

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

2006

Rafael Gómez
and Pablo Hernández de Cos

**Documentos Ocasionales
N.º 0604**

BANCO DE ESPAÑA



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

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

Rafael Gómez

LONDON SCHOOL OF ECONOMICS AND BANCO DE ESPAÑA RESEARCH VISITOR FELLOW

Pablo Hernández de Cos

BANCO DE ESPAÑA

(*) We are particularly grateful to Isabel Argimón, Susanto Basu, Cristina Barceló, Olympia Bover, Ignacio Hernando, Morley Gunderson, Eloisa Ortega, Gabriel Pérez Quirós and Javier Vallés for their suggestions and comments and all participants to seminar at the Research Department of the Banco de España. The helpful research assistance of Wanja Eiche, Kenny Sandorffy and Konstantinos Tzioumis is greatly appreciated.

The Occasional Paper Series seeks to disseminate work conducted at the Banco de España, in the performance of its functions, that may be of general interest.

The opinions and analyses in the Occasional Paper Series are the responsibility of the authors and, therefore, do not necessarily coincide with those of the Banco de España or the Eurosystem.

The Banco de España disseminates its main reports and most of its publications via the INTERNET at the following website: <http://www.bde.es>.

Reproduction for educational and non-commercial purposes is permitted provided that the source is acknowledged.

© BANCO DE ESPAÑA, Madrid, 2006

ISSN: 1696-2222 (print)

ISSN: 1696-2230 (on line)

Depósito legal: M.28977-2006

Imprenta del Banco de España

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

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 than 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 component⁸ 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

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*:

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

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:

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

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

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).

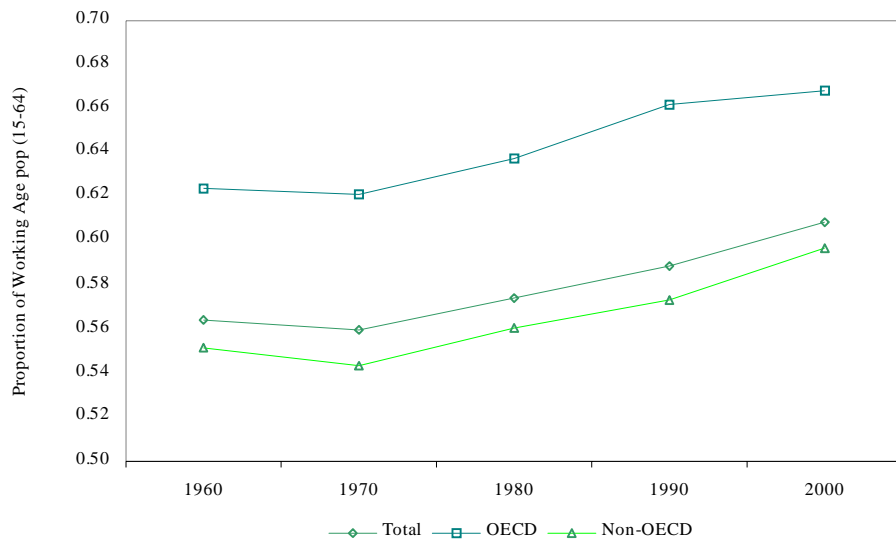
11. One potential problem with our composite dataset, is that it treats countries as diverse in population size as India and Sao Tome as independent data points with equal weights. However, this is not as bad an approximation as it sounds, since as noted by Sala-i-Martin (2002), when the analysis centres 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.

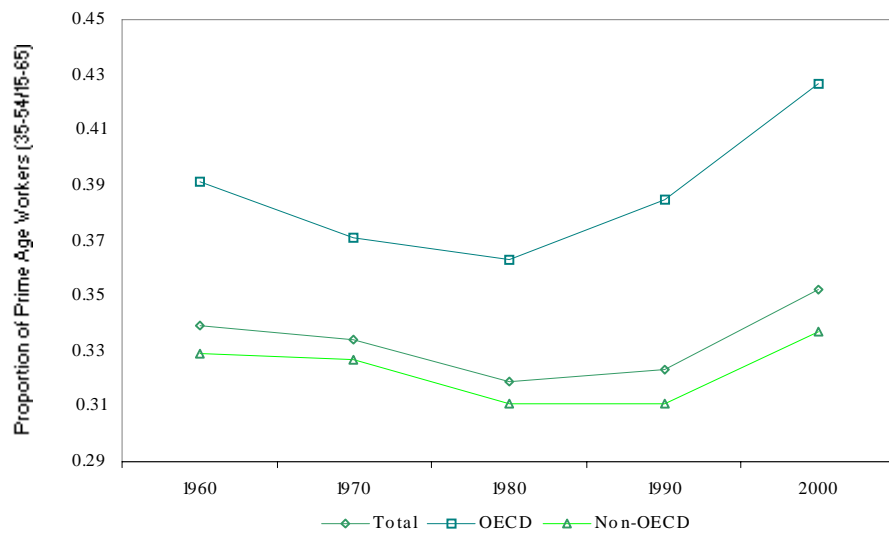
Panel A of figure 1 shows an increase in the size of the working age population *MATURE* from 1960 to 2000. For the global economy, the percentage of persons aged 15 to 64 increased from 56.4 in 1960 to 60.9 in 2000. In Panel B, we see the clear U shaped pattern of our second age structure measure *PRIMEAGE* –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 (0.884)	0.620 (0.884)	0.728 (1.025)	0.934 (1.025)	0.737 (1.152)	0.817 (1.152)
13. Interquartile Range (p75 – p25)	1.096 (1.299)	0.906 (1.299)	0.584 (1.684)	1.444 (1.684)	1.183 (1.809)	1.453 (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 (0.884)	0.781 (0.884)	0.500 (1.025)	0.800 (1.025)	0.740 (1.152)	0.802 (1.152)
13. Interquartile Range (p75 – p25)	0.756 (1.299)	1.025 (1.299)	0.514 (1.684)	1.275 (1.684)	1.326 (1.809)	1.398 (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 dispersed 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 that¹⁸

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 $E[\varepsilon_i^m | \text{mature}] = E[\varepsilon_i^g | \text{young}] = 0$. The log per capita output gap between mature and young countries at time t will be denoted by

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

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:

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

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)

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

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

$$y_t^g = E[y_t^g]$$

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:

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

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	
	[1] Raw	[2] Adjusted	[3] Raw	[4] Adjusted
1960				
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 (Δy)	1.233	0.573	1.168	0.385
4. Relative Demographic Maturity Effect ($y - y^s$)	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 (Δy)	1.712	1.190	1.696	1.081
4. Relative Demographic Maturity Effect ($y - y^s$)	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 ($y_{00} - y_{00}^s - (y_{60} - y_{60}^s)$)	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 ($y_{00} - y_{00}^s - (y_{60} - y_{60}^s)$)	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 $(Y_{60} - Y_{60}^g)$ denote the relative effect of demographically mature countries on global GDP per capita in 1960 and let $(Y_{00} - Y_{00}^g)$ 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

$$D = \underbrace{(Y_{00} - Y_{00}^g)}_{\Delta(Y_{00})} - \underbrace{(Y_{60} - Y_{60}^g)}_{\Delta(Y_{60})} \quad (6)$$

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

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

and

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

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:

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

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

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

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 $\lambda > 0$.

