THE IMPORTANCE OF BEING MATURE: THE EFFECT OF DEMOGRAPHIC MATURATION ON GLOBAL PER-CAPITA INCOME

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Abstract

Given that savings and productivity follow a hump shaped profile with respect to age and given that demographic profiles vary across countries, population age structure may be linked to differences in levels of economic development. In this paper we measure the importance of age structure in accounting for differences in per capita income levels and the dispersion of those income levels across countries. We find that even after adjusting for country-specific effects, age structure variation can account for a large portion of differences in per capita income and the lack of sigma convergence observed in cross-country data. For the global economy as a whole, we find that demographic maturation has had a strong and positive effect on the evolution of global per-capita income since 1960.

Keywords: age structure, life cycle savings model, cross-country growth.

JEL Classification: J13, J22, J24, O11, O40.

1 Introduction

> "In 1980…living standards, as measured by purchasing power per head, were roughly the same [in India and China]. Then, as China embraced modernity…it left India behind. In the next 21 years, India outperformed its neighbour in almost nothing but population growth."
>
> The Economist (2003, p.21)

As workers mature and gain labor market experience, they earn higher wages and save greater shares of their income. Combine this observation with the fact that age profiles vary considerably across countries (i. e., some countries are young while others are significantly older) and it would appear that demographic age structure may play a significant role in the process of economic development. This paper explores the connection between demographic age structure and the evolution of global per capita income. Specifically, the paper asks how much, if any, of the increase in per capita GDP across countries since 1960 is attributable to the growth in experiential human capital (i. e., demographic maturation which increases the number of mature persons as a share of the total population); and similarly, what proportion of the observed variation in global per capita GDP between 1960 and 2000 can be accounted for by differences in age structure across countries?

To answer these questions the paper applies empirical techniques that have proved useful elsewhere in the study of labor market phenomenon; such as the effect of declining unionization on US wages [Freeman (1980); Card (2001)]. In our case, these same techniques are used to estimate the impact of increasing shares of mature working age persons (demographic maturation) on global per capita income. The remainder of the paper proceeds as follows. Section 2 examines the causal mechanisms linking demographic maturity to economic performance. Section 3 presents the data. Section 4 describes the basic set up and presents our estimates for the impact of demographic maturity on the evolution of global per capita income. Section 5 presents the results of our estimates of the impact of demographic age variation across countries on global income dispersion. Section 6 concludes.

2 Analytical Background

Research into the causal effects of demographic change has historically focused on the negative impact of high fertility and population growth on the level of output per worker.[1] Indeed most growth models dating back to Barro (1991) and Mankiw et al. (1992), among many others, cite the negative coefficient on the rate of population growth as one of the strongest observable correlations in cross-country data [(Galor and Weil (1996)]. Today, however, there is a growing recognition that birth rates and fertility are as much by-products, as sources,[2] of economic growth [Jones (2003)].[3]

In recognition of these facts, several recent studies have focused on the mechanisms by which demographic age structure may affect economic development.[4] Bloom and Williamson (1998) set out what is perhaps the most direct approach. In their framework, population growth is not the mechanism that impedes (or advances) economic performance; rather the so-called 'demographic transition' induced by falls in infant mortality is the driving force. A demographic transition helps to trigger a prolonged fall in fertility and an economic expansion that passes through three phases: Initially, expansion is impeded by falling infant mortality, as growing youth dependency cohorts swell into the economy; it is then greatly abetted in the next phase (fifteen to twenty years later) when the swollen cohort reaches working age; and it is modestly impeded again as these workers begin to retire. These age distribution effects are therefore transitional, although as the authors note, a full transition can take more than 50 years. The authors estimate that age distribution effects can account for nearly one-third of East-Asia's annual growth in GDP per capita from 1965 to 1990. Bloom et al. (2001) extend their analysis beyond East Asian economies and find that increases in the size of working age population can produce a similar demographic dividend. Feyer (2002) considers a model in which a high economy-wide share of mature workers relative to the total workforce, leads to higher output per worker. The causal mechanism is essentially Mincerian; as workers age they gain experience and this peaks sometime during the middle period of a worker's career. Increases in labour force productivity, brought about by workforce maturation, cause output per worker to increase. In his panel estimates he finds that roughly one-fifth (17%) of the variation in output per worker across countries is attributable to differences in the proportion of 40 to 50 year olds in an economy. He finds negative effects for all other age groups relative to this "prime-age" cohort.[5] Persson's (2002) empirical study of growth across US states finds that the age structure of the population affects total factor productivity in a similar fashion to that of the workforce, in that mature

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1. In the model of Kremer (1993) the growth rate of output is indirectly related to fertility via the size of the population and its effect on technological change which in turn affects the growth rate of output.

2. Family economists, for example, have traditionally emphasized the strong links that both variables have with respect to changes in economic performance, which in turn, lead families to reduce fertility as countries become wealthier [Becker et al. (1990)].

3. Jones (2003) has recently estimated that world population growth, although partly endogenous, is also a contributor to the global production of ideas and hence economic growth. He estimates that roughly 10 to 20 percent of US economic growth from 1950 to 1993 is due to population growth.

4. Sarel (1995) appears to be the first published paper to estimate and find a significant effect of the age structure of the population on output in a cross-section of countries. However, Sarel' estimates were performed with only a cross-section of countries and lagged output as the only added explanatory variable, making his demographic point estimates subject to considerable omitted variables bias.

5. A subset of Feyer's analysis also deals with the factor accumulation effects of demographic age structure. He finds that prime age cohorts in their 40s and 50s are positively related with higher levels of capital stock. All cohorts younger that 40 and older than 60 are negatively related to capital stock levels.

age cohorts are positively associated with faster productivity growth.[6] Gómez and Hernández de Cos (2003) find that the size of the working age population has a strongly positive effect on economic performance but that prime-age cohorts have a curvilinear association with respect to per capita output growth. That is, there is an optimal ratio of prime age workers (35-54 year olds) beyond which, diminishing returns set in.[7]

In this paper we adhere to an analytical framework similar to Feyer (2002) and Gómez et al. (2003) in that we link demographic maturity and economic performance via life-cycle models of worker productivity and consumer behavior. Specifically, our argument has two parts. The first part begins when a country undergoes a fall in fertility. Irrespective of the cause, the country experiences an initial decline in the ratio of dependents to working age persons, which in turn, has an effect on economic output through increases in the relative size of the potentially active workforce (those aged 15 to 64) over total population. We term this the *working age (relative) size* effect. Savings rates and labor force productivity will also be affected by a growing ratio of working age persons; though the direction of these latter two channels is more ambiguous, given that savings behaviour and productivity (embodied in either education or experience) varies systematically by age of worker.

These observations highlight a second but no less important link between demographic transitions and economic performance. Falling birth rates affect, with a certain lag, not only the size, but also the *structure of the working age* population. A country with a greater number of prime-age persons (aged 35-54) will differ substantially from one that has greater numbers of young workers (aged 15-34), even if both have workforces that are of the same relative size. In particular, if we consider that three bedrocks of economic growth –labor force participation, personal capital accumulation and individual productivity– all have a life-cycle component[8] and peak when the balance between formal education and experience reaches an optimum (i. e., sometime during the prime working ages of 35 and 54), it follows that the productive capacity of a society with a large fraction of 35 to 54 year olds should be greater than of one with many young entrants in the labor force.[9]

The twin experiences of countries like China and India, highlighted in our opening quotation, illustrate the relevance of this second factor and the explanatory framework more generally. Consider that in 1980 China's working age structure was younger than India's –as measured by the fraction of person's aged 15 to 34 over the potentially active population aged 15 to 64. It was during this period that China, in addition to embracing "modernity", also began implementing its now infamous "one child policy". Twenty years on, the effects have been striking; the fraction of prime age workers (those aged 35 to 54) over the total working age population has risen by 20 percent in China whereas in India that fraction has barely registered a change. Such a large and rapid process of workforce maturation abetted by a conscious political decision to limit family size, should have noticeable effects on major economic aggregates (i. e., savings rates, labour force

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6. Lindh and Malmberg (1999) working with OECD data find similar results, although they include the added savings channel to their list of causal factors induced by age structure maturation.

7. In that paper, a growing cohort of working age persons (15-64) was found to have a large positive effect on growth of GDP per capita. In addition, an increase in the number of prime age workers (35-54) as a fraction of the total working age population (15-64) was found to have a positive but diminishing effect on per capita GDP growth. We also found that growth peaks when the ratio of prime age workers over the potentially active population reaches 0.36. Beyond this ratio, diminishing returns set in.

8. See Gómez and Hernández de Cos (2003) for a discussion of the different channels between saving decisions, human capital accumulation and technical efficiency, and age.

9. This is partly attributable to experiential returns, whereby senior employees (other things equal) are more productive than younger counterparts. See Mincer (1974) for a classic reference in this regard.

participation, productivity, asset prices, capital per worker etc.,) and in turn over economic performance.

There is an addendum to this two-part story. As noted by Bloom and Williamson (1998), the positive effects of a demographic transition with respect to economic growth are ultimately just that: transitional. Persistently low birth rates eventually produce a decline in the size of the working age population and an increase in old-age dependency ratios. This process of population "aging" has raised fears of dampened economic performance and the sustainability of public pension systems in many high-income economies (i. e., Japan and Germany). Ultimately, however, whether the beneficial effects of demographic maturation are transitional or not is secondary, since the transitional element only relates to rates of economic growth. In this paper we are interested in the cumulative effects of demographic maturation, so for our purposes, any boost to per capita growth, transitional or otherwise, will have a permanent effect on the level of per capita income. This, we believe, may help account for differences in those income levels far into the future, especially across countries that at present appear very similar.

Examining whether demographic shifts have had an appreciable effect over per capita income levels across a broad sample of countries is the question that we now turn to.

3 The Data

We employ a composite dataset made up of version 6.1 of the Penn World Tables (PWT) and data provided by the United Nations Population Division. The latest version of PWT, which Summers and Heston (2002) have been collecting for more than a decade, includes PPP adjusted measures of income per-capita for approximately 144 countries from 1950 to 2000.[10] The United Nations World Population Prospects (2001), provides corresponding demographic data for 160 countries from 1950 to 2000.[11] Merging both datasets produces an unbalanced panel of 142 countries and 842 observations.[12]

Figure 1 provides a descriptive overview of the changes in population age structure that have occurred across our sample of countries over the past four decades. The figure documents changes in two key demographic measures of maturity. Our first measure is the ratio of the potentially active working age population (15-64) over the total population, which we capture with the variable MATURE:

$$MATURE_{it} = \frac{\sum_{15}^{64} W_{it}}{\sum_{0}^{99} P_{it}} \tag{1}$$

The variable is a ratio, showing the number of potentially active persons (15-64) *W* over the total population *P*. The expectation is that countries with higher shares of 15 to 64 year olds, all things constant, will experience faster growth and ultimately contribute to higher levels of GDP per capita.

Our second measure captures the structure of this working age population, and it is the share of prime aged workers (35-54) within the 15 to 64 age group. This second effect is identified with the variable PRIMEAGE, which captures the fact that both productivity and labour force participation vary by age of worker. We use the number of person's aged 35 to 54, w over the total number of potentially active persons *W* to measure:

$$PRIMEAGE_{it} = \frac{\sum_{35}^{54} w_{it}}{\sum_{15}^{64} W_{it}} \tag{2}$$

We sometimes refer to (1) and (2) above as the *size* and *structure* of the working age population respectively.

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10. Naturally, if our goal was to estimate global welfare, a population-weighted GDP per capita measure is preferable. See Theil (1979 and 1996) and references contained therein for early work on this question. For more recent work see Schultz (1998); Firebaugh (1999); Melchior, Telle and Wig (2000); Dowrick and Akmal (2001); and Bourguignon and Morrisson (2002).

11. One potential problem with our composite dataset, is that it treats countries as diverse in population size as India and Sao Tome as independent data points with equal weights. However, this is not as bad an approximation as it sounds, since as noted by Sala-i-Martin (2002), when the analysis centres on the effect of certain country characteristics on per capita GDP, as in our case, it is sensible to treat each country as a single data point.

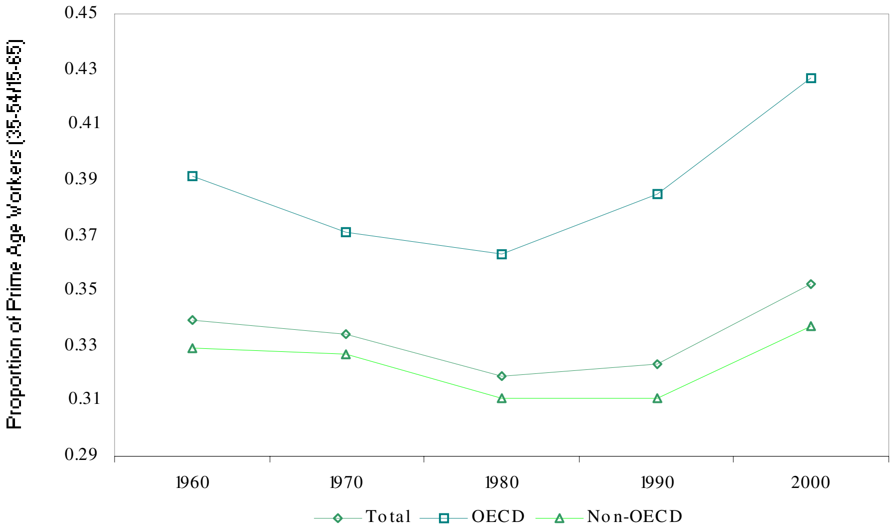
12. Including countries for which age structure or per capita GDP figures were not missing in at least one observed time period.

Panel A of figure 1 shows an increase in the size of the working age population *MATURE* from 1960 to 2000. For the global economy, the percentage of persons aged 15 to 64 increased from 56.4 in 1960 to 60.9 in 2000. In Panel B, we see the clear U shaped pattern of our second age structure measure *PRIMEAGE* –the ratio of prime-age workers over the total working age population. The shape is the delayed consequence of the post-war baby boom, which from 1960 to 1980 swelled the 15 to 64 population with young workers. Figure 1 also shows that age structure patterns differ across country groupings; e. g., OECD and Non-OECD countries display a marked diversity of age profiles. Countries in the OECD, for example, have had larger shares of potentially active working age person from the 1960s onward, and despite having grown younger in the 1980s, the OECD's age structure never approached levels found in the Non-OECD world. In Panel B, we see that in 2000, 42.7 percent of the OECD´s working age population was aged 35 to 54 versus only 33.7 percent for non-OECD countries.

Figure 1: Size and Structure of the Working Age Population, 1960-2000

Panel A. Size: Ratio of Potentially Active Population (15-64) over Total Population

Panel B. Structure: Ratio of Prime Aged (34-54) to Total Working Age Population (15-64)



Tables 1a and 1b compare the characteristics of demographically mature countries against younger country counterparts in three periods 1960s, 1980s, and 2000. The tables are constructed first by creating dichotomous versions of the two working age population ratios defined above.[13] In Table 1a, we categorise those countries with a ratio of prime-age workers greater than 0.365 over the working age population as being mature, and those with a ratio less than or equal to 0.365, as being young. In Table 1b a ratio of the working age population of 0.65 over the total population is used as the cut-off point between young and mature countries.[14] The results in both tables are broadly congruent. Mature countries, however defined, typically have higher savings rates (row 2), lower income inequality (row 3), and greater levels of political participation (row 5). Rows 6 through 11 show mean income levels for mature and young country groupings, as well as a set of "raw" income gaps between the two groupings.

In both tables, mean income levels are higher in mature countries, with a widening in this gap observed from 1980 onward. In Table 1a, for example, we see that in 1960 the raw gap in real per capita GDP (row 7) between prime and non prime-age countries was 4475 ($US); and that by 2000 that gap had reached 11933 ($US).

13. This is suitable not only for descriptive purposes but also on the grounds that this will allow us to better estimate the effect of population maturation across different country-club demographic groupings. This parallels recent work by Durlauf and Quah (1999), among others, who find evidence of convergence club groupings and twin-peak distributions across development indicators. A list of mature countries which fall into these dichotomous categories are available from the authors upon request.

14. Different cut-off ratios points were tested for both definitions of maturity. The ratios finally selected were those generating the largest real GDP gaps between the two groups. In the case of the prime-age variable, the selected cut-off ratio is also equal to the ratio at which growth peaks, as found by Gómez and Hernández de Cos (2003). See footnote 7 for more details.

Table 1a: Characteristics of Countries by Structure of Working Age Population (Mature, Young) in 1960, 1980, 2000

	1960		1980		2000	
	Ratio 35-54/15-64		Ratio 35-54/15-64		Ratio 35-54/15-64	
	Mature > 0.36	Young = < 0.35	Mature > 0.36	Young = < 0.35	Mature > 0.36	Young = < 0.35
1. Working Age Population Ratio (15-64/0-65+)	0.612	0.537	0.647	0.553	0.669	0.557
2.National Savings Rate (percent)	22.0	8.5	22.0	7.2	17.6	3.3
3.Inequality (Gini ratio X 100)	39.2	46.5	29.1	41.6	29.7	42.2
4.Openess (Exports + Imports/GDP)	55.4	69.8	73.8	74.5	106.3	74.6
5.Voter Turnout (percent)	75.7	52.0	79.3	63.4	67.9	58.4
6.Real GDP per capita (mean)	6323	1848	12685	4579	14864	2931
7.Real GDP Gap	--	4475	--	8106	--	11933
8.Per Capita GDP relative to US (US=100)	51.8	15.2	60.3	22.5	45.0	9.0
9.Relative GDP Gap	--	36.6	--	37.8	--	36.0
10.Log Real GDP per capita(mean)	8.504	7.336	9.285	7.999	9.377	7.681
11.Log Real GDP Gap	--	1.168	--	1.286	--	1.696
12. Std. Dev. Log Real GDP	0.825	0.620	0.728	0.934	0.737	0.817
	(0.884)	(0.884)	(1.025)	(1.025)	(1.152)	(1.152)
13. Interquartile Range (p75 – p25)	1.096	0.906	0.584	1.444	1.183	1.453
	(1.299)	(1.299)	(1.684)	(1.684)	(1.809)	(1.809)
14.Number of Observations	37	75	22	102	67	75
15.Proportion of Total (percent)	32.1	77.9	17.8	82.2	47.1	52.9

Notes: Demographic data based on United Nations World Population Prospects. A full account of all variables can be found in Appendix Table 1. The GINI measures for 2000 are for 1990. Numbers in brackets in rows 13 and 14 are the all-country (global) variance measure.

Table 1b: Characteristics of Countries by Size of Working Age Population (Mature, Young) in 1960, 1980, 2000

	1960		1980		2000	
	Ratio 15-64/Total Population		Ratio 15-64/Total population		Ratio 15-64/Total population	
	Mature > 0.65	Young = < 0.65	Mature > 0.65	Young = < 0.65	Mature > 0.65	Young = < 0.65
1.Prime Working Age Population (35-54/15-64)	0.380	0.328	0.365	0.299	0.403	0.298
2.National Savings Rate (percent)	26.9	10.1	26.0	4.2	17.0	2.5
3.Inequality (Gini ratio X 100)	37.7	45.1	30.0	43.6	31.6	42.5
4.Openess (Exports + Imports/GDP)	48.5	55.3	85.7	71.8	103.5	74.3
5.Voter Turnout (percent)	77.8	56.7	77.3	61.5	67.5	57.9
6.Real GDP per capita (mean)	7219	2531	13772	3320	13961	2685
7.Real GDP Gap	--	4688	--	10452	--	11276
8.Per Capita GDP relative to US (US=100)	59.3	20.6	64.2	17.1	42.3	8.2
9.Relative GDP Gap		38.6		47.0		34.0
10.Log Real GDP per capita (mean)	8.746	7.512	9.437	7.807	9.302	7.589
11.Log Real GDP Gap		1.233		1.630		1.712
12. Std. Dev. Log Real GDP	0.607	0.781	0.500	0.800	0.740	0.802
	(0.884)	(0.884)	(1.025)	(1.025)	(1.152)	(1.152)
13. Interquartile Range (p75 – p25)	0.756	1.025	0.514	1.275	1.326	1.398
	(1.299)	(1.299)	(1.684)	(1.684)	(1.809)	(1.809)
14.Number of Observations	19	93	32	92	74	68
15.Proportion of Total (percent)	16.9	83.1	25.8	79.2	52.1	47.9

Notes: Demographic data based on United Nations World Population Prospects. A full account of all variables can be found in Appendix Table 1. The GINI measures for 2000 are for 1990. Numbers in brackets in rows 13 and 14 are the all-country (global) variance measure.

Rows 12-13 in Tables 1a and 1b present measures of dispersion in per capita income between mature and non-mature country groupings. The first entry is the standard deviation of log per capita real GDP and the second represents the inter-quartile range of log GDP. These simple measures of income dispersion illustrate several important facts. First, per capita incomes are generally less disperse within mature country groupings than in younger ones. Second, income dispersion has risen more dramatically for non-mature countries from 1960 to 1980, whereas it fell for the mature sector during that same time period. Third, there is no evidence of global sigma-convergence as overall dispersion (the number in brackets in rows 12 and 13) has increased year-on-year since 1960. This latter result is consistent with other studies [Salai-i-Martin (1996)] which show that the standard all country (i. e., global) measure of sigma convergence has widened since 1960, but that within certain convergence club groupings (i. e., as within the OECD or as in our case, for mature-aged countries) dispersion narrowed and sigma-convergence can be said to have occurred between 1960 and 1990.

4 The Effect of Maturity on Per-Capita Income levels

4.1 Assumptions

How much, if any, of the global increase in per capita GDP since 1960 is attributable to demographic maturation? Similarly, what proportion of the observed variation in per capita GDP across countries can be accounted for by differences in age structure? These questions lie at the heart of our paper. To answer them, a few simplifying assumptions are required. In particular, we need to assume that countries can be assigned to different working age categories (e. g., young or mature); that these working age categories are imperfect substitutes in production at the micro-level, e. g., young workers may perform well on the shop floor but perform rather poorly in the boardroom;[15] that population age structure, especially that of the working age population aged 15 to 64, is predetermined with a lag of roughly fifteen years and hence exogenous with respect to current economic conditions; that external migration is not large enough to mute the impact of historical fertility declines;[16] and finally, that productivity and savings rates are generally higher amongst prime-age working age cohorts (i. e., workers aged 35-54) than younger ones (15-34).[17] Taken together, these five assumptions imply that countries that are demographically mature (i. e., greater shares of mature and prime-age working age populations) should, other things equal, display higher per capita income levels than younger counterparts.

4.2 The Basic Set-up and Baseline Results

In modelling the effect of demographic maturity on cross-country income differentials and the dispersion of those income levels over time, we start by adopting an empirical approach first used by Freeman (1980) and later elaborated by Card (2001) to measure the effect of unionisation on wage structures in union and non-unionised sectors of the economy. This basic set-up is based on the previously mentioned assumptions and, in particular, on the assumption that countries can be categorized in homogeneous groups according to their working age characteristics (mature and young countries), implying that differences in income between mature and young countries are attributable to the effect of age structure only, thus ignoring other causes of income differences and unobserved heterogeneity across countries. In our case, we appropriate the same techniques to make a first approximation to the quantification of the relationship between population age structure and per capita income differentials across country groupings. The previous assumptions will be relaxed later in order to provide a more robust estimate of the importance of demographic maturity with respect to per-capita income differentials over time.

Let y_{it}^{m} represent the log income per capita that country *i* at time *t* would attain with a mature age working age population *m*, and let y_{it}^{g} represent the log income per capita for the same country if it had a young working age population *g*. Assume that[18]

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15. We follow Kremer and Thomson (1998) who make this the cornerstone of their own paper on the impact of demographic age structure in forestalling economic convergence across countries.

16. As noted by Bloom and Williamson (1998): "In the late twentieth century, international migrations are simply not great enough to matter…They mattered a great deal, however, in the age of relatively unrestricted mass migration prior to World War 1."

17. In this regard both Weil (1994) and Feyer (2002) find evidence that savings rates peak for workers in their fifties. This is consistent with life-cycle models of saving as first proposed by Modigliani (1986).

18. We assume as well that countries can be classified into distinct country groupings based on some observable demographic data.

$$y_{it}^{m} = y_{t}^{m} + \varepsilon_{i}^{m},$$
$$y_{it}^{g} = y_{t}^{g} + \varepsilon_{i}^{g},$$

where y_t^m and y_t^g are the mean log per capita income levels of mature and young countries at time *t*. Homogeneity within country groups is reflected in the assumption that $\mathrm{E}\left[\varepsilon_i^m \mid \text{mature}\right] = \mathrm{E}\left[\varepsilon_i^g \mid \text{young}\right] = 0$. The log per capita output gap between mature and young countries at time *t* will be denoted by

$$\Delta_t^y = y_t^m - y_t^g, \qquad (3)$$

which based on our theoretical discussion should be positive, $\Delta_t^y > 0$.

If we let m_t denote the fraction of countries at time *t* which fall into our predefined demographically mature category, then the mean log per capita income level for all countries in the global economy at time *t* is simply:

$$y_t = y_t^g + \underbrace{m_t \cdot \Delta_t^y}_{y_t^m}. \qquad (4)$$

Note that the mean log per-capita income gain for the global economy associated with demographic maturity is the product of the proportion of countries categorised as being mature and the (positive) mature income gap.

In the presence of mature countries, the estimate of global log per-capita income at time *t* is simply the expectation of (4)

$$y_t = E\left[y_t\right] = E\left[y_t^g + m_t \cdot \Delta_t^y\right] = E\left[y_t^g\right] + E\left[m_t \cdot \Delta_t^y\right] \qquad (4')$$

If every country had a young working age population then global per capita outcomes would simply be

$$y_t^g = E\left[y_t^g\right]$$

Thus, the effect of demographic maturity on global per capita income, relative to that which would occur if all countries achieved output levels with young working age populations, is:

$$y_t - y_t^g = E\left[m_t \cdot \Delta_t^y\right] \qquad (5)$$

We use the simple two-sector framework above to measure the effect of changing age structure on changes in per capita income across all countries in our sample. A comparison of this differential over time provides an unconditional measure of the changing effect of demographic maturity on global income per capita. Table 2 illustrates the application of this formula in 1960 and 2000: the underlying data are drawn from Table 1. Recall that we divided the global economy into two groups –a mature and a young sector– and two definitions of maturity were used to produce this classification. The first captured demographic maturity through the relative size of the working age population. A ratio of 0.65

for the number of 15 to 64 year olds over the total population functioned as our cut off in this regard. Countries below this margin were considered young and countries above were defined as mature. Our second measure of maturity focused on the proportion of 15 to 64 year olds who were of prime working age (35 to 54). A ratio greater than 0.365 served as our age structure measure of maturity.

Table 2: Estimates of the Contribution of Demographic Maturation to the Change in Global Per-capita Income, 1960 to 2000

	Mature Working Age Size		Mature Working Age Structure	
1960	[1] Raw	[2] Adjusted	[3] Raw	[4] Adjusted
1. Mean of Global Real Income Per-capita in Logs (y)	7.722	7.722	7.722	7.722
2. Relative Fraction of Countries with Mature Working Age Population (m)	0.169	0.169	0.321	0.321
3. Per-capita Income Gap Between Mature and Young Sectors in Logs (Δ^{y})	1.233	0.573	1.168	0.385
4. Relative Demographic Maturity Effect ($y - y^{g}$)	0.208	0.097	0.374	0.124
2000				
1. Mean of Global Real Income Per-capita in Logs (y)	8.482	8.482	8.482	8.482
2. Relative Fraction of Countries with Mature Working Age Population (m)	0.521	0.521	0.471	0.471
3. Per-capita Income Gap Between Mature and Young Sectors in Logs (Δ^{y})	1.712	1.190	1.696	1.081
4. Relative Demographic Maturity Effect ($y - y^{g}$)	0.892	0.620	0.798	0.509
Changes between 2000 and 1960				
1.Change in Mean of Global Real Income Per-capita ($y_{00} - y_{60}$)	0.760	0.760	0.760	0.760
2.Change in Demographic Maturity Effect ($y_{00} - y^{g}_{00}$)-($y_{60} - y^{g}_{60}$)	0.684	0.523	0.424	0.386
3.Share of Global Income Change Due to Demographic Maturity Effect (%)	89.9	68.8	55.8	50.7
Decomposing the Maturity Effect between 2000 and 1960				
1.Change in Demographic Effect ($y_{00} - y^{g}_{00}$)-($y_{60} - y^{g}_{60}$)	0.684 (100)	0.523 (100)	0.424 (100)	0.386 (100)
2.Total due to Change in Income Gap (D1)	0.145 (21.1)	0.184 (35.2)	0.175 (41.3)	0.182 (47.1)
3.Total due to Change in Share of Mature Countries (D2)	0.538 (78.6)	0.340 (64.9)	0.249 (58.7)	0.203 (52.9)

Notes: Size refers to the dummy created from the ratio of mature working age population to 15 to 64 year olds over the total population. Structure refers to the dummy created from the ratio of prime age workers aged 35 to 54 over the working age population. See text equations (3) to (5) for an explanation of formulas and Table 1a and 1b for underlying data. Columns [1] and [3] represent the unconditional estimates of the gap in GDP per capita (row 3 in 1960 and 2000 panels) between mature and young country groups. Columns [2] and [4] represent the fixed-effect adjusted estimates of the gap in GDP per capita between mature and young country group.

Examination of columns [1] and [3] of Table 2 shows that ignoring other causes of income differences and unobserved heterogeneity across countries, the increase in our first and second measures of maturity between 1960 and 2000 would have been expected to cause global income to rise by 0.684 and 0.424 respectively. During this period, the actual mean of per capita (log) global income rose by 0.760. Thus, a naïve calculation suggests that growth in the size and structure of the working age population can each explain about 90 and 56 percent of the rise in global income per capita respectively since 1960.

This basic set-up and the results it generates provide a transparent way of characterising the *importance of demographic maturity* with respect to per-capita income differentials over time. Apart from this, the set-up also facilitates the use of standard shift-share techniques, which can more formally evaluate the effects of demographic maturity on the evolution of global income.

To illustrate, consider the change in mean per capita income of mature countries relative to young countries between 1960 and 2000. Let $\left(y_{60} - y_{60}^{g}\right)$ denote the relative effect of demographically mature countries on global GDP per capita in 1960 and let $\left(y_{00} - y_{00}^{g}\right)$ denote the same effect in 2000. Using this notation, the change in the income gap between mature and young countries from 1960 to 2000 is

$$D = \underbrace{\left(y_{00} - y_{00}^{g}\right)}_{\Delta(Y_{00})} - \underbrace{\left(y_{60} - y_{60}^{g}\right)}_{\Delta(Y_{60})} \tag{6}$$

The distribution of global income may change for a variety of reasons, one of which may be shifting proportions of mature countries or a widening in the income gap between mature and young countries. Equation (4) allows us to capture the relative importance of each effect. To see this more clearly, let $\Delta Y_{60|00}$ denote the income gap that would have occurred if the 1960 difference in per capita GDP between mature and young country groups is re-weighted to have the same fraction of mature countries as in 2000. The relative change D can be decomposed as:

$$D = D_1 + D_2$$

where

$$D_1 = \underbrace{E\left[m_{00} \cdot \Delta_{00}^{y}\right]}_{\Delta(Y_{00})} - \underbrace{E\left[m_{00} \cdot \Delta_{60}^{y}\right]}_{\Delta(Y_{60|00})} \tag{7}$$

and

$$D_2 = \underbrace{E\left[m_{00} \cdot \Delta_{60}^{y}\right]}_{\Delta(Y_{60|00})} - \underbrace{E\left[m_{60} \cdot \Delta_{60}^{y}\right]}_{\Delta(Y_{60})}$$

The first of these components represents the change in relative income that would have occurred if there had been no change in the fraction of countries with a mature workforce. The second component represents the difference between the counterfactual income-gap in 1960 (constructed to have the 2000 fraction of mature countries) and the actual gap in that year.

Our decomposition of these maturity effects can be found in the last panel of Table 2. In column 1 row 3 we see that 0.538, or a majority (78.6 percent) of the working age size effect (i. e., MATURE), is attributable to the rise in the fraction of countries with mature working age populations. Slightly less than a quarter (21.1 percent) of this effect is due to the increase in the income gap between mature and non-mature countries (0.145).[19] Although the overall effect was much smaller in magnitude for the PRIMEAGE ratio, in column 3 we see that it displays much the same pattern of results, as both panels show that the share of mature countries, however defined, had a much stronger impact on the evolution of global income in the period from 1960 to 2000.

4.3 Controlling for Other Causes of Income Differences

In order to properly isolate the importance of demographic maturity we need to estimate (rather than simply measure) structural parameters associated with mature working age populations and their effect on real income levels. Such an approach is possible using a simple descriptive model of the form:

$$y_{it} = \alpha + \lambda P_{it}^{35-54} + \varphi S_{it}^{15-64} + \delta Z_{it} + e_{it} \tag{8}$$

where y_{it} is the log level of real income per capita of country *i* at time *t* , α is our constant, P_{it}^{35-54} is a binary indicator of mature working age structure that equals 1 if country i have greater than 0.365 percent of their working age population aged 35 to 54 in period *t*, S_{it}^{15-64} is our dummy measure of maturity which is 1 if the share of persons aged 15-64 over the population is greater than 0.65 *i* at time *t*, and where Z_{it} is some vector of time dummy variables.

Although seemingly straightforward, this type of exercise is crucial if we wish to partial out the effect of each maturity channel on the income gap.[20] In addition, with a minor addition, the simple descriptive model above also allows us to calculate income gaps between mature and non-mature countries with unobserved heterogeneity taken into account. If mature countries have characteristics that simultaneously make them more productive and more mature, then even the estimated gaps may exaggerate the demographic effect. In order to account for cross-country heterogeneity, we use the conventional within-estimation technique (fixed-effect estimator) that essentially transforms equation (6) into a differenced equation. Our expectation is that the fixed effect estimation should lower the prime age coefficient relative to the raw measures, but not eliminate its significance. Table 3 shows the results of these panel adjusted estimates. It compares the raw log gaps in

19. The increase in the income gap between sectors is interesting. One explanation lies in the divergence in the percentage of prime age workers observed in both sectors during this time period. As seen in first row of Table 1a and 1b, the non-mature sector became even younger while the mature sector became even more mature.

20. Note that if the size of the working age population is related to its age structure at the national level –i. e., relatively large working age populations tend to have mature age structures– a regression of (6) that omits the share of prime-age working age persons and only includes the size of the working age population dummy regressed against income, would yield a coefficient with probability limit

$$\varphi + \lambda \frac{Cov(S_{it}, P_{ti})}{Var(S_{it})}.$$

If the share of prime age workers in an economy is positively related to national income, as our theoretical overview suggests, and if this share also tends to be larger for countries with larger working age populations, then our unconditional estimates of φ would be biased upwards since $\lambda > 0$.

per capita GDP from row 11 in Tables 1a and 1b with a series of "panel-data adjusted" gaps based on fixed effect estimates of equation (6). The results for our fixed effect estimations are in line with our expectation; i. e., the magnitudes of our estimated gaps are 30 percent lower than the raw estimates.

Table 3: Estimates of the Effect of Unobserved Heterogeneity and Age Structure on the Income Gap between Mature and Young Countries.

	Size of Log per capita GDP gap	
Panel A: Working Age Size Effect	Raw Gap $\Delta_t^y = y_t^m - y_t^g,$ [1]	Adjusted Gap $\Delta^y = \varphi$ [2]
Year		
1960	1.233	0.573
1980	1.630	1.097
2000	1.712	1.190
	Size of Log per capita GDP gap	
Panel B: Prime Age Structure Effect	Raw Gap $\Delta_t^y = y_t^m - y_t^g,$ [1]	Adjusted Gap $\Delta^y = \lambda$ [2]
Year		
1960	1.168	0.385
1980	1.286	0.882
2000	1.696	1.081

Notes: Raw income gaps are actual differences in mean log income per capita between prime and non-prime age countries in each period. These gaps are taken from Tables 1a and 1b rows 11. Panel data adjusted income gaps are taken from a fixed effect regression with time period dummies added. The fixed effect coefficients on our mature and prime-age variables are then added to each common time period effect. See text and equation (6) for a fuller explanation of column [2] adjusted gaps.

If we use our adjusted results together with data from our original Table 2 to re-estimate the contribution of changing demographic maturity to rising global income, we find that the results are qualitatively very similar to the naïve calculations with one noticeable difference; the magnitudes of the mature size and structure effects are substantially reduced. In Table 2 column 2 (last panel), we see that the proportion of the overall rise in income that can be explained by our first measure of demographic maturity –the relative size of the 15 to 64 year old population over the total– drops from 90 percent under the naïve calculations to 68 percent using the conditional fixed-effect estimates. In terms of the prime-age structure effect, in Table 2 column 4 (last panel) it falls from 57 percent under the unconditional estimates to 50 percent in the conditional fixed-effect estimates.

5 Demographic Maturity and Sigma-Convergence

Can the widening of global income dispersion –the so-called decline in "sigma-convergence"– that has occurred since the 1980s be linked to similar polarizations in age structures?[21] That is, in addition to affecting the mean level of income per capita, can demographic variation across countries also affect the dispersion of per capita income within the global economy? We turn now to this issue. Let

$Var\left[\varepsilon_{it}^{m}\right] = v_t^m$ and

$Var\left[\varepsilon_{it}^{g}\right] = v_t^g$,

represent the variances of log income per capita for countries with mature and young populations at time *t*, respectively. The "variance gap" between mature and non-mature countries will be denoted by

$$\Delta_t^v = v_t^m - v_t^g. \tag{9}$$

The variance of log income per-capita for the global economy at time t can therefore be computed in a fashion similar to our estimate of global mean income in (3):

$$v_t = v_t^g + \underbrace{m_t \cdot \Delta_t^v}_{\text{Within Effect}} + \underbrace{m_t(1 - m_t) \cdot \Delta_t^{y\,2}}_{\text{Between Effect}}. \tag{10}$$

This equation shows that the presence of countries with mature population age structures can exert a within-age-category effect on global income dispersion –associated with any lowering (or raising) of the dispersion of per-capita income outcomes relative to countries with a non-mature population– and a between-age-category effect associated with any widening of mean per-capita incomes between mature and non-mature countries. The implications for sigma convergence arising from these twin (and potentially offsetting) effects are discussed in more detail below.

In the presence of age structure variation, the dispersion in income per capita for the global economy in a given time period is

$$v_t = Var\left[y_t^g\right] + E\left[v_t^g + m_t \cdot \Delta_t^v + m_t \cdot (1 - m_t) \cdot \Delta_t^{y\,2}\right]$$

$$v_t = Var\left[y_t^g\right] + E\left[v_t^g\right] + E\left[m_t \cdot \Delta_t^v\right] + E\left[m_t \cdot (1 - m_t) \cdot \Delta_t^{y\,2}\right],$$

where variances and expectations are taken over countries. If every country attained income levels based on those in young countries, the variance of global (all country) incomes would be:

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21. Although Sala-i-Martin (1996) finds general support for both absolute and conditional convergence in a variety of datasets, the only dataset that displays absolute divergence is the global dataset of 100 countries. Others have found divergence in the form of "twin peak" distributions, or a clustering of rich and poor countries [Quah (1997)]. See Jones (1997) for a useful summary.

$$v_t^g = Var\left[y_t^g\right] + E\left[v_t^g\right] \quad (11)$$

Thus, the effect of demographic maturity on the variance of global income per capita, relative to the variance that would occur if all countries obtained the income of non-mature working age populations, is:

$$v_t - v_t^g = \underbrace{E\left[m_t \cdot \Delta_t^v\right]}_{\text{Within Effect}} + \underbrace{E\left[m_t \cdot (1 - m_t) \cdot \Delta_t^{y\,2}\right]}_{\text{Between Effect}} \quad (12)$$

As before, this produces a "within" and a "between" mature country effect. Given our prior expectation about the role of a mature population in increasing income levels relative to younger country counterparts, the second effect has a necessarily positive influence on the variance of cross-country income differentials (i. e., an inhibiting influence on the process of cross-country income convergence). The first effect, however, could be positive or negative depending on whether income levels are relatively less disperse *within* mature countries. To the extent that these two forces work in the opposite direction, the question of whether demographic maturation minimizes or increases income differentials across countries is chiefly an empirical one.

A comparison of this size differential over time provides us with a measure of the effect of changing age structure on sigma-convergence. Equation (10), through its separation of between and within age structure effects, also shows the relative balance of demographic forces acting upon global inequality. A greater proportion of countries with mature working age populations can foster convergence, since income dispersion within this sector has generally been lower than in the young sector. However, since income levels between the two sectors are so disparate, growth in the income gap between sectors is equally capable of fostering inequality and thus inhibiting convergence.

Examination of columns 1 and 3 in Table 4 demonstrates that the maturing of the global economy, both in terms of the size and structure of the working age population, between 1960 and 2000 should have caused the variance of global income to rise by 0.526 and 0.231 respectively. As shown in columns 1 and 3 of row 8 of Table 4, between 1960 and 2000, the observed dispersion of (log) per-capita income in the global economy rose by 0.510. Thus a naïve calculation would suggest that changes in our first measure of maturity –the size of the potentially active working age population– are associated with 100 percent of the growth in global per capita income variance and that age structure change can explain roughly 45 percent of the rise in global income inequality since 1960. In both cases, the increase in variance is fully attributable to the between-age-category effect, since the within variance effect would have actually lowered global dispersion by 0.188 in the case of our structural measure of maturity and contributed to only a negligible rise (0.008) in the case of the size of the working age population measure.

Table 4: Estimates of the Contribution of Demographic Maturation to Changes in Global Log per-capita Income Dispersion (Inter-quartile Range), 1960 to 2000

	Mature Working Age Size		Mature Working Age Structure	
1960	[1] Raw	[2] Adjusted	[3] Raw	[4] Adjusted
1.Global Variance of Real Income Per-capita (v_t)	1.299	1.299	1.299	1.299
2.Relative Fraction of Countries with Mature Working Age Populations (m)	0.169	0.169	0.321	0.321
3.Per-capita Income Gap Between Mature and Young Sectors in Logs (Δ^y)	1.233	0.523	1.168	0.385
4.Log Variance Gap Between Mature and Young Sectors (Δ^v)	-0.269	-0.269	0.190	0.190
5. Between-Age-Category Effect $m_t(1-m_t)\Delta_t^{y2}$	0.214	-0.046	0.297	0.032
6.Within-Age-Category Effect ($m_t\Delta_t^v$)	-0.045	0.046	0.061	0.061
7.Total Demographic Maturation Effect ($v - v^g$)	0.168	0.001	0.358	0.093
2000				
1.Global Variance of Real Income Per-capita (v_t)	1.809	1.809	1.809	1.809
2.Relative Fraction of Countries with Mature Working Age Populations (m)	0.521	0.521	0.471	0.471
3.Per-capita Income Gap Between Mature and Young Sectors in Logs (Δ^y)	1.712	1.190	1.696	1.081
4.Log Variance Gap Between Mature and Young Sectors (Δ^v)	-0.072	-0.072	-0.270	-0.270
5. Between-Age-Category Effect ($m_t(1-m_t)\Delta_t^{y2}$)	0.393	0.353	0.717	0.291
6.Within-Age-Category Effect ($m_t\Delta_t^v$)	-0.038	-0.038	-0.127	-0.127
7.Total Demographic Maturation Effect ($v - v^g$)	0.694	0.316	0.589	0.164
Change between 2000 and 1960				
8.Change in Global Variance of Real Income Per-capita ($v_{00} - v_{60}$)	0.510	0.510	0.510	0.510
9.Change in Between-Age-Category Effect	0.518	0.307	0.419	0.259
10.Change in Within-Age-Category Effect	0.008	0.008	-0.188	-0.188
11.Change in Total Demographic Maturity Effect ($v_{00} - v_{00}^g$) − ($v_{60} - v_{60}^g$)	0.526	0.315	0.231	0.071
12.Share Attributable to Demographic Maturation (Percent)	100.0	61.8	45.2	13.8

Notes: Size refers to the dummy created from the ratio of mature working age population to 15 to 64 year olds over the total population. Structure refers to the dummy created from the ratio of prime age workers aged 35 to 54 over the working age population. See text equations (8) to (9) for an explanation of formulas and Table 1a an 1b for underlying data. Columns [1] and [3] represent the unconditional estimates of the between effect based on the raw GDP per capita gap. Columns [2] and [4] represent the fixed-effect adjusted estimates of the between effect based on the adjusted GDP per capita gap between mature and young country groups.

Again, there are several reasons to suspect that the unconditional calculations of the mature income gap used in columns 1 and 3 of Table 4 may misrepresent the role of demographic maturity. The effects ascribed to our first measure of maturity, in particular, seem quite large. The first problem is that the naïve calculations for the mature working age size income gap fail to condition on the structure of the working age population (and vice versa). Second, the results above have failed, even in the most standard way, to control for the potential role of unobserved heterogeneity across countries.

Conditioning on demographic measures of maturity and controlling for unobserved characteristics does have a significant impact on our estimates of the effect of changing age structure on sigma-convergence. When unobserved characteristics are taken into account and the adjusted conditional income gaps are plugged into equation (10), as in section 4.3 above and represented in rows 3 of columns 2 and 4 of Table 4, the share of variation in global income dispersion explained by changes in the size of the working age population drops from 100 to 62 percent (column 2, row 12). Similarly, the importance of changes in age structure with regards to global sigma-convergence falls from 45 to 14 percent (column 4 row 12) under the fixed effect adjusted estimates. This fall occurs primarily because the between-effect loses much of its force when the smaller income gaps (which control for unobserved country components) are used.[22]

22. This result, however, is partly misleading because the within sector variance gaps have been kept constant. In reality, when this procedure has been performed in other contexts, the variance structure is re-estimated to take into account possible age structure effects within groups. Unfortunately, this is where the limitations of using macro-data alongside micro-methods start to take hold. We simply do not have enough independent observations to create similar style "convergence club groupings" –akin to the skill groupings used in Card (2001)– to re-estimate the within group effects of age structure properly.

6 Conclusions

Given that savings and productivity follow a hump shaped profile with respect to age and given that demographic profiles vary across countries, population age structure may be linked to differences in levels of economic development. The primary purpose of this paper was precisely to assess this connection between demographic and economic developments. Our results point to several key finding on this issue. In particular we show that countries defined as being demographically mature are significantly better off in terms of income per head than younger counterparts. Using two definitions of demographic maturity –a measure of potentially active persons (aged 15-64) as a share of the total population and a measure identifying the share of prime-aged persons (aged 34-54) within the potentially active working age population– we show that, even after adjusting for country-specific effects, demographic maturation (i. e., the growing proportion of countries with mature populations) has largely contributed to the increase in global per capita GDP since 1960. We also find that demographic maturation has contributed significantly to the widening of global inequality across countries (i. e., the lack of observed sigma-convergence). This effect is present despite the fact that cross-country income dispersion is lower within mature country-club groupings. The reason for the overall widening is that this *within* group effect has not been large enough to offset income differentials *between* young and mature country groupings, meaning that demographic maturation has, on balance, served to retard rather than abet the process of sigma-convergence.

Taken as a whole, these results complement recent theoretical and empirical work on population size and economic development [Alesina et al. (2003); Jones (2003)] and reinforce the findings of Bloom et al. (2001), Feyer (2002), and Gómez and Hernández de Cos (2003) who have found positive links between mature demographic age structures and cross-country economic growth rates.

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APPENDIX: VARIABLE DEFINITIONS AND SOURCES

Variable	Definition	Source
1. Prime Age Share	The fraction of the working age population aged 35-54.	United Nations (1998)
2. Prime Age Sector	An indicator variable is constructed whereby countries with more that 36 percent of the working age population prime aged are assigned 1 and 0 otherwise.	United Nations (1998)
3. Income Per Capita (In Constant Prices)	Log of Real GDP per capita is a chain index (in 1996 $US prices). For more details, see Data Appendix in Penn World Tables 6.1.	Heston and Summers (2002)
4. Voter Turnout	The fraction of votes cast by the voting age population in national elections.	IDEA (2003)
5. National Savings	The percentage share of current savings to GDP. Derived by subtracting gross consumption and government consumption from 100.	Heston and Summers (2002)
6. Openness	Exports plus imports divided by real GDP (chain).	Heston and Summers (2002)
7. Inequality	Measured as the GINI coefficient.	Deininger and Squire (1996)

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