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In 2006 all ECB publications feature a motif taken from the €5 banknote.

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Abstract

Given that savings behaviour and worker productivity have strong life-cycle components and given that demographic profiles vary across countries, population age structure should be linked to differences in levels of economic development. In this paper we measure the economic importance of age structure variation for the global economy. We find that even after adjusting for country-specific effects, demographic maturation has been associated with nearly half of the evolution of global per-capita GDP since 1960. We also find that age structure differences can account for just over half of the variation in worldwide per capita GDP (i.e. the lack of sigma convergence) observed since 1960. Taken as a whole, these results complement recent theoretical and empirical work on the importance of population size and economic development and reinforce empirical work linking mature demographic age structures with faster cross-country economic growth rates.

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

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

NON TECHNICAL SUMMARY

Several authors have shown that a link exists between demographic maturity and economic performance. The causal relationship between these two variables 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 maturation and economic performance. By making a country more mature, falling birth rates affect not only the size but the structure of 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.

In this paper we explore the connection between both maturity effects and the evolution of global per capita income. Specifically, our paper focuses on two empirical questions not yet addressed in the most recent literature. First, we ask how much of the increase in global per capita GDP since 1960 is attributable to the increase across countries in the number of mature persons as a share of the total population? Second, we ask 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 methods that have proved useful in the study of labor market phenomenon. In our case, these same shift-share techniques are used to divide the global economy into two sets of demographic groupings; 'mature' and 'young' and 'primeage' and 'non-primeage' country-clubs respectively. The distribution of per capita GDP in these two sets of demographic country-clubs is shown to be an important factor explaining over time evolution in global income and in the dispersion of per capita income across countries.

In particular, using a large cross-country panel spanning the past fifty years, we show that countries defined as being demographically mature are significantly better off in terms of GDP per head than non-mature counterparts. Using two definitions of demographic maturity – a measure of potentially active persons (aged 15-64) as a share of the total population and a measure identifying the share of prime-aged persons (aged 34-54) within the potentially active working age population – we show that demographic maturation (i.e., the growing proportion of countries with mature or prime-age populations) has contributed to over half of the increase in global per capita GDP averaged across countries since 1960. We also find that population maturation has been associated with the widening of global inequality.

Taken as a whole, these results complement recent theoretical and empirical work on the importance of population size and economic development and on the positive links between mature demographic age structures and cross-country economic growth rates.

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 grater shares of their incomes. Combine these observations with the fact that age profiles have matured considerably across countries (i.e., some countries have remained young while many others have grown significantly older) and it would appear that population age structure plays a significant role in the process of economic development. Several authors have posited similar arguments and shown, empirically, that a positive link between demographic maturity and economic growth exists[1]. Unfortunately, as evidenced by the opening quote, much of their work has yet to permeate mainstream discussions of cross-country growth. Demography is still seen, by and large, as a byproduct of economic development rather than as a plausible explanatory channel.

As a means of partially redressing this 'demographic deficit', our paper explores the connection between population age structure and the evolution of global per capita income. Specifically, our paper focuses on two empirical questions not yet addressed in the most recent literature. First, we ask how much of the increase in global per capita GDP since 1960 is attributable to the addition of experiential human capital (i.e., increases across countries in the number of mature persons as a share of the total population)? Second, we ask 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 methods that have proved useful in the study of labor market phenomenon; such as the effect of declining unionization on U.S. wage structures (Freeman, 1980; Card 2001). In our case, these same shift-share techniques are used to divide the global economy into two sets of demographic groupings; 'mature' and 'young' and 'primeage' and 'non-primeage' country-clubs respectively. The distribution of per capita GDP in these two sets of demographic country-clubs is shown to be an important factor explaining over time evolution in global income and in the dispersion of per capita income across countries.

The remainder of the paper proceeds as follows. Section 2 examines the mechanisms linking demographic maturity to economic performance, identifies our measures of demographic maturity and presents the data. Section 3 describes the empirical set up and presents our estimates for the impact of demographic maturity on the evolution of global per capita income. Section 4

[1] See Krueger (1968) and work by Modigliani (1986) for some of the earliest empirical analyses of this link. More recently, Sarel (1995), Bloom and Williamson (1998), Lindh and Malmberg (1999), Persson (2002), Feyrer (2002) and Gómez and Hernández de Cos (2003) have confirmed the empirical importance of demographic age structure to the growth process.

presents the results of our estimates of the impact of demographic maturation on global income dispersion. Section 5 concludes.

2. Empirical Setting and Data

In this paper we adhere to a two part analytical framework, which links demographic maturity and economic performance via life-cycle models of consumer and worker behaviour. 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 independent effect on economic output through increases in the relative size of the potentially active workforce (broadly speaking those aged 15 to 64). We term this the working age size effect and this is the first way in which a country is affected by demographic maturation. Savings rates and labor force productivity are also affected by a growing ratio of working age persons; 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 observations highlight a second, but no less important link between demographic maturity and economic performance. Falling birth rates eventually affect not only the size, but also the structure of the working age population. A country with more prime-age working persons will differ substantially from one that has greater numbers of younger workers, even if both have workforces that are of the same relative size.[2] In particular, if we consider that the three bedrocks of economic growth -- labor force participation, personal capital accumulation and workforce productivity -- all 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 will differ substantially from one with many younger labor force entrants (aged 15-34).[3]

The twin experiences of China and India, highlighted in our opening quotation, illustrate the relevance of this explanatory framework. Consider that in 1980, China's age structure was younger than India's -- as measured by the fraction of person's aged 15 to 34 over those 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-six years on the effects have been

[2] Although it may seem that what happens to the working age structure is always prefigured by the working age size effect, it is not necessarily the case that all prime-age countries are subsets of countries with mature working age populations. In fact, Japan is now (or very soon will be) entering a phase in which its working age population will actually be getting younger, but its working age population will shrink in relative terms. This is because, as a whole, Japan is getting older (i.e., there is a growing share of young workers in the 15-65 population, but the 15-65 share is actually shrinking relative to the whole population because of the growth of the 65+ group. So the prime age effect is not exclusively an additional effect located only among already mature countries.

[3] 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.

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 conscious family planning policies, should have had noticeable effects on major economic aggregates (such as savings rates, labour force participation, productivity, asset prices, capital per worker etc.,) and in turn over economic performance. [4] The question, therefore, is not *whether* demographic maturation has had an effect on economic development, but rather, by *how much*?

Against this analytical background, two key demographic measures of demographic maturity are employed. The first is the ratio of the potentially active working age population (15-64) *W* over the total population *P*, captured with the variable MATURE:

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

The expectation is that countries with higher shares of 15 to 64 year olds, all things equal, will experience faster growth and ultimately contribute to higher levels of GDP per capita.

Our second measure of maturity captures the structure of this working age population and is identified with the variable name PRIMEAGE; highlighting the fact that both productivity and labour force participation peak during a determined period in a workers lifecycle. We use the number of person's aged 35 to 54, *w* over the total number of potentially active persons *W* to calculate:

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

We sometimes shorten the two variable names above and refer to measures [1] and [2] as the <u>size</u> and <u>structure</u> of the working age population respectively. Both will function as measures of demographic maturity in the empirical analysis that follows.

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 PWT, which Summers and Heston (2002) have been collecting for more than a decade, includes PPP adjusted measures of GDP per-capita for approximately 144 countries from 1950 to 2000.The United Nations World Population Prospects (2001), provides corresponding demographic data for 160 countries from

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[4] There is an addendum to this two-part story. As noted by Bloom and Williamson (1998), persistently low birth rates eventually produce a decline in the size of the working age population and an increase in old-age dependency ratios. Ultimately, however, whether the beneficial effects of a demographic maturation are merely transitional 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 will have a permanent effect on the level of per capita GDP. This, we believe, may help account for differences in those GDP levels far into the future, especially across countries that at present appear very similar.

1950 to 2000.[5] Merging both datasets produces an unbalanced panel of 142 countries and 842 potential observations.[6]

In figure 1, panel A, we show the evolution in our MATURE variable -- the size of the working age population -- from 1960 to 2000. We see that for the global economy as a whole, the percentage of persons aged 15 to 64 increased from 56.4 to 60.9 between 1960 and 2000. In Panel B, we see the U shaped pattern of our PRIMEAGE variable. The shape is the consequence of the post-war baby boom, which from 1960 to 1980 swelled the 15 to 64 year old population with younger workers.

[Figure 1]

More detailed demographic statistics and variable definitions are relegated to the appendix (Tables A1, A2, A3 and A4).

3. The Effect of Maturity on Per-Capita GDP levels.

Before modelling the effect of demographic maturity on cross-country income differentials, a few simplifying assumptions are required. In particular, we assume: (1) that countries can be assigned to different working age categories (e.g., young or mature, primeage or non-primeage); (2) that population age structure, like 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 economic conditions measured in the current period; and that (3) participation, productivity and savings rates are generally higher the greater the potentially active population (i.e., persons aged 15-64) and highest amongst prime-age working age cohorts (i.e., workers aged 35-54).[7]

Taken together, these assumptions imply that countries that are demographically more mature (in the sense of having greater shares of mature and/or prime-age working age populations) should, other things equal, display higher per capita GDP levels than younger counterparts.[8]

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[5]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. Naturally, if our goal was to estimate global welfare more generally, a population-weighted GDP per capita measure is preferable. See Theil (1979, 1996) and references contained therein for work on this question.

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

[7] In this regard both Weil (1994) and Feyrer (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).

[8] A further two assumptions can also be invoked. First, 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 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. Second that external migration is not large enough to mute the impact of historical fertility declines. 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.”

There are two potential caveats surrounding the exogeneity assumption that bear mentioning. First, in our measure of working age population, MATURE, there are components in the denominator that could very well be endogenous. In particular, because we are dividing the number of 15-64 year olds by the total population; the youngest (those under the age of 5) and the oldest age groups (those over the age of 65) could be related to current economic conditions. The reason is that longevity and fertility are both highly correlated with levels of economic development (countries that are generally poorer have higher fertility and lower longevity). The second issue centres on path dependency, in the sense that past levels of economic development affect past fertility, and at the same time could affect economic conditions in the current period through path dependent mechanisms highlighted in the endogenous growth literature.

The first of these concerns is perhaps less of a problem, in our case, for two reasons. The first is the historical and political record of most countries in our sample. Since we are focusing on the post war period exclusively, most countries at similar levels of development actually displayed quite differing demographics, due primarily to the peculiarities of the post-war period. Canada, for example, despite having a GDP per capita similar to Australia's in the 1940s and early 1950s, nevertheless had a much larger baby boom whereas Japan and Germany, despite having very poor economic conditions in the early post war period, saw fertility rates fall continuously without much of an upturn. Ireland is another interesting case. Because of institutional and religious factors, it maintained higher than average fertility rates within Europe, well after they had fallen in other "Catholic" countries such as Italy and Spain. The second reason why this first concern is less of a problem than one might imagine is that fertility and longevity are altered gradually by economic forces. Therefore, we would not expect the demographic denominator to be affected as dramatically by current economic conditions (this would not be the case with a variable like labour force participation or unemployment).

As regards the second caveat, concerning the effect from past levels of economic development on age structure making it difficult to disentangle the effect of age structure on economic outcomes, this could be partially addressed in the empirics in two ways. Firstly, if we were running a standard OLS for each period on our sample of countries, we could introduce lagged economic development variables into the equation with current age structure, in order to strip away the effects of past economic outcomes. This is not perfect since there still would be considerable cross-country heterogeneity that would not be picked up by the OLS estimates. The other technique –the one used in our paper – is to use a panel of countries and apply a fixed effect estimation which essentially takes the first differences between each period, so that we are no longer examining effects of static demographics on current levels, bit rather, changes in age structure within each country against changes in per capita income. This is still not perfect, as a better empirical design would take advantage of truly exogenous historical, policy and/or institutional changes in demographic age structure within a group of countries (things like the one child policy in China, Aids crisis in Africa, wars, legalization of contraception or abortion etc.,) and compare those outcomes to a matched set of countries who otherwise are the same, but which did not experience exogenous events affecting demography. Unfortunately, we do not as yet have a sufficiently large enough sample of countries to draw inferences beyond the case study approach identified in our opening quote comparing India and China.

So with these assumptions (and caveats) in mind, let y_{it}^{m} represent the log GDP 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 GDP per capita for the same country if it had a young working age population *g*. Assume that

$$y_{it}^{m} = y_t^{m} + \varepsilon_i^{m},$$
$$y_{it}^{g} = y_t^{g} + \varepsilon_i^{g},$$

where y_t^m and y_t^g are the mean log per capita GDP levels of mature and young countries at time *t*. Homogeneity within country groups is reflected in the assumption that $\mathrm{E}\left[\varepsilon_i^m \mid \text{mature}\right] = \mathrm{E}\left[\varepsilon_i^g \mid \text{young}\right] = 0$. Although this assumption will be relaxed later, at present, it implies that differences in GDP between mature and young countries are attributable to the effect of age structure only. The log per capita GDP gap between mature and young countries at time *t* will be denoted by

[3] $$\Delta_t^y = y_t^m - y_t^g,$$

which based on our analytical underpinnings 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 GDP level for all countries in the global economy at time *t* is simply:

[4] $$y_t = y_t^g + \underbrace{m_t \cdot \Delta_t^y}_{y_t^m}.$$

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

In the presence of mature countries, the estimate of global log per-capita GDP at time *t* is simply the expectation of [4]

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

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

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

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

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

This basic set-up helps us to identify in a transparent way the importance of demographic maturity with respect to per-capita GDP differentials over time. This 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 GDP per head.

As an illustration, consider the change in mean per capita GDP 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 GDP gap between mature and young countries from 1960 to 2000 is

[6] $$D = \underbrace{(y_{00} - y_{00}^g)}_{\Delta(Y_{00})} - \underbrace{(y_{60} - y_{60}^g)}_{\Delta(Y_{60})}.$$

The distribution of global GDP may change for a variety of reasons, one of which may be shifting proportions of mature countries or a widening in the GDP gap between mature and young countries. Equation [5] allows us to capture the relative importance of each effect. To see this, let $\Delta Y_{60|00}$ denote the GDP gap that would have occurred if the 1960 difference in per capita GDP between mature and young country groups were 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

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

and

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

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

To apply this framework to the data, we first create dichotomous versions of the two working age population ratios defined earlier as MATURE and PRIMEAGE.[9] In short, we categorise those countries with a ratio of prime-age workers greater than or equal to 0.365 over the working age population as being "prime-age" countries and those countries with a ratio less

[9] 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

than 0.365, as being “non prime-age”. [10] 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. [11]

Based on this grouping, and in order to properly isolate the importance of each demographic maturity measure, we estimate structural parameters associated with our dichotomous measures of mature and prime-age populations and their effect on real GDP levels. Such an approach is possible using a simple estimation model of the form:

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

where y_{it} is the log level of real GDP per capita of country i at time t, α is our constant, P_{it}^{35-54} is a binary indicator of prime-age working age structure that equals 1 if country i has a share higher than or equal to 0.365 percent of their working age population aged 35 to 54 in period t, S_{it}^{15-64} is our dummy measure of mature working age size, which is 1 if if country i has a share of persons aged 15-64 over the population that is greater than or equal to 0.65 at time t, and where Z_t is a vector of time dummy variables for each decade capturing the temporary effects that are common to all countries. Finally, e_{it}, following the traditional fixed effect model, can be decomposed into two terms: the first one refers to all non-observable country effects, assumed to be time invariant, and the second refers to an error term that is assumed to be white noise. In order to account for cross-country heterogeneity, we use the conventional within-estimation technique (fixed-effect estimator) applicable to panel data.

Table 1 shows the results of our panel adjusted estimates[12] along with the simple differences in log means (or the unadjusted raw gaps). The table also presents the figures in real US dollar amounts for illustrative purposes. The results for our fixed effect estimations are in line with our expectation. That is, both dummy variables of maturity -- though smaller in magnitude than the raw differentials -- are found to be positive and significant. Next, we use these coefficients to calculate the contribution of changing demographic maturity to rising global GDP, following our previously defined framework in equations [3] through [7].

[Table 1]

Durlauf and Quah (1999), among others, who find evidence of convergence club groupings and twin-peak distributions across development indicators.

[10] See Appendix Tables A2 and A3 for a detailed descriptive analysis of the characteristics of demographically mature and prime-age countries against younger and non prime-age country counterparts in three periods 1960s, 1980s, and 2000. Bottom line is that mature and prime-age countries typically show higher savings rates, lower income inequality, and greater mean GDP levels, with a widening in the gap between mature (or prime-age) and young (or non-prime age) observed from 1980 onward.

[11] 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 rates peak, as found by Gómez and Hernández de Cos (2003). A list of mature and prime-aged countries which fall into these dichotomous categories are available in the Appendix Table A4.

[12] The adjusted gaps are taken from the fixed effect regression of eq [8] with the time period dummies added. The estimated fixed effect coefficients on our mature and prime-age variables are then added to each common time period effect. All time dummy variables showed positive and highly significant coefficients.

Examination of columns [1] and [2] of Table 2 shows that the increase in our MATURE and PRIMEAGE measures of demographic maturity between 1960 and 2000 would have been expected to cause global GDP to rise by 0.523 and 0.386 respectively (row 2, third panel, table 2). During this period, the actual mean of per capita (log) global GDP rose by 0.760. Thus, after accounting for changes in non-demographic characteristics in our within-group estimates, the mature and prime-age nature of the working age population can each explain about 69 and 51 percent of the rise in global GDP per capita respectively since 1960 (row 3, third panel, table 2).

[Table 2]

When we decompose the demographic results above, we see that 0.340 (column 1, row 3, fourth panel) or a majority (65 percent) of the working age size effect is attributable to the rise in the fraction of countries with mature working age populations. Slightly more than a third (35 percent) of this effect is due to the increase in the GDP gap between mature and young countries (0.184).[13] Although the overall effect was much smaller in magnitude for the PRIMEAGE ratio, (column 2, row 3, fourth panel) both columns show that the growing share of mature and prime-age countries had a much stronger impact on the evolution of global GDP in the period from 1960 to 2000 than the GDP gap between the country club groupings (fourth panel).

4. Demographic Maturity and Sigma-Convergence

In addition to affecting the mean level of GDP per capita, demographic variation across countries may also affect the dispersion of per capita GDP within the global economy. That is, the widening of global income dispersion -- the so-called decline in "sigma-convergence" – that has occurred since the 1980s can also be linked to similar polarizations in age structure.[14] We turn now to this issue.

Let $Var\left[\varepsilon_{it}^{m}\right]=v_{t}^{m}$ and $Var\left[\varepsilon_{it}^{g}\right]=v_{t}^{g}$, represent the variances of log GDP per capita for countries with mature and young populations (or, alternatively, prime-age and non-prime age populations) at time *t*, respectively. The "variance gap" between mature (or prime-age) and young (or non-prime age) countries will be denoted by

[9] $$\Delta_{t}^{v}=v_{t}^{m}-v_{t}^{g}.$$

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

[13] The increase in the GDP gap between country groups is interesting. One explanation lies in the divergence in the percentage of prime age workers observed in both country groups during this time period: the non-mature country group became even younger while the mature country group became even more mature.

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

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

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

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

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

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

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

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

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

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

When the adjusted GDP gaps are plugged into equation [12], we find that the maturing of the global economy, both in terms of the size and structure of the working age population, between 1960 and 2000 should have caused the variance of (log) per capita global GDP to rise by 0.315 and 0.071 respectively (columns 1 and 2 of row 9, table 3). Between 1960 and 2000, the observed dispersion of (log) per-capita GDP in the global economy rose by 0.510 (columns 1 and 2 of row 8 of Table 3). Thus our calculations would suggest that changes in our first measure of maturity – the size of the potentially active working age population – were associated with 61.8 percent of the growth in global per capita GDP variance, while change in our primeage (structure) variable can explain roughly 13.8 percent of the rise in global income inequality since 1960 (columns 1 and 2 of row 12 of Table 3).

In both cases, the increase in variance is fully attributable to the between-age-category effect (i.e., some countries remaining young or non-prime age while others remaining or becoming mature or prime-age) since the within variance effect would have actually lowered global dispersion by 0.188 in the case of our prime-age measure of maturity, and contributed to a virtually negligible rise (0.008) in the case of our mature working age population measure. That is, once a country enters a mature or prime-age country club grouping, its GDP per head is much closer to the club's overall mean and therefore serves to increase sigma convergence.

[Table 3]

5. Conclusions

This paper has assessed the empirical connection between demographic maturation and global economic development. Our results point to several key findings. First, we find that countries defined as being demographically mature are significantly better off in terms of GDP per head than non-mature counterparts. Using two definitions of demographic maturity – a measure of potentially active persons (aged 15-64) as a share of the total population and a measure identifying the share of prime-aged persons (aged 34-54) within the potentially active working age population – we show that demographic maturation (i.e., the growing proportion of countries with mature or prime-age populations) has contributed to over half of the increase in global per capita GDP averaged across countries since 1960. This effect remains significant even after adjusting for country-specific effects.

We also find that population maturation has been associated with the widening of global inequality (i.e., the lack of observed sigma-convergence). This association is present despite the fact that cross-country income dispersion is lower within mature and prime-age country-club groupings. The reason for the overall widening is that this within group effect has not been large enough to offset per capita GDP differentials between young (or non-prime age) and mature (or prime-age) country clubs, meaning that demographic maturation has, on balance, served to retard rather than abet the process of sigma-convergence.

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

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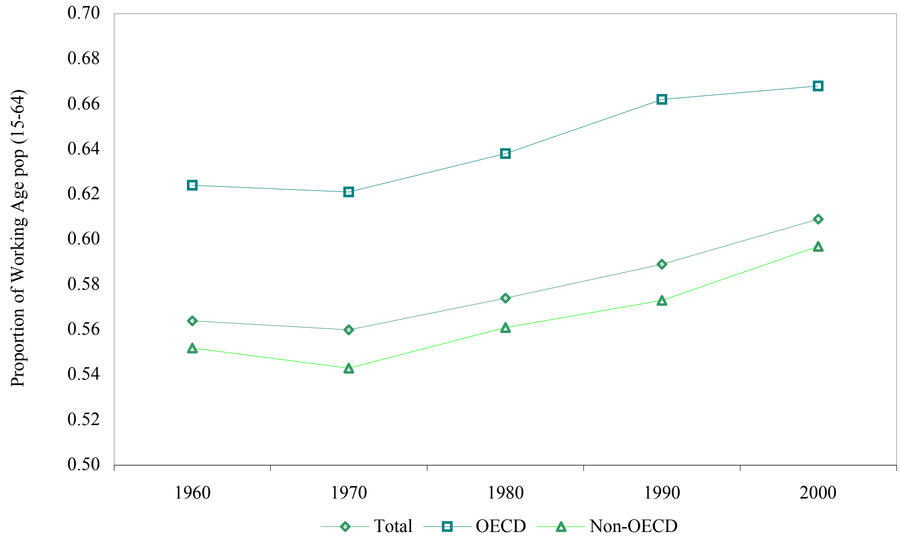
Figure 1: Size and Structure of the Working Age Population, 1960-2000

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



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

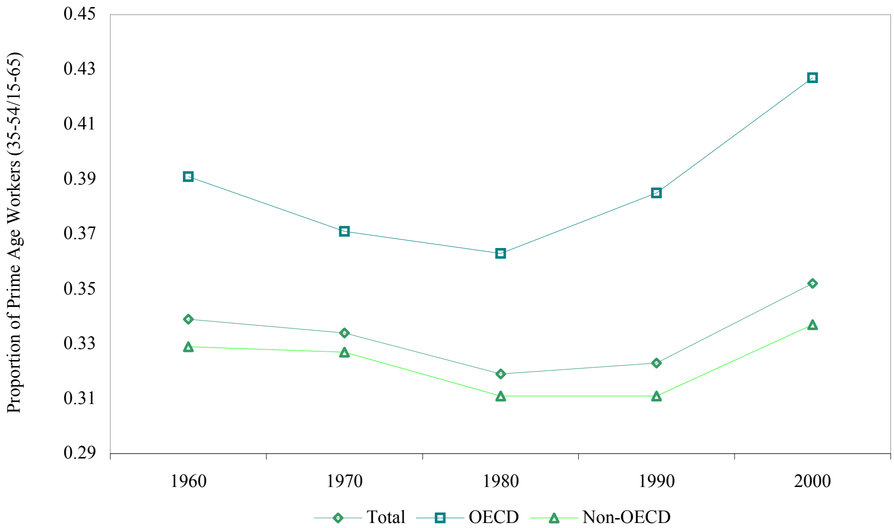


Table 1: Estimates of the GDP Gap between Mature or Prime-Aged and Young or Non-primeaged Countries.

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

Notes: Raw GDP gaps are actual differences in mean log GDP per capita between mature/prime and young/non-prime age countries in each period. These gaps are taken from Appendix Tables A2 and A3 rows 9. Adjusted GDP gaps are taken from a fixed effect regression with time period dummies added. The fixed effect coefficients on our mature and prime-age variables are then added to each common time period effect. See text and eq. [8] for a fuller explanation of the equation used to calculate the adjusted gaps. ***Denotes significance at 1% level. ** denotes significance at 5% level.

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

	Working Age Size	Working Age Structure
1960	[1]	[2]
1. Mean of Global Real GDP Per-capita in Logs (y) [USD]	7.722 [3,326]	7.722 [3,326]
2. Relative Fraction of Countries with Mature (or Prime-Aged) Working Age Population (m)	0.169	0.321
3. Per-capita GDP Gap Between Mature (or Prime-Aged) and Young (Non-prime-aged) Sectors in Logs (Δ^y)	0.573	0.385
4. Relative Demographic Maturity Effect ($y - y^g$)	0.097	0.124
2000		
1. Mean of Global Real GDP Per-capita in Logs (y) [USD]	8.482 [8,615]	8.482 [8,615]
2. Relative Fraction of Countries with Mature (or Prime-Aged) Working Age Population (m)	0.521	0.471
3. Per-capita GDP Gap Between Mature (or Prime-aged) and Young (or Non-Prime-Aged) Sectors in Logs (Δ^y)	1.190	1.081
4. Relative Demographic Maturity Effect ($y - y^g$)	0.620	0.509
Changes between 2000 and 1960		
1.Change in Mean of Global Real GDP Per-capita in Logs ($y_{00} - y_{60}$)	0.760	0.760
2.Change in Demographic Maturity Effect ($y_{00} - y^g_{00}$)-($y_{60} - y^g_{60}$)	0.523	0.386
3.Share of Global GDP Change Due to Demographic Maturity Effect (%)	68.8	50.7
Decomposing the Maturity Effect between 2000 and 1960		
1.Change in Demographic Effect ($y_{00} - y^g_{00}$)-($y_{60} - y^g_{60}$)	0.523 (100)	0.386 (100)
2.Total due to Change in GDP Gap (D_1)	0.184 (35.2)	0.182 (47.1)
3.Total due to Change in Share of Mature (or Prime-Aged) Countries (D_2)	0.340 (64.9)	0.203 (52.9)

Notes: In column [1] size refers to the dummy created from the MATURE variable (the ratio of mature working age population aged 15 to 64 over the total population). In column [2] structure refers to the dummy created from PRIMEAGE variable (the ratio of prime age workers aged 35 to 54 over the working age population). See text equations [3] to [7] for an explanation of formulas. Columns [1] and [2] represent the fixed-effect adjusted estimates of the log gap in GDP per capita (rows 3 in 1960 and 2000 panels) between mature and young country group. Numbers in [ ] represent mean real GDP in US dollars [USD] to provide some sense of the amounts involved.

Table 3: Estimates of the Contribution of Demographic Maturation to Changes in Global Log per-capita GDP Dispersion (Inter-quartile Range), 1960 to 2000

1960	Working Age Size [1]	Working Age Structure [2]
1.Global Variance of Real GDP Per-capita in Logs (v_t) [USD]	1.299 [3,158]	1.299 [3,158]
2.Relative Fraction of Countries with Mature (or Prime-Aged) Working Age Populations (m)	0.169	0.321
3.Per-capita GDP Gap Between Mature (or Prime-Aged) and Young (Non-prime-aged) groups in Logs (Δ^y)	0.523	0.385
4.Log Variance Gap Between Mature (or Prime-Aged) and Young (or Non-prime-aged) groups (Δ^v)	-0.269	0.190
5. Between-Age-Category Effect $m_t(1-m_t)(\Delta_t^y)^2$	-0.046	0.032
6.Within-Age-Category Effect ($m_t\Delta_t^v$)	0.046	0.061
7.Total Demographic Maturation Effect ($v - v^g$)	0.001	0.093
2000		
1.Global Variance of Real GDP Per-capita in Logs (v_t) [USD]	1.809 [8,624]	1.809 [8,624]
2.Relative Fraction of Countries with Mature (or Prime-Aged) Working Age Populations (m)	0.521	0.471
3.Per-capita GDP Gap Between Mature (or Prime-Aged) and Young (Non-prime-aged) Groups in Logs (Δ^y)	1.190	1.081
4.Log Variance Gap Between Mature (or Prime-aged) and Young (Non-prime-aged) Groups (Δ^v)	-0.072	-0.270
5. Between-Age-Category Effect ($m_t(1-m_t)(\Delta_t^y)^2$)	0.353	0.291
6.Within-Age-Category Effect ($m_t\Delta_t^v$)	-0.038	-0.127
7.Total Demographic Maturation Effect ($v - v^g$)	0.316	0.164
Change between 2000 and 1960		
8.Change in Global Variance of Real GDP Per-capita ($v_{00} - v_{60}$)	0.510	0.510
9.Change in Between-Age-Category Effect	0.307	0.259
10.Change in Within-Age-Category Effect	0.008	-0.188
11.Change in Total Demographic Maturity Effect ($v_{00} - v_{00}^g$) $-$ ($v_{60} - v_{60}^g$)	0.315	0.071
12.Share Attributable to Demographic Maturation (Percent)	61.8	13.8

Notes: In column [1] size refers to the dummy created from the MATURE variable (the ratio of mature working age population aged 15 to 64 over the total population). In column [2] structure refers to the dummy created from PRIMEAGE variable (the ratio of prime age workers aged 35 to 54 over the working age population). See text equations [9] to [12] for an explanation of formulas. Numbers in [ ] represent the standard deviation of real GDP in US dollars [USD] to provide some sense of the amounts involved.

Appendix

A1: Variable Definitions and Sources

Variable	Definition	Source
1. Prime Age Share	The fraction of the working age population (15-64) aged 35-54.	United Nations (1998, 2001)
2. Prime Age Sector	An indicator variable is constructed whereby countries with more that 36 percent of the working age population prime aged are assigned 1 and 0 otherwise.	United Nations (1998, 2001)
3. Mature Age Share	The fraction of the total population aged 15-64.	United Nations (1998, 2001)
4. Mature Age Sector	An indicator variable is constructed whereby countries with more that 65 percent of the population aged 15-64 are assigned 1 and 0 otherwise.	United Nations (1998, 2001)
5. GDP Per Capita (In Constant Prices)	Log of Real GDP per capita is a chain index (in 1996 $US prices). For more details, see Data Appendix in Penn World Tables 6.1.	Heston and Summers (2002)
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. Inequality	Measured as the GINI coefficient.	Deininger and Squire (1996)

Table A2: Characteristics of Countries by Structure of Working Age Population (Prime-age vs. Non-prime-age) in 1960, 1980, 2000

	Year					
	1960		1980		2000	
	Ratio 35-54/15-64		Ratio 35-54/15-64		Ratio 35-54/15-64	
	Prime-age >=0.36	Non-Prime-age <0.35	Prime-age >=0.36	Non-Prime-age <0.35	Prime-age >=0.36	Non-Prime-age <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.Real GDP per capita (mean in $USD)	6323	1848	12685	4579	14864	2931
5.Real GDP per capita Gap ($USD)	--	4475	--	8106	--	11033
6.Per Capita GDP relative to US (US=100)	51.8	15.2	60.3	22.5	45.0	9.0
7.Relative GDP per capita Gap	--	36.6	--	37.8	--	36.0
8.Log Real GDP per capita (mean)	8.504	7.336	9.285	7.999	9.377	7.681
9.Log Real GDP per capita Gap	--	1.168	--	1.286	--	1.696
10. Std. Dev. Log Real GDP per capita	0.825 (0.884)	0.620 (0.884)	0.728 (1.025)	0.934 (1.025)	0.737 (1.152)	0.817 (1.152)
11. Interquartile Range ($p^{75} – p^{25}$) of Log Real GDP per capita	1.096 (1.299)	0.906 (1.299)	0.584 (1.684)	1.444 (1.684)	1.183 (1.809)	1.453 (1.809)
12.Number of Observations	37	75	27	102	67	75
13.Proportion of Total (percent)	32.1	77.9	20.9	79.1	47.1	52.9

Notes: Demographic data based on United Nations World Population Prospects. A full account of all variable definitions can be found in Appendix Table A1. The GINI measures for 2000 are for 1990. Numbers in brackets in rows 10 and 11 are the all-country (global) variance measures.

Table A3: Characteristics of Countries by Size of Working Age Population (Mature vs. Young) in 1960, 1980, 2000

	Year					
	1960		1980		2000	
	Ratio 15-64/0-65+		Ratio 15-64/0-65+		Ratio 15-64/0-65+	
	Mature >=0.65	Young <0.65	Mature >=0.65	Young <0.65	Mature >=0.65	Young <0.65
1.Prime Age Population Ratio (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.Real GDP per capita (mean in $USD)	7219	2531	13772	3320	13961	2685
5.Real GDP per capita Gap ($USD)	--	4688	--	10452	--	11276
6.Per Capita GDP relative to US (US=100)	59.3	20.6	64.2	17.1	42.3	8.2
7.Relative GDP per capita Gap		38.6		47.0		34.0
8.Log Real GDP per capita (mean)	8.746	7.512	9.437	7.807	9.302	7.589
9.Log Real GDP per capita Gap		1.233		1.630		1.712
10. Std. Dev. Log Real GDP per capita	0.607	0.781	0.500	0.800	0.740	0.802
	(0.884)	(0.884)	(1.025)	(1.025)	(1.152)	(1.152)
11. Interquartile Range ($p^{75} – p^{25}$) of Log Real GDP per capita	0.756	1.025	0.514	1.275	1.326	1.398
	(1.299)	(1.299)	(1.684)	(1.684)	(1.809)	(1.809)
12.Number of Observations	19	93	32	92	74	68
13.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 variable definitions can be found in Appendix Table A1. The GINI measures for 2000 are for 1990. Numbers in brackets in rows 10 and 11 are the all-country (global) variance measures.

Table A4: List of Prime-aged and Mature countries

Country list for TableA2 if Ratio [35-54/15-64]>=0.365			Country list for TableA3 if Ratio [15-64/0-65+] >=0.65		
1960	1980	2000	1960	1980	2000
ARGENTINA	ARGENTINA	ALBANIA	AUSTRALIA	AUSTRALIA	ALBANIA
AUSTRALIA	AUSTRALIA	ARMENIA	BULGARIA	AUSTRIA	ANTIGUA
AUSTRIA	BELGIUM	ANTIGUA	SWITZERLAND	BELGIUM	ARMENIA
BELGIUM	BULGARIA	AUSTRALIA	CZECH REP	BULGARIA	AUSTRALIA
BULGARIA	BELARUS	AUSTRIA	ESTONIA	BELARUS	AUSTRIA
BARBADOS	CROATIA	AZERBAIJAN	GERMANY	CANADA	AZERBAIJAN
CANADA	CZECH REP	BELGIUM	GREECE	CROATIA	BELGIUM
CZECH REP	DENMARK	BULGARIA	CROATIA	CYPRUS	BULGARIA
DENMARK	ESTONIA	BELARUS	HUNGARY	DENMARK	BELARUS
FINLAND	GERMANY	BARBADOS	ITALY	ESTONIA	BRAZIL
FRANCE	GREECE	CANADA	LITHUANIA	FINLAND	BARBADOS
GABON	HUNGARY	CHILE	LUXEMBOURG	GERMANY	CANADA
GERMANY	ITALY	CHINA	LATVIA	HONG KONG	CHILE
HONG KONG	JAPAN	CYPRUS	ROMANIA	HUNGRY	CHINA
HUNGARY IRELAND	LITHUANIA	CZECH REP	ST. VINCENT & G.	ITALY	CYPRUS
ICELAND	LUXEMB.	DOMINICA	ST.KITTS &NEVIS	JAPAN	CZECH REP
ISRAEL	LATVIA	DENMARK	SWEDEN	LITHUANIA	DOMINICA
ITALY	ROMANIA	ESTONIA	UK	LUXEMBOURG	DENMARK
LUXEMB.	RUSSIA	FINLAND	UKRAINE	LATVIA	ESTONIA
MACAU	ST.KITTS &NEVIS	FRANCE		MACEDONIA	FIJI
MEXICO	SAO TOME	GERMANY		MACAU	FINLAND
NETHERL.	SLOVENIA	GREECE		MOLDOVA	FRANCE
NORWAY	SPAIN	GRENADA		MALTA	GERMANY
NEW ZEALAND	SWEDEN	HONG KONG		NETHERLANDS	GREECE
POLAND	SWITZERLAND	CROATIA		POLAND	GRENADA
PORTUGAL	UKRAINE	HUNGARY		RUSSIA	GUYANA
ST.KITTS &NEVIS	URUGUAY	IRELAND		ST.KITTS &NEVIS	HONG KONG
ST. VIN. & GRENS.		ICELAND		SINGAPORE	CROATIA
SLOVAKIA		ISRAEL		SLOVENIA	HUNGARY
SPAIN		ITALY		SWITZERLAND	ICELAND
SWEDEN		JAPAN		UKRAINE	IRELAND
SWITZERLAND		KAZAKHSTAN		USA	ISRAEL
UK		KOREA			ITALY
UKRAINE		ST. LUCIA			JAPAN
URUGUAY		SRI LANKA			KAZAKHSTAN
USA		LITHUANIA			KOREA
		LUXEMBOURG			ST. LUCIA
		LATVIA			SRI LANKA
		MACAU			LITHUANIA
		MOLDOVA			LUXEMBOURG
		MACEDONIA			LATVIA
		MALTA			MACAU
		MAURITIUS			MACEDONIA
		NETHERLANDS			MALTA
		NORWAY			MAURITIUS
		NEW ZEALAND			MOLDOVA
		POLAND			MORROCO
		PUERTO RICO			NETHERLANDS
		PORTUGAL			NORWAY
		ROMANIA			NEW ZEALAND
		RUSSIA			PANAMA
		ST. VINCENT & G.			POLAND
		ST.KITTS &NEVIS			PUERTO RICO
		SINGAPORE			PORTUGAL
		SAO TOME			ROMANIA
		SLOVAKIA			RUSSIA
		SLOVENIA			ST. VINCENT & G.
		SPAIN			ST.KITTS &NEVIS
		SWEDEN			SEYCHELLES
		SWITZERLAND			SINGAPORE
		SEYCHELLES			SAO TOME
		TRINIDAD			SLOVAKIA
		TAIWAN			SLOVENIA
		UK			SPAIN
		UKRAINE			SWEDEN
		URUGUAY			SWITZERLAND
		USA			THAILAND
					TRINIDAD
					TUNISIA
					TURKEY
					TAIWAN
					UK
					UKRAINE
					USA

NOTE: We have used the most recent designations for countries such as Czech Republic and Slovakia (formerly Czechoslovakia) that have subsequently changed names and/or split from larger federation(s). The United Nations provides separate demographic statistics, based on reclassifications of census data, for these 'new' countries going back to 1950. However, in the Penn World Tables, most of these countries do not have independent economic statistics until they were newly formed and therefore only appear in our unbalanced panel estimates when GDP figures became available.

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