence is inconsistent with a view that would have each country belong to its own club. First, because it would remain to explain the evidence for global divergence, and second, because there are significant common phenomena across groups that cannot be due simply to random differences between countries. The convergence and divergence pattern supports the stylized fact of three large-scale convergence clubs mentioned above.

	Income per Capita		**Life Expectancy**	
Groups	**z**	**p**	**z**	**p**
1, 2, 3, 4, 5	**-6.89**	**0**	**5.45**	**0**
1, 3, 4, 5	**-6.45**	**0**	**5.23**	**0**
1,2	**4.45**	**0**	**4.01**	**0**
2,3	**-4.54**	**0**	1.68	0.09
3,4	-1.75	0.08	**5.01**	**0**
4,5	**-3.85**	**0**	**-5.37**	**0**

Table III. Test for the divergence and convergence of income and life expectancy growth rates across groups of countries and by pairs of successive groups.

Within and Between Group Inequality in Income and Life Expectancy

I now decompose income and life expectancy inequality by groups of countries, following the methodology of Cowell and Jenkins (1995). The results are very similar for $\alpha = -1/2$, 0 and 1, indexes of the family of the generalized entropy class of inequality measures. $\alpha = 0$ is reported in Figures 4.1 and 4.2. Income inequality between groups of countries increased, while inequality within groups decreased. According to this methodology, the evolution of income inequality is mainly explained by what is happening *between* the groups, that is, by differences in the growth pattern followed by the different groups of countries, providing evidence for a pattern of global divergence of income across groups of countries. Quah's (1993, 1996, 1997) findings of an increasingly twin-peaked distribution also express the increase in income inequality observed between 1970 and 1985.

In the case of life expectancy, inequality between groups of countries first decreased but this trend ended in the late 1980's mainly because of life expectancy problems in Group 5. Figures 4.3 and 4.4 show the evolution of the proportion of variance that is between groups.

Within and Between Group Variance of Income and Life Expectancy.

Next, I examine σ-convergence by decomposing variance between and within groups of countries. The results, shown in Figures 5.1 to 5.4, are very similar to those obtained for the inequality decompositions. Variance of income between groups of countries increased, while variance within groups decreased. In the case of life expectancy, variance between groups of countries first decreased but this trend ended in the late 1980's mainly because of life expectancy problems in Group 5.

Convergence and Divergence in Regression Models

The above three sections give econometric evidence for income divergence between groups and convergence within groups, as well as specific regions of divergence and convergence, independently of a regression model. Here we turn to convergence regression models.

Each of the theories of economic growth mentioned in the introduction models economic processes tending to states of equilibria represented by a single or multiple steady states. Thus, to analyze convergence I assume that each country's economic trajectory tends to some steady state trajectory. By analyzing the properties of these steady states, it is usually possible, for economic indicator functions such as income and life expectancy (as shown in Appendix 2), to arrive at a convergence equation of the form

$$\tfrac{1}{T}(y_{it+T} - y_{it}) = c_i + \gamma_i t + B_i y_{it} + \eta_{it} \qquad \text{(C)}$$

Here y_{it} represents log income per capita, B_i represents the rate of convergence to the steady state trajectory, γ_i is a multiple of the characteristic growth rate of the steady state, and c_i are country-specific fixed effects. Equation (C) implies that as the income trajectory y_{it} approaches the steady state trajectory y_{it}^* from below, growth tends to slow down. If it is assumed that life expectancy is a function of the underlying economic variables, then it also obeys an analogous convergence equation.

Constant Coefficients by Groups of Countries: Convergence Clusters

Cross-country empirical studies of convergence usually assume that there is a single convergence club. Here we test the hypothesis that there is divergence between the five groups of countries, convergence within them, and also that the five groups have significantly distinct convergence properties.

I begin by assuming that all steady states have the same rate of growth, and that the convergence rates are the same. Then a simple regression can be applied to distinguish if the different groups have different steady states: group specific dummies and also a dummy for each time period are introduced in equation (C). This regression is compared to the single club model in which the group specific dummies are excluded. The results are in Table IV. The single club model obtains absolute divergence (as opposed to absolute convergence). The five club model obtains a negative convergence coefficient and highly significant group-specific constant terms representing different steady states, expressed in comparison to Group 1. The magnitudes are strictly ordered (according to the group index), except that Group 2's constant is higher than Group 1's. Wald tests show that all of the coefficients are different with p-value less than 0.001, supporting the hypothesis that the five groups have significantly different steady states. An F-test finds the five club model to be more significant than the single club model at better than one in a million, although the significance may be biased upward by the clustering by levels.

In the case of life expectancy there is absolute convergence, and life expectancy improves fastest in Groups 3 and 2. Group 4's rate of improvement is statistically indistinguishable from Group 1, while Group 5's life expectancy deteriorated significantly, and is responsible for the negative sign in the only significant time dummy. The five club model is also much more significant than the one-club model.

However, steady states growth rates and convergence coefficients need not be the same. To estimate them properly, it is necessary to include country fixed effects. Hence convergence properties independent of country-specific steady state levels will be tested. I assume that each of the five groups of countries has common coefficients (instead of the usual assumption that *all* countries have the same coefficients).[9] Although Group 2 may be transiting to the same steady state as Group 1, so that they would belong to the same convergence club, testing this hypothesis is beyond the scope of this paper, because it probably involves several kinds of non-linearities. The same holds for the relationship between Groups 4 and 3. Thus I analyze each group separately, even if these two pairs may each belong to the same broad convergence club. For this reason, the concept of *convergence clustering* is restricted to mean only that its group-specific convergence coefficient is negative. Thus I estimate:

$$\tfrac{1}{T}(y_{it+T} - y_{it}) = c_i + \sum_j \gamma_j D_{ji} t + \sum_j B_j D_{ji} y_{it} + \eta_{it}, \tag{1}$$

where D_{ji} is 1 if country i is in group j and 0 otherwise, and a similar equation for log life expectancy. The first column in Table V shows the income results. Each of the groups has a significant negative convergence coefficient for income per capita. They also have significant, positive steady-state growth coefficients, except for Group 4, which is near 0 with a similar standard deviation, and Group 5, for which the coefficient is negative. The growth coefficients rise with the income level of the groups, except for Group 2, which grows faster. To test for this tendency I estimate the following regression:

$$\tfrac{1}{T}(y_{it+T} - y_{it}) = c_i + \sum_j B_j D_{ji} y_{it} + \delta_0 t + \delta_2 D_{2i} t + \delta_G \sum_j j D_{ji} t + \eta_{it}. \tag{2}$$

Here δ_0 represents a parallel growth term, δ_2 represents additional growth in Group 2, and δ_G represents additional group-specific growth, parameterized by the group index j. Since this index is decreasing in income, a significant, negative δ_G implies divergence of growth rates across groups of countries. The results, column 2 of Table V show that there is indeed highly significant divergence between groups of countries, and that Group 2 grows even faster. Because modeling by the group index is somewhat arbitrary, I also tested the model given by the coefficients of regression (1) as follows:

$$\tfrac{1}{T}(y_{it+T} - y_{it}) = c_i + \sum_j B_j D_{ji} y_{it} + \delta_0 t + \delta_{DIV} \sum\nolimits_j \gamma_j D_{ji} t + \eta_{it}. \tag{3}$$

Here $\sum_j \gamma_j D_{ji}$ is the divergence pattern estimated in regression (1). The significance of δ_{DIV} (whose value must be 1) is the joint significance of this divergence pattern, which is higher than the significance of δ_G, as can be seen in column 3 of Table V. δ_0 obtains a value of 0, and is completely insignificant, as is to be expected.

Column 4 of Table V has the results for life expectancy. The steady state growth coefficients are not very significant, as is to be expected, since life expectancy must tend to a bounded steady state. The convergence coefficients, however, are significant for all of the groups except Group 2.

Tables VI.1 and VI.2 show the results of Wald tests for the pair-wise equality the coefficient vectors (B_j, γ_j) between groups of countries for the income and life expectancy regressions in columns 1 and 4 of Table V. The pairs of coefficient vectors are mostly significantly different. Tables VII.1 and VII.2 show the results of a Kruskal-Wallis equality of populations rank test (adjusted for ties) for the

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[9] Below we drop this assumption and investigate the coefficient distributions, showing that they differ significantly between groups.

fixed effects of these regressions by groups of countries. The fixed effects distributions are always significantly different. These two sets of test show that the group of countries follow significantly different income and life expectancy dynamics. However, that the presence of a strong, significant divergence pattern means that steady states cannot be readily compared across groups of countries, since the steady state growth rates involved in their definition are different.

Finally, an F-test comparing the single-club model for income and life expectancy with the five-club model found that the five-club structure was significant at better than one in a million in both cases. The significance may nevertheless be biased upwards by the clustering by levels.

The convergence observed within groups, which recovers the robust relative convergence finding, is evidence that there are equilibrium processes keeping group members to their group trajectories.[10] This supports the hypothesis of a convergence club structure, or multiple steady states, since the evidence for divergence implies that there are economic forces maintaining income differences in spite of the forces that lead to convergence. Evidence for these forces has been found in the case of OECD countries, for instance, corresponding approximately to convergence within Group 1 in this study.

Distribution of Convergence Properties by Groups of Countries

I now drop the assumption that each group of countries has common convergence coefficients, maintained in the previous section, and look at the distributions of the coefficients c_i, B_i, γ_i to test if these are the same across groups of countries. One of the reasons it is necessary to drop this assumption is that each group of countries may itself be subdividable into clubs. Differences in the distributions of the coefficients of the convergence equations between groups reflect differences in their economic dynamics. I test for these differences by applying the Kruskal-Wallis equality of populations rank test (adjusted for ties) of the hypothesis that the several subsamples are from the same population.

Groups Tested	**a) 1,2,3,4,5**		**b) 1, {3,4,5}**		**c) 1, {3,4}**		**d) 3,4,5**	
Coefficients	**Income per Capita**	**Life Expect.**	**Income per Capita**	**Life Expect.**	**Income per Capita**	**Life Expect.**	**Income per Capita**	**Life Expect.**
γ_i	**0.0001**	**0.0423**	0.5441	0.1717	0.4332	0.7881	**0.0126**	**0.0415**
B_i	**0.0112**	**0.017**	**0.0297**	**0.0007**	*0.0851*	**0.0012**	0.5922	0.8577
c_i	**0.0402**	**0.0048**	0.4248	**0.0001**	0.5008	**0.0003**	0.5984	0.899

(p-value; bold used for better than 5% significance, italics for 10%.)

Table VIII. Results of Kruskal-Wallis equality of populations rank test (corrected for ties) for the distributions of coefficients of the convergence estimates for income per capita and life expectancy by countries: a) divided into the five groups of countries; b) Group 1 compared with all countries in Groups 3, 4 and 5; c) Group 1 compared with all countries in Groups 3 and 4; d) Groups 3, 4 and 5 compared.

The first pair of columns in Table VIII shows that the steady state growth rates, convergence coefficients, and fixed effects of income per capita and life expectancy for the five groups of countries

[10] The convergence coefficient found by cross-country studies assuming a single convergence club arises as a weighted average of group-specific convergence coefficients, with divergence factored in.

are very unlikely to belong to the same distribution. To eliminate the possibility that these results are driven by Group 2 (which is shown to differ significantly from the other groups in Table VIII) the second pair of columns shows that Group 1 can be distinguished from the joint group formed by Groups 3, 4 and 5 (i.e. developed from underdeveloped countries), mainly by the convergence coefficients and life expectancy fixed effects. When Group 5 is eliminated, the same results hold except that for income convergence the significance is reduced (recall that the sample is down to 75). The final pair of columns shows that Groups 3, 4 and 5 differ significantly amongst each other, mainly in their growth rates.

Table IX shows the results for pair-wise Kruskal-Wallis tests between the groups of countries, applied to the coefficient distributions for the convergence equations for income and life expectancy. All pairs can be distinguished on some count. Pairs of groups 1 and 3, 3 and 4 and 4 and 5 can only be distinguished in terms of life expectancy. Every other pair-wise distinction has some significant difference in the behavior of the income growth.

To test for divergence, I apply Cuzick's (1985) nonparametric test for a trend across ordered groups in the steady-state growth rates $g_i = -\gamma_i / B_i$ for income and life expectancy.[11] The results are in Table X. The significant negative relationships imply that the income and life expectancy steady state growth rates of higher income groups are higher (because the group index is decreasing in income), independently of whether Group 2 is included or not.[12] Also the coefficient for life expectancy fixed effects was found to be higher for higher income countries.

Groups	Income per Capita Steady State Growth Rates z	p	Life Expectancy Fixed Effects z	p
1, 2, 3, 4, 5	**-1.92**	**0.05**	**-5.22**	**0**
1, 3, 4, 5	**-1.95**	**0.05**	**-5.49**	**0**

Table X. Test for the divergence of steady state income growth rates and for a trend in life expectancy fixed effects across groups of countries.

The tests applied to the distributions of the convergence regression coefficients support the finding of global income divergence across groups of countries. They also show that each group follows its own distinct income and life expectancy dynamics, though the possibility of non-linearities is not being taken into account.

Summary

A whole sequence of tests has been applied to examine convergence and divergence within and between the five groups of countries. First, the pattern of convergence and divergence found for growth rates across groups of countries shows that there is global divergence, and supports the existence of the large scale, three club structure mentioned above. Second, inequality and variance decompositions

[11] This is an extension of the Wilcoxon rank-sum test and incorporates a correction for ties (Altman, 1991).

[12] Divergence of the growth rate coefficients γ_i was also found for income per capita, independently of the inclusion of Group 2.

show that inequality between groups has increased, while inequality within groups has decreased. This gives direct evidence of divergence between groups of countries, independently of any theoretical modeling. Third, if it is assumed that countries share steady-state growth rates and convergence coefficients, then the five club model is much more significant than the single club model and implies each group has different steady states. Fourth, it is assumed that instead countries move along trajectories tending to country-specific steady states, but that otherwise countries in each of the five groups follow the same dynamics. Then it is found that income growth rates are significantly divergent and that there is a significant negative convergence coefficient within each group of countries, both for income and life expectancy. Thus, the groups of countries form a diverging set of convergence clusters. The five group model is very significantly better than the single club model, and the dynamics followed by each group of countries are significantly distinct. Fifth, the convergence regressions are estimated separately for each country. Tests on the coefficients of these regressions then show that average and steady state income growth rates are significantly divergent, independently of Group 2, while life expectancy fixed effects were significantly higher for the higher income groups. Also, the convergence regression coefficients were significantly different across groups of countries, showing that they follow distinct income and life expectancy dynamics.

The income and life expectancy trajectories (Figure 3, Table III) suggest the presence of three large-scale convergence clubs. The poorest, semi-stagnant countries face barriers to human development. When these are overcome, income and especially life expectancy rise quickly. At this level, the trajectories suggest a further set of barriers to high income that may involve the process of technological change, distinguishing semi-developed from developed countries, which have overcome them.

Conclusions

The subdivision of non-mainly-petroleum-exporting market economies into five groups of countries presented herein provides the opportunity to test the conditional convergence hypothesis. In fact, what is found is global divergence. The convergence hypothesis is rejected even in its weakest form, which is convergence to parallel paths. Instead, what is observed is that convergence occurs within groups of countries, consistently with the robust finding of relative convergence across countries, while the groups themselves diverge.

Our findings confirm Pritchett's (1997) findings of divergence in the cross-country distribution of income. Pritchett's method is to find a minimum level of income for the less developed countries in 1870, and to therefore infer a maximum rate of growth for these countries during the period 1870-1990. The data I use covers the last portion of this period and exhibits this divergence directly, in manner consistent with the relative convergence that has also been observed, once countries are subdivided appropriately into groups. The results also show that divergence and inequality rose to even higher levels after 1980, consistently with Quah's (1993, 1996, 1997) findings. Thus, the divergence observed by Pritchett continues to this day.

The recognition of multiple convergence clubs allows the definition of *states of development*, which in the language of dynamics correspond to lying in the basin of attraction of a specific configuration of economic of growth. A fuller knowledge of the underlying economics can lead to policies aimed at dissolving specific physical and human capital, technological, institutional and other low income traps, perhaps involving geography, and therefore at *changing states of development*, rather than just policies seeking macroeconomic stability and poverty alleviation. The descriptive statistics suggest, as stylized facts, the existence of three large-scale convergence clubs, *semi-stagnation* (low income and life expectancy), *semi-development* (middle income and high life expectancy) and *development* (high income and life expectancy). These are broadly consistent with the Howitt and Mayer-Foulkes (2002) model. However the monotonic relation that exists between levels of income and rates of growth between the remaining Groups 1, 3, 4 and 5 is not sufficiently explained.

It cannot be helped but to observe that the explanations for economic growth that were current during the period failed to be consistent with the facts. Perhaps countries compete for growth or growth-producing resources, and richer countries have an advantage in this competition.

The existence of multiple convergence clusters is only consistent with multiple convergence clubs or prolonged transitions, rather than a single convergence club, or a club for each country, and has important implications for policy. Multiple steady states tend to arise from disadvantages faced by the poor or from advantages enjoyed by the rich, either individually, as classes of people, or as countries, originating in production, education, technology, institutions, geography or market failures. These give rise to non-convexities in the process of growth and lead to barriers that markets cannot remove on their own. This need not be considered a question of orthodoxy. What is needed, first of all, is to understand the main kinds of barriers that exist. This will make it possible to propose the policies, and perhaps to find the resources that may be required to achieve the miracle rises in human well-being that are so badly needed.

Appendix 1. The Regression Clustering Algorithm

The algorithm for finding the partition of the sample of countries into N groups with the minimum joint R-squared for the four equations (RC) mentioned above works as follows. Given an initial partition into N groups, the algorithm passes through each country and switches it to that group of countries for which the highest R-squared improvement is obtained. This procedure is applied successively until no country can be changed to another group in such a way that the joint R-squared increases. The maximum to the problem is not unique, as can be ascertained by considering a problem with sufficient symmetry. However, the solutions obtained (see Figures 1.1 and 1.2) do look unique, because there is no obvious way in which the clusters could be arranged differently other than by shifting their boundaries, which the algorithm can do. In any case it is sufficient for the purposes of this article to produce any partition yielding the results. The initial partitions were obtained by splitting optimal partitions for lower N. The algorithm is implemented in a Delphi program (the Windows version of Pascal) written for the purpose by the author.

Appendix 2. The Convergence Equation

Assume that the economic growth experienced by the countries in the sample over the period under consideration obeys some dynamic model in which each country is tending to some steady state. Each country i is described at time t by a vector x_{it} of fundamental variables, such as human and physical capital, and two observed variables, log income y_{it} and log life expectancy LE_{it}, which the model describes as functions of the underlying economic variables x_{it}, such as $y_{it} = g(x_{it}, \theta_i)$ and $LE_{it} = h(x_{it}, \theta_i)$ where θ_i are country-specific parameters.[13] Suppose further, for example by using a log-linearization, that near the steady state

$$\hat{x}_{it+T} - \hat{x}_i^* = M_i(\hat{x}_{it} - \hat{x}_i^*),$$
$$y_{it} = a_i' x_{it} + \varepsilon_{it}^y$$
$$LE_{it} = b_i' x_{it} + \varepsilon_{it}^{LE},$$

where M_i is a country-specific matrix (for example a Jacobian matrix in the case of a differential model), and a_i, b_i are fixed, country-specific vectors. Each steady state has a characteristic growth rate g_i. The fundamental variables and their steady states levels are expressed in terms of transformed variable $\hat{x}_{it}, \hat{x}_{it}$ defined in terms of g_i by the following relation: $x_{it} = \hat{x}_{it} + g_i et$ where $e = (1,...,1)'$, in such a way that the steady states $\hat{x}_i^*$ are constant. These equations can be derived for most growth models, so long as life expectancy is considered to depend on the underlying economic variables and country-specific parameters.

Suppose for simplicity that cycles have been excluded from the theory (as is usually the case), and that the steady states are stable, so that M_i has real negative eigenvalues. Let β_i be the eigenvalue

[13] For example, life expectancy can be considered a function of one or several of income, capital, technology, inequality, etc., see Mayer (2001c).

with the smallest absolute value. Near the steady state, $\hat{x}_{it} - \hat{x}_i^*$ is close to being an eigenvector of β_i and so the log-linearized model becomes:

$$\tfrac{1}{T}(\hat{x}_{it+T} - \hat{x}_i^*) = \tfrac{1}{T} e^{\beta_i T}(\hat{x}_{it} - \hat{x}_i^*) + \mu_{it}$$

where μ_{it} is an error term. Hence

$$\begin{aligned}
\tfrac{1}{T}(y_{it+T} - y_{it}) &= \tfrac{1}{T} a_i'(x_{it+T} - x_{it}) + \Delta\varepsilon_{it}^y \\
&= a_i'(\tfrac{1}{T}(\hat{x}_{it+T} - \hat{x}_{it}) + g_i e) + \Delta\varepsilon_{it}^y \\
&= B_i a_i'(\hat{x}_{it} - \hat{x}_i^*) + g_i a_i' e + v_{it} \\
&= B_i a_i'(x_{it} - g_i te - \hat{x}_i^*) + g_i a_i' e + v_{it} \\
&= B_i a_i'(-g_i te - \hat{x}_i^*) + B_i y_{it} + g_i a_i' e + \eta_{it} \\
&= c_i + \gamma_i t + B_i y_{it} + \eta_{it} \qquad \text{(C)}
\end{aligned}$$

where $\Delta\varepsilon_{it}^y = \tfrac{1}{T}(\varepsilon_{it+T}^y - \varepsilon_{it}^y)$, $v_{it} = a_i'\mu_{it} + \Delta\varepsilon_{it}^y$, $B_i = -\tfrac{1}{T}(1 - e^{\beta_i T}) < 0$, $\eta_{it} = v_{it} - B_i \varepsilon_{it}^y$, $c_i = g_i a_i' e - B_i a_i' \hat{x}_{it}^*$ and $\gamma_i = -B_i g_i a_i' e$. If the fundamental variables $\underline{x}_{it}$ have the same steady state growth rate as income, as is usually assumed, then $a_i' e = 1$. I shall refer to c_i, γ_i, and B_i as the fixed effect, steady state growth rate and convergence coefficients respectively. Although the error term derived here has an order one autoregressive structure, turn out to be insignificant. This is the equation that we estimate for income. An analogous derivation holds for life expectancy.

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Figure 1. Empirical Phase Diagrams: Change against Initial Levels

Figure 1.1 Life Expectancy

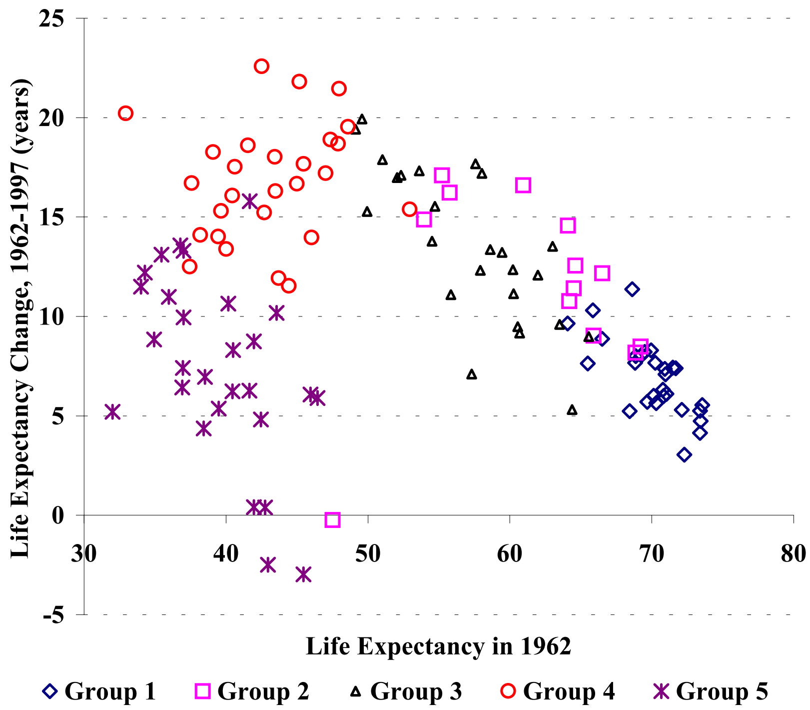


Figure 1.2 Income per Capita

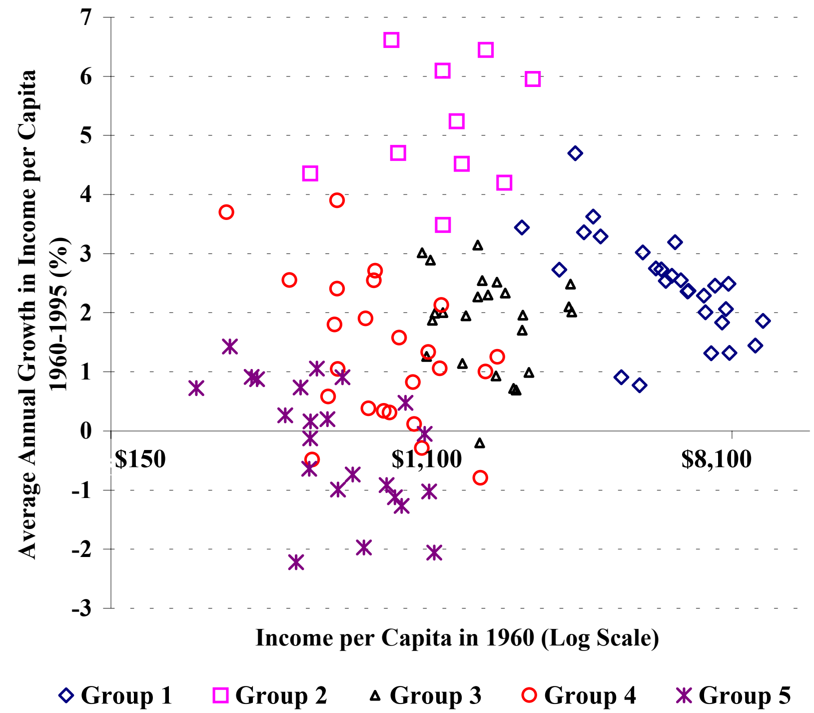
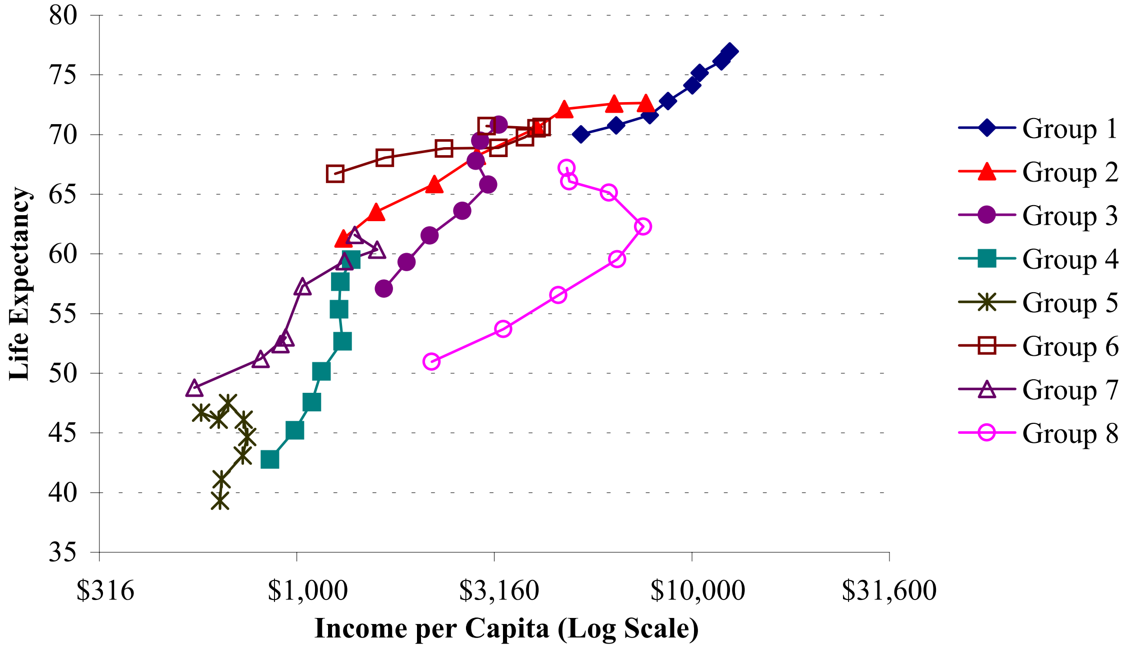


Figure 2. Average Life Expectancy versus Income per Capita by Groups of Countries



(The trajectories run through the following years, with life expectancy trending upwards: Life Expectancy, 1962, 1967, ...,1997; income per capita, 1960, 1965, ...,1995, in 1985 PPP US dlrs.)

Figure 3. Income per Capita and Life Expectancy

Three Standard Deviation Corridors by Groups of Countries

(Constructed on the Logarithmics of the Variables)

Figure 3.1 Income per Capita

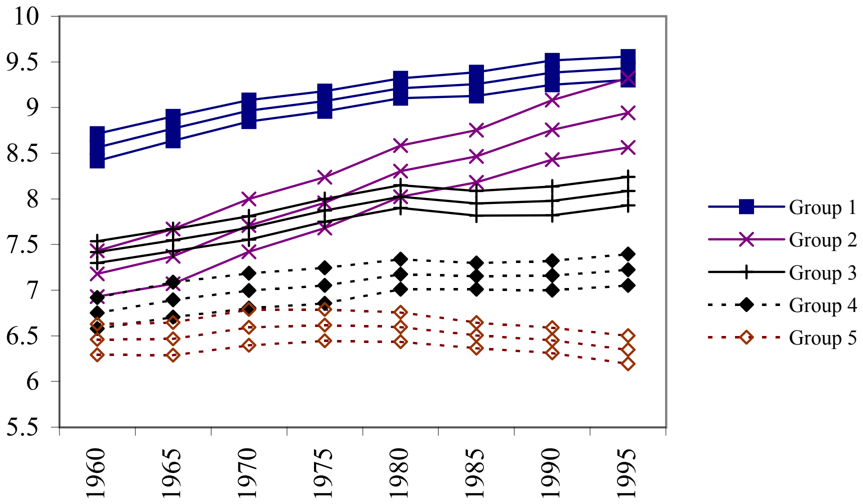


Figure 3.2 Life Expectancy

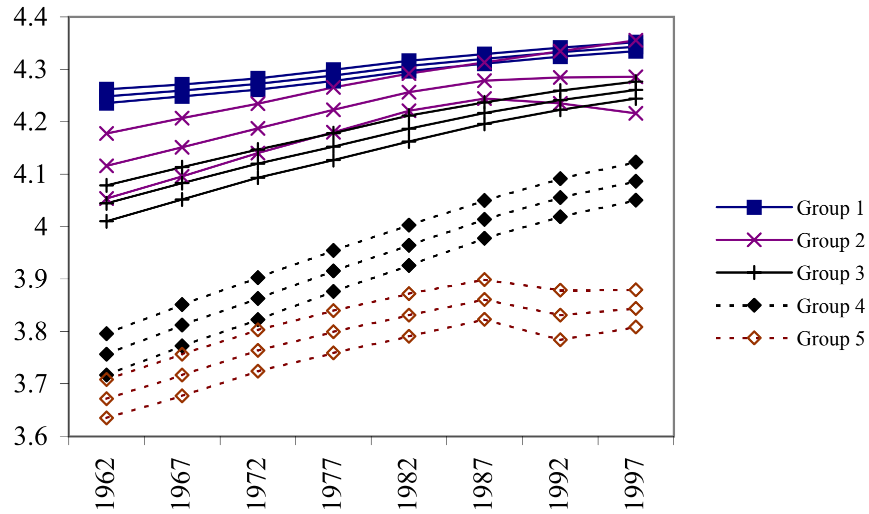


Figure 4. Within and Between Group Inequality Decomposition (Generalized Entropy Inequality Measure, alpha = 0) (Constructed on the Logarithms of the Variables)

Figure 4.1 Income per Capita

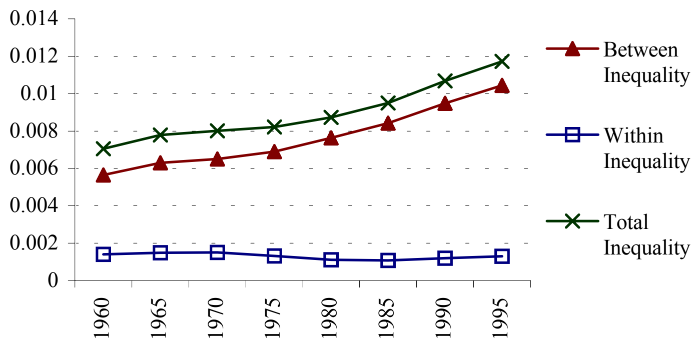
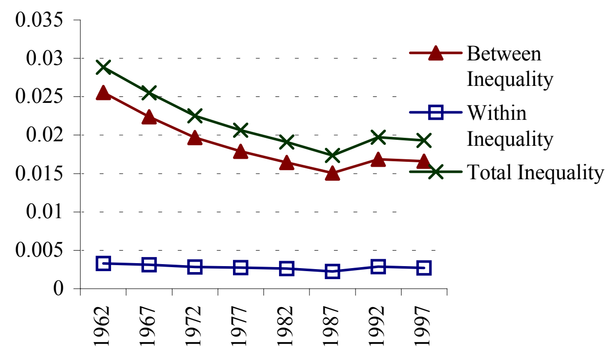


Figure 4.2 Life Expectancy



Proportion of Inequality that is Between Groups

Figure 4.3 Income per Capita

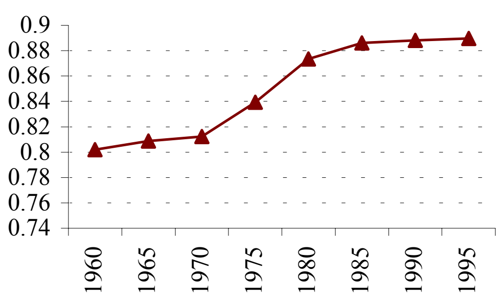


Figure 4.4 Life Expectancy

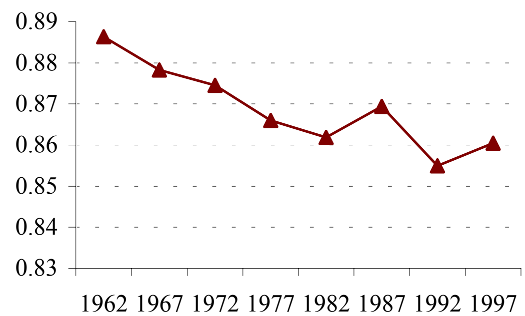


Figure 5. Within and Between Group Variance Decomposition (Constructed on the Logarithms of the Variables)

Figure 5.1 Income per Capita

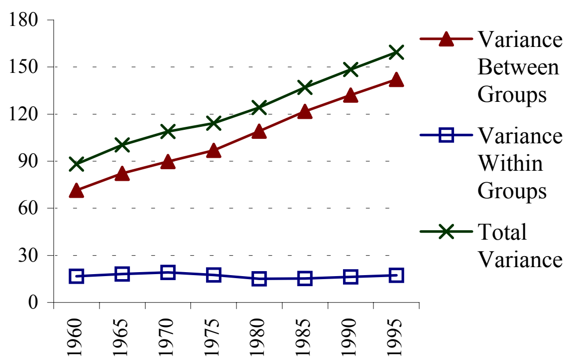
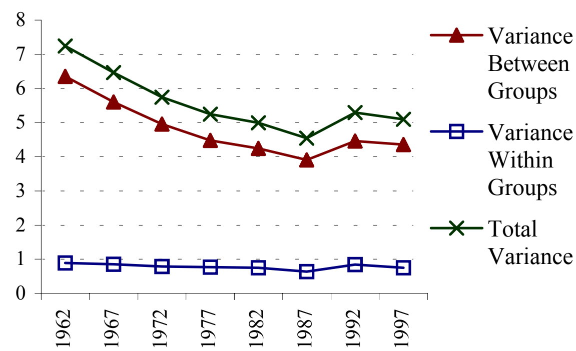


Figure 5.2 Life Expectancy



Proportion of Variance that is Between Groups

Figure 5.3 Income per Capita

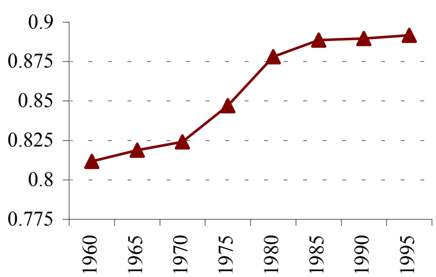


Figure 5.4 Life Expectancy

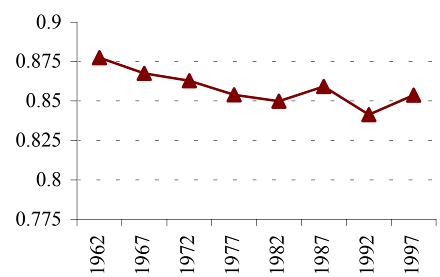


Table IV. Single and Five-Club Convergence Regressions (White Heteroskedasticity Correction)

	Income per Capita		Life Expectancy	
	Single Club	Five-Club	Single Club	Five-Club
Constant	**-0.0264**	**0.1185**	**0.0362**	**0.0623**
	(0.001)	**(0)**	**(0)**	**(0)**
Dummy for Group 2		**0.0159**		**0.0011**
		(0)		**(0.017)**
Dummy for Group 3		**-0.0177**		**0.0015**
		(0)		**(0.006)**
Dummy for Group 4		**-0.0299**		0.0015
		(0)		(0.264)
Dummy for Group 5		**-0.0525**		**-0.0048**
		(0)		**(0.014)**
Initial log income per capita or life expectancy	**0.0072**	**-0.0098**	**-0.0073**	**-0.0138**
	(0)	**(0)**	**(0)**	**(0)**
Dummy for 1965 or 1967	0.0034	0.0056	0.0002	0.0004
	(0.362)	(0.109)	(0.66)	(0.308)
Dummy for 1970 or 1972	-0.0066	-0.0015	0	0.0005
	(0.127)	(0.72)	(0.915)	(0.28)
Dummy for 1975 or 1977	-0.0046	0.0024	-0.0001	0.0006
	(0.292)	(0.556)	(0.804)	(0.298)
Dummy for 1980 or 1982	**-0.0324**	**-0.0234**	-0.0005	0.0004
	(0)	**(0)**	(0.356)	(0.522)
Dummy for 1985 or 1987	**-0.0174**	**-0.0091**	**-0.0039**	**-0.0028**
	(0)	**(0.017)**	**(0.001)**	**(0.008)**
Dummy for 1990 or 1992	**-0.0202**	**-0.0107**	**-0.0028**	-0.0016
	(0)	**(0.007)**	**(0.002)**	(0.161)
R-Squared	0.152	0.316	0.152	0.259
Adjusted R-Squared	0.144	0.307	0.145	0.249
Durbin-Watson	1.707	1.944	1.797	1.999
F-Statistic	20.2	33.1	21.7	26.8
Prob (F-Statistic)	0	0	0	0

(p-value in parenthesis, 5% significance in bold, 10% in italics)

Table V. Five-Club Convergence Regressions
(Fixed Effects, White Heteroskedasticity Correction)

	Income	Income	Income	Life Expectancy
Steady State Growth Decomposition Coefficients				
Group 1	**0.0055**			**0.001**
	(0.001)			**(0)**
Group 2	**0.0206**			-0.0011
	(0)			(0.492)
Group 3	**0.0042**			*0.0005*
	(0.006)			*(0.095)*
Group 4	-0.0001			0.0006
	(0.963)*			(0.379)
Group 5	**-0.0046**			0.0003
	(0)			(0.741)
Parallel Growth		**0.0111**	0	
		(0)	(1)	
Group 2 Additional Growth		**0.0154**		
		(0.005)		
Group Index Additional Growth		**-0.003**		
		(0)†		
Divergence Pattern Growth			**1**	
			(0)‡	
Convergence Coefficients				
Group 1	**-0.0793**	**-0.0956**	**-0.0793**	**-0.0724**
	(0)	**(0)**	**(0)**	**(0)**
Group 2	**-0.0793**	**-0.0793**	**-0.0793**	-0.0068
	(0)	**(0)**	**(0)**	(0.886)
Group 3	**-0.0798**	**-0.0679**	**-0.0798**	**-0.0344**
	(0)	**(0)**	**(0)**	**(0)**
Group 4	**-0.0557**	**-0.0517**	**-0.0557**	**-0.0255**
	(0)	**(0)**	**(0)**	**(0.045)**
Group 5	**-0.0661**	**-0.0666**	**-0.0661**	**-0.0706**
	(0)	**(0)**	**(0)**	**(0.003)**
R-Squared	0.472	0.468	0.472	0.415
Adjusted R-Squared	0.371	0.369	0.374	0.307
Durbin-Watson	2.075	2.091	2.075	2.103
F-Statistic	66.424	84.541	100.083	56.850
Prob (F-Statistic)	0.000	0.000	0.000	0.000

(p-value in parenthesis, 5% significance in bold, 10% in italics)

* The std. devs. for these coefficients for Groups 1 to 5 are: 0.0017, 0.0054, 0.0015, 0.0012, 0.0012.

† t-statistic: -5.628. ‡ t-statistic: 6.605.

Single-Club Convergence Regression
(Fixed Effects, White Heteroskedasticity Correction)

	Income	Life Expectancy
Steady State Growth Coefficient	**-0.0008**	0.0003
	(0.227)	(0.37)
Convergence Coefficient	**-0.0329**	**-0.0378**
	(0)	**(0.001)**
R-Squared	0.400	0.353
Adjusted R-Squared	0.295	0.242
Durbin-Watson	2.199	2.145
F-Statistic	451.842	396.770
Prob (F-Statistic)	0.000	0.000

(p-value in parenthesis, 5% significance in bold)

Table VI. Wald Test for Equality of Steady State Growth and Convergence Coefficients Between Groups of Countries for Five-Club Model

Table VI.1. Income per Capita

	Group 1	Group 2	Group 3	Group 4
Group 2	**31.5** **(0)**			
Group 3	0.8 (0.447)	**25.2** **(0)**		
Group 4	**4.3** **(0.014)**	**16.9** **(0)**	*2.4* *(0.091)*	
Group 5	**14.2** **(0)**	**20.4** **(0)**	**11.2** **(0)**	**4.5** **(0.012)**

(F-test with p-value in parenthesis, 5% significance in bold, 10% in italics)

Table VI.2. Life Expectancy

	Group 1	Group 2	Group 3	Group 4
Group 2	0.9 (0.402)			
Group 3	**8.5** **(0)**	**4** **(0.019)**		
Group 4	**15.8** **(0)**	**4.1** **(0.016)**	**3.6** **(0.028)**	
Group 5	1.6 (0.194)	2 (0.136)	**7.9** **(0)**	**10.6** **(0)**

(F-test with p-value in parenthesis, 5% significance in bold)

for Fixed Effects by Groups of Countries for Five-Club Model

Table VII.1. Income per Capita

	Group 1	Group 2	Group 3	Group 4
Group 2	**0.0001**			
Group 3	**0.0001**	*0.077*		
Group 4	**0.0001**	**0.0001**	**0.0001**	
Group 5	**0.0001**	**0.0001**	**0.0001**	**0.0001**

(p-value, 5% significance in bold)

Table VII.2. Life Expectancy

	Group 1	Group 2	Group 3	Group 4
Group 2	**0.0001**			
Group 3	**0.0001**	**0.0001**		
Group 4	**0.0001**	**0.0001**	**0.0001**	
Group 5	**0.0001**	**0.0001**	**0.0001**	**0.0001**

(p-value, 5% significance in bold)

Table IX. Test of Equality of the Distributions of Country-Specific Regression Coefficients by Groups of Countries. (Pair-Wise Kruskal-Wallis Equality of Populations Rank Test, Corrected for Ties)

Convergence Coefficients

Income per Capita

Group	1	2	3	4
2	**0.005**			
3	0.2575	**0.0022**		
4	**0.07**	**0.0257**	0.3223	
5	0.1824	**0.0077**	0.5513	0.6396

(P-values, 5% signif in bold)

Life Expectancy

Group	1	2	3	4
2	**0.0053**			
3	**0.0031**	0.9142		
4	**0.0088**	0.4105	0.4922	
5	**0.0325**	0.6141	0.9715	0.8137

(P-values, 5% signif in bold)

Steady State Growth Coefficients

Income per Capita

Group	1	2	3	4
2	**0.0001**			
3	0.8209	**0.0001**		
4	0.1173	**0.0001**	0.1609	
5	**0.0094**	**0.0001**	**0.0036**	0.1058

(P-values, 5% signif in bold)

Life Expectancy

Group	1	2	3	4
2	**0.0115**			
3	0.1217	0.6334		
4	0.3115	*0.0912*	*0.0511*	
5	*0.08*	0.8227	0.2932	**0.0286**

(P-values, 5% signif in bold, 10% in italics)

Fixed Effects

Income per Capita

Group	1	2	3	4
2	**0.034**			
3	0.7199	**0.0052**		
4	0.428	**0.0156**	0.6207	
5	0.8381	**0.0013**	0.5371	0.3382

(P-values, 5% signif in bold)

Life Expectancy

Group	1	2	3	4
2	**0.0049**			
3	**0.0017**	0.9142		
4	**0.0024**	0.4441	0.6405	
5	**0.0061**	0.7157	0.8307	0.7491

(P-values, 5% signif in bold)