Convergence and Demographic Transition: A Club Approach
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Abstract

This paper evaluates the role of demographics in post-war growth and convergence. The different timing of the demographic transition has segmented countries into different regimes and their simultaneous existence makes the concept of convergence meaningless if neglected. This paper classifies countries into demographic clubs by the regression tree method and applies convergence tests to the clubs. The tests range from the traditional cross-section tests to the second generation unit root tests, the latter giving less support to convergence than the former. Continuous progress towards more mature stages of the demographic transition implies bi-polarization of future incomes.

JEL classification: O47, J11, C23

Key words: Convergence, Demographic transition, demographic clubs, Panel stationarity tests

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1 Introduction

The literature on the cross-country convergence of incomes is full of controversies and puzzles, but recently it has been suggested that the demographic transition may explain many conflicting observations (Galor 2007). The main argument is that differences in the timing of the demographic transition have segmented countries to the different regimes and simultaneous existence of these regimes makes the observations difficult to understand if their demographic background is not properly understood.

Demographics can increase our understanding in two ways. It is well known that convergence fails in heterogenous samples of countries. Hence, it has been suggested earlier that countries should be classified into homogenous clubs according to common history (Baumol 1986), geographical location (Maddison 1994), mutual trade (Ben-David and Loewy 1998), or productivity thresholds (Azariadis and Drazen 1990). Given that in the post-war period countries were in different stages of their demographic transitions, classifying according to these stages should generate homogenous clubs. The underlying tendency for convergence should then manifest itself within these clubs. On the other hand, the demographic transition can also increase our understanding about the convergence in the future. Because this transition is a dynamic process which is far from completed everywhere, many countries will move ahead toward more mature stages. Therefore, an important question is whether these movements imply the more equal distribution of world incomes, i.e., is the convergence in the future stronger than in the past.

In the demographic transition, considerable changes in all demographic variables take place, but different authors emphasize different factors. Soares (2007), for example, maintains that infant mortality has the leading role: once it starts to fall fertility follows and the transition proceeds according to its internal laws. On the other hand, Ram (1998), Fogel (1994, 2004), Becker et al. (2005), and Lorenzen et al. (2008) claim that life lengthening is decisive as short-sighted and deterministic attitudes give way to optimistic views, whereas Bloom and Williamson (1998) stress the practical role of the dependence rate. In the "Unified Growth Theory", Galor and Weil (2000) emphasize the interplay between population growth and technical change. The number of demographic clubs has been disputed as well. Bloom and Williamson (1998) argue that this number should be limited to two, whereas Galor and Weil (2000) advocate three clubs, the "Malthusian", "Post Malthusian" and "Modern". Chesnais (1992), in turn, claims that the correct number of the demographic stages is six.

To collect, in order to evaluate the role of the demographic transition in the convergence of incomes, one has to evaluate whether demographic clubs exist in the data, what is their number, and which demographic factors best discriminate between the clubs. The next question concerns economic convergence within the clubs and, finally, one has to evaluate, what the observations can tell about the future.

To answer these question, we discover the number and boundaries of the clubs by the regression tree method suggested by Breiman et al. (1984) and Durlauf and Johnson (1995). The main advantage is that this method chooses the variables and factors which most efficiently classify the data, thus providing important information about the clubs.

We apply various convergence tests to the clubs. The interest on growth and convergence has been extensive recently and a number of papers evaluate the topic from different perspectives. Li and Papell (1999) maintain that the failure to find convergence is due to structural changes, finding evidence for convergence if breaks are allowed. Their results are confirmed by Strazicich et al. (2004) for the OECD countries and by Cunado and Perez de Garcia (2006) for 43 African countries. Authors, such as Pedroni (2007) and Li and Papell (1999) find, however, that even within the OECD, there is only a sub-set of countries that is prone to convergence. While Pesaran (2007c) finds evidence for pair-wise convergence across the Middle East, North Africa and the Rest of the World, his findings, however, indicate that in a panel of countries one can rarely expect to find a convergence as a significant fraction of each sub-set fails to converge to the output mean. Hineline (2008) also highlights the merits of clustering the data when different countries obey different laws of motion.

While the shortcomings of the cross-sectional test have been known, our results highlight the potential problems in the first generation unit root tests when the data exhibits cross-section dependence, undermining the reliability of these tests. In the context of output convergence, this means that convergence may be found where it does not exist. We provide new evidence on the presence of cross-section dependence and show the variation of the convergence tests by different techniques from strong evidence in the traditional β-convergence tests to the failure to reject the null by the second generation unit root tests. Thus, our results are best in line with the critical findings of Pedroni (2007), Li and Papell (1999), and Pesaran (2007c). To understand the implications of the demographic transition we evaluate its progress in the future, predicting take-offs even among the poorest countries. These take-offs, however, will be insufficient for rising their incomes to meet the income of the rich, implying bi-polarization in the future.

The paper is structured as follows. Section 2 reviews the data and methods, Section 3 generates the clubs, Section 4 provides the convergence tests, and Section 5 discusses the future growth prospects. Section 6 discusses the merits of the findings.

2 Data and Methods

To investigate the role of demographics in the convergence of countries, we collect data for incomes and demographic variables. There are several candidates for demographic threshold variables but we choose the total fertility rate, dependence rate, life expectancy, and infant mortality rate since their role is frequently discussed in the literature. Thus the variables are

y_t = log of real per capita GDP (international dollars, base year 2000).

$GROWTH$ = annual average growth rate of real per capita GDP defined by $(y_{t_0+T} - y_{t_0})/T$.

TFR = Total fertility rate (children per woman).

DEP = Dependency rate (ratio of population aged 0-14 and 65+ per 100 population 15-64).

LIF = Life expectancy (at birth, both sexes).

IMR = Infant mortality (infant deaths per 1,000 live births).

To keep the threshold variables exogenous, they are measured at the beginning of the research period which extends from 1960 to 2003. Data for these variables is available for 85 countries. The countries that have experienced extreme economic or social changes are excluded.[1] The demographic data come from the United Nations (2007) and the economic data from Heston et al. (2006).

To see whether multiple regimes should be taken seriously we make data splits according to the mean of each demographic threshold variable in country i (x_i), and test whether $GROWTH$ is identical in the sub-samples by estimating

$$(y_{i,t_0+T} - y_{i,t_0})/T = \varphi + \lambda x_i + \epsilon_i. \tag{1}$$

The Wald-test for the similarity of the coefficients φ and λ in the sub-samples yields a highly significant $F-$statistics for three of the four splits. Thus, we reject the similarity in favor of the sub-samples.

Even though the specification test suggests that some demographic clubs exist in the data, their number and boundaries are not properly revealed

[1]The excluded countries are the highest AIDS prevalence countries (Lesotho, South-Africa and Zimbabwe), the oil countries (OPEC members), and the East-European countries. We also exclude Rwanda and China because of the mass murders in the former and the population policy in the latter. The demographic data for Taiwan is replaced by that of South Korea which has a quite similar demographic history. The need to keep Taiwan arises because of the scarcity of countries with remarkable slow-downs in fertility.

by mechanical splits. Hence, clubs are discovered by using the regression tree analysis, suggested by Durlauf and Johnson (1995).[2] Regression tree analysis is a data-sorting method that splits the range of the regressors to find the best piecewise linear model. Its algorithm chooses both the splitting variable and the split value to generate the largest possible decreases in the residual deviance. Only one-step look ahead and binary splits are used. Successive splits grow up a tree, starting from the root (the full sample) to the leaves (clubs). To choose the best number of the clubs, several criteria are available. The cross-validation method, for example, can be used to control for the potential over-fitting. In our case, however, one faces the limits of the convergence tests, implying that clubs should not be too small, so that we apply the pre-determined club-size criteria of ten members here. A detailed description of the regression tree method is available in Breiman et al. (1980) and Durlauf and Johnson (1995).

Another important question is whether the generated clubs exhibit the convergence of incomes. In this paper, we apply several types of tests to compare our results with previous studies.

A cross-section of countries is said to exhibit unconditional $\beta-$convergence if the estimated β in the model

$$\text{Model 1: } \left(y_{i,t_0+T} - y_{i,t_0}\right)/T = \alpha + \beta y_{i,t_0} + \varepsilon_{i,t}$$

is negative, indicating that economic growth in the poorer countries is faster than in the richer (Barro and Sala-i-Martin 1992). Evans (1998) first applied the unit root tests for the stationarity of output differences. Thia propwery can be tested by using three nested specifications from general to specific:

[2]Hansen (2000) develops an asymptotic distribution theory for threshold coefficients and calculates their confidence limits while Fiaschi and Lavezzi (2007) apply Markov transition matrices to uncover non-linearities in the data.

$$\text{Model 2} \quad : \quad \Delta\left(y_{i,t}-\bar{y}_t\right)=\alpha_i+\theta_i t+\rho_i\left(y_{i,t-1}-\bar{y}_{t-1}\right)+\left(u_{i,t}-\bar{u}_t\right),$$
$$\text{Model 3} \quad : \quad \Delta\left(y_{i,t}-\bar{y}_t\right)=\alpha_i+\rho_i\left(y_{i,t-1}-\bar{y}_{t-1}\right)+\left(u_{i,t}-\bar{u}_t\right),$$
$$\text{Model 4} \quad : \quad \Delta\left(y_{i,t}-\bar{y}_t\right)=\rho_i\left(y_{i,t-1}-\bar{y}_{t-1}\right)+\left(u_{i,t}-\bar{u}_t\right),$$

where $\bar{y}=\frac{1}{N}\sum_{i=1}^{N}y_{i,t}$ and $u_{i,t}$ is *iid*. *Models 2* and *3* include a country-specific constant α_i, necessary if some slowly-changing factor wedges the incomes from the mean. *Model 2* also includes a country-specific trend $\theta_i t$, adressing time-related factors, such as the diffusion of technology, which may take place at different pace in different countries (Lee et al. 1997). It is often necessary to allow this kind of heterogeneity even within the clubs since a complete control of heterogeneity by clustering may not be possible. Only the test with no intercept and trend (*Model 4*) always refers to decreasing income gaps, i.e., to unconditional convergence, whereas *Models 2* and *3* refer to the conditional one. For discussion see Pesaran (2007b) and Pedroni (2007).

In *Models 2-4*, country i converges to the mean (has a stationary time series of income differences) if the estimate for ρ_i is negative, but several test variants exist in terms of similarity of this estimate across countries. Levin, Lin and Chu (LLC, 2002) assume convergence at a common rate, i.e., $\rho_i = \rho$ for all i. Im, Pesaran and Shin (IPS, 2003) propose a test statistics which builds on Augmented Dickey Fuller (ADF) test. This test, as well as the Fisher inverse square test by Maddala and Wu (M&W, 1999) and the inverse normal test by Choi (2001) all assume individual unit root processes, indicating that countries may convergence at different rates and some countries may not converge at all. For the convergence of the sample it is then enough to show that $\bar{\rho} < 0$. The difference between LLC and the other tests is that LLC pooles the data while the other tests pool the test statistics, hence different assumptions about ρ_i.

Recently, Pesaran (2007a) has criticized the use of the so called first generation panel unit root tests above because they do not account for cross-section dependence, arising across countries due to spatial and spill over effects or due to unobserved common factors (Baltagi and Pesaran 2007). Although IPS and Choi both allow for a limited amount of cross-correlation due to demeaning in the presence of common time effects (common business cycles, for example), demeaning does not help if reaction to shocks differs across countries.[3] Pesaran (2007a) investigates the properties of the IPS, M&W, and Choi tests in the presence of cross-sectional dependence by Monte Carlo simulations. With low dependence, IPS and Choi perform reasonably well, whereas M&W begins to work when T increases. With high cross-section dependence, all tests tend to over-reject the null.

There are methods for correcting the bias from cross-section dependence. Pesaran (2007a), for example, proposes a panel unit root test to modify IPS in the presence of a single unobserved common factor but this does not come without costs: if no dependence exists the corrected IPS (CIPS) performs worse than the original test.[4] While the CIPS test rarely over-rejects the null, its power is often relatively low, i.e., if the null hypothesis is false the test may fail to reject it. The second pitfall is that since Pesaran's test builds on IPS, the unconditional convergence in *Model 4* can not be tested with it.

There are several techniques to discover the cross-sectional dependency on the data.[5] The CD-test proposed by Pesaran (2007a) calculates

[3]The essential difference here is that assume $u_{i,t=}\lambda_j f_t + \varepsilon_{i,t}$.If $\bar{\lambda}_j = \lambda$ for all j then demeaning as suggested in *Models 2 to 4* is enough to whiten the error term, otherwise we need to resort to second generation unit root tests.

[4]The development in this field is rapid. Pedroni (2007) utilices B-trace and J-trace tests, to check the robustness of unit root test results in the presence of cross-section dependecy. To our knowledge, these tests are, however, not available for the users of Stata.

[5]The development in this field is rapid. For instance, Pesaran et al. (2007) proposed the use of a bias-adjusted LM test. They show that this test is more robust than the other two. The problem with the adjusted LM test is that it assumes strong exogeneity, which does not hold in our data.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\gamma}_{ij} \right), \tag{2}$$

where T and N are the number of observations in time and cross-sections, and $\hat{\gamma}_{ij}$ is the residual correlation between countries i and j, these residuals being obtained from individual ADF(p) regression, similar to *Models 2-4* augmented with the lags of order p. The statistics of this easy-to-apply test is normally distributed with $N(0,1)$, but the drawback is that it lacks power if the population average pair-wise correlation is (close to) zero. Another relatively simple test, proposed by Breusch and Pagan (1980)

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\gamma}_{ij}^2 \tag{3}$$

is based on $\chi^2_{N(N-1)/2}$ distribution. While this test is not affected by the zero averages, it is likely to exhibit substantial size distortions when N is large and T is small.

3 Demographic Clubs

Figure 1 reports the results of the regression tree analysis. The algorithm chooses the first split in terms of life expectancy, the split value being $LIF = 48.01$. Countries with $LIF_i < 48.01$ constitute the first club (35 countries). The algorithm then suggests the second split in terms of the dependence rate with the split value $DEP = 94.94$ but, unfortunately, the number of the members in the club with $DEP_i \geq 94.94$ is too low (eight countries), thus violating the pre-determined minimum size for the clubs. To be able to continue the partition further we exclude the dependence rate from the threshold candidates. The algorithm then makes the next split in terms of the life expectancy again, the split value being $LIF = 55.785$, thus partitioning the rest of the sample into the sub-samples of 12 and 38 countries

($LIF_i < 55.785$ and $LIF_i \geq 55.785$). The next split again violated the club-size requirement. Hence, the (maximum) number of clubs is three. Most developing countries are allocated into Club I, the East-Asian Tigers into Club II, and the Western countries into Club III. A complete list of countries and clubs with demographic and economic statistics is given in Appendix A.

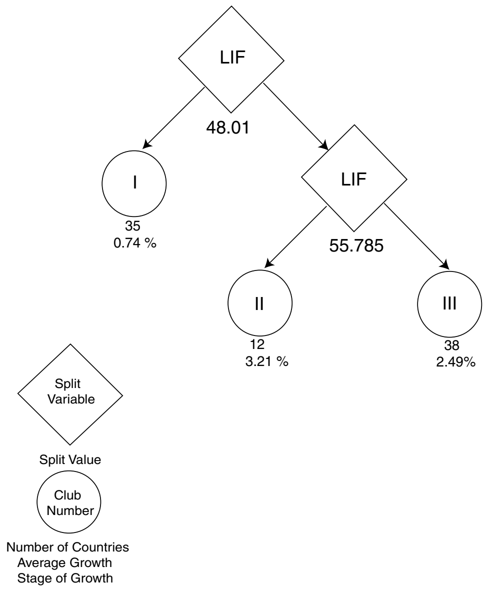

Figure 1: The regression tree. The left arrow indicates the observations for which the split variable < Split Value. The right arrow indicates the observations for which the split variable ≥ Split Value.

The order by which the threshold variables enter to partition the data refers to their importance in terms of the dependent variable. In our case, the importance of the life expectancy is emphasized. Three types of intuitive explanations arise. The first relies on the close connection between life-time health and life expectancy, stressing the role of physical capacity of humans as workers (Fogel 1994, 2004) whereas the second highlights the mental change associated with the lengthening of life, and the interaction between short-term costs and long-term benefits in actions like saving and educational investments (Ram 1998, Weil 2007, Lorentzen et al. 2008). Those who die young will fail to take such actions, while longer life encourages them. Furthermore, the premature deaths of adults also totals a considerable human capital loss. According to the third explanation, the diffusion of production and health technologies go hand in hand and the life expectancy may be a measurable indicator of both (Soares 2007).

The life-expectancy differentials should also explain the growth differentials between the clubs. To the extent that life expectancy refers to the productivity of workers, the slow economic growth in the low-life-expectancy club (Club I) and the rapid economic growth in the high-life-expectancy club (Club III) is natural, but this does not explain why the growth is the highest in the medium-life-expectancy club (Club II). If life expectancy is, however, understood as an indicator for technical diffusion, the efficiency of which depends both on the gap to the leaders and on the ability to adopt knew knowledge, then one can see that these *both* only hold in Club II, while Club I, in spite of its large gap, fails sufficient human capital for the adoption of technology.

The number of the demographic clubs is tree, being identical with that suggested by Galor and Weil (2000). As the discussion above suggests, their driving variables, human capital and technical change, may not be so different from our life expectancy. Furthermore, the increasing life-expectancy status from Club I to Club III seems to give support to the interpretation of our clubs as successive demographic stages, denoted as "Malthusian", "Post Malthusian" and "Modern" by Galor and Weil (2000). Fiaschi and Lavezzi (2007) also find three clubs out of 122 countries although based on initial incomes. The number of the literacy and income-based regimes (96 countries) in Durlauf and Johnson (1995) is four, their club 1 being a sub-set of our Club I, while their club 4 is a sub-set of our Club III. Their intermediate clubs consist of countries from all of our clubs.

4 Convergence Within the Clubs

4.1 Unconditional $\beta-$Convergence

In this section we concentrate on the convergence of incomes within demographic clubs, starting from the unconditional β-convergence defined in *Model 1.* Table 1 shows that the estimated β in the full sample is positive and significant, i.e., the sample diverges. By contrast, β is negative in clubs although significant at the 5 % level only in Clubs I and III. Convergence in samples similar to Club III has been shown in earlier studies but the now-shown β-convergence in Club I is a new result. The estimated β in Club II is large but significant only at the 8 % level. A closer examination shows that its members have changed their relative positions and the correlation of rank orders in 1960 and 2003 is -0.06, i.e., there is "leapfrogging" in this club. This possibility was discussed by Sala-i-Martin (1996) and is now exemplified in Club II.

club	*Model 1*		
	β	t-test	prob.
Full sample	0.354	2.212	0.015
Club I	-0.640	-2.339	0.013
Club II	-1.912	-1.511	0.081
Club III	-0.479	-1.836	0.037

Table 1: The results for *Model 1*

4.2 Cross-Section Dependence and Unit Root Tests

To evaluate the presence of cross-sectional dependence, we ran the ADF(p) regressions with the individual values of p to compute the pair-wise cross-section correlations for the residuals (Pesaran 2007a). Table 2 shows that the average correlations are -0.021, -0.061, and -0.01 for Clubs $I-III$, respectively.[6] The CD statistics for Clubs $I-III$ are -3.33, -3.31, and -1.85.

[6]Since we are testing the convergence hypothesis, we ran the ADF(p) regressions for the demeaned data. If the cross-section dependence is still present, it is off more complex

	Club I	Club II	Club III
N	35	12	38
$\bar{\gamma}_{ij}$	-0.021	-0.061	-0.011
CD	-3.333	-3.307	-1.852
LM	641.7	105.3	1181.0
df	595	66	703

Table 2: Descriptive statistics from Clubs I– III.

The first two values are highly significant, while the value for the third club is not significant at 5 % level (CD$< |1.96|$). Even though the CD test is adversely affected by zero means, it indicates strong cross-section dependence in Clubs I and II. Moreover, since the power of this test is low when the average correlations tend to zero as in Club III, it may be the case that Club III is prone to cross-section dependence as well. The LM test statistics are also high and significant although Clubs I and III are probably too large to yield reliable results. Hence, there is at least some cross-section dependence on the data, thus rendering the use of second generation tests.

Table 3 summarizes the first generation unit root tests for *Model 2*, showing that no convergence exists in the full sample.[7] The tests also accept the null of no convergence for Clubs II and III, while the LLC and M&W tests offer weak support for convergence in Club I. The second generation test (Pesaran's CIPS), on the other hand, gives the test statistics of -2.016, -1.760, and -1.607 for the clubs, and -1.926 for the full sample, respectively. Given that the critical values for Pesaran's CIPS, with T=44 and $12 < N < 85$ and 5%-level of significance, are all around -2.61, the null of non-stationarity cannot be rejected for any of the clubs.[8] The power of the CIPS test is relatively low in the presence of trends, so that the rejection of the conver-

form than expected by the first generation tests so that they are biased.

[7]All first generation tests were performed by Eviews and cross-checked with Stata. We allowed automatic selection of lags based on Scwartz Information Criteria and when kernels had to be used, we used Newey-West bandwidth selection by Bartlett. The second generation test is only available in Stata; individual lags were allowed here.

[8]The critical values of CIPS-test are tabulated by Pesaran (2007a) Tables II(a)-II(c).

	Club I		Club II		Club III		Full sample	
	test	p-value	test	p-value	test	p-value	test	p-value
LLC	-2.010	0.022	0.513	0.696	0.615	0.731	-0.277	0.391
IPS	-0.538	0.295	-0.408	0.342	1.839	0.967	0.127	0.551
M&W	89.57	0.058	26.84	0.312	58.72	0.929	188.42	0.159
Choi	86.67	0.086	26.11	0.348	46.72	0.997	158.82	0.720

Table 3: Results for *Model 2*.

	Club I		Club II		Club III		Full Sample	
	test	p-value	test	p-value	test	p-value	test	p-value
LLC	-0.110	0.456	-0.445	0.328	-3.619	0.000	-2.735	0.003
IPS	0.380	0.648	2.381	0.991	-0.373	0.355	2.522	0.994
M&W	79.58	0.203	15.58	0.900	100.35	0.032	180.49	0.277
Choi	86.80	0.085	15.32	0.911	92.76	0.093	202.87	0.043

Table 4: Results for *Model 3*.

gence is somewhat expected. This rejection, however, is supported by the conventional IPS and the Choi tests, the tests that are likely to be robust in the presence of moderate cross-section dependence. Moreover, as they tend to over-reject the null in this case, the fact that they don't, strengthens the finding.

Table 4 reports the results with intercept but without trend (*Model 3*). The first generation unit root tests (with the exception of IPS) now suggest that Club III exhibits convergence. LLC and Choi also suggest convergence for the data as a whole. The CIPS test statistics for clubs and the full sample are -1.369, -0.726, -1.323, and -1.186. As the critical value of CIPS test for the 5% level is around -2.11 for all sample sizes here, the CIPS test rejects convergence in each case. Hence, the tests that are most robust in the presence of cross-section dependence fail to support convergence again.

Table 5 presents the first generation test results for unconditional convergence (*Model 4*) providing a result which replicates the common finding that the rich countries exhibit convergence while convergence is not found in other clubs. Unfortunately, this test cannot be performed by IPS so that no

	Club I		Club II		Club III		Full Sample	
	test	p-value	test	p-value	test	p-value	test	p-value
LLC	-0.795	0.213	1.440	0.925	-1.633	0.051	7.264	1.000
IPS	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
M&W	70.47	0.462	26.27	0.340	114.21	0.003	112.40	1.000
Choi	70.35	0.468	26.43	0.332	107.52	0.010	107.44	1.000

Table 5: Results for *Model 4*.

second generation test is available yet.

To summarize, we find unconditional β-convergence (*Model 1*) in all clubs, indicating that the regression tree analysis has succeeded in uncovering three traditional convergence clubs on the demographic basis alone. Those first generation unit root tests which provide opportunities to control for the heterogeneity within the clubs (*Models 2* and *3*) also support conditional convergence in Club I but none in Club II. The tests, however, are likely to be biased by the cross-section dependency and the more robust second generation tests do not find conditional convergence in these clubs. Furthermore, no unconditional convergence (*Model 4*) can be found by the first generation tests for these clubs. Maybe the most interesting is Club III as countries move ahead in the demographic transition and ultimately enter this club. Here, the first generation tests give some support to conditional convergence (*Model 3*), this result being undermined by the second generation test again. On the other hand, the support for unconditional convergence is strong (*Model 4*) from the first generation tests. Unfortunately, unavailability of the second generation test for *Model 4* leaves many questions open as the cross-section dependency is indicated also in this club.

How do we now conclude with the argument that convergence, if it exists, should manifest itself in homogenous clubs? From the technical point of view, our findings are in line with the development of the literature, running from the earlier findings of no β-convergence in broad samples but some in clubs (Baumol 1986, Mankiw et al. 1992, Maddison 1994, Ben-David and

Loewy 1998) to the markedly skeptical findings from the recent second generation unit root tests (Li and Papell 1999, Pedroni 2007, Pesaran 2007c), indicating that the quest of convergence is far from settled.[9] On the other hand, a demographic explanation for the mixed evidence can also be found since the demographic transition is a continuous rather than discrete process, necessarily leaving some timing-heterogeneity into the clubs. Furthermore, Chesnais (1992) has emphasized that the phase of the demographic transition differs across countries as some proceed much faster than others. Therefore, by controlling for the initial state alone, we may have failed to control for the differences in this phase. The heterogeneity, measured by the standard deviation of the life expectancy, actually increased from 1960 to 2003 within the first two clubs. Furthermore, life-expectancy leapfrogging was typical of Club II, i.e., the rank orders of some countries decreased (Thailand) or increased (Syria) to a great extent, thus explaining the less promising convergence results in this club. Hence, a control for the heterogeneity from the different phases of the demographic transition is a necessary future task although this task is challenging, as some of these differences may be dictated by economic growth itself.

5 Demographic Transition and Future Prospects

The demographic transition provides a framework to understand the findings from the past and helps to evaluate the prospects in the future, driven by the growth differentials between the clubs. To illustrate, consider the club-specific average incomes in the beginning and end of the period 1960-2000 (Figure 2) and compare Clubs I and III, for example. Due to the consider-

[9] To compare our results with earlier works, we performed the unit root tests to the club 4 of Durlauf and Johnson (1995), as it is a sub-set of our Club III. While they find that club 4 exhibited unconditional β-convergence at 1960-1985, we find that it also shows both β- convergence and the convergence in the first generation unit root tests but no convergence in the second generation unit root test at 1960-2003.

able differences in the growth rates (0.74% versus 2.49%), the income gap increased from five to tenfold, this increase being exacerbated by a massive demographic expansion in the former club (Figure 2). By contrast, the income gap between Clubs III and II decreased from four to two point fivefold due to rapid growth (3.21%) in the latter.

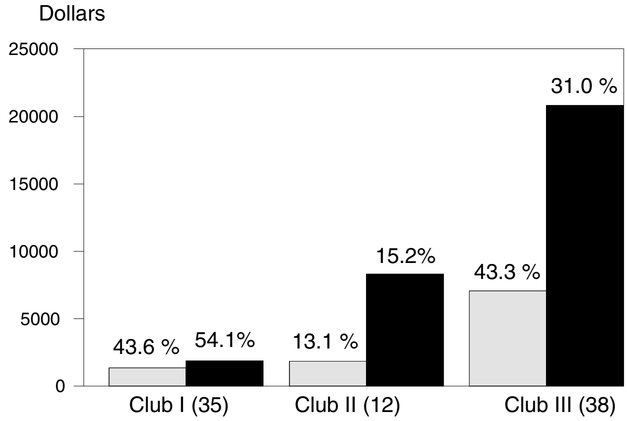

Figure 2: The per capita GDP in 1960 (grey bar) and 2003 (black bar). Population shares indicated above the bars.

The theory of the demographic transition presupposes that countries move ahead to more mature stages, i.e., the demographic clubs are transitional rather than permanent, and multiple steady states may not be present in the data (Galor and Weil 2000, Galor 2007). Unfortunately, none of the techniques above can identify the data generating processes, but the dynamics of the demographic variables can give some hints. Figure 3 shows that the life expectancy has increased everywhere such that in 2003 its average value in Club I (Club II) exceeded that in Club II (Club III) in 1960. Analogous information is given by total fertility, infant mortality, and the by the dependence rate, all of which have much decreased since 1960 as most countries have reached the higher stages, thus supporting transitional clubs.

This makes some future explorations possible. Consider a new classification derived by applying the earlier boundaries of the clubs to the values of

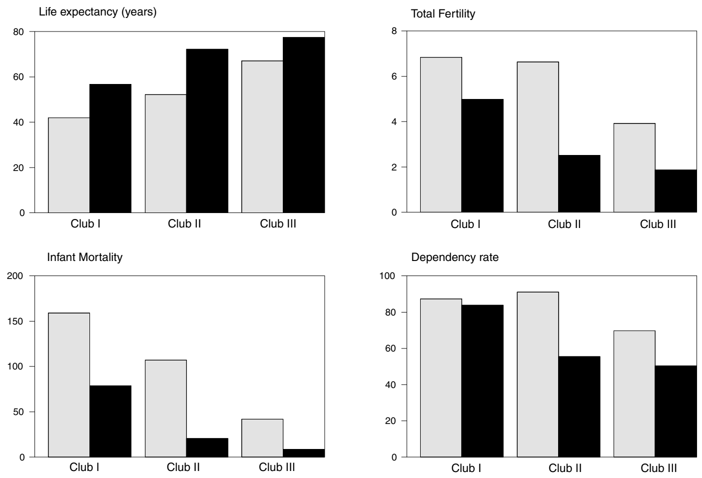

Figure 3: Demographic indicators in 1960 (grey bar) and 2003 (black bar).

the life expectancies in 2003. This classification shows that only six countries still stay in Club I and twelve in Club II, while all other countries (67) have proceeded to Club III.[10] One can now predict the average incomes, say, in 2040 illustrated in Figure 4.[11] A comparison of Figures 4 and 2 shows that the future does not replicate the past. On the contrary, while the average income in Club II approached that in Club III in the period 1960-2003, in the period 2004-2040 it will fall behind since the inherited low incomes provide a limited basis regardless of rapid growth (3.21%). Thus, the countries which have migrated from Club I to Club II will experience a take-off, but this take-off is only in terms of country's own history and does not raise its income closer to the more advanced countries which have already proceeded too far. Therefore, the catching-up opportunity which was gained by the countries that arrived Club II in the post-war period is not open for those

[10]The countries staying in Club I are: Burundi, Cote d'Ivoire, Guinea-Bissau, Mozambique, Malawi, and Zambia. The countries in Club II are: Benin, Burkina Faso, Cameroon, Congo, Ethiopia, Guinea, Kenya, Mali, Niger, Chad, Tanzania, and Uganda.

[11]There are few attempts to predict the evolution of the future incomes, and to our knowledge, none in a cross-country set-up. Holz (2008), however, extrapolates Chinese real GDP growth rates past from 1978-2000 to evaluate when the size of Chinese economy would surpass that of US in absolute terms.

who will arrive later.

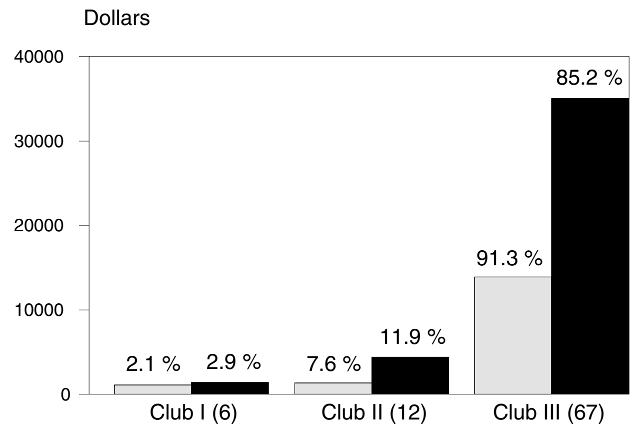

Figure 4: The per capita GDP in 2003 (grey bar) and 2040 (black bar).

Club III may also experience changes as 29 of its 67 members will be new-comers. While these new-comers may grow at the rate which was typical of this club in the past, the old members may meet new growth-hampering problems, such as ageing, not visible in the period 1960-2003 yet. Hence, new convergence tendencies may arise within Club III. This, together with the limited perspectives from Clubs I and II, refers to bi-polarization rather than convergence of world incomes as a whole. The number of countries in Clubs I and II, however, has decreased and their population share will be smaller than earlier (Figure 4).

6 Discussion

This paper explores the role of demographics in the post-war growth and convergence of countries. Differences in the timing of the demographic transition have segmented countries to the different regimes or clubs and simultaneous existence of these clubs makes the concept of convergence meaningless if the existence of such clubs neglected. We evaluate the relevance of demographics by classifying countries into demographic clubs by the regression tree method.

The discriminating variable turns out to be life expectancy, probably due to its role as an indicator of technical diffusion and as a necessary condition for investment in human capital, classifying countries in tree demographic clubs.

The traditional β-convergence and first generation unit root tests offer support for convergence in demographic clubs but the second generation unit root test undermines this result so that the evidence is equivocal. In this way, our findings are in line with the trends in the literature, where the earlier tests suggest convergence but the most recent tests show that homogenous clubs are difficult to uncover even among the OECD countries. The rapid progress in the field of panel unit root tests may shed further light on this subject in the future. On the other hand, the demographic transition as a source of mixed evidence calls for further research efforts because its phase may differ across countries and controlling for the initial state alone may not lead to convergence clubs. Hence, a control for the heterogeneity from the different phases may be necessary, although challenging, as the phase of transition may be dictated by economic growth itself.

Continuous demographic transition elevates countries to higher clubs, providing important implications for future incomes. Unfortunately, this information gives no unequivocal support to convergence of world incomes as the income gaps have already widened to such an extent that even the take-offs, typical to the second stage or club, is unable to rise the incomes of the poor sufficiently. Thus, new economic miracles will hardly arise on the demographic basis alone. Therefore, economic policies should be targeted to help the countries which still stay in the lowest clubs. The good news from the analysis here is that the ever-richer majority of countries face better opportunities to manage this task since the number of these countries is small and their population share is low. An interesting question is, whether the most efficient policy is to concentrate on health and life-expectancy, as longer and healthier life should give incentives to save and invest in human capital, both of which are the impetus of growth.

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A Appendix: Countries and Clubs

Country	GDP60	LIF60	IMR60	TFR60	DEP60	GDP03	LIF03	IMR03	TFR03	DEP05
Benin	956	41.48	165	6.96	99.49	1345	54.68	105	5.82	88.32
Bolivia	2431	42.65	164	6.63	85.35	3006	64.06	55	3.91	74.30
Burkina F.	768	36.36	197	7.00	76.47	1071	50.81	109	6.33	97.05
Burundi	677	41.29	149	6.80	88.85	763	47.56	106	6.81	91.35
Cameroon	1947	41.52	145	5.90	78.97	2713	49.86	90	4.84	82.82
Chad	1142	40.79	169	6.09	79.30	884	50.50	124	6.51	96.80
Comoros	1354	43.44	154	6.91	90.47	1278	63.21	57	4.83	80.65
Congo	1010	46.69	130	5.99	81.50	1420	53.15	75	4.76	82.22
Cote d‘Iv.	1334	43.67	154	7.31	85.97	2019	46.90	121	5.00	81.47
Egypt	1469	45.74	180	7.07	84.30	4759	70.00	35	3.14	61.72
Ethiopia	400	40.06	160	6.90	89.08	688	50.96	95	5.73	89.93
Gambia	722	32.99	223	6.50	74.64	937	58.18	79	5.12	81.42
Ghana	412	45.62	124	6.90	88.65	1440	58.64	63	4.32	74.34
Guatemala	2494	45.47	127	6.85	93.87	3805	69.11	38	4.55	90.27
Guinea	3072	35.12	201	7.00	83.19	2887	53.92	112	5.81	86.72
Guinea-B.	493	33.99	196	5.99	70.97	584	45.56	120	7.11	101.88
Honduras	1715	46.34	135	7.42	97.14	2291	68.77	31	3.68	79.02
India	892	41.87	140	5.81	76.75	2990	63.07	62	3.08	61.18
Jordan	4151	46.82	110	8.00	94.17	3743	71.41	23	3.49	67.75
Kenya	1179	46.29	117	8.12	100.78	1218	51.32	69	5.00	82.90
Madagascar	1268	39.87	155	6.80	87.14	759	57.54	74	5.24	88.51
Malawi	460	37.80	203	7.00	93.44	771	45.47	100	5.99	100.30
Mali	797	36.13	216	7.11	80.65	1184	52.11	137	6.71	105.49
Morocco	1299	46.68	145	7.15	90.14	4061	69.79	37	2.50	55.06
Mozambique	838	35.01	185	6.50	82.05	1452	43.79	106	5.49	90.19
Nepal	800	38.50	187	6.06	79.22	1441	61.66	63	3.64	74.27
Nicaragua	4428	47.02	131	7.33	100.95	3409	71.07	26	2.97	71.96
Niger	1167	39.08	196	7.90	100.83	834	54.77	118	7.43	104.51
Pakistan	801	46.61	148	6.28	82.70	2593	63.78	75	3.95	69.64
Peru	3129	47.68	136	6.85	87.80	4351	70.09	29	2.67	59.59
Senegal	1776	40.39	186	7.00	82.23	1407	61.78	69	5.17	86.70
Tanzania	502	43.63	136	6.80	93.05	912	49.90	78	5.60	89.99
Togo	833	42.55	159	7.10	88.96	789	57.64	93	5.31	86.37
Uganda	873	43.95	130	6.90	94.27	1113	48.01	83	6.73	107.67
Zambia	910	45.07	127	6.62	90.17	946	39.44	101	5.60	94.69
Club1	1386	41.95	159	6.84	87.24	1882	56.81	79	4.99	83.92

Continued

Country	GDP60	LIF60	IMR60	TFR60	DEP60	GDP03	LIF03	IMR03	TFR03	DEP05
Brazil	2644	54.51	109	6.15	87.02	7205	71.18	27	2.33	51.43
Cape Verde	1417	51.98	105	7.00	91.67	5117	70.38	29	3.71	78.03
Dominican R.	2080	51.69	124	7.32	101.67	6904	71.03	34	2.94	64.08
El Salvador	2991	50.42	123	6.85	94.99	4751	70.90	26	2.86	65.55
Korea	1458	54.20	70	5.63	82.72	17597	77.23	5	1.24	39.05
Malaysia	1801	53.92	63	6.72	94.89	12133	73.18	10	2.84	55.63
Philippines	2039	53.20	96	6.85	95.64	3575	70.46	27	3.51	66.61
Syria	837	49.22	119	7.60	98.61	2016	73.19	18	3.42	65.99
Taiwan	1444	54.20	70	5.63	82.72	19885	77.23	5	1.24	39.05
Thailand	1059	54.89	83	6.40	87.39	7274	68.80	12	1.83	41.79
Tunisia	2103	48.34	155	7.25	90.59	7601	73.16	22	2.01	47.72
Turkey	2250	50.26	176	6.19	84.53	5633	70.96	31	2.22	51.23
Club 2	1843	52.24	108	6.63	91.04	8308	72.31	20	2.51	55.51
Argentina	7838	64.88	60	3.09	57.04	10170	74.45	15	2.34	57.77
Australia	10815	70.73	20	3.27	62.77	27872	80.44	5	1.76	48.43
Austria	8444	68.74	32	2.78	51.90	27567	79.03	5	1.38	46.97
Barbados	7039	65.87	61	4.26	81.20	15707	76.09	12	1.50	39.02
Belgium	8070	70.10	27	2.66	55.03	25264	78.36	4	1.64	52.26
Canada	10576	71.07	26	3.61	69.61	27845	79.92	5	1.52	44.43
Chile	5086	56.90	109	5.28	79.45	12141	77.91	8	1.99	49.18
Colombia	2819	56.68	92	6.76	98.11	6094	71.82	20	2.44	54.90
Costa Rica	4513	61.45	81	7.22	98.05	8586	78.21	10	2.26	51.92
Denmark	11438	72.16	20	2.59	55.82	27970	77.42	5	1.76	51.28
Finland	7785	68.52	19	2.58	60.28	23784	78.48	4	1.76	49.90
France	8531	70.48	25	2.85	61.31	25664	79.72	4	1.88	53.14
Greece	4177	68.73	50	2.20	53.24	15785	78.43	8	1.28	48.28
Hong Kong	3322	66.32	33	5.31	77.60	27658	81.60	4	0.94	37.18
Iceland	8380	73.37	17	3.94	74.26	26347	81.06	3	2.00	51.12
Ireland	5294	69.69	28	3.98	73.23	28248	77.88	5	1.97	46.73
Israel	6750	68.70	29	3.85	69.28	20713	79.81	5	2.89	61.34
Italy	7167	69.31	40	2.50	51.69	22925	80.00	5	1.29	50.89
Jamaica	3477	64.28	61	5.64	85.11	4585	72.12	14	2.60	64.36
Japan	4509	67.91	25	2.02	56.12	24037	81.91	3	1.29	50.67
Luxembourg	12920	68.81	29	2.37	47.42	49262	78.22	5	1.67	48.58
Mauritius	3662	59.63	61	5.72	96.35	16464	72.03	15	1.90	44.95
Mexico	3719	56.95	88	6.82	96.98	7938	75.07	20	2.37	57.70
Netherlands	10462	73.24	16	3.17	63.93	26157	78.81	5	1.72	48.28

Continued

Country	GDP60	LIF60	IMR60	TFR60	DEP60	GDP03	LIF03	IMR03	TFR03	DEP05
New Zealand	12063	70.92	21	4.02	71.02	22195	79.30	6	1.97	50.64
Norway	9473	73.41	17	2.90	58.73	34011	79.37	4	1.81	52.12
Panama	2499	60.65	63	5.92	89.61	8244	74.81	20	2.69	57.11
Paraguay	2510	63.77	62	6.55	104.30	4716	70.85	35	3.44	68.34
Portugal	3689	63.34	76	3.07	59.08	17334	77.31	5	1.45	48.28
Singapore	4219	64.54	30	4.93	82.79	26999	78.91	3	1.34	38.96
Spain	4881	69.18	42	2.89	55.37	20644	80.09	4	1.30	45.45
Sri Lanka	866	61.97	63	5.50	85.97	4272	71.02	12	2.00	44.22
Sweden	11065	73.11	15	2.32	51.45	26136	80.18	3	1.67	52.99
Switzerland	15253	71.27	20	2.51	50.79	28792	80.82	4	1.41	47.34
Trinidad T	6274	63.52	48	4.99	88.72	18417	69.03	15	1.60	40.16
UK	10323	70.64	22	2.81	53.71	26046	78.57	5	1.71	51.62
USA	12892	69.88	25	3.31	66.72	34875	77.52	7	2.04	49.42
Uruguay	6143	67.71	48	2.90	56.25	8855	75.44	14	2.19	59.55
Club 3	7077	67.06	42	3.92	69.74	20798	77.42	9	1.86	50.41
Full Sample	3995	54.63	100	5.51	79.96	11246	68.21	39	3.24	64.93