DOCUMENTO DE TRABAJO

DEMOGRAPHIC MATURITY AND ECONOMIC PERFORMANCE: THE EFFECT OF DEMOGRAPHIC TRANSITIONS ON PER CAPITA GDP GROWTH

Documento de Trabajo n.º 0318

Rafael Gómez
and Pablo Hernández de Cos

BANCO DE ESPAÑA
SERVICIO DE ESTUDIOS

DEMOGRAPHIC MATURITY AND ECONOMIC PERFORMANCE: THE EFFECT OF DEMOGRAPHIC TRANSITIONS ON PER CAPITA GDP GROWTH (*)

Documento de Trabajo nº 0318

Rafael Gómez
LONDON SCHOOL OF ECONOMICS

Pablo Hernández de Cos
BANCO DE ESPAÑA

(*) We are particularly grateful to Cristina Barceló, Olympia Bover, Ignacio Hernando, Morley Gunderson, Eloísa Ortega, Gabriel Pérez Quirós, Javier Vallés and an anonymous referee 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 Weiche, Kenny Sandorffy and Konstantinos Tzioumis is greatly appreciated.

BANCO DE ESPAÑA
SERVICIO DE ESTUDIOS

ISSN: 0213-2710 (print)
ISSN: 1579-8666 (online)
Depósito legal: M. 1662-2004
Imprenta del Banco de España

Abstract

This paper estimates the response of per capita GDP growth to changes in the proportion of mature workers across countries. We define and estimate the effect of demographic maturity in two ways. First, a growing cohort of working age persons (15-64) is found to have a large positive effect on growth of GDP per capita. Second, an increase in the number of prime age workers (35-54) as a fraction of the total working age population (15-64) is found to have a positive but diminishing effect on per capita GDP growth. We find 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. Several well known theoretical models of economic growth and labour market performance are consistent with these findings. In particular, the standard life-cycle framework, "Mincerian" earnings equations and personnel economic models of optimal mixes of youth and mature human capital all find confirmation in these estimates.

Keywords: growth, demography, age structure

JEL classification: J13, J16, O11, 040

1. Introduction

"What will you do, when you have built all the houses, roads, town halls, electric grids, water supplies and so forth, which the stationary population of the future can be expected to require?" Keynes (1937:100).

A Spanish woman reaching childbearing age in 1970 could expect to have 3.6 children; a similarly aged Spanish woman in 2000 could expect to have only 1.2 children. In countries such as Spain, with declining fertility rates and slow growing populations, mature cohorts account for larger shares of the total population than they do in fast growing ones [Greenwood and Seshadri (2002)]. Demographic transitions such as this, though partly endogenous, can also exert independent effects on the macro-economy. This is because the size and structure of the current working age population is a function of past fertility and hence predetermined with respect to current economic conditions and institutional arrangements (Feyer 2002). Demographic transitions are therefore both a product of, and a causal factor in, economic growth; the latter of which is the focus of this paper[1].

The causal relationship between demographic maturity and economic growth can be viewed in two ways. First, a country that undergoes a fall in its birth rate experiences an initial decline in the ratio of dependents to working age persons. This, in turn, has a positive effect on economic growth through declines in the dependency ratio (i.e., fewer mouths to feed) and consequent increases in the relative size of the workforce. Savings rates and labour force productivity may also be affected by a growing working age population; though the direction of these latter two channels is more ambiguous, given that savings follows a lifecycle profile and that general human capital embodied in education and specific human capital embodied in experience varies systematically by age of worker.

These latter two observations highlight a less often discussed, but equally important link between demographic transitions and economic performance. By making a country more mature, falling birth rates affect not only the size but the structure of

[1] Galor and Weil (1996) made fertility decline part of their feedback-loop model, whereby declines in fertility (brought about by rising woman's wages) raise capital per worker, and hence growth.

the working age population. A country with a greater number of mature persons will differ substantially from one that is younger, even if both have workforces that are of the same relative size. In particular, if we consider that labour force participation and productivity peak sometime during the prime working ages of 35 and 54 –when the balance between formal education and experiential human capital reaches its optimum– then the productive capacity of a society with a large fraction of prime age persons (35 to 54 year olds) should be greater than of one with many new entrants in the labour force. Insights from the firm-level simultaneously reinforce and attenuate this view [Lazear and Freeman (1997)]. Not only do firms require workers with experience, they also require the right combination of youth and maturity; highlighting the need for an optimal, rather than a strictly greater, number of prime age workers in order to maximise output.

In this paper we analyse both maturity effects in the context of the empirical growth literature. Using a large cross-country panel spanning the past fifty years, we show that there is a positive relation between the ratio of working age persons (aged 15 to 64) over the total population and per capita GDP growth. This finding is quite robust to specification changes and specifications which consider the potential role of endogeneity caused by outward and inward migration. We also find that just as experience tends to have a curvilinear relationship with respect to individual productivity, so too at the macro-level, the maturity of a given working age population – proxied by the ratio of prime age persons (aged 35 to 54) over the total working age population (aged 15 to 64)– exhibits positive but decreasing returns. We calculate that the turning point for maximum growth occurs when roughly 36 percent of a country's working age population is aged 35 to 54.

Apart from their empirical value, these findings are important in three other respects. First, they help explain a number of the well known productivity "miracles" of the last half century. In keeping with recent findings by Feyer (2002) and Bloom and Willimson (1998), much of Southeast Asia's robust economic performance –in particular Japan's post-war economic takeoff and its decade long slump during the 1990s– can be attributed to changes in both the size and structure of the working age population. The results also shed light on the divergence over the last twenty years between rich and poor nations, which has occurred at the same time as rich nations have aged while poor nations have seen their working age populations grow younger.

Lastly, the findings may also be relevant for the future as the positive effect of a demographic transition with respect to economic growth may be ultimately just that: transitional. According to United Nations demographic projections, persistently low birth rates will produce a decline in the size of the working age population and an increase in old-age dependency ratios in most high income economies over the next fifty years. This process of population "aging" has already raised concerns over spiralling healthcare costs, the sustainability of public pension systems and fears of dampened economic performance. Our results show, however, that in terms of economic growth, the impact of population aging will not be so clear-cut[2]. In particular, taking current population projections as given, our empirical results suggest that the negative impact of falling working age populations will be partially compensated for by positive age structure effects during the first half of the coming century. This is particularly relevant for a number OECD countries (i.e., Germany, Italy, and Japan) currently affected by low fertility rates and rapid demographic transitions.

The remainder of the paper proceeds as follows. Section 2 asks how it is that age structure might affect economic growth and income per capita. It discusses both macro and micro evidence related to the age structure of the population and suggests why there may be a benefit to countries that witness a demographic transition of the type described in our opening paragraph. Section 3 discusses the empirical approach. Section 4 describes the data. Section 5 presents the results along with robustness checks. Section 5 also presents the results of our sensitivity analysis. Section 6 uses the results to inform us about historical cross-country episodes and about the future growth prospects for a selected group of OECD and Non-OECD countries facing the most acute aging pressures. Section 7 concludes.

[2] The current literature on the effects of population aging has mainly looked the consequences of falling working age populations and has failed to adjust for changes in the age structure of the population. A well known example are the ECOFIN (2001) projections, which only use the size of the working age population (1[st] order effects) to predict future growth rates. These overstate productivity and growth rate declines for countries with persistently low birth rates over the last thirty years (i.e., principally Germany and Japan).

2. How Does Demographic Maturity Affect Economic Growth?

2.1. Maturity and the "Canonical" Growth Literature.

Can demographic maturation stimulate, rather than dampen, economic growth? To answer that question we first examine the potential effects of a maturing population on the growth rate of income per-capita through the lens of the neo-classical production function, where output growth is a function of factor accumulation and technological efficiency. To fix ideas, consider the basic Solow-Swan production function augmented with human capital:

$$[1] \qquad Y_{it} = (K_{it}^{\beta} H_{it}^{\alpha}) A (L_{it})^{1-\alpha-\beta}$$

Here the impact of maturity will depend on the adjustment of the determinants of output –i.e., labour supply L, physical capital K, human capital H and an index of technical efficiency A– to changes in age structure.

The most obvious link between maturity and output can be seen if we simply trace through the effect on labour supply L of a constant or rising birth rate in *t-1* followed by a subsequent decline at time t (i.e., the effect of a "baby boom" and a "baby-bust" on the economy). As a reference point we take the case of Japan, which as seen in Figure 1 and Table 1, follows this pattern fairly closely. At time t, the demographic transition which began a decade earlier begins to have an impact over potential labour supply, since an increasing ratio of working age persons over the total population increases $L_{i,}$ which in turn positively affects Y_{it}. This is the positive first order (mechanical) effect of a demographic transition.

[Figure 1]

However, demographic transitions affect not only the size but the structure of the working age population, thus playing a potentially important role in capital accumulation, both physical K and human H. This is the second order effect of a demographic transition on growth[3]. In a country where the birth rate has fallen for any length of time, a predetermined maturation of the working age population will occur at time *t+15* –the earliest age at which a person typically can start to work. A higher ratio of working age persons and a working age population made up of a larger cohort of mature (35 to 54 year olds) versus young (15 to 34 year olds) workers, in turn, affects the stock of physical capital through its impact on savings. Under the standard life-cycle model, individuals smooth consumption over the course of their lifetime, hence, they borrow when they are young and save when they are economically active, and in particular, save most when they are of prime working age[4]. This implies that a demographic transition will have a positive impact on aggregate savings –and indirectly affect the stock of capital– in that fewer dependents and a greater percentage of prime-age persons will increase the savings rate. An increase in exogenous savings brought about by the growth and maturation of the working age population should therefore have a positive (second-order) effect on per capita output.

[Table 1]

The link between age structure and human capital accumulation *H* centres on education and learning-by-doing, two factors essential in fostering productivity. The stock of individual human capital peaks when the balance between formal education and experience reaches its optimum[5]. This tends to happen sometime during the prime working ages of 35 and 54, after which diminishing returns begin to set in[6]. An economy with a fat cohort of prime age workers should therefore be more productive than an

[3] To see this more clearly, imagine two countries sharing working age populations of the same relative size. Both are equally mature in the sense that both share the same relative "mean" level of working age persons. The first order effect should therefore be identical. However, one country by virtue of having had more recent falls in its fertility rate has a greater mature share of workers than the other. Two workforces of the same relative size may therefore be composed of either a greater share of young (15-34) or prime-age (35-54) workers.

[4] See Modigliani (1986) and Modigliani and Ando (1963) for classic references in this regard.

[5] Fougere and Merette (1999) also suggest that under a situation of scarce employment, incentives to human capital investment increase.

[6] More precise estimates can be found if we consider the typical Mincer (1974) wage regression, where experience is entered along with its square to reflect the rising but diminishing returns of experience with respect to productivity. Empirical evidence suggests that wages peak for US workers with 33 years of experience [Kruger and Pischke (1992)]. If workers earn their marginal product, then earnings equations imply a 50 percent difference between the productivity of a 20 year old worker as compared to that of a 50 year old with the same formal level of schooling. This Mincerian regression evidence, though fast approaching its thirty year mark, is still considered by most labour economists as the most useful "workhorse" model of wage determination [Lemieux (2002)].

economy populated by younger workers. This type of "Mincerian" evidence also implies that a turning point should be observed with respect to output per person, whereby too many workers at the mature end of their working lives should be associated with slower output growth.

Finally, with regards to the potential impact of maturity on technical efficiency, A, endogenous growth models allow for the introduction of several links between demography and technology. At the macro-level, some authors argue that new entrants in the labour market are the main channel for the creation of new knowledge and innovation [Simon (1986) and Ermisch *et al.,* (1987)]. At the individual level, there is evidence to suggest that the capacity to invest in new technology is significantly constrained by age, but that technological adoption may actually be accelerated, rather than hindered, by the presence of mature workers [Weinberg (2002)].

The Mincerian and technological adoption evidence above suggests that economies benefit from having more experienced workers, but only up to a certain point, since a mix of young and old workers is likely to produce the most productive work environment. Imperfect substitutability between the human capital of young and old workers may therefore be a key feature of aggregate production and may even help explain why per capita output does not converge instaneously, as some open-economy growth models suggest [Kremer and Thomson (1998)]. Micro-level evidence drawn from the field of personnel economics [Lazear and Freeman (1996)] reinforces this view, in that mature workers are easier to monitor, have greater firm specific human capital and more general skills learned on the job, whereas young workers, though they impose larger monitoring costs on the firm[7], bring with them new ideas and general human capital embodied in formal education.

2.2. The Effect of Second Order Maturity

In order to explore the implications of the above reasoning a bit further, consider a variant of eq. [1], where an economy consists of firms that produce output Y with

[7] This emerges because true ability and effort is difficult to observe, and takes time to be realized by employers.

technology A but instead of utilising one type of labour, utilize mature L^m and young L^y labour inputs,

$$[2] \quad Y = (K^{\beta} H^{\alpha}) A (L^m + \theta L^y)^{1-\alpha-\beta} ,$$

where θ is the marginal product of L^y relative to L^m. If workers were perfect substitutes then relative productivity would be $\theta = 1$, and there would be no single mix of both labour inputs that would maximise output. In equilibrium with perfect substitutability, firms would be indifferent to the proportional mix of young and mature labour employed. However, if mature and young labour are not perfect substitutes (i.e., mature labour is more productive $\theta < 1$), but both young and mature human capital are necessary in production, then firms maximise labour output using a production function similar to that found in Neumark (1988):

$$[3] \qquad Y = A(L^m + \theta L^y) - \delta\left(L^y \,/\, L^m\right),$$

where δ is akin to a "discrimination" coefficient capturing the desire of firms (other things equal) for mature workers. In this set up, however, employers care about the relative level of L^m rather than the absolute level since they recognize that some balance between youth and experience is required. Maximization of [3] implies that the (falling) marginal product from one additional unit of L^y is not fixed, but depends of the relative level of L^y. The impact of this type of production structure on output is captured in Figure 2, where the effect of maturity with respect to output growth follows an inverted U pattern. A country populated with an optimal level of mature human capital L_o^m relative to the total working population, will grow faster than a country which has either too few L_1^m or too many L_2^m mature workers. Note, as well, that persistent birth rate declines will push countries past the optimal maturity ratio, ultimately dampening rather than promoting growth.

[Figure 2]

This model does not preclude heterogeneity as δ may vary across firms or different economies; i.e., economies with a higher δ will employ more L^m at the expense of L^y. Why would firms or economies differ in their need for mature labour? Two reasons seem plausible. First, the more idiosyncratic are firm or country experiences, the higher will be δ since mature workers are likely to have better knowledge of these idiosyncratic details. Second, to the extent that on-the-job skills are relatively more important than skills learned in formal education, mature workers will again be more desired since there will be a greater need for "mentors" and senior workers fill that role better than younger ones.

At the cross-country level, this model implies that second order maturity may not always be associated with improved economic performance. Specifically, a greater cohort of mature workers unambiguously benefits a country's output per capita only if an economy is are already below the optimum[8]; if firm or country experiences are highly idiosyncratic; or if on-the-job skills are relatively more important than general skills. Otherwise, most countries prefer a more balanced workforce composed of both young and mature human capital.

3. Empirical Methods

The theoretical discussion above has highlighted two testable implications related to maturity and economic performance: (1) that the first order effect of a demographic transition should have an unambiguously positive impact on economic growth (i.e., the coefficient associated with the ratio of working age persons aged 15 to 64 over total population should always have a positive sign with respect to growth); and (2) that second order maturity should have a positive but curvilinear effect with respect to economic growth (i.e., increases in the proportion of working age persons aged 35 to 54 over the potentially active population should exhibit positive diminishing returns with respect to economic growth). Methods for estimating each of these empirical propositions are modelled below.

[8] If firms are already past the optimum, they benefit from a falling rather than a rising ratio of mature age workers.

Most empirical studies that analyse cross-country economic growth make use of the so-called convergence equation, popularised by Barro and Sala-i-Martin (1991), and Mankiw, Romer and Weil (1992), which follows a general specification like this:

$$[4] \quad \ln y_{it+1} - \ln y_{it} = \Delta \ln y_i = a_i + \beta \ln y_{it} + \theta X_{it} + e_{it} ,$$

where $\Delta \ln y_i$ is the growth rate of per capita GDP for country *i* between time *t* and time *t+1*, and is regressed against y_{it} the per capita GDP for country *i* at time *t* ,a time-invariant country specific effect a_i , a vector of determinants of growth X_{it} , and e_{it} the error term. This framework is generally used to test the conditional convergence proposition, which states that the rate of growth between two periods is a decreasing function of initial levels of income per-capita and distance to the steady state. The vector X_{it} therefore controls for differences in the steady state across countries, which is generally proxied by the share of output devoted to accumulated physical s_k and human capital s_h , the growth rate of population *n*, the exogenous rate of technological progress (ϑ) and the depreciation rates (σ_k and σ_h assumed to be equal).

An equation like this can be derived from the augmented Solow model in eq.[1] with constant returns to scale, but is also consistent with some endogenous growth models that predict different forms of convergence to the steady state. In this paper we are not interested in validating different models of economic growth. We instead use this specification because it captures most of the common factors that have traditionally been considered as determinants of growth[9]. Specifically, we treat the age structure of the population as an added proxy for the steady state to estimate a version of [5] with demographic measures added. Both first and second order age structure effects are captured with these added measures. The variable *mature* captures the first-order aging effect and is defined as:

[9] The specification also resembles recent work by Persson (2002), Malmberg (2001) and Bloom, Williamson and Canning (2001) which has linked age structure to growth and therefore provides some approximate comparably for our results.

$$[5a] \quad mature_{it} = \frac{\sum_{i=15}^{64} W_i}{\sum_{i=0}^{99} P_i}.$$

The variable is a ratio which measures the number of potentially active persons (15-64) *W*, over the total population *P*. Our expectation based on our theoretical discussion in section 2, is that countries with higher shares of mature persons will experience faster growth. Our second ratio measure, *primeage,* captures the fact that both productivity and labour force participation rates vary by age. We use the number of persons aged 35 to 54 over the total number of potentially active persons to estimate:

$$[5b] \qquad primeage_{it} = \frac{\sum_{i=35}^{54} w_i}{\sum_{i=15}^{64} W_i}.$$

This measure recognizes that the productive capacity of a society with a high fraction of people in the prime age of their careers is higher than that of a society with many new entrants in the labour force. Beyond a certain threshold, however, having too many mature workers may actually dampen growth. Our preferred estimates therefore preserve the *primeage* variable as a ratio measure along with its square:

$$[6] \quad \Delta \ln y_i = a_i + \beta \ln y_{it} + \theta X_{it} + \delta \cdot \ln mature_{it} + \varphi_1 \cdot primeage_{it} - \varphi_2 \cdot primeage_{it}^2 + e_{it}.$$

Second order maturity effects estimated as in [6] will test whether there is a significant turning point in the data and allow us to more accurately identify the non-linear effects of second order maturity implied under the Mincerian and personnel economic literature surveyed. Finally, note that by controlling for the stock of physical capital and technical progress, the only age structure channels captured by [6] are those arising from experiential human capital and firm level maturity effects described in sections 2.1 and 2.2, respectively.

4. The Data and Descriptive Findings

This paper employs a composite dataset made up of version 6.1 of the Penn World Tables (2002) and data provided by the United Nations Population Division. The Penn World Tables, which Summers and Heston (2002) have been collecting for more than a decade, includes observations from 1950 to 2000 for approximately 144 countries. It is used primarily for its PPP adjusted measures of income per-capita across countries. A second data source, the United Nations World Population Prospects, provides corresponding demographic data for 160 countries from 1950 to 2000 –with age structure and population projections running until 2050.

Table 2 provides a descriptive overview of the patterns of changing age structure that have occurred across countries over the past four decades. The table documents changes in our two key measures of maturity; i.e., *mature* [the share of the potentially active working age population (15-64) over total (15-65+)] and *primeage* (the proportion of workers aged 35-54 over the entire size of the potential active working age population) as well as a third measure *primeyouth* [the ratio of prime-age workers (35-54) over the young (15-34)]. The first row of the table documents the all country total and shows no dramatic shift in first order maturity from 1960 to 2000 (the percentage of persons aged 15 to 64 increased from 56.4 in 1960 to 60.9 in 2000). Instead it confirms the U shaped pattern in second order maturity brought about by the delayed effect of the post-war baby boom, which from the 1960s to 1980s, made many national workforces younger than their historical averages.

Comparisons of age structure patterns for different country groupings –such as between OECD and Non-OECD countries as seen in Row 2 and in Figure 3– show that the all country average masks a marked diversity of age structures. Countries in the OECD have had larger percentages of mature persons over the total working age populations from the 1960s onward, and despite having grown younger in the 1970s and 1980s, the OECD never approached levels found in the Non-OECD world. In 2000, 42.7 percent of the OECD´s working age population was aged 35 to 54 versus 33.7 percent for the non-OECD world. Specific country examples in Row 6 also show the heterogeneity that is masked if we look only at world totals in Row 1.

[Figure 3]

Rows 3 through 5 of Table 2 illustrate what are probably more interesting facts about age structure over the past 40 years: the dramatic difference in the proportion of prime age workers between countries with high and low indices of civil liberties and individual freedom and the consistently higher proportions of prime age workers in more equal societies (as measured by the Gini ratio) and in countries with greater political participation (as measured by the percentage of voting age population who casts a vote).

[Table 2]

One way to summarize the shifts in age structure across country groupings and illustrate the resulting differences in the distribution of per capita income and savings rates is to define convergence club groups based on quartiles of per capita income and savings rates, and then compare the percentage of prime age workers in these convergence clubs over four periods[10]. This method is illustrated in Figures 4 and 5 which show the percentage of mature workers (using our three definitions) for two different quartiles –a quartile grouping based on real GDP *per capita* (measured in PPP terms) and a second based on savings rates. Panel A in figure 4 shows that in all three periods, the percentage of potentially active workers was highest among countries in the upper income quartiles. Panel A in Figure 5 shows an even more consistent tendency towards increasing proportions of working age persons amongst countries with high saving rates.

Panels B and C use *primeage* and *primeyouth* measures of maturity. The pattern in Panel C demonstrates perhaps the most dramatic divergence in age structure between upper and lower convergence club countries, with countries in the lower quartiles demonstrating a much lower share of prime age workers relative to the young. By the year 2000, top quartile countries basically have equal shares of young and mature workers whereas in lower quartiles that share is still below 50 percent (i.e., two young workers for ever one prime age worker).

[Figures 4 and 5]

[10] Each period is defined as the average in and around the year identified. For example, 1960 refers to the average of observations made from 1958 to 1962. This is done to smooth out any possible cyclical and measurement variation in the data.

Finally, note that the 1980 data for figure 4, which shows a similar pattern to the 1960 and 2000 observations, has the lowest percentage of prime age workers for all quartiles and also the least mean difference between upper and lower convergence club groups. This is the effect of the post-war baby boom that was mentioned above, and which made mature countries converge, in demographic terms at least, with their younger counterparts. The fact that income gaps between the two sectors remained relatively stable during this period is indicative of the possible significance of demographics in accounting for convergence (divergence) episodes and the sustained divergence of per capita output observed across countries today. In summary, the descriptive cross-country evidence indicates the following:

- Table 2 and Figure 3 demonstrate that the post war baby boom (the period of high birth rates from 1945 to 1965 in many occidental economies) made mature and young countries converge in terms of the *primeage* ratio (35-54/15-64) between 1960 and 1980 and then diverge again afterwards.
- Figures 3 and 4 show that the convergence in age structures during this period also corresponds to relative stability in the income differential between mature and young countries (compare 1980 to 1960 and 2000 respectively in Figure 4).
- Figure 5 shows that savings rates in particular are highly correlated with a more mature population as predicted under the standard life-cycle framework.

To see how quantitatively "important" these age structure differences are in explaining cross-country growth rates, we turn now to the results of our formal empirical analysis as outlined in section 3.

5. Results

We estimate [6] using a balanced panel of 84 countries[11]. The sample is split into 4 ten year periods beginning in 1960 and ending in 2000. This gives us a total of 364 observations. Our dependent variable is the percentage change of GDP per capita over a 10 year period[12]. The values of our steady state and demographic variables are all initially proxied by their ten year averages. A list of countries along with variable definitions is provided in the Appendix.

We use fixed-effect (within group) estimations as our benchmark since no justification is needed for treating country specific effects as uncorrelated with our steady state variables (as is assumed under the random effects model). Furthermore, the within-group estimates are the most appropriate form of panel estimation for inter-country comparisons since we can be confident that differences between countries are treatable as parametric shifts of the regression function (Green 2001: 567). However, recognizing that there is also some cause for treating individual effects as random (Mundlak 1978) and that the specification of our model may need to distinguish between the effects of permanent and transitory changes in maturity on growth (see section 6 below), we present the random effect results alongside the within estimations.

Table 3 reports estimates of equation [6], with all variables measured in logs[13]. The coefficients in column 1 imply that the unconditional first order effect of maturity is decidedly positive[14]. Specifically, a one percent increase in the ratio of persons aged 15 to 64 over the total population increases economic growth by 1.08 percent over the course of a decade. Given that the ten year compound average GDP growth rate was 19.8 for the entire sample period, these impacts appear very small. However, if we calculate this

[11] Countries are often missing data and hence drop out of our sample. Out of the 106 countries that had complete LHS data, 22 were either missing two or more key pieces of RHS data or were categorised as having low quality data by Summers and Heston. We therefore chose to focus on a high quality balanced sample in order to run our estimates.

[12] The decision to employ a 10 year period is threefold. First, demographic variables are collected by a national census prepared every decade, while intervening figures are often obtained by merely linearly interpolating figures of two consecutive census periods. More importantly, it is difficult to find significant changes in the demographic variables in shorter time-periods. Finally, 10 year growth rates also smooth out any short-run output fluctuations.

[13] As is common in the literature, the values 0.02 and 0.03 are employed for our measure of technological progress θ and depreciation σ, respectively.

[14] The estimate is unconditional in the sense that we leave out the structure of the working age population (*primeage*) as a control.

unconditional first order effect using a more realistic increase in the ratio of working age persons (over the course of decade) we get a slightly different picture. A five percent increase in the average number of persons aged 15 to 64 over the total population –which is equivalent to a 3 percentage point increase in a mature ratio whose starting level is 60 percent– now leads to a more important 5.4 increase in the ten year growth rate.

Controlling for second order effects (column 2) dampens the *mature* coefficient slightly –a five percent increase in the relative size of the working age population shifts decade growth by 4.5 percent– but with the estimates remaining significantly positive. The findings in column 2 also suggest that second order effects have a positive impact on medium term growth[15]. However, the estimates for the *primeage* coefficient are half those of first order effects and insignificant at conventional 10 percent levels.

[Table 3]

Two problems, however, exist with the estimations in columns 1 and 2. First, one possible reason for the lower than expected and insignificant *primeage* coefficient is that the effect of second order maturity with respect to growth is not properly captured with the log share of *primeage* workers. What we need is a squared term that accurately identifies the turning point in the data, as specified in eq. [6]. The results in columns 1 and 2 have therefore not confirmed, or, refuted our expectations surrounding the non-linear effects of a working age population with respect to growth. Moreover, a second and potentially more serious specification problem exists with the endogeneity of our demographic variables, which are measured as ten year averages. The problem of endogenity is addressed below.

5.1 Does Faster Growth Induce Greater Demographic Maturity?

One possible explanation that is not captured in the estimates above is the possibility that the relationship between maturity and economic performance is largely spurious and the result of either endogenous fertility decisions or *ex post* migration

[15] The coefficient attached to *primeage* should be interpreted with respect to the log ratio of the population aged 15 to 34 and 55 to 64 over total working age population since these ratios sum to 1. The decision to drop these two variables allows for a more intuitive interpretation of the *primeage* coefficient.

decisions. Taking each possibility in turn, the first question we may ask is the following: "Why might an increase in the mature share of the working age population caused by a period of rising then falling birth rates twenty years earlier lead to an increase in economic growth and levels of income per capita today?" As noted by Shimer (1999), one possibility is that birth rates are endogenously determined by the collective decisions of parents[16]. While endogenous fertility decisions are undoubtedly important, they seem an unlikely source of endogeneity in this instance. Our growth estimates are based upon a 10 year growth rate and our demographic age structure measures are predetermined at a minimum fifteen years prior to our performance measures. This means that parents in a given country from year *t-25* would have to anticipate the state of the economy in year *t* in order for our results to be compromised. Economists rarely agree on the performance of the economy in the next quarter let alone quarter of a century. Such precise beliefs amongst households not only seem implausible but stand opposed to much of the empirical evidence[17].

The second possibility, which is harder to ignore, is that the relationship between age structure and growth may be caused by migration patterns. It may be that working age person's move from regions that are depressed to regions where the economy is strong. Part of this effect would be picked up in our panel estimation since countries with persistently stronger economic performance would be captured by the country *i´*s fixed effect. A remaining portion of the migration effect, however, would remain since a temporary increase in economic performance in country *i* might temporarily attract more working age person's and simultaneously lower the proportion of working age persons in slower growing country *j*. To mitigate the possibility of reverse causality we measure our first and second order demographic variables –*mature* and *primeage*– at the beginning of

[16] Suppose parents expect strong economic growth in the future, this may lead to an increase in fertility today, as parents anticipate being able to support more children. This effect, however, is only transitory as more parents begin to realise that by having more children, the relative opportunity of each individual child diminishes by labor market overcrowding, and so the fertility rate begins to fall thus producing the demographic transition described earlier.

[17] This does not contradict the generally accepted notion of the *modern growth regime*, which is characterized by steady state growth in both income per capita and technology [Galor and Weil (2000)]. In this regime there is a negative relationship between the level of output and the growth rate of population. According to Galor and Weil (1996), however, a positive feedback loop may also be present, whereby falling birth rates raise capital per worker and accelerate growth even further. What we are doing, therefore, is isolating the "delayed" effect of this latter demographic reinforcing mechanism on growth.

each growth period rather than as the decade average[18]. The econometric specification can be improved upon even further by controlling for the possible simultaneity bias of our steady-state regressors (i.e., education and investment). Columns [3] and 4] in Table 3 show the results if we measure all RHS variables as initial starting period values.

Controlling for potential endogeneity does indeed have an important effect over our initial first order estimations. In column [3] one notices quite strikingly that the coefficient for *mature* falls by almost 50 percent as compared to column [1] (from 1.080 to 0.593). Though the coefficient remains significant, such a drop is indicative that controlling for potential endogeneity provides a more conservative estimate of the effect of demographic maturity on economic performance. What is also noticeable in column [4] is how well the anticipated non-linear second order maturity effect shows up in our estimations with the squared *primeage* term. In column 4 a turning point is significantly identified for our *primeage* variable. Increases in the ratio of workers aged 35 to 54 over total population increase the 10 year growth rate up to 0.361 and thereafter increase growth at a decreasing rate. Or, alternatively stated, evaluated at an initial level of 34 percent, the effect of a 1 percentage point increase in the ratio of prime age workers over total population on the 10 year growth rate is 5.6 percent, whereas a 5 percentage point change increases growth by only 2.8 percent.

In terms of our steady state variables, results are broadly consistent with the "classical" convergence literature [Sala-I-Martin (1996)], in that the coefficient attached to initial *per capita* GDP Y_{it} is significantly negative across all specifications, and that s_k (as proxied by the average investment share) is significant and positive. Both the average rate of population growth n (adjusted for rates of depreciation and technological

[18] This of course is not a perfect solution. The use of lagged instrumental variables could perhaps provide more credible results. The problem is that if we take prior period demographic measures as our instruments we lose at least one period of observations, (which in a four period panel means 25 percent of our sample). The ideal solution would be to find immigration data by age and adjust the *mature* and *primeage* ratios accordingly. Unfortunately UN population data only provided immigration numbers for a select number of countries. Moreover, emigration numbers were not included for any countries.

progress) and human capital s_k (proxied by the average years of schooling) were insignificant[19].

5.2 Robustness Check I: Estimates Using Per Capita Output Levels

An added check of the demographic maturity effect is conducted in table 4, which repeats the estimations in Table 3 using per capita income levels as our dependent variable. Apart from the exclusion of the conditional convergence term, the same specification as in our growth estimation is used in both tables. The results are supportive of a positive first order and an inverse second order effect. The first order effect is larger and the turning point in our fixed effect estimation is slightly lower than for our growth estimates; income levels peak (other things equal) when roughly 0.345 of the working age population is aged 35 to 54.

[Table 4]

5.3 Robustness Check II: OECD Sub-sample Estimates

The estimates in Tables 3 and 4 are repeated for a sub-sample of OECD countries in Tables 5 and 6. We restrict our focus to the 23 countries which have been part of the OECD since the 1960s. The advantage of analysing this sub-sample is that institutionally these countries are much more similar than the entire sample, but demographically they still differ quite significantly from each other. This may help to isolate more precisely the effects of maturity on growth. The results in Table 5, as judged by the R^2, confirm that our OECD estimates offer a far better prediction of model [6]. The point estimates do not change appreciably from comparable all country results in Table 3. The turnaround point for second order maturity occurs at 0.359 and the first order effects appear slightly less important (a coefficient of 0.370 vs 0.590). This is not surprising since the OECD sample has experienced a relatively greater change in the structure of the working age population (see Figure 1 and Table 2) than in its relative size over the last fifty years.

[Tables 5 and 6]

[19] Using initial periods does very little to alter our steady state variables except for investment share of GDP whose coefficient falls from 0.177 to 0.086 when initial periods are used.

5.4 Robustness Check III: Why not adjust for labour force participation rates?

It is important to note that the data used in the previous estimations did not control for the size of the economically active population. As such, we have measured the unconditional effect of the size and structure of the potentially active working age population on output, rather than these effects conditioned on effective labour supply. We preferred these UN population measures to a similar ILO dataset that adjusts for effective labour supply, primarily because participation rates are less reliably measured across countries than demographic data and participation rates also likely to suffer from greater endogeneity problems with respect to economic performance.

In principle, however, the different channels through which population might impact growth, as described in section 2, would be better captured by the effective labour force rather than by the potentially active working age population. Indeed, the choice between these two measures might not be irrelevant for the results, since major changes in participation rates have been observed in the last four decades in many countries. The participation of women, for example, has significantly increased in many countries while that of people over 50 has dramatically fallen. Likewise, irregular participation in the labour market might be quite relevant in some developing countries. Lastly, the use of the potentially active working age population posses the problem that this variable might be capturing not only supply side effects as outlined in our theoretical framework, but also demand effects related to differences in the composition of expenditure by age group.

In order to see whether our results are robust to the inclusion of effective labour supply, three different robustness checks were made. First, total participation rates were added to our growth estimates. Specifically, using data from the ILO (http://laborsta.ilo.org/), the ratio of the total labour force to total population was used as an added control. Apart from this change, the same specification as our growth estimation in columns 3 and 4 of Table 3[20] was used (available upon request). The

[20] This corresponds to our fixed effect estimation with initial values for correcting for adjusting for endogeneity problems.

coefficient on this alternative mature variable is again highly significant, though its value does fall. When, for example, the same specification as in our growth estimation in column 4 of Table 3 is used, the coefficient on our first order effect is 0.571 instead of 0.590. These results also hold for our level estimates.

Second, we estimated equation [6] replacing our previous definition of mature (the size of the potentially active working age population) by the ratio of total participation in the labour market to total population. The results (available upon request) are again supportive of a positive first order effect, and an inverse second order effect. The results, in fact, turn out to be larger and more significant. These estimates were repeated for the OECD and level estimates, and again the results are significant and robust to inclusion of participation rates.

Third, in order to control further for potential demand-side effects associated with our population variables we included in our estimates two additional regressors, the ratios of private and public consumption to GDP respectively. These variables take into account the fact that a more mature population results in a different level and structure of government consumption, which, in addition, might have consequences for productivity and growth. When including these additional regressors in our estimates, the results do not change significantly; the coefficient on *mature* 0.590 in our original estimate in Table 3 falls to 0.573.

5.5. Sensitivity Analysis: Distinguishing Between Transitory and Permanent Changes to Maturity

The estimations above have captured the positive effects of changes in demographic maturity; but what happens to a country whose birth rate drops and fails to recover? One of the implications of section 2.2 was that the positive effect of a demographic transition on economic growth may be ultimately just that –transitional. This is because a prolonged fall in the birth rate will, in the absence of large scale immigration, give rise to working age maturation beyond the point which is optimal, thus reversing the positive maturation effects which occur in the short-to-medium term. As noted earlier in Figure 2, a country with a long-run average ratio of mature workers located at L_2^m will experience slower growth than a country with a slightly younger population located at L_3^m. Persistent falls in the birth rate also imply that the number of working age persons in incoming cohorts is smaller than in outgoing ones, causing the relative size of the working age population (our first order effect) to decline.

In light of these observations, one of the noticeable and somewhat bothersome results in Table 3 is the large discrepancy between our fixed and random effect results. A standard Huasman test confirms that the coefficients from both estimations are not the same. This means that either eq. [6] is incorrectly specified, or that country specific effects are indeed correlated with the X's and that the random effect model is untenable. While the latter is the most likely candidate, given our discussion above, the former is also a possibility. A clue as to how important this former possibility may be, is the fact that the random effect estimator is a weighted average of the estimates produced by the between-effect and fixed-effect estimations. One reason, therefore, for the discrepancy between the random and fixed-effect estimates may be that average (four-decade) changes to second order maturity have a distinct affect on average (four-decade) growth.

To deal with the potential consequences of prolonged maturation we consider a variation of model [6], where changes in the (four-decade) average value of *primeage* for an individual country will have a different effect than single period departures from the (four-decade) average. To fix ideas, consider equation [7] below:

$$[7] \quad \Delta\overline{\ln y_i} = a_i + \beta\overline{\ln y_i} + \theta\overline{X_i} + \delta \cdot \overline{mature_i} + \varphi_1 \cdot \overline{primeage_i} - \varphi_2 \cdot \overline{primeage}^2_i + e_{it}\ ,$$

which is simply a version of model [6] estimated using a between effect estimator. The between effect estimator is therefore a proxy for the impact of prolonged (four-period) maturation on growth. The coefficient attached to our *primeage* variable in eq.[7] should therefore be attenuated by the effect of permanent falls in the birth rate and consequent prolonged *primeage* maturity beyond the optimal turning point. In other words, if permanent and transitory changes in second order maturity exert distinct effects, then when we estimate our original model [6] using both between and fixed-effect estimators, we will expect to find significant differences with regards to our *primeage* coefficients[21]. The coefficient attached to our measure of first order maturity, however, should not be lowered using the between estimator, since a growing working age population has an unambiguously positive effect on growth.

Table 7 repeats all four specifications in Table 3 with the between estimator and shows that the *primeage* coefficient is not only smaller than the fixed-effect estimate, but reverses its sign –implying that permanent increases in the percentage of prime age workers have negative effects on average growth– while the *mature* coefficient remains positive and significant. The fact that a positive change in the permanent ratio of prime age workers is associated with slower long run growth implies that, in our sample at least, the negative effect of countries who are past their "prime" dominates the effect of countries that are below the optimum and which would presumably benefit from more long-term working age maturation.

[Table 7]

In terms of our demographic maturity coefficients, we find in Column [2] of Table 7 that a one percent increase in the (four period) average size working age population increases the 10 year rate of growth by 1.75 percent while a similar percentage increase in *primeage* causes growth to decline by 1.57 percent. Annualised, this would imply a net 0.018 percent increase in the yearly growth of GDP per capita over the course of four decades due to demographic maturation. The relevance of this type of long run calculation will be seen more clearly in section 6, where we use cross-country demographic data estimate the specific contribution of first and second order maturity to economic growth, both over the sample period as well as over the next fifty years[22].

[21] A sign reversal is also possible, depending on whether the *primeage* average lies well beyond the optimum for most of the sample countries.
[22] In results not shown, we also conduct the same analysis for the OECD country sample only. Although the signs of our coefficients line up with Table 7, the results are insignificant. This is because we only have 23 OECD countries to produce our four decade average growth estimates of the between-effect estimator. The point estimates in such a small sample are measured with very little precision.

6. Implications

To underscore the importance of the above findings, we take the point estimates for countries facing the greatest aging pressures (i.e., the OECD countries in Table 5) and make historical "backcasts" and projected estimates of the proportion of annualised economic growth that can be accounted for by demographic maturity. The annualised 10 year growth rate for the OECD as a whole and selected country examples are estimated along with the relative contribution of first and second order maturity effects.

As seen in Table 8 panel B, for the OECD as a whole, the overall effect of demographic change from 1960 to 2000 is close to zero (last row of column 5). This does not imply that demographic change had no significant impact on growth, rather it means that the combined effects of changing working age size and working age structure offset each other over the course of four decades (a finding prefigured by our between effect estimates). For example, in Table 8 column 1 we see how between 1960 and 1970, the effect of second order maturity had a positive effect on growth, contributing 0.15 to annual per capita GDP growth (or roughly four percent of the 4.11 in annualised growth observed over the course of that decade was due to working age maturation). However, this 2^{nd} order effect was slightly attenuated by the fall in the size of the working age population during the decade (contributing to a -0.02 drag on annualised growth). The overall effect of demographic maturity, expressed in terms of annualised growth, was therefore 0.13 out of an average of 4.11 per year.

[Table 8]

On average, from 1960 to 2000, the effects of a rising working age population were offset by those of a maturing workforce, which to put it bluntly, moved well past its "prime". The effect of the baby boom worked its way through the populations of most OECD countries, and stopped contributing to higher economic growth by the late 1980s. The last two decades in columns [3] and [4], in particular, witnessed negative 2^{nd} order effects. Specific countries, however, fared better than others. As seen in Figure 6 (and Appendix Tables 3a and 3b), while Japan, Germany, and Italy were all badly hurt in the 1990s by a combination of falling working age ratios and prime age ratios that moved past their prime, Ireland still witnessed positive overall maturity effects. More significant in this regard were the experiences of countries like China and India, which felt the double benefits of growing 1st and 2nd order maturity.

[Figure 6]

Estimates based on United Nations forecasts in Panel D of Table 8 for the OECD show that the gloomy predictions associated with population aging are both right and wrong. A declining working age population will affect growth negatively, especially beginning from 2010 onward. Viewed in isolation, this effect should slow annual growth by 0.12 and 0.16 percentage points in the two decades between 2010 and 2030 (columns 2 and 4). However, the positive effect of a working age structure which moves back to its optimal ratio, compensates for this drag on growth for all decades except from 2020 to 2030 (column 3). Between 2010 and 2020 and between 2040 and 2050, for example, second order maturity moves back to the optimum, and more than compensates for the fall in first order maturity; making the overall affect of demographic maturity positive.

In the case of specific countries like Spain, Italy, Germany and Japan, the impacts of falling working age populations will have a larger than average negative effect on growth over the coming four decades that will not be compensated by 2nd order maturity effects. For other OECD countries such as the United States and Ireland, declines in the working age population will be less dramatic, more gradual and mostly offset by the positive effects of 2nd order maturity (see Appendix Table 3).

7. Conclusion

This paper estimated the response of per capita GDP growth to changes in the proportion of mature workers across countries. We defined and estimated the effect of demographic maturity in two ways. First, a growing cohort of working age persons (15-64) was found to have a large positive effect on the ten year growth rate of GDP per capita. Second, 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 estimated that the optimal ratio of prime age workers over the potentially active population is approximately 0.360, after which diminishing returns set in.

These point estimates were then combined with current UN demographic projections to forecast the impact of demographic change on economic growth for countries facing the greatest aging pressures; namely those in the OECD. We found that despite the general concerns expressed by some, the effect of demographic maturity will actually be fairly neutral over the coming fifty years. There are two reasons for this. First, falls in the size of the working age population brought about by rising old age dependents will be partly compensated for by *primeage* ratios that move back to their optimum. Second, the falls in first order maturity will be gradual in most cases, and thus in any given decade, the negative effects of a shrinking working age population will not be as pronounced.

Several limitations and prospects for future research characterize this study. First, in terms of limitations, one noticeable problem is the fact that by constraining technical progress with a predetermined value and using the investment ratio as a proxy for the stock of capital, we have not properly identified the lifecycle and technological effects of demographic maturity on growth. It may be that the indirect effects of maturation on growth, operating through savings and technical efficiency channels, are stronger than the direct productivity effects, currently captured in our estimations of GDP growth. A second limitation centres on the use of the potentially active working age population and its effect on output, rather than examining the demographic effects conditioned on effective labour supply. Although endogeneity problems and the lack of reliable long-run series of participation rates across countries justify our decision, several robustness checks were made to explore the potential impact of this decision on our results. Some doubts may still remain about how the use of participation rates by age groups would affect our results of the prime-age coefficient. Finally, the use of growth as proxy for economic performance can be seen as an additional limitation. As seen in section 5.2, one of the implications of demographic maturity may be that it places countries in different converge club groupings [Durlauf and Quah (2000)]. Indeed, much of the modern literature seems to suggest that modelling the determinants of per capita income differentials can tell us as much (or more) about the process of long run growth and the long term effects of state variables, than any other method currently available in the empirical growth literature [Hall and Jones (1999)]. These limitations therefore provide for plenty future work. Papers which formally model the causal channels linking maturity and economic growth and those which estimate the impact of demographic maturity in explaining income differentials appear to be fruitful avenues of research.

References

BARRO, R and J. LEE (1993). «International Comparisons of Educational Attainment», *Journal of Monetary Economics*, December, *32* (3), pp. 363–394, Updated version of data (2002).

BARRO, R. and X. SALA-I-MARTÍN (1995). *Economic Growth*, New York: McGraw-Hill.

BLOOM, E. D. and J. G. WILLIAMSON (1998). «Demographic Transitions and Economic Miracles in Emerging Asia», *World Bank Economic Review* 12 (3), pp. 419-455.

BLOOM, D. E. and D. CANNING (2000). «Demographic Change and Economic Growth: The Role of Cumulative Causality», in Nancy Birdsall, Allen C. Kelley, and Stephen Sinding (eds.), *Population Does Matter: Demography, Growth, and Poverty in the Developing World,* New York: Oxford University Press.

CHARI, V. V. and H. HOENHAYN (1991). «Vintage Human Capital, Growth, and the Diffusion of New Technology», *Journal of Political Economy,* 99 (6), pp. 1142–1165.

DEININGER, K. and L. SQUIRE (1998). «New ways of looking at old issues: inequality and growth», *Journal of Development Economics.* 57(2), pp. 259-288

DURLAUF, S. and D. QUAH (1999). *The New Empirics of Economic Growth,* NBER Working Paper n.º 6422, January.

ERMISCH, J. and J. HEATHER (1987). *Demographic change, economic growth and social welfare in Europe,* CEPR Discussion Paper n.º 179.

FEYER, J. (2002). *Demographics and Productivity*, Dartmouth College, Department of Economics Working Paper.

FOUGERE, M. and M. MERETTE (1999). «Population aging and economic growth in seven OECD countries», *Economic Modelling*, 16, pp. 411-427.

GALOR, O. and D. N. WEIL (1996). "The Gender Gap, Fertility, and Growth," *American Economic Review*, 86 (3), pp. 374-387.

_____ (2000). «Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond», *American Economic Review*, Vol. 90 (4), pp. 806-828.

GREENE, W.H. (2001). *Econometric Analysis: International Edition*, London: PrenticeHall.

GREENWOOD, J., A. SESHADRI, and G. VANDENBROUCKE (2002). *The Baby Boom and Baby Bust: Some Macroeconomics for Population Economics,* Economie d'avant garde, Research Report n.º 1, University of Rochester.

GREENWOOD, J. and A SESHADRI (2002). «The U.S. Demographic Transition», *American Economic Review.* Vol. 92 (2), pp.153-159.

HALL, R. and CH. I. JONES (1999). «Why Do Some Countries Produce So Much More Output per Worker Than Others?», *Quarterly Journal Of Economics* 114, pp. 83-116.

JUDITH, K. H., D. NEUMARK, and K. R. TROSKE (1996). *Wages, Productivity and Worker Characteristics Evidence from Plant-Level Production Functions and Wage Equations,* NBER Working Paper n.º 5626.

KEYNES, J.M. (1937). «Some Economic Consequences of a Declining Population», *Eugenics Review*, Vol. 60, pp. 91-109.

KREMER, M. (1993). «Population Growth and Technological Change: One Million BC to 1990», *Quarterly Journal of Economics* 108(3), pp. 681-716

KREMER, M. and J. THOMSON (1998). «Young Workers, Old Workers and Convergence», *Journal of Economic Growth*, Vol. 3, n.º1, pp. 5-28.

KRUEGER, A. and J. Y-S. PISCHKE (1992). *A Comparative Analysis of East and West German Labor Markets Before and After Unification,* NBER Working Paper n.º 4154, August.

LAZEAR, E. P. (1998). *Personnel Economics for Managers*, New York: John Wiley.

LAZEAR, E. P. and R. B. FREEMAN (1996). *Relational Investing: The Worker's Perspective,* NBER Working Papers n.º 5436, National Bureau of Economic Research.

LEMIEUX, T. (2002). *Schooling, Experience and Earnings: Twenty Five Years of "Mincer" Equations,* Department of Economics, University of British Columbia.

LINDH, T. and B. MALMBERG (1999). «Age structure effects and growth in the OECD, 1950-1990», *Journal of Population Economics*, Vol. 12 (3), pp. 431-449.

MANKIW, N., D. Romer, and D. WEIL (1992). «A Contribution to the Empirics of Economic Growth», *Quarterly Journal Of Economics*, 107, pp. 407–437.

MINCER, J. (1974). *Schooling, Experience and Earnings*, New York: National Bureau of Economic Research.

MODIGLIANI, F. (1986). «Life Cycle, Individual Thrift, and the Wealth of Nations», *American Economic Review*, Vol. 76 (3), pp. 297-313.

MODIGLIANI, F. and A. ANDO (1963). «The life-Cycle Hypothesis of Savings: Aggregate Implications and Tests», *American Economic Review,* 53:2, pp. 55-84.

MUNDLAK, Y. (1978). «On the Pooling of Time Series and Cross-Sectional Data», *Econometrica*, 56, pp. 69-86.

MURPHY, K. M. and F. WELCH (1990). «Empirical Age-Earnings Profiles», *Journal of Labor Economics,* 8(2), pp. 202-229.

NEUMARK, D. (1988). «Employers' Discriminatory Behavior and the Estimation of Wage Discrimination», *Journal of Human Resources,* 23, pp. 279-95.

PERSSON, J. (2001). *Demographic and Per Capita Income Dynamics: A Convergence Study on Demographics, Human Capital, and Per Capita Income for the US States,* FIEF Working Paper n.º 156.

SALA-I-MARTÍN, X. (1996). «The Classical Approach to Convergence Analysis», *Economic Journal*, Vol. 106, pp. 1019-1036.

SHIMER, R. (2001). «The Impact of Young Workers on the Aggregate Labor Market», *Quarterly Journal of Economics,* 116, pp. 969-1007.

SIMON, J. (1986). «Theory of Population and Economic Growth», *Basil Blackwell,* Oxford, pp. 61-79.

SUMMERS, R. and A. HESTON (2002). «The Penn World Tables Mark 6.1 (updated supplement to The Penn World Tables (Mark 5): An Expanded Set of International Comparisons 1950-1988)», *Quarterly Journal Of Economics*, 1991, 106, pp. 327–368.

TEMPLE, J. (1999). «The New Growth Evidence», *Journal of Economic Literature*, Vol. 37 (1), pp. 112-156.

WEINBERG, B. A. (2002). «Experience and Technology Adoption», *Ohio State University Working Paper*, May.

UNITED NATIONS (1998). *World Population Prospects,* NewYork, NY: United Nations, 1950-2050.

Table 1: Illustrative Effects of Demographic Transition on Maturity and Output Per Capita

		Demographic Transition	Effect on Maturity		Anticipated Effect on Per Capita GDP Growth		
					Maturity Effect		
Year	Period	Birth Rate	1st order $\frac{15\text{-}64}{0\text{-}65+}$	2nd order $\frac{35\text{-}54}{15\text{-}64}$	1st order	2nd order	Overall Effect
1950-64	t(1)	↓	↑	↔	+	0	+
1965-79	t(2)	↓	↑	↑	+	+	++
1980-94	t(3)	↔	↔	↑	0	+	+
1995-09	t(4)	↔	↓	↓	−	−	—

Note: The table is illustrative of the Japanese case. See figure 1 for source of cell entries. Note that the constant proportion of retirees (65+) in later periods (3 and 4) is a function of increases in life expectancy which counteract the falls induced by falling birth rates fifty years prior.

Table 2: Measures of Maturity Across Countries by Selected Characteristics, 1960-2000

	Year														
	1960			1970			1980			1990			2000		
	Ratio 15-64 / 0-65+	Ratio 35-54 / 15-65	Ratio 35-54 / 15-34	Ratio 15-64 / 0-65+	Ratio 35-54 / 15-34	Ratio 35-54 / 55-65	Ratio 15-64 / 0-65+	Ratio 35-54 / 15-65	Ratio 35-54 / 15-34	Ratio 15-64 / 0-65+	Ratio 35-54 / 15-65	Ratio 35-54 / 15-34	Ratio 15-64 / 0-65+	Ratio 35-54 / 15-65	Ratio 35-54 / 15-34
1. All	0.564	0.339	0.612	0.556	0.334	0.601	0.574	0.319	0.552	0.589	0.323	0.571	0.609	0.352	0.642
2. OECD	0.624	0.391	0.861	0.621	0.371	0.791	0.638	0.363	0.741	0.662	0.385	0.822	0.668	0.427	1.021
Non-OECD	0.552	0.329	0.573	0.543	0.327	0.572	0.561	0.311	0.521	0.573	0.311	0.532	0.597	0.337	0.592
3. Inequality (Gini Ratio)															
<.300	0.617	0.377	0.814	0.631	0.365	0.793	0.639	0.364	0.752	0.651	0.381	0.821	--	--	--
.300-.349	0.574	0.362	0.722	0.599	0.350	0.691	0.594	0.331	0.611	0.607	0.335	0.643	--	--	--
.350-.449	0.589	0.358	0.702	0.568	0.341	0.642	0.573	0.302	0.502	0.572	0.310	0.532	--	--	--
>.450	0.538	0.332	0.591	0.520	0.314	0.532	0.538	0.297	0.483	0.543	0.292	0.461	--	--	--
4. Freedom Score															
High [1-3]	--	--	--	0.588	0.356	0.711	0.633	0.345	0.661	0.643	0.367	0.732	0.661	0.412	0.921
Medium [4-8]	--	--	--	0.550	0.328	0.583	0.563	0.307	0.512	0.581	0.314	0.541	0.599	0.331	0.571
Low[9-12]	--	--	--	0.531	0.294	0.482	0.548	0.296	0.481	0.539	0.292	0.473	0.576	0.324	0.552
5. Voter Turnout															
70%-100%	0.584	0.368	0.751	0.591	0.350	0.702	0.605	0.332	0.632	0.613	0.342	0.672	0.633	0.372	0.772
50%-69%	0.573	0.351	0.672	0.535	0.321	0.561	0.564	0.301	0.512	0.575	0.309	0.532	0.611	0.354	0.693
<49%	0.530	0.319	0.545	0.526	0.311	0.521	0.543	0.299	0.491	0.557	0.307	0.521	0.585	0.328	0.592
6. Selected Country															
Argentina	0.637	0.381	0.761	0.637	0.378	0.771	0.614	0.365	0.732	0.604	0.363	0.723	0.626	0.360	0.692
Canada	0.590	0.396	0.826	0.619	0.365	0.723	0.679	0.327	0.593	0.680	0.384	0.791	0.683	0.459	1.131
China	0.563	0.356	0.652	0.560	0.339	0.612	0.598	0.312	0.531	0.667	0.324	0.562	0.683	0.386	0.752
Egypt	0.542	0.331	0.571	0.543	0.318	0.571	0.565	0.289	0.462	0.563	0.313	0.523	0.606	0.344	0.593
India	0.568	0.313	0.513	0.559	0.327	0.561	0.574	0.326	0.552	0.592	0.305	0.501	0.617	0.331	0.573
Japan	0.641	0.334	0.592	0.689	0.366	0.702	0.674	0.415	0.911	0.696	0.428	1.062	0.681	0.409	1.023
S.Africa	0.552	0.335	0.582	0.552	0.321	0.541	0.572	0.309	0.512	0.593	0.318	0.533	0.614	0.337	0.582
Spain	0.644	0.380	0.791	0.623	0.404	0.90	0.627	0.382	0.811	0.668	0.350	0.721	0.684	0.401	0.893

Notes: Demographic data based on United Nations World Population Prospects. A full account of all variables can be found in Appendix Table 1.

Table 3: The Effect of Maturity on Economic Growth: Dependent Variable is the 10 year compound growth rate (non-annualised)

	Fixed Effect				Random Effect			
Independent Variables	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Initial period measures	No	No	Yes	Yes	No	No	Yes	Yes
1. $\text{Ln}(Y_0)$	-0.411	-0.411	-0.377	-0.376	-0.172	-0.169	-0.164	-0.157
	(-9.67)	(-9.70)	(-8.99)	(-8.97)	(-6.68)	(-6.83)	(-5.93)	(-5.98)
2. $\text{Ln}(s_k)$	0.178	0.177	0.093	0.086	0.241	0.227	0.159	0.142
	(4.83)	(4.81)	(3.21)	(2.99)	(9.61)	(9.15)	(6.72)	(6.09)
3. $\text{Ln}(s_h)$	-0.16	-0.002	-0.002	0.025	0.027	0.041	0.047	0.065
	(-0.49)	(-0.08)	(0.04)	(0.74)	(1.17)	(1.75)	(2.03)	(2.84)
4. $\text{Ln}(N+\theta+\sigma)$	1.209	0.672	-2.41	-2.51	-1.703	-0.790	-3.08	-1.582
	(0.42)	(0.23)	(-0.84)	(-0.87)	(0.82)	(0.39)	(-1.45)	(0.76)
5. Ln(mature)	1.080	0.987	0.593	0.590	0.512	0.326	0.395	0.230
	(4.78)	(4.16)	(2.98)	(2.98)	(2.93)	(1.75)	(2.35)	(1.46)
6. Ln(primege)		0.251				0.364		
		(1.27)				(2.23)		
7. Primeage Ratio				9.975				10.206
				(2.02)				(2.17)
Primeage Ratio_sq				-13.849				-13.102
				(-1.95)				(-1.91)
Obs:	336	336	336	336	336	336	336	336
Grps:	84	84	84	84	84	84	84	84
R^2	0.36	0.37	0.31	0.32	0.30	0.31	0.31	0.30

Notes: Initial level of GDP is always measured in its initial period to control for conditional convergence. All other independent variables are measured as the 10 year period average except for columns 3 and 4 where the initial levels of each variable measured at the start of each 10 year growth period are used. The stock of physical capital is the investment share of GDP per capita. The stock of human capital is the average years of schooling. The t-statistics are in parentheses.

Table 4: The Effect of Maturity on Per Capita Income: Dependent Variable is the real level of GDP per capita (chain index)

	Fixed Effect				Random Effect			
Independent Variables	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Initial period measures	No	No	Yes	Yes	No	No	Yes	Yes
1. Ln(s_k)	0.224	0.223	0.202	0.197	0.281	0.214	0.283	0.261
	(4.59)	(4.57)	(5.26)	(5.11)	(8.28)	(7.99)	(7.75)	(7.04)
2. Ln(s_h)	0.125	0.140	0.165	0.185	0.181	0.268	0.247	0.283
	(2.98)	(3.18)	(4.02)	(4.10)	(4.58)	(5.33)	(6.50)	(7.06)
3. Ln(N+ θ+ σ)	3.687	3.060	-8.061	-7.577	-0.766	-1.074	-9.793	-9.242
	(0.96)	(0.78)	(2.07)	(-1.93)	(-0.21)	(-0.30)	(-2.67)	(-2.54)
4. Ln(mature)	3.036	2.924	2.243	2.233	3.109	2.758	2.492	2.434
	(12.90)	(11.43)	(9.91)	(9.88)	(13.46)	(11.09)	(11.06)	(10.85)
5. Ln(primege)		0.291				0.826		
		(1.11)				(3.46)		
6. Primeage Ratio				11.155				15.066
				(1.65)				(2.17)
Primeage Ratio_sq				-16.135				-20.214
				(-1.70)				(-2.06)
Obs:	336	336	336	336	336	336	336	336
Grps:	84	84	84	84	84	84	84	84
R^2	0.55	0.55	0.48	0.48	0.78	0.79	0.77	0.77

Notes: Level of GDP per capita is at purchasing parity adjusted levels (using chain index). All independent variables are measured as the 10 year period average except for columns 3 and 4 where the initial levels of each variable measured at the start of each 10 year growth period are used. The stock of physical capital is the investment share of GDP per capita. The stock of human capital is the average years of schooling. The t-statistics are in parentheses

Table 5: OECD Estimates of the Effect of Maturity on Economic Growth: Dependent Variable is the 10 year compound growth rate (non-annualised)

	Fixed Effect				Random Effect			
Independent Variables	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Initial period measures	No	No	Yes	Yes	No	No	Yes	Yes
1. Ln(Y_0)	-0.400	-0.404	-0.384	-0.404	-0.380	-0.383	-0.383	-0.392
	(7.13)	(7.03)	(-7.24)	(7.57)	(8.43)	(8.54)	(-8.83)	(9.34)
2. Ln(s_k)	0.099	0.107	0.052	-0.038	0.179	0.173	0.08	0.072
	(1.03)	(1.08)	(0.67)	(0.50)	(3.00)	(2.91)	(1.55)	(1.41)
3. Ln(s_h)	0.061	0.066	0.195	0.260	0.169	0.165	0.181	0.197
	(0.48)	(0.51)	(1.73)	(2.22)	(2.97)	(2.92)	(3.41)	(3.73)
4. Ln(N+ θ+ σ)	6.921	6.476	5.140	6.490	-0.277	-0.146	-2.12	-0.428
	(1.75)	(1.57)	(1.26)	(1.66)	(0.11)	(0.06)	(-0.86)	(0.18)
5. Ln(mature)	1.075	1.052	0.383	0.370	0.605	0.529	0.461	0.417
	(3.81)	(3.64)	(1.73)	(1.73)	(2.88)	(2.45)	(2.62)	(2.42)
6. Ln(primege)		0.078				0.225		
		(0.40)				(1.35)		
7. Primeage Ratio				14.685				19.072
				(1.86)				(3.18)
Primeage Ratio_sq				-20.583				-25.97
				(1.96)				(-3.20)
Obs:	92	92	92	92	92	92	92	92
Grps:	23	23	23	23	23	23	23	23
R^2	0.68	0.68	0.63	0.66	0.57	0.58	0.53	0.57

Notes: Initial level of GDP is always measured in its initial period to control for conditional convergence. All other independent variables are measured as the 10 year period average except for columns 3 and 4 where the initial levels of each variable measured at the start of each 10 year growth period are used. The stock of physical capital is the investment share of GDP per capita. The stock of human capital is the average years of schooling. The t-statistics are in parentheses.

Table 6: OECD Estimates of The Effect of Maturity on Per Capita Income: Dependent Variable is the real level of GDP per capita (chain index)

	Fixed Effect				Random Effect			
Independent Variables	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Initial period measures	No	No	Yes	Yes	No	No	Yes	Yes
1. Ln(s_k)	0.003	0.036	0.035	0.083	0.041	0.035	0.07	0.079
	(0.03)	(0.30)	(0.26)	(0.64)	(0.45)	(0.40)	(0.73)	(0.81)
2. Ln(s_h)	0.954	0.938	1.103	1.143	0.750	0.743	0.751	0.771
	(5.73)	(5.72)	(6.82)	(7.70)	(9.22)	(9.10)	(10.05)	(10.32)
3. Ln(N+ θ+ σ)	7.827	4937	-0.791	-1.413	0.824	1.077	-5.301	-3.606
	(1.20)	(0.74)	(-0.11)	(-0.20)	(0.18)	(0.23)	(-1.13)	(-2.54)
4. Ln(mature)	1.943	1.760	1.095	0.976	1.960	1.815	1.272	1.238
	(4.26)	(3.82)	(2.93)	(2.74)	(5.80)	(5.14)	(4.19)	(10.85)
5. Ln(primege)		0.546				0.401		
		(1.78)				(1.46)		
6. Primeage Ratio				39.118				22.142
				(3.00)				(2.01)
Primeage Ratio_sq				-52.581				-30.214
				(-3.02)				(-2.08)
Obs:	336	336	336	336	336	336	336	336
Grps:	84	84	84	84	84	84	84	84
R^2	0.76	0.77	0.70	0.74	0.83	0.83	0.81	0.82

Notes: Level of GDP per capita is at purchasing parity adjusted levels (using chain index). All independent variables are measured as the 10 year period average except for columns 3 and 4 where the initial levels of each variable measured at the start of each 10 year growth period are used. The stock of physical capital is the investment share of GDP per capita. The stock of human capital is the average years of schooling. The t-statistics are in parentheses

Table 7: Comparison of Between and Within (Fixed-Effect) Estimates of the Effect of Maturity on Economic Growth: Dependent Variable is the 10 year compound growth rate (non-annualised)

	Permanent Changes (Between Effect)				Transitory Changes (Fixed Effect)			
Independent Variables	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Initial period measures	No	No	Yes	Yes	No	No	Yes	Yes
1. Ln(Y_0)	-0.095	-0.074	-0.084	-0.068	-0.411	-0.411	-0.377	-0.376
	(3.35)	(2.83)	(-2.72)	(2.34)	(9.67)	(9.70)	(-8.99)	(8.97)
2. Ln(s_k)	0.162	0.125	0.157	0.120	0.178	0.177	0.093	0.086
	(4.49)	(3.67)	(4.49)	(3.53)	(4.83)	(4.81)	(3.21)	(2.99)
3. Ln(s_h)	0.049	0.026	0.047	0.030	-0.16	-0.002	-0.002	0.025
	(1.69)	(0.99)	(1.67)	(1.14)	(0.49)	(0.08)	(0.04)	(0.74)
4. Ln(N+ θ+ σ)	1.008	-2.125	-0.787	-3.165	1.209	0.672	-2.41	-2.51
	(0.37)	(-0.81)	(-0.27)	(-1.15)	(0.42)	(0.23)	(-0.84)	(0.87)
5. Ln(mature)	0.607	1.753	0.382	1.529	1.080	0.987	0.593	0.590
	(2.38)	(4.82)	(1.49)	(3.97)	(4.78)	(4.16)	(2.98)	(2.98)
6. Ln(primege)		-1.568				0.251		
		(-4.01)				(1.27)		
7. Primeage Ratio				-9.855				9.975
				(1.02)				(2.02)
Primeage Ratio_sq				7.66				-13.849
				(0.55)				(1.95)
Obs:	336	336	336	336	336	336	336	336
Grps:	84	84	84	84	84	84	84	84
R^2	0.51	0.59	0.45	0.53	0.36	0.37	0.31	0.32

Notes: Initial level of GDP is always measured in its initial period to control for conditional convergence. All other independent variables are measured as the 10 year period average except for columns 3 and 4 where the initial levels of each variable measured at the start of each 10 year growth period are used. The stock of physical capital is the investment share of GDP per capita. The stock of human capital is the average years of schooling. The t-statistics are in parentheses.

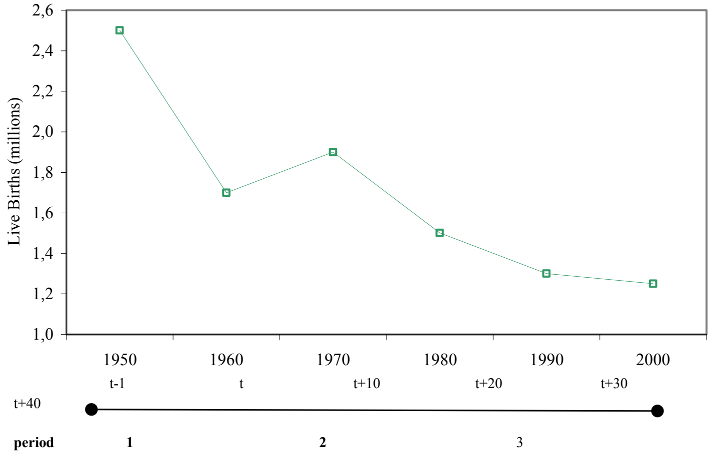
Table 8: Historical and Projected Within Sample Estimates of 1_{st} and 2_{nd} Order Maturity Effects on 10 Year Per Capita Growth Rates: OECD

Panel A		Initial Period Levels					Panel B	Estimated Contribution of Maturity To Annual Economic Growth Rate				
	Measures	1960 [1]	1970 [2]	1980 [3]	1990 [4]	2000 [5]	Maturity Effects	1960-70 [1]	1970-80 [2]	1980-90 [3]	1990-00 [4]	1960-00 [5]
							GDP growth rate	4.11	2.60	2.00	1.96	2.66
OECD (23 countries)	*Mature* Ratio (1^{st} order)	0.624	0.621	0.638	0.662	0.667	1^{st} order Effect	-0.02	0.10	0.14	0.03	0.06
	Primeage Ratio (2^{nd} order)	0.387	0.371	0.364	0.387	0.418	2^{nd} order Effect	0.15	0.03	-0.17	-0.58	-0.14
							Overall Effect	0.13	0.13	-0.04	-0.55	0.08

Panel C		Projected Initial Period Levels					Panel D	Forecasted Contribution of Maturity To Annual Economic Growth Rate					
	Measures	2010 [1]	2020 [2]	2030 [3]	2040 [4]	2050 [5]	Maturity Effects	2000-10 [1]	2010-20 [2]	2020-30 [3]	2030-40 [4]	2040-50 [5]	2000-50 [6]
OECD (23 countries)	*Mature* Ratio (1^{st} order)	0.671	0.650	0.623	0.602	0.592	1^{st} order Effect	0.02	-0.12	-0.16	-0.13	-0.06	-0.09
							2^{nd} order Effect	-0.15	0.24	-0.01	0.11	0.10	0.06
	Primeage Ratio (2^{nd} order)	0.423	0.414	0.414	0.409	0.405	Overall Effect	-0.13	0.13	-0.17	-0.02	0.04	-0.08

Figure 1: The Effect of Demographic Transition on Population Age Structure

Panel A: Live Births in Japan 1950 to 2000



Panel B: Japanese Working Age Structure 1950 to 2000

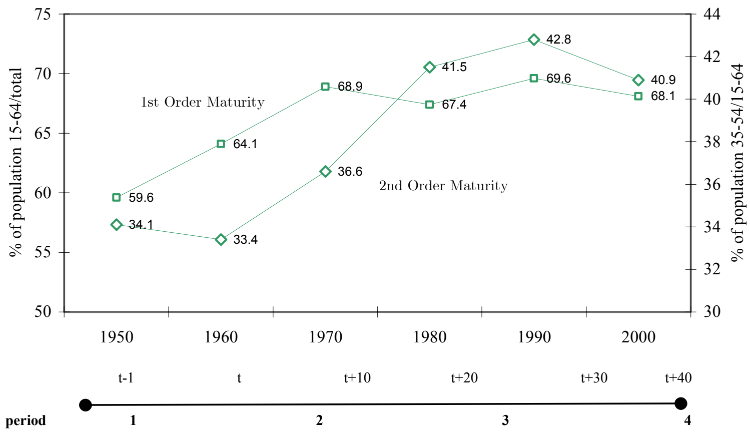


Figure 2: The Hypothesised Effect of Second Order Maturity on the Medium Term Growth Rate

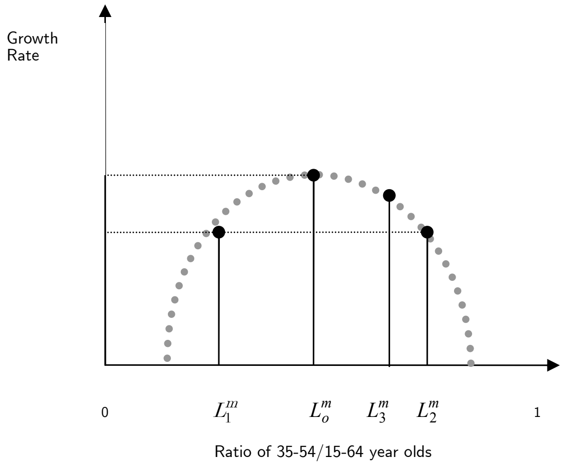
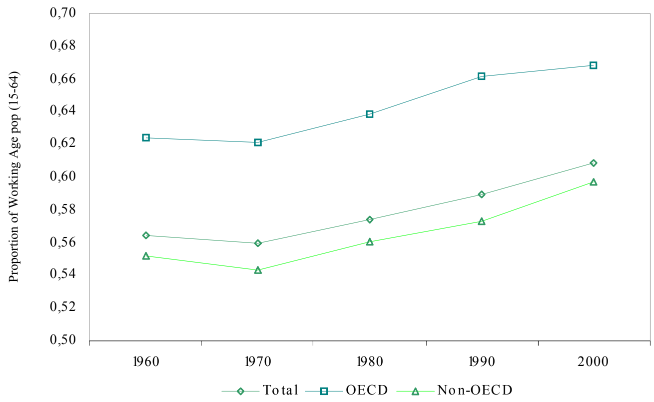
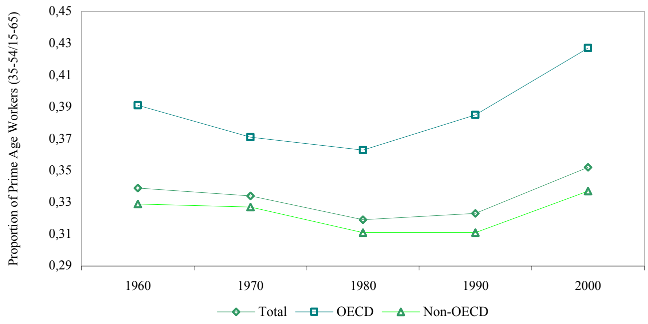


Figure 3: Age Structure across Countries, 1960-2000

Panel A: Ratio of Potentially Active Population (15-64) over Total Population (0-65+)



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



Panel C: Ratio of Prime Age (35-54) to Young (15-34)

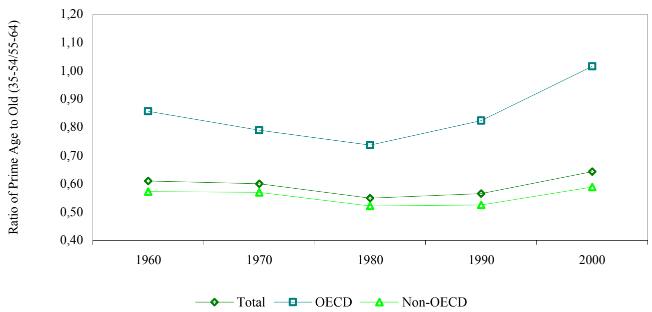
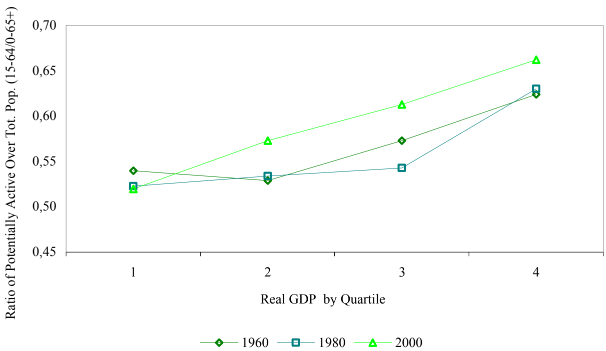
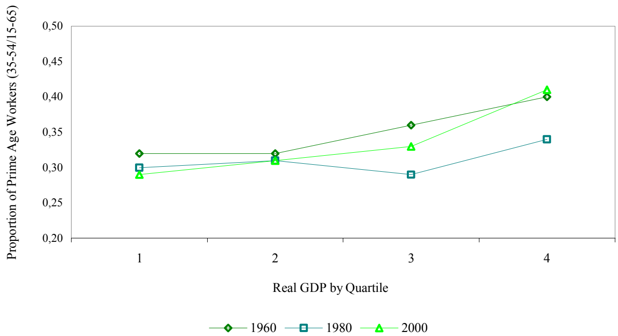


Figure 4: Age Structure by GDP per capita Convergence Club Grouping, 1960, 1980 and 2000

Panel A: Ratio of Potentially Active population (15-64) over total Population (0-65+)



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



Panel C: Ratio of Prime Age (35-54) to Young (15-34)

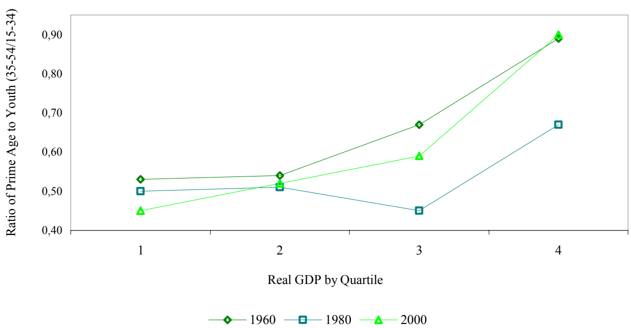
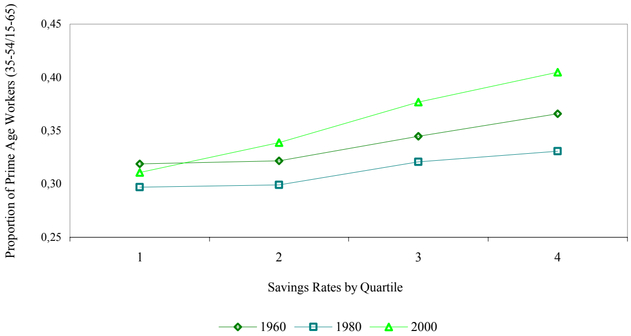


Figure 5: Prime Age Workers by National Savings Rate Grouping, 1960, 1980 and 2000

Panel A: Ratio of Potentially Active population (15-64) over Total Population (0-65+)

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



Panel C: Ratio of Prime Age (35-54) to Young (15-34)

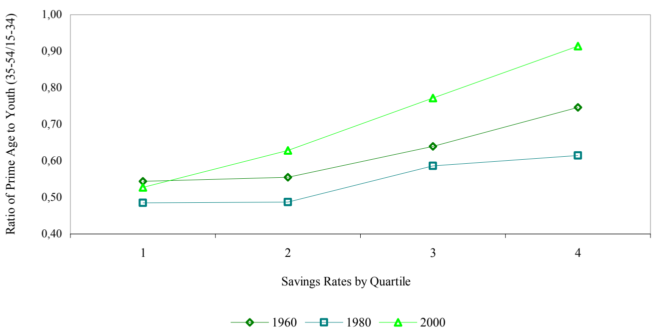
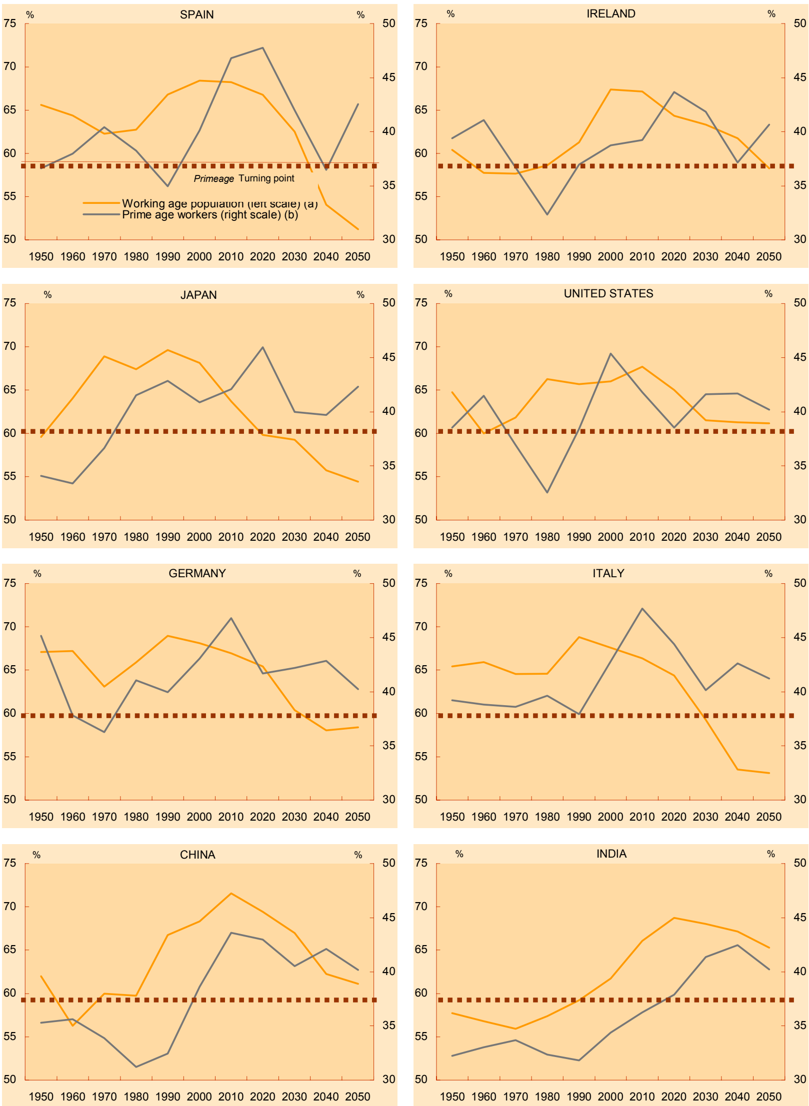


Figure 6: Working age population and prime age workers for Selected countries (1950-2050)



Source: United Nations.

(a) Population of age 15 to 64 over total population.

(b) Population of age 35 to 54 over population of age 15 to 64.

Appendix Table 1: Variable Definitions and Sources

Variable	Definition	Source
1. Growth Rate of GDP per capita (In Constant Prices)	Ln 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. The 10 year growth rate was calculated as the differences between initial and final period, compounded.	Heston and Summers (2002)
2. Mature	The fraction of the total population of potential working age 15-64.	United Nations (1998)
3. Primege	The fraction of the working age population aged 35-54.	United Nations (1998)
4. Voter Turnout	The fraction of votes cast by the voting age population in national elections.	IDEA (2003)
5. Freedom Score	An indicator of the levels of freedom in a country's political system. We have added together the "political rights" and "civil liberties" ratings to yield a number from 2 to 14, where 2 indicates the highest possible level and 14 the lowest.	Freedom House (2003)
6. National Savings	The percentage share of current savings to GDP. Derived by subtracting gross consumption and government consumption from 100.	Heston and Summers (2002)
7. Openness	Exports plus imports divided by real GDP (chain).	Heston and Summers (2002)
8. Inequality	Measured as the GINI coefficient.	Deininger and Squire (1996)
9. Consumption & Government Share	The component shares of real GDP are obtained directly from a multilateral Geary aggregation. For more details, see Data Appendix in Penn Woprd Tables 6.1.	Heston and Summers (2002)
10. Price Level	Price Level of GDP is the PPP over GDP divided by the exchange rate times 100. For more detail, see Data Appendix in Penn Woprd Tables 6.1.	Heston and Summers (2002)
11. Education	Average years of schooling.	Barro and Lee (2000)
12. Investment Ratio	Ratio of private investment to GDP	Heston and Summers (2002)

Appendix Table 2: List of Countries (Balanced Panel)

Country	Non-OECD	OECD	Total Observations	Country	Non-OECD	OECD	Total Observations
ARG	1		4	MWI	1		4
AUS		1	4	MYS	1		4
AUT		1	4	NER	1		4
BEL		1	4	NIC	1		4
BGD	1		4	NLD		1	4
BOL	1		4	NOR		1	4
BRA	1		4	NPL	1		4
BRB	1		4	NZL		1	4
BWA	1		4	PAK	1		4
CAF	1		4	PAN	1		4
CAN		1	4	PER	1		4
CHE		1	4	PHL	1		4
CHL	1		4	PNG	1		4
CMR	1		4	PRT		1	4
COL	1		4	PRY	1		4
CRI	1		4	ROM	1		4
CYP	1		4	SEN	1		4
DNK		1	4	SGP	1		4
DOM	1		4	SLV	1		4
DZA	1		4	SWE		1	4
ECU	1		4	SYR	1		4
ESP		1	4	TGO	1		4
FIN		1	4	THA	1		4
FJI	1		4	TTO	1		4
FRA		1	4	TUN	1		4
GBR		1	4	TUR		1	4
GHA	1		4	UGA	1		4
GRC		1	4	URY	1		4
GTM	1		4	USA		1	4
GUY	1		4	VEN	1		4
HKG	1		4	ZAF	1		4
HND	1		4	ZAR	1		4
IDN	1		4	ZMB	1		4
IND	1		4	ZWE	1		4
IRL		1	4	Countries	61	23	94
IRN	1		4	Total Obs.	244	92	336
ISL		1	4				
ISR	1		4				
ITA		1	4				
JAM	1		4				
JOR	1		4				
JPN		1	4				
KEN	1		4				
KOR	1		4				
LKA	1		4				
LSO	1		4				
MEX		1	4				
MLI	1		4				
MOZ	1		4				
MUS	1		4				

Appendix Table 3a. Historical Within Sample Estimates of first and second order maturity effects of 10 Year Per Capita Growth Rates

Panel A							Panel B					
	Measures	1960	1970	1980	1990	2000	Maturity Effects	1960-70	1970-80	1980-90	1990-2000	1960-2000
SPAIN	Mature Ratio	0.64	0.62	0.63	0.67	0.68	Mature Ratio	-0.12	0.03	0.23	0.09	0.06
	Primeage Ratio	0.38	0.40	0.38	0.35	0.40	Primeage Ratio	-0.36	0.33	0.13	-0.40	-0.07
							Overall Effect	-0.48	0.36	0.36	-0.31	-0.02
IRELAND	Mature Ratio	0.58	0.58	0.59	0.61	0.67	Mature Ratio	0.00	0.06	0.16	0.35	0.14
	Primeage Ratio	0.41	0.37	0.32	0.37	0.39	Primeage Ratio	0.58	-0.21	0.19	-0.16	0.10
							Overall Effect	0.57	-0.14	0.36	0.19	0.24
JAPAN	Mature Ratio	0.64	0.69	0.67	0.70	0.68	Mature Ratio	0.27	-0.08	0.12	-0.08	0.06
	Primeage Ratio	0.33	0.37	0.42	0.43	0.41	Primeage Ratio	0.09	-0.69	-0.35	0.50	-0.11
							Overall Effect	0.36	-0.77	-0.23	0.42	-0.05
US	Mature Ratio	0.60	0.62	0.66	0.66	0.66	Mature Ratio	0.11	0.26	-0.03	0.02	0.09
	Primeage Ratio	0.41	0.37	0.33	0.38	0.45	Primeage Ratio	0.66	-0.17	0.05	-1.79	-0.31
							Overall Effect	0.77	0.09	0.02	-1.77	-0.22
GERMANY	Mature Ratio	0.67	0.63	0.66	0.69	0.68	Mature Ratio	-0.23	0.16	0.17	-0.05	0.01
	Primeage Ratio	0.38	0.36	0.41	0.40	0.43	Primeage Ratio	0.09	-0.59	0.22	-0.74	-0.26
							Overall Effect	-0.15	-0.43	0.39	-0.79	-0.25
ITALY	Mature Ratio	0.66	0.65	0.65	0.69	0.68	Mature Ratio	-0.08	0.00	0.23	-0.07	0.02
	Primeage Ratio	0.39	0.39	0.40	0.38	0.43	Primeage Ratio	0.03	-0.14	0.22	-0.94	-0.21
							Overall Effect	-0.05	-0.14	0.45	-1.01	-0.19
CHINA	Mature Ratio	0.56	0.60	0.60	0.67	0.68	Mature Ratio	0.38	-0.02	0.65	0.14	0.29
	Primeage Ratio	0.36	0.34	0.31	0.32	0.39	Primeage Ratio	-0.06	-0.26	0.14	0.08	-0.02
							Overall Effect	0.31	-0.28	0.80	0.22	0.26
INDIA	Mature Ratio	0.57	0.56	0.57	0.59	0.62	Mature Ratio	-0.09	0.16	0.19	0.24	0.12
	Primeage Ratio	0.33	0.34	0.32	0.32	0.34	Primeage Ratio	0.05	-0.11	-0.06	0.20	0.02
							Overall Effect	-0.05	0.05	0.13	0.45	0.14

Appendix Table 3b. Projected Within Sample Estimates of first and second order maturity effects of 10 Year Per Capita Growth Rate

Panel A	Measures	2010	2020	2030	2040	2050	Panel B Maturity	2000-10	2010-20	2020-30	2030-40	2049-50	2000-2050
SPAIN	Mature Ratio	0.68	0.67	0.62	0.54	0.51	Mature Ratio	-0.01	-0.08	-0.24	-0.54	-0.20	-0.21
	Primeage Ratio	0.47	0.48	0.42	0.36	0.43	Primeage Ratio	-2.14	-0.46	2.18	0.81	-0.96	-0.11
							Overall Effect	-2.15	-0.54	1.94	0.27	-0.12	-0.12
IRELAND	Mature Ratio	0.67	0.64	0.63	0.62	0.58	Mature Ratio	-0.01	-0.16	-0.06	-0.09	-0.22	-0.11
	Primeage Ratio	0.39	0.44	0.42	0.37	0.41	Primeage Ratio	-0.07	-1.06	0.53	0.74	-0.47	-0.06
							Overall Effect	-0.08	-1.21	0.48	0.65	-0.04	-0.04
JAPAN	Mature Ratio	0.64	0.60	0.59	0.56	0.54	Mature Ratio	-0.25	-0.23	-0.03	-0.23	-0.09	-0.17
	Primeage Ratio	0.42	0.46	0.40	0.40	0.42	Primeage Ratio	-0.29	-1.34	1.80	0.05	-0.58	-0.07
							Overall Effect	-0.54	-1.57	1.77	-0.18	-0.13	-0.13
US	Mature Ratio	0.68	0.65	0.62	0.61	0.61	Mature Ratio	0.09	-0.15	-0.20	-0.01	-0.01	-0.06
	Primeage Ratio	0.42	0.39	0.42	0.42	0.40	Primeage Ratio	1.17	0.60	-0.56	-0.02	0.33	0.30
							Overall Effect	1.26	0.45	-0.76	-0.03	0.23	0.23
GERMANY	Mature Ratio	0.67	0.65	0.60	0.58	0.58	Mature Ratio	-0.06	-0.08	-0.30	-0.15	0.02	-0.11
	Primeage Ratio	0.47	0.42	0.42	0.43	0.40	Primeage Ratio	-1.43	1.80	-0.13	-0.18	0.63	0.14
							Overall Effect	-1.49	1.72	-0.42	-0.33	-0.13	-0.13
ITALY	Mature Ratio	0.66	0.64	0.59	0.54	0.53	Mature Ratio	-0.07	-0.11	-0.30	-0.38	-0.03	-0.18
	Primeage Ratio	0.48	0.44	0.40	0.43	0.41	Primeage Ratio	-1.92	1.41	1.15	-0.59	0.37	0.08
							Overall Effect	-1.99	1.30	0.85	-0.96	-0.20	-0.20
CHINA	Mature Ratio	0.72	0.69	0.67	0.62	0.61	Mature Ratio	0.27	-0.18	-0.21	-0.43	-0.11	-0.13
	Primeage Ratio	0.44	0.43	0.41	0.42	0.40	Primeage Ratio	-0.71	0.13	0.39	-0.37	0.44	-0.02
							Overall Effect	-0.43	-0.05	0.18	-0.80	-0.28	-0.28
INDIA	Mature Ratio	0.66	0.69	0.68	0.67	0.65	Mature Ratio	0.40	0.23	-0.06	-0.07	-0.17	0.07
	Primeage Ratio	0.36	0.38	0.41	0.42	0.40	Primeage Ratio	0.04	-0.05	-0.35	-0.18	0.33	-0.04
							Overall Effect	0.44	0.18	-0.41	-0.26	-0.01	-0.01