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Demographic and Per Capita Income Dynamics: A Convergence Study on Demographics, Human Capital, and Per Capita Income for the US States

by

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Abstract

This paper finds that age distribution, educational attainment, and government size converge across the US states at rates rather similar to the convergence rate for per capita income. The main part of the paper takes age distribution variables as exogenous in conditional convergence regressions. Using panel data, the estimated partial relation between age and the subsequent growth rate of per capita income is hump-shaped and of quantitative importance. This result is robust to conditioning on other variables and appear not only to reflect capital-dilution. Another result is that average years of schooling has a positive effect on growth *only* if age distribution is controlled for. These findings are consistent with an explanation that the age distribution reflects the growth effects of human capital accumulated through experience.

Keywords: Age distribution; Economic growth; Convergence
JEL codes: O11; O18; O47

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1 Introduction

The overall aim of this paper is to improve our understanding of demographic changes and their relations to the dynamics of per capita income. These interrelations are largely ignored in the voluminous recent empirical literature on growth. Most of the modern theories of economic growth, including the standard neoclassical model (see Solow, 1956; Cass, 1965; Koopmans, 1965; and others) assume also a constant population or a constant population growth rate.

More specifically, this paper studies the effects of the age distribution on the subsequent growth rate of per capita income when initial per capita income is held constant. Even though the recent literature on conditional convergence has examined empirical linkages between a large number of variables and the rate of economic growth, age distribution variables are typically omitted. This is e.g. illustrated by a recent survey (Durlauf and Quah, 1998) on regressors used in cross-country growth regressions which includes 87 specific examples. The only age distribution variables included among these specific examples are the contemporaneous changes of the shares of the population under age 15 and over age 65 [1]. That age distribution variables typically are omitted is surprising considering that focus has been on variables, such as the size of the government sector, that are likely to be correlated with, or partially determined by, the age distribution[2].

There are also several reasons why the age distribution may matter for subsequent growth. The most obvious one being that the net contribution to output of kids and elderly might be negative. If that is the case, an economy that experiences increased youth and old age dependency ratios should grow slower than otherwise would be the case. Another motivation for thinking about the age distribution and economic growth is that measures of human capital is a weak spot in the empirical growth literature. Only various educational variables, such as the average years of schooling, are typically used as proxies for the human

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[1] However, there are some growth related studies that focus on age distribution and demographics. Lee and Ling (1994) relates economic growth to the young and the old age dependency ratios using the Summers-Heston data. Sarel (1995) reports evidence of differences in productivity across age groups also using the Summers-Heston data. Lindh and Malmberg (1996) find a positive partial correlation between the growth rate of GDP per worker and the age group 50-64 years (expressed as a share of labor force) using panel data for the OECD. McMillan and Baesel (1990) is a time series study on annual GDP growth and age structure for the US. Bloom and Sachs (1998) provide some cross-country evidence that the contemporaneous difference between the growth rate of working-age population and the growth rate of total population is positively related to per capita income growth.

capital stock, which theoretically includes both schooling and on-the-job-training (Mankiw, 1995, p. 293; Temple, 1999, p. 139). As a result, the human capital that is accumulated through on-the-job-training tends to be neglected. In view of the microeconomic evidence on age-wage profiles (e.g. Murphy and Welch, 1992), it appears that age distribution variables might reflect this type of human capital accumulation. This is e.g. argued in some earlier paper on age distribution and growth (Lindh and Malmberg, 1996; Persson and Malmberg, 1996). A different, but yet somewhat related view, is expressed in Mulligan and Sala-i-Martin (1995a,b) who propose some measures of human capital that are based on labor income. Moreover, BS (1995, Ch. 12) and Barro (1996) use as empirical measures of human capital not only educational attainment variables but also life expectancy. Furthermore, another possible mechanism through which the age distribution may affect growth is through aggregate saving. According to the life-cycle model, one expect high youth and old age dependency ratios to depress aggregate saving. There is also some evidence of a negative association between dependency ratios and saving rates (Deaton, 1995; Higgins and Williamsson, 1997; Kelley and Schmidt, 1996).

The remainder of the paper contains two parts. The first part (section 3) focuses on the determination of the age distribution and the population growth rate (net of migration flows) across the US states. It examines whether there is cross-state demographic convergence and relates the results to earlier findings on cross-state per capita income convergence (see Barro and Sala-i-Martin, henceforth BS, 1991; 1992; 1995, Ch. 11). The main finding is that there is demographic convergence. Both the age distribution and the population growth rate (net of migration) converge across the US states during the 1900s. Moreover, it is also found that educational attainment and the size of state and local government sector exhibit cross-state convergence. Corresponding to other empirical studies (see e.g. the survey article by Erlich and Lui, 1997), it is found that also for the US states the population growth rate tends to be negatively related to per capita income, which is not in favor of the empirical validity of the one-sector AK model. This is because the AK model *may* be consistent with the empirical evidence on absolute per capita income convergence for the US states *if* fertility and population growth is positively related to per capita income (see discussion in Sala-i-Martin, 1996a, p. 1347). The neoclassical growth model, on the other hand, appears consistent with data. For example, BS (1995, Ch. 9.2) present a model with endogenous fertility based on

[2] For example, Lee and Ling (1994) report a positive partial correlation between total government

previous work of Becker and Barro (1988) and Barro and Becker (1989). This model generates a negative relation between the fertility rate and per capita income, and it predicts that both fertility and per capita income, over time, converge across economies that are similar in terms of preferences and technology but different in terms of initial conditions[3]. Thus, even though this model only analyzes one of the determinants of the age distribution and the population growth rate, namely fertility, it is consistent with the empirical results on age distribution, population growth and per capita income obtained in this paper.

The second and the main part of the paper (sections 4 and 5) contains the conditional convergence regressions with age distribution variables as explanatory variables. Thus, the focus is here on the variation in the age distribution that is not related to the level of per capita income. The empirical specification is based on the Solow model. I extend the version of the Solow model developed by Mankiw, Romer, and Weil (1992), henceforth MRW, by allowing the different age groups of the population to differ in productivity to e.g. reflect differences in human capital accumulated through experience As this study uses data for the US states, it relates to previous work on convergence by BS (1991; 1992; 1995, Ch. 11)[4].

The main results from these panel regressions are: First, the estimated partial relation between age and the subsequent growth rate of per capita income is hump-shaped and of quantitative importance. This result is robust to conditioning on variables such as the population growth rate, the net migration rate, educational attainment and government size as well as regional and state dummies, a finding that provides information on the potential mechanisms by which the age distribution matter for growth. For example, the hypothesis that the estimated growth effects of age distribution variables only reflect the capital-dilution effect in the neoclassical model, i.e. the effect of population growth, is strongly rejected. Second, average years of schooling has a positive effect on growth only if age distribution is controlled for. These empirical findings are consistent with the experience-based human capital explanation put forward in this paper; that is, with the augmented MRW-model of this paper. Other mechanisms, e.g. via savings, through which the age distribution affects subsequent growth can however not be excluded. Due to lack of state data on aggregate saving and aggregate investment, I could not investigate the empirical validity of a saving-mechanism.

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expenditures, expressed as a ratio to GDP, and the dependency ratio using the Summers-Heston data.

[3] However, for some parameter values the model generates a hump-shaped relation between these variables.

[4] In addition to their absolute convergence regressions, BS also estimated conditional convergence regressions that included net migration as well as regional dummies (corresponding to the census regions). BS (1992) also mention that educational and government variables are used as regressors.

Finally, the empirical findings on growth and demographics are also robust in the sense that they apply to Swedish regions. A separate appendix, that is available upon request, includes evidence from the Swedish regions for the period 1910-1990.

2 Data for the 48 contiguous US states

The data on income for the 48 contiguous US states for the period 1929-1990 are from the US Commerce Department. The income concept used is per capita personal income excluding government transfers. Data on incomes for 1880, 1900 and 1920 are from Easterlin (1960). No income figures for 1890 and 1910 are available. Income data for Oklahoma is missing for 1880. As a result, I use the same data as BS (1992) use. Moreover, following BS (1992), I compute real income by dividing the nominal figures on personal income by the national values of the consumer price index (1982-1984 = 100). (I use the figures from the Statistical Abstract of the US for all items since 1960. Before 1960, I use the overall index from the US Commerce Department (1975), series E135.)

The data on age distribution for the period 1880-1990 are from the US Department of Commerce (1975) and from the Statistical Abstract of the US and they are available for every ten years. There are some missing values in these series: Oklahoma and South Dakota in 1880 and Oklahoma in 1890. The division of age groups is determined by the statistics (US Department of Commerce, 1975). The data on educational attainment are taken from Mulligan and Sala-i-Martin (1995a, Table 8). They compute average years of schooling per person aged 25-65 in the civilian labor force for every ten years since 1940. The data on labor earnings (including those from self-employment) since 1929 broken down into nine sectors, including state and local government, are from the US Department of Commerce. This data source is used to calculate a measure of the size of state and local government.

3 Convergence in distribution

The age distribution of a population tends to change as a country or a region develops as fertility and mortality rates, that (together with migration) determine the age distribution, tend to depend on the level of per capita income. Poor countries typically have higher birth rates, higher population growth and younger populations than rich countries (see e.g. Ehrlich and Lui, 1997; Ray, 1998, Ch. 2 and 9)[5].

This section studies the cross-sectional dispersion of the age distribution across the US states for the period 1880-1990 and relates it to the dispersion of per capita income. The upper window of Figure 1 shows the standard deviations of the log of different age groups (expressed as ratios to total population) across states for every 10 years for the period 1880-1990, whereas the lower window shows the standard deviation of the log of per capita income for 1880, 1900, 1920 and annually from 1929 to 1990[6]. Figure 1 demonstrates that there is a great deal of variation in the age distribution across the US states - particularly in the early part of the sample period. Further, the figure provides evidence of convergence across states not only for per capita income (as documented earlier by BS, 1992), but also for four of the five age groups. Only one age group (15-24 years) does not converge: the dispersion is about the same in 1990 as it is in 1880. (Incidentally, this age group is the smallest in size - it covers only a time span of ten years.) Hence, the whole age distribution converges between 1880 and 1990. This means that states that started out with relatively young populations in 1880 have over time caught up with states that started out with more mature populations. (Convergence is here defined in the s sense; that is, convergence is defined to occur for a variable if the dispersion of the log of this variable across states – measured by the standard deviation – declines over time.) Actually, most of the convergence both for per capita income and the age distribution takes place during the period up to 1970; that is, between 1970 and 1990 the dispersions of per capita income and the age group variables typically do not decrease. For per capita income and the two youngest age groups (0-24 years) the standard deviations actually increase somewhat between 1970 and 1990. For the middle-aged groups (25-64 years), the standard deviations stay about constant, and for only one of the variables, the age group 65+, the standard deviation decreases.

The standard deviations of the log of the age groups fall between 1880 and (1970) 1990; from 0.196 to (0.055) 0.085 for ages 0-14; from 0.062 to (0.055) 0.066 for ages 15-24; from 0.204 to (0.056) 0.052 for ages 25-44; from 0.199 to (0.062) 0.061 for ages 45-64; and from 0.496 to (0.172) 0.140 for ages over 65. For the log of per capita income, the standard deviation falls from 0.545 in 1880 to (0.169) 0.177 in (1970) 1990. Quantitatively,

[5] At very low levels of per capita income, the empirical relation between population growth and per capita income is by some researcher found to be positive (see e.g. Ray, 1998, Ch. 2) as very poor countries tend to be characterized by both high birth rates and high death rates.

between 1880 and 1990 the declines, in percentage terms, of the standard deviation of log per capita income and of the standard deviations of the log of the age groups (apart from the age group 15-24 years) are strikingly similar; ranging from 57 percent (for ages 0-14) to 75 percent (for ages 25-44)[7].

Figure 1 also shows that when the standard deviation of log per capita income increases, the standard deviation of the youngest age group (0-14 years) tends also to go up. Towards the end of the sample period the dispersions of both these variables increase somewhat. Moreover, the standard deviation of log per capita income is higher during the period 1929-1940 than it is in 1920, and the standard deviation of the youngest age group is also higher in 1940 than it is in 1920 (albeit about the same in 1930 as it is in 1920).

The high degree of covariation between the standard deviation of log per capita income and the standard deviation of the log of the youngest age group is indicated by a high correlation coefficient: 0.91 (*t-statistic* = 6.20)[8]. This positive correlation should reflect a negative relation between fertility and per capita income. Table 1 reports also a negative sample correlation, -0.61, between the average annual population growth rate (net of migration flows) and the level of per capita income for the 1940s. However, since the population growth rate includes mortality, not only changes in fertility affect it. (The sample correlation matrices for the other subperiods of the period 1880-1990 are reported in the appendix (Table A2) and they give the same picture: the population growth rate and per capita income tend to be negatively correlated. The correlation is typically particularly strong in the earlier subperiods when cross-state differences in per capita income are large.)

Figures 2a-d display the behavior over time of the cross-sectional distributions of other variables. Figure 2c shows that the standard deviation of the average annual population growth rate (net of migration) is somewhat lower in the 1980s, 0.0044, than it is in the 1910s, 0.0048, indicating s convergence. (The observation for the 1910s (1980s) is along the x-axis of the figure plotted at 1915 (1985).) The figure also shows that the decline of the dispersion is not monotonic over time. The standard deviation is higher for the 1970s, 0.0033, and 1980s than for the 1960s, 0.233, which is the lowest value of the whole period, 1910s-1980s. In

[6] For summary statistics see Table A1 of the appendix.

[7] For ages 45-64 the decline is 69 percent, for ages 65+ 72 percent, and for log per capita income 68 percent.

[8] The correlation coefficient is calculated on the basis of those years that both age distribution and income data are available. For the other age groups (that do converge) the correlation with the standard deviation of log per capita income is: 0.57 (1.94) for ages 24-44; 0.52 (1.70) for ages 45-64; and 0.63 (2.32) for ages 65+.

addition, the standard deviation is higher for the 1930s than it is for the 1920s[9]. These results correspond qualitatively largely to the behavior of the dispersions for log per capita income and the youngest age group. As already noted, also the dispersions of these variables increase toward the end of the sample period as well as around the period 1930-1940. Figure 2d shows that the standard deviation of the net migration rate does not exhibit any clear convergence pattern over the period 1910s-1980s.

A measure of government size given by the ratio of labor earnings in state and local government as a share of total labor earnings is plotted in Figure 2a[10]. The standard deviation of the log of this measure falls marginally from 0.140 in 1930 to 0.137 in 1990. This contrasts to the evolution of educational attainment - the standard deviation of the log of average years of schooling per labor force person aged 25-65 falls substantially from 0.115 in 1940 to 0.024 in 1990.

Reverting to Table 1, in addition to the negative sample correlation between per capita income and the population growth rate, the table shows that it is the poor states that have a high proportion of the population in the youngest age groups (ages 0-24), a high out-migration rate, a low level of educational attainment, and, of course, a high subsequent growth rate of per capita income. (The sample correlation matrices for the other subperiods of the period 1880-1990 (Table A2 of the appendix) indicate that the correlations between per capita income and the younger and middle-aged age groups (ages 0-65) are particularly strong in the earlier periods when the cross-state differences in these variables were large[11].)

As s convergence is different from the concept of absolute b convergence, I will test for absolute b convergence for the variables included in Figures 1-2. We say that there is absolute b convergence in a cross section of economies if there is a statistically significant negative relation between the growth rate of a variable and the initial level of this variable (see e.g. Sala-i-Martin, 1996b.) Neither s nor b convergence has (to the best of my knowledge) previously been studied for these variables, except of course for per capita income (BS, 1992).

[9] The coefficient of variation (CV) can be calculated using the data in Table A1 of the appendix. It gives the same basic picture as the standard deviation does.

[10] Federal grants as a share of total state and local government revenues has increased since 1930 and amounts to around 13 percent in 1990 (Stiglitz, 1988, Ch. 2, Table 2.10; Statistical Abstract of the US 1996, Table no. 471). Even though the size of federal grants, relative to total revenues, is fairly small, a potential problem for the economic interpretation of the empirical results on this variable is that federal grants are not distributed equally across states.

In addition, the standard deviation of the log of average years of schooling is documented by Mulligan and Sala-i-Martin (1995b, Figure 10). To test for absolute b convergence I estimate the nonlinear regression equation

$$\ln\left[z_{i,t} / z_{i,t-t}\right] / t \; = a \; - \left[(1 - e^{-bt}) / t\right] \cdot \ln z_{i,t-t} \; + \; u_{i,t} \;, \qquad (1)$$

where z is identified by the variables in Figures 1-2. A positive value of b implies absolute b convergence and a higher value of b corresponds to a faster convergence rate. The estimation method is nonlinear least squares, except for the population growth rate, n (column 9), for which linear estimation is used[12].

Table 2 shows that all variables exhibit absolute b convergence[13]. Column 1 reports that the US states, with respect to per capita income, converge at a rate of 1.7 percent per year for the period 1880-1990, which reassuringly is consistent with the findings of BS (1995, Ch. 11). Columns 2-6 show the regression results for the age groups (expressed as ratios to total population) for the same sample period. All age groups exhibit absolute b convergence, even the age group 15-24 years which did not exhibit s convergence for this period. The age group estimates tend also to be fairly close to the estimate of b for per capita income. The values of R^2 for these regressions, except for the age group 15-24 years, are also close to the corresponding high value of R^2 for per capita income. Furthermore, the regression for the population growth rate for the period 1910s-1980s (column 9) also indicate absolute b convergence; that is, there is a significant inverse relation between the initial population growth rate and the subsequent rate of change of this variable. As concerns government size (GOV), it converges across states at a rate of around 3 percent per year for the period 1930-1990 (column 7), whereas average years of schooling (SCH) converges at a rate of 4 percent for the period 1940-1990 (column 8). Table 2 also reports estimates of b for per capita

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[11] We can (from Table 1 and from Table A2 of the appendix) also note that the correlation between per capita income and the age group 65+ changes signs during the period 1880-1990: the correlation is positive during the most of the period up until 1960, after which it turns weakly negative.

[12] The linear regression equation that is estimated for n is given by

$$(n_{i,t} \; - \; n_{i,t-t}) / (\left|n_{i,t-t}\right| \cdot t) = \; a \; + \; b \cdot n_{i,t-t} \; + u_{i,t} \, .$$

Thus, a negative value of b implies convergence. Because not all values of n are positive, the log of n is not defined. Since there is overshooting when the lagged value of n is used as regressor, the nonlinear regression equation cannot be estimated.

income and the age groups for the shorter sample period 1930-1990. These estimates tend to be close in magnitude to the ones obtained for the long sample period[14].

To conclude, this section finds that not only per capita income but also age distribution, population growth (net of migration), educational attainment, and size of government exhibit s and absolute b convergence across the US states. Quantitatively, it is found that the estimated rates at which states converge to each other with respect to per capita income, age group variables, educational attainment and government size are rather similar[15]. The result that the population growth rate (net of migration) typically is negatively correlated with per capita income is not in favor of the empirical validity of the AK-model. This is because one possibility for the AK-model to be consistent with the empirical evidence on absolute per capita income convergence is that fertility and population growth is positively related to per capita income. The neoclassical growth framework, on the other hand, appears consistent with data. For example, the neoclassical model with endogenous fertility presented by BS (1995, Ch. 9.2) is, provided that the differences in preferences and technologies are small across states, consistent with the estimated negative relation between the population growth rate and per capita income as well as with the observed convergence for per capita income, the age distribution and the population growth rate.

The next sections of the paper study the relation between age distribution and the subsequent growth rate of per capita income when initial per capita income is held constant. Thus, the focus is here on the exogenous variation in age distribution; that is, on the variation in age distribution that is not linked to the level of per capita income. The meaning of b in these conditional convergence regressions is different from the meaning of b in the absolute convergence regressions: it is no longer a measure of the rate at which the states converge to each other, but rather a measure of the rate at which the gap between the actual and the steady state level is eliminated in an augmented MRW-model.

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[13] The net migration rate is, due to space limitations, not included in the table. It did not exhibit b convergence.

[14] Moreover, if the sample is split into 10-year periods, it turns out that absolute convergence takes place during most of the 10-year periods for all variables included in Table 2.

[15] Recall that for the population growth rate, the rate of convergence could not be estimated (see footnote 11).

4 The MRW model augmented with age distribution

4.1 A theoretical framework

The model is an extension of the model developed by MRW, which is the basis for numerous empirical studies (Durlauf and Quah, 1998, p.23). The MRW model is the standard Solow model augmented with human capital. The reasonable extension of the MRW model made in this paper is that it is recognized that the different age groups of the population may differ in productivity. Apart from this extension, the model of this paper is identical to the MRW model. Heterogeneity in productivity is allowed by the aggregate production function, which is assumed to exhibit constant returns to scale:

$$Y(t) = AK(t)^{a} H(t)^{l} (N_1(t)e^{g\cdot t})^{g_1} (N_2(t)e^{g\cdot t})^{g_2} \cdot \ldots \cdot (N_m(t)e^{g\cdot t})^{1-a-l-\sum_{j=1}^{m-1} g_j}$$

$$= AK(t)^{a} H(t)^{l} \cdot \left\{ \prod_{j=1}^{m-1} (N_j(t)e^{g\cdot t})^{g_j} \right\} \cdot (N_m(t)e^{g\cdot t})^{1-a-l-\sum_{j=1}^{m-1} g_j}, \qquad (2)$$

where $j = 1, \ldots, m$, $a > 0$, $l > 0$, $a + l < 1$, $A > 0$.

Y is output and K is physical capital. The number of people in age group j is denoted N_j, m is the number of age groups, and $e^{g\cdot t}$ represents the effect of exogenous labor-augmenting technological progress. H is *educational* human capital as opposed to human capital accumulated through experience. *Experience-based* human capital is assumed to be reflected by the productivity parameters, g_j, of the different age groups. The values of g_j can be positive, negative or zero. A is an index representing the level of the technology. I assume that $Y > 0$, which, *inter alia,* means that the age groups are sufficiently broadly defined so that all of them are populated.

As a comparison, the MRW production function is given by

$$Y(t) = K(t)^{a} H(t)^{l} (L(t)A(0)e^{g\cdot t})^{1-a-l} \qquad (3)$$

where L is labor, which is assumed to grow at a constant rate. In the empirical analysis, MRW use working-age population (ages 15-64 years) as a proxy for L. Thereby, MRW assume that only people of working age affect aggregate production and that people between 15-64 are identical with respect to productivity, which should imply that they possess the same amount of human capital, have the same labor force participation rates, work the same number of hours, exert the same effort, etc.. In contrast, the empirical analysis of this paper incorporates all age groups and allows them to influence aggregate production differently.

Most empirical growth studies use production functions similar to that of MRW but proxy L by total population (e.g. BS, 1992; 1995, Ch. 11-12)[16]. Thus, these studies assume that the different age groups are perfect substitutes in the aggregate production function.

Rewriting the production function in equation (2) in intensive form:

$$\hat{y}(t) = A\hat{k}(t)^{a}\,\hat{h}(t)^{l}q \ , \qquad\qquad q = \left(\prod_{j=1}^{m-1}\tilde{n}_j^{\,g_j}\right)\cdot \tilde{n}_m^{\,1-a-l-\sum_{j=1}^{m-1} g_j} \qquad (4),$$

(5)

where $q > 0$, $\tilde{n}_j = N_j / N$, $\tilde{n}_m = N_m / N$, $N = \sum_{j=1}^{m} N_j$, i.e. N is total population,

$\hat{y} = Y / AN$, $\hat{k} = K / AN$ and $\hat{h} = H / AN$.

The age structure, reflected by q, is assumed to be exogenously given. This paper also makes the assumption that total population grows at the exogenously given rate n[17].

Although the MRW model is a closed economy model, it is here applied to the US states, which is a set of economies that are far from closed with respect to each other. However, it is by no means unusual to apply closed economy models to regional data sets: BS (1992) use the closed economy Ramsey model as a framework in their convergence study of the US states. The typical justification (see Sala-i-Martin, 1996a) for the closed economy assumption, in the regional setting, is that (1) the neoclassical growth model with perfect capital mobility predicts instantaneous convergence, which is contradicted by the empirical evidence; (2) there are open economy neoclassical growth models with partial capital mobility

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[16] BS (1992) use the production function, $Y(t) = AK(t)^{a}\,(L(t)e^{g\cdot t})^{1-a}$.

[17] Thus, the time derivative of $\ln q$ is assumed to be zero (see appendix). A sufficient condition for this to hold is that all age groups, N_j, grow at the rate *n*, i.e. at the same rate as *N* grows.

that behave similarly to the closed economy model; e.g., the model developed by Barro, Mankiw, and Sala-i-Martin (1995) predicts rates of convergence (for reasonable parameter values) very similar to those predicted by the closed economy model.

Life-cycle saving is one potential channel through which the age distribution can affect growth. There is, e.g., some (although not universal) support for explaining international differences in saving rates by international differences in age distribution (Deaton, 1995, p. 12). However, I stick to the MRW model and assume that the saving rate for physical capital accumulation, s^k, is exogenous and independent of age. I also assume an exogenous saving rate for educational human capital, s^h. Thus, the dynamics of the economy is given by

$$\dot{\hat{k}}(t) = s^k \cdot \hat{y}(t) - (n + g + d)\hat{k}(t)\,, \qquad \dot{\hat{h}}(t) = s^h \cdot \hat{y}(t) - (n + g + d)\hat{h}(t) \qquad \text{(6a), (6b)}$$

where d is the constant rate of depreciation, which is assumed to be equal for the two types of capital. As a result of these assumptions, the model of this paper differs relative to the MRW model *only* with respect to the production function.

Equations (6a) and (6b) imply that the economy converges to a steady state defined by:

$$\hat{k}^* = \left[\frac{A(s^k)^{1-l}(s^h)^{l} q}{n + g + d}\right]^{1/(1-a-l)}\,, \qquad \hat{h}^* = \left[\frac{A(s^k)^{a}(s^h)^{1-a} q}{n + g + d}\right]^{1/(1-a-l)} \qquad \text{(7a), (7b)}$$

Shifts in the age distribution are likely to change the value of q. If this is the case, the steady state levels of physical and educational human capital per effective capita change, which then induces (positive or negative) transitional growth in the model.

The transitional dynamics is, as usual, quantified by a log linearization of equations (6a) and (6b) around the steady state. Let $\hat{y}^*$ be the steady state level of income per effective capita given by equations (4), (7a) and (7b), and let $\hat{y}(t)$ be the actual value at time *t*. The log-linear approximation around the steady state (see appendix) gives

$$\frac{d \ln \hat{y}(t)}{dt} = -\, b \cdot \ln(\hat{y}(t) / \hat{y}^*)\,, \qquad (8)$$

where $b = (1-a-l)(n+g+d)$. b is the rate of convergence from $\ln \hat{y}(t)$ to $\ln \hat{y}^*$. If we consider the period from the initial time t to the later date $t+t$, equation (8) implies that the average growth rate of per capita income between time t and time $t+t$ is given by

$$\frac{1}{t}\cdot\ln\left(\frac{y(t+t)}{y(t)}\right) = g + k\cdot\left[\ln \hat{y}^* - (\ln y(t) - g\cdot t)\right], \tag{9}$$

where $k = (1-e^{-b\cdot t})/t$ and *y(t)* is per capita income. Equation (9) shows that the growth rate over the period is equal to the rate of technological progress, *g*, plus a factor that applies to the transition to steady state, which depends on the distance between $\ln \hat{y}^*$ and $\ln \hat{y}(t)$ (= ln *y(t)* - $g\cdot t$). Substituting for $\hat{y}^*$ gives:

$$\frac{1}{t}\cdot\ln\left(\frac{y(t+t)}{y(t)}\right) = g + k\cdot\frac{1}{1-a-l}\ln A + k\cdot g\cdot t + k\cdot\frac{a}{1-a-l}\ln s^k$$

$$+ k\cdot\frac{l}{1-a-l}\ln s^h + k\cdot\frac{1}{1-a-l}\ln q - k\cdot\frac{a+l}{1-a-l}\ln(n+g+d) - k\cdot\ln y(t) \tag{10}$$

Note that equation (5) implies that $\ln q = \left(\sum_{j=1}^{m-1} g_j \ln\tilde{n}_j + (1-a-l-\sum_{j=1}^{m-1} g_j)\ln\tilde{n}_m\right)$.

The growth effects of all variables included in equation (10), except for the age groups variables, are unambiguous. *A* is often interpreted broadly (see e.g. Sala-i-Martin, 1996b). Furthermore, the model predicts that the growth rate is increasing in *t*, the time trend, which reflects the effect of the exogenous technological progress during the transition to steady state. The fourth, fifth, seventh and eight terms imply that the growth rate increases with higher investment rates in physical and educational human capital, but decreases with higher population growth and higher initial per capita income.

4.2 Empirical setup

Equation (10) is given a panel data interpretation. For an economy *i*, a discrete period version of equation (10) that includes a disturbance term is:

$$\ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = a_{i,t} + k \cdot \frac{1}{1-a-l} \ln q_{i,t-1} - k \cdot \frac{a+l}{1-a-l} \ln(n_{i,t-1,t} + g + d) - k \cdot \ln y_{i,t-1} + u_{i,t} \tag{11}$$

where $a_{i,t} = g + k \cdot \left[\frac{1}{1-a-l} \left(\ln A_i + a \cdot \ln s^k_{i,t-1} + l \cdot \ln s^h_{i,t-1} \right) + g \cdot (t-1) \right]$,

$\ln q_{i,t} = \left(\sum_{j=1}^{m-1} g_j \ln \tilde{n}_{j,i,t} + (1 - a - l - \sum_{j=1}^{m-1} g_j) \ln \tilde{n}_{m,i,t} \right)$, $n_{i,t-1,t}$ is the population growth rate between time $t-1$ and t. Thus, the time length, t, between observations is normalized to unity in equation (11). Except for *A*, the determinants of economy *i*'s steady state level of per capita income are indexed by time to allow the steady state to change from period to period: q, s^k and s^h are indexed by time $t-1$. In the empirical analysis $g + d$ is set equal to 0.07 for all states and periods in the expression $\ln(n + g + d)$. (These values are taken from BS, 1995, p. 37.) Although the model suggests that b may vary both over economies and periods due to, e.g., differences in population growth rates ($b_{i,t} = (1-a-l)(n_{i,t-1,t} + g + d)$), it is assumed to be constant across states, which corresponds to assumptions made by BS (1992) and MRW. The technology parameters (a, l and g_j) are assumed to be the same across states and periods.

$a_{i,t}$ captures any state-specific effect, m_i, and any common period-specific effect, h_t; thus, $a_{i,t} = m_i + h_t$. Different intercepts across i, m_i, may arise due to differences in the level of technology *A* as well as due to differences in e.g. s^k and s^h that cannot be controlled for due to lack of data. However, for the sample period 1940-1990, an educational attainment variable is used as a proxy for *h*; hence, s^h can be substituted away in equation (11). The period-specific effect captures the joint growth effects of the time trend and of any other common time-specific effects from excluded variables.

Equation (11) is estimated both by assuming away possible state-specific effects (see BS, 1995, Ch. 11-12) and by allowing for such effects to reflect possible unobservable heterogeneity across states. Thus, in the first approach $a_{i,t}$ is assumed to be the same for all states; that is, $a_{i,t} = a_t$. This approach is taken in the next two sections of the paper.

By using the assumption of CRS on equation (11), the number of coefficients of the age group variables, to be estimated, are reduced by one:

$$\ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = a_{i,t} + k \cdot \frac{1}{1-a-l}\left[\sum_{j=1}^{m-1} g_j \ln\left(\frac{\tilde{n}_{j,i,t-1}}{\tilde{n}_{m,i,t-1}}\right)\right] - k \cdot \frac{a+b}{1-a-b}\ln(n_{i,t-1,t} + g + d) - k \cdot \ln\left(\frac{y_{i,t-1}}{\tilde{n}_{m,i,t-1}}\right) + u_{i,t}$$

(12)

Note that: $\frac{\tilde{n}_{j,i,t}}{\tilde{n}_{m,i,t}} = \frac{N_{j,i,t}}{N_{m,i,t}}$, $\frac{y_{i,t}}{\tilde{n}_{m,i,t}} = \frac{Y_{i,t}}{N_{m,i,t}}$

5 Empirical results

5.1 Panel growth regressions for 1930-1990

To estimate equation (11) without state-specific effects, following BS (1995, Ch. 12) in their country study, I use the (nonlinear) seemingly unrelated (SUR) technique on six cross-sectional (i = 1, 2, …, 48) equations,

$$\ln\left(y_{i,t} / y_{i,t-10}\right)/10 = a_t - \left[(1-e^{-bg10})/10\right] \cdot \ln y_{i,t-10} + X_{i,t-10} \cdot p + u_{i,t} \qquad (13)$$

where t = 1940,1950,…,1990, $X_{i,t-10}$ is the vector of conditioning variables, and p is the coefficient vector of these variables. a_t is a time-effect (which is not reported in the tables). The p-vector is assumed to be constant over the equations. b, on the other hand, is allowed to vary over time since the hypothesis that b is the same over the equations is statistically rejected, which was found by BS (1992). Nevertheless, in the regressions presented in the last two rows of Table 3, both b and the p-vector are restricted over the equations. Only the estimates of b from these regressions are, however, reported. Equation (12) is given a similar empirical implementation.

The SUR method allows for state random effects that are correlated over time. Some of the estimations employ a method of instrumental variable SUR. In these IV regressions the predetermined variables (that are dated at time $t - t$) enter as their own instruments, whereas the variables that are measured over each period (the population growth rate and the net migration rate) are instrumented by initial per capita income, age group variables (dated

$t-t$) and the lagged value of the respective variable (for details see notes to tables). Lagged values may be satisfactory instruments, if the correlation of the error terms between adjacent periods is not substantial[18].

Age distribution

Column 4 of Table 3 presents the results from the estimation of equation (11) without the inclusion of *ln(n + 0.07)*. The age groups variables are in equation (11) in logs and expressed as ratios to total population. The results indicate a hump-shaped relation between subsequent growth and initial age structure. The estimated coefficients on the age groups 0-14 and 65+ are negative and significant, whereas the estimated coefficients on the rest of the age groups are statistically insignificant. The point estimates mean that a one-standard-deviation decrease of each of the age groups 0-14 and 65+ (0.023 and 0.016 for 1960, which is in the middle of the sample period) is associated with an increase of the annual growth rate by 0.64 percentage points over a subsequent 10-year period. Of course, the share of the population in some age groups can, by definition, not decrease without an increase of the share of population in the other age groups. If I take this into account by assuming that each of the other three age groups increase by an equal number of people and jointly equivalent to what the decrease of the age groups -14 and 65+ implies so that total population is constant, then this reshuffling of the age distribution is associated with an increase of the annual growth rate by 0.80 percentage points. Thus**,** these results indicate that the estimated relation between growth and age structure is of quantitative importance.

Furthermore, the R^2 values in column 4 are for some equations (the 1950s, 1960s, and 1980s) substantially higher than the R^2 values for the absolute convergence regression in column 1 indicating an improvement in explanatory power. However, for one period (the 1970s), the R^2 value in column 4 is slightly lower than the corresponding value in column 1, which indicates that the assumption that the coefficients of the age groups are equal over the equations does not work particularly well for this period. A LR test also rejects this hypothesis of equality over equations: the p-value is 0.003. (Under the null, this LR ratio statistic is asymptotically chi-squared distributed with twenty-five degrees of freedom.)

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[18] The correlation coefficients of the residuals between adjacent 10-year periods are reported in Persson (1998) and they are typically low.

The age groups (expressed as ratios to total population) are highly correlated among each other (see Table 1), which should make it difficult to estimate the individual coefficients of the age group variables with precision. If, for example, these age group variables were expressed in levels instead of in log-levels, perfect collinearity would be present. To lessen this problem of collinearity and thereby obtain more precise estimates, equation (12) is estimated, in which the $m - 1$ age groups and total income are expressed as ratios to the mth age group. The youngest age group is selected to be the numeraire. As a result, the income variable in equation (12) is total income divided by the number of people below age 15 and the $m - 1$ age group variables are the number of people aged 15-24, 25-44, 45-64, and over 65 years, respectively, all divided by the number of people below age 15. (These age group variables enter the regressions in logs.) Thus, I use information on the whole age structure, but tackle the potential problem of collinearity by imposing the testable restriction of CRS. Provided that this restriction is correct, this approach should tend to generate more reliable estimates compared to regressions based on equation (11). In contrast, empirical growth studies that do include age group variables typically do not use information on the whole age distribution (see McMillan and Baesel, 1990; Lee and Ling, 1994; Lindh and Malmberg, 1996)[19]. Unless the growth effects of the omitted age groups are zero, this approach is likely to lead to biased estimates of the coefficients of the age groups included in the regression due to the plausible correlation between the omitted and the included age groups.

The regressions reported in columns 5-8 are all based on equation (12). Focusing on the regression with age groups as the only conditioning variables: the results in column 5 show significantly positive coefficients on the age groups 25-44 and 45-64 years, 0.015 (2.02) and 0.026 (4.21) respectively, and a significantly negative coefficient, -0.008 (-2.54), on the age group over 65 years. The estimated coefficient of the age group 15-24 years is statistically insignificant. The CRS assumption that underlies the columns 5-8 regressions is tested by LR tests that are based on the assumption that the coefficients of the conditioning variables are equal over the equations. (Given this assumption, the LR statistic is, under the null hypothesis of CRS, asymptotically chi-squared distributed with one degree of freedom.) The p-values reported in columns 5-8 are all above the 5 percent significance level; thus, the assumption of CRS is not rejected.

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19 In addition, Fair and Dominguez (1991), who study the effects of a changing age distribution on various macroeconomic variables (albeit not GDP) using US time series, exclude the youngest age groups from the analysis. Sarel (1995) is an exception in the sense that he uses information on the whole age distriburion.

Population growth, net migration, size of government, and rate of convergence

Ln(n + 0.07) and the net migration rate (MIG) between time $t - t$ and time t are included in some of the Table 3 regressions. Note again that *n* is average annual population growth net of migration. Since *ln(.)* and MIG are measured over each period, they may, obviously, be correlated with the error term. For example, the SUR regression in column 6 regression shows a highly significant and positive coefficient on MIG, 0.015 (4.47), whereas the IV regression in column 7, on the other hand, generates only a marginally significant coefficient, 0.008 (1.98). (For a list of the instruments used see notes to Table 3.) In contrast, both the columns 6 and 7 regressions show statistically insignificant coefficients on *ln(·)* [20]. Hence, these regressions indicate that the population growth rate, in contrast to MIG, does not seem to respond to more favorable growth prospects due to factors not held constant by the included regressors.

The IV estimation in column 2 shows that if the age group variables are omitted, which is typically the case in empirical growth studies, the estimated coefficient on *ln(·)* becomes significantly negative. Thus, it changes from being statistically insignificant, becoming significantly negative when the age groups are excluded, which, of course, is a reflection of a correlation between the population growth rate and the age structure. The IV estimate of the coefficient on MIG, on the other hand, is not dramatically changed when the age group variables are excluded. A negative partial correlation between growth and population growth is consistent with some cross-country evidence. As already mentioned, these studies tend typically not to include age group variables as explanatory variables. For example, the IV regression by BS (1995, Table 12.3) indicate a significantly negative partial correlation between growth and the log of the fertility rate. However, other empirical studies report the opposite effect of population growth or fertility on growth (for a brief survey see Brander and Dowrick, 1994).

The column 5-7 regressions show that the estimated coefficients and t-statistics of the age group variables are fairly insensitive to the inclusion of *ln(·)* and MIG as explanatory variables. A relevant question is as to whether the age distribution, on the one hand, and the

[20] The estimated coefficients of *ln(·)* and MIG do not, in any major way, depend on the specification given by equation (12): using equation (11), instead, yields basically the same results. This observation also turns out to hold more generally. Thus, the estimated coefficients of the conditioning variables (other than the age group variables) tend not, in any major way, depend on whether equation (11) or equation (12) is estimated.

population growth rate (and MIG), on the other, only are two faces of the same coin, i.e. whether they only capture the same growth mechanism, namely the capital-dilution effect in the neoclassical growth model. The alternative hypothesis would be that the age structure also captures other growth mechanisms, such as e.g. the effect of experience-based human capital. To address this question, I test whether the effects of the age group variables remain after controlling for $ln(\times)$. The unrestricted regression is based on equation (11), i.e. the column 4 regression with $ln(\times)$ added as a regressor, whereas the restricted regression omits the age groups variables. IV estimation is applied and the sets of instruments are identical for the two regressions. The hypothesis that the coefficients of the age group variables are all equal to zero is strongly rejected by a LR test (with five degrees of freedom), which gives a p-value of 0.003. Thus, this result suggests that the age structure variables do not only capture the capital-dilution effect, but also other growth mechanisms. Moreover, if MIG, in addition to $ln(\times)$, is included as an explanatory variable, the hypothesis that the coefficients of the age group variables are all equal to zero is also rejected: the p-value is 0.017.

The column 8 regression includes GOV as an explanatory variable. (It is measured at time $t - t$.) Government sector variables, such as the size of this sector, are, in empirical growth studies, often treated as proxies for the level of technology in the Solow framework. The result in column 8 shows a significantly positive coefficient on GOV: 0.088 (2.93). This estimated coefficient implies that a one-standard-deviation increase in GOV (which is equivalent to 0.011 for 1960) is associated with an increase of the annual growth rate by 0.1 percentage points. Also when age group variables are omitted (column 3), the estimated coefficient of GOV is significantly positive: 0.066 (2.47). These results contrast to those reported by BS (1992, footnote 13). BS state that "we have not had much success in finding growth rate effects related to cross-state differences in government expenditures".

The estimates of b increase when age group variables are included. For example, the restricted estimate of b is 2.5 percent per year for the absolute convergence regression (column 1) and about 3.5 percent per year if conditioning on age structure. Thus, if the equation for b, given in (8), is used to structurally interpret these estimates and assuming that n equals 0.01 (BS, 1995, p. 37), then the estimated capital share of physical and *educational* human capital ($a + l$) decreases from 0.69 to 0.56.

5.2 Panel growth regressions with educational attainment for 1940-1990

In this section, I include average years of schooling per labor force person (aged 25-65) as an explanatory variable. The sample period is now 1940-1990 due to limitation of data. Since this educational attainment variable is a stock variable, it corresponds more to the *level* of educational human capital per capita in the model rather than to the rate of investment in human capital (see e.g. also MRW; Islam, 1995). As a result, I use the expression for $\tilde{h}^*$ in equation (7b) to replace s^h in equation (10). Moreover, assuming that $\tilde{h}^* = \tilde{h}(t)$ and using the identity $\tilde{h}(t) = h(t)e^{-g \cdot t}$, the regression equation for the growth rate of per capita income, that now is a function of the per capita level of educational human capital, is given by

$$\ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = \tilde{a}_{i,t} + k \cdot \frac{1}{1-a}\ln q_{i,t-1} + k \cdot \frac{l}{1-a}\ln h_{i,t-1} - k \cdot \frac{a}{1-a}\ln(n_{i,t-1,t} + g + d) - k \cdot \ln y_{i,t-1} + u_{i,t} \tag{14}$$

where $\tilde{a}_{i,t} = g + k \cdot \frac{1}{1-a}\left(\ln A_i + a \cdot \ln s^k_{i,t-1} + (1-a-l) \cdot g \cdot (t-1)\right)$. $\tilde{a}_{i,t}$ is assumed to be same for all states also in this section. Using the assumption of CRS on equation (14) gives:

$$\ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = \tilde{a}_{i,t} + k \cdot \frac{1}{1-a}\ln\left[\sum_{j=1}^{m-1} g_j \ln\left(\frac{\tilde{n}_{j,i,t-1}}{\tilde{n}_{m,i,t-1}}\right)\right] + k \cdot \frac{l}{1-a}\ln\left(\frac{h_{i,t-1}}{\tilde{n}_{m,i,t-1}}\right)$$

$$- k \cdot \frac{a}{1-a}\ln(n_{i,t-1,t} + g + d) - k \cdot \ln\left(\frac{y_{i,t-1}}{\tilde{n}_{m,i,t-1}}\right) + u_{i,t} \tag{15}$$

The column 1 regression of Table 4 is based on equation (14) whereas the columns 2-5 regressions are based on equation (15). Thus, the educational attainment variable in column 1 is defined by the log of the average years of schooling per labor force person aged 25-65, $\ln(h)$, whereas in columns 2-5 it is defined by $\ln(h)$ minus the log of the proportion of the population under age 15; that is, by $\ln(h/\tilde{n}_m)$ [21].

[21] As a comparison it can be noted that Islam (1995) uses the Barro and Lee (1993) human capital variable (HUMAN), which measures the average years of schooling for the adult population (over 25 years), as a proxy for *h* in the MRW model.

The main results from the previous section remain valid when educational attainment is held constant and the sample period shortened by 10 years. They are summarized as follows:

(i) The estimated pattern between growth and age is hump-shaped: the CRS regressions in columns 2-5 show significantly positive coefficients on the age groups 25-44 and 45-64 years, statistically insignificant coefficients on the age group 15-24 years, and negative coefficients on the age group 65 + that are statistically significant for columns 3-4.

(ii) The estimated effects on growth from the age group variables appears not only to reflect the capital-dilution effect: a LR test, based on IV estimation, rejects the hypothesis that the coefficients of the age group variables are all equal to zero when *ln(.)* and MIG are controlled for: the p-value (which is not reported in Table 4) is 0.021.

(iii) The IV estimate of the coefficient on *ln(n + 0.07)* is insignificant and the estimated coefficient on GOV is positive and significant (at least marginally) when age groups are included (column 4).

(iv) The restricted estimate of b increases substantially, relative to the absolute convergence estimate, when age group variables are included.

However, there is one main difference compared to the results obtained in the previous section: the CRS regression with age groups as the only conditioning variables (column 2) indicates that the hypothesis of equality, over the equations, of the coefficients of these age groups can no longer be rejected: the p-value is 0.130.

The columns 3-4 regressions, which include age groups, show significantly positive coefficients on the educational attainment variable[22]. The estimated coefficient in column 3, 0.023 (3.09), implies that a one-standard-deviation increase in $\ln(h/\tilde{n}_m)$ is associated with an increase in the growth rate by 0.25 percentage points per year. If, on the other hand, age group variables are not included (column 1), the educational attainment variable, $\ln(h)$, is statistically insignificant. This result corresponds to evidence reported by BS (1992, footnote 13) for the US states. BS state that “educational differences aside from college attainment were not important”. Thus, I find that the partial correlation between growth and educational attainment is significantly positive *only* when age structure is held constant, which is consistent with the theoretical model of this paper.

[22] If equation (14) is estimated with $\ln(h)$ included as an explanatory variable, the estimated coefficient on this variable is also significantly positive. This result is not reported in Table 4.

The column 5 regression includes regional dummies corresponding to the four main census regions. It shows that the hump-shaped relation between age structure and growth remains valid also when these regional dummies are included.

5.3 Panel growth regressions with state-specific effects

Knight et al. (1993), Islam (1995), and Caselli et al. (1996), among others, allow for country-specific effects as a way to account for unobservable heterogeneity in growth regressions for countries. Their estimations provide empirical evidence of individual effects, even when a number of conditioning variables are included as explanatory variables. Similar results are obtained for regional economies by e.g. Canova and Marcet (1995). On the issue of convergence, these panel studies report substantially higher estimates of the speed of convergence than the 2-3 percent reported by MRW and BS (1995, Ch. 11-12), which is due to a positive correlation between initial per capita income and the individual effect. Not surprisingly, these studies also find that the estimated coefficients on several of the conditioning variables change dramatically when country-specific effects are accounted for.

In view of these findings, this section allows for state-specific effects to check the robustness of the results on growth and demographics obtained in previous sections. In this section I abandon the nonlinear estimation methods used earlier and instead use linear methods. Thus, the econometric model based on equations (11) and (14) is given by

$$(\ln y_{i,t} - \ln y_{i,t-10})/10 = m_i \ + \ h_t \ + \ g \cdot \ln y_{i,t-10} \ + \ X_{i,t-10} \cdot p \ + \ u_{i,t} \qquad (16)$$

where m_i is the individual effect, h_t is the time effect, and $g = -(1-e^{-b10})/10$.

To estimate equation (16) the within-group or Least Squares Dummy Variable (LSDV) estimator is used and the results are reported in Table 5. Since the hypothesis that the coefficient on $\ln y_{t-t}$ is constant over the time periods is rejected also when individual effects are accounted for, this coefficient is allowed to vary by interacting $\ln y_{t-t}$ with the time dummies, D_t. In the regressions reported in the last rows of Table 5 the coefficient on $\ln y_{t-t}$ is, however, restricted over the time periods. The IV estimation shown in column 6 corresponds to the IV estimations of previous sections. Thus, only the contemporaneous variables, *ln(n + 0.07)* and MIG, are instrumented whereas the predetermined variables (that are dated at $t - t$) as well as the time- and state dummies enter as their own instruments (for details see notes to Table 5). In all columns but 1 and 3 the assumption of CRS is invoked. The sample period is 1930-1990 in columns 1 and 2 whereas it is 1940-1990 in columns 3-6.

The regressions provide empirical evidence of state-specific effects. The p-values from F-tests of the null hypothesis that all state-specific fixed effects are zero are all 0.000[23]. Nevertheless, the regressions results on growth and demographics obtained in the previous sections remain essentially unchanged when state dummies are included. This is in stark contrast to the country-study by Caselli et al. (1996) that finds that the estimated coefficients on several of the usual[24] (see Barro and Lee, 1994) conditioning variables change dramatically when individual effects are accounted for. Thus, I find that:

(i) The estimated pattern between growth and age is hump-shaped and of economic importance. The estimated coefficient on the age group 45-64 years is positive and highly significant in all regressions.

(ii) The estimated growth effects of the age group variables appears not only to reflect the capital-dilution effect in the neoclassical model: a LR test strongly rejects the hypothesis that the coefficients on the age groups are all equal to zero when *ln(.)* and MIG are included. (For the column 2 regression, the p-value is 0.000.)

(iii) The IV estimate of the coefficient on *ln(n + 0.07)* is insignificant when age group variables are included (column 6).

(iv) The estimated coefficient on the educational attainment variable is significantly positive when age groups are included (columns 5-6).

However, there are some differences compared to the regressions without state-specific effects: (i) The estimated coefficient on educational attainment remains significantly positive also when age groups are excluded (column 3). Also panel country studies tend to find that the partial correlation between growth and (male) educational attainment change when country-specific effects are accounted for (see e.g. Caselli et al., 1996). (ii) The estimated coefficient on GOV is still positive when state-specific effects are accounted for, but it is no longer statistically significant (column 6).

Another difference, compared to the regressions that ignore state-specific effects, is that the (implied) estimates of b become higher when such effects are accounted for. The implied

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[23] In a separate appendix that is available upon request I speculate that the empirical evidence of state-specific effects may be due to a measurement error since regional differences in cost-of-living are not accounted for.

[24] Thus, age structure variables are not included in this set of conditioning variables.

joint "unconditional" estimate of b is 0.058 when state dummies are included (column 1). Since similar results have been reported in other studies, a more interesting result with the respect to b is that our previous result that the estimates tend to increase substantially when age structure variables are included continue to hold. For example, for the period 1940-1990 the implied joint estimates of b are between 0.21 and 0.29 when age groups are included (columns 4-6), indicating a very fast conditional convergence rate. For these regressions the hypothesis that b is constant over time cannot be rejected: the p-values are all well above conventional levels of significance.

Some studies (e.g. Caselli et al., 1996) use various IV methods (see Baltagi, 1995, Ch. 8) when accounting for economy-specific fixed effects. As it turns out that the LSDV estimator produce very similar estimates of regression coefficients as well as of their respective standard errors compared to the IV estimator proposed by Arellano and Bond (1991), I have chosen to present results only from the LSDV estimations[25] [26]. These estimators are compared in Persson (1998) as well as in the appendix of this paper.

To conclude this section, for the US state sample no major changes occur with respect to the estimated coefficients on the demographic variables when state-specific effects are accounted for. This means that the estimated relation between growth and age is hump-shaped and of economic importance.

6 Conclusions

One main finding is that age distribution, population growth rate (net of migration), educational attainment, and size of government exhibit s and absolute b convergence across the US states. Quantitatively, the estimated rates at which states converge to each other with respect to age structure, educational attainment, and size of government are rather similar to the estimated convergence rate for per capita income. Simple sample correlations indicate that it is the poor states that tend to have a high proportion of the population in the youngest age groups (0-25 years), a high population growth rate (net of migration), a high out-migration rate, a low level of educational attainment, and a high subsequent growth rate of per capita

[25] One reason for focusing on the LSDV estimations is that it is found in simulation studies (see e.g. Kiviet, 1995) that IV estimation may lead to poor finite sample efficiency.

[26] Also Islam (1995) finds that LSDV and the IV estimator proposed by Chamberlain (1982, 1984) produce very similar results to one another.

income. If the US states have roughly similar preferences and technologies, i.e. have roughly similar steady-state positions, I interpret these results as consistent with the neoclassical growth model (see e.g. the model with an endogenous fertility rate presented by BS, 1995, Ch. 9.2). The empirical results are, on the other hand, not favorable for the empirical validity of the AK-model. This is because one possibility for the AK-model to be consistent with the empirical evidence on absolute per capita income convergence is that fertility and population growth is positively related to per capita income. Similar empirical results are obtained for the Swedish regions. It is e.g. found that both the age distribution and per capita income converge in the s and absolute b sense during the period 1910-1990. (These results are reported in a separate appendix that is available upon request). It could be noted that this paper does not investigate whether or not migration has contributed to the observed convergence in age distribution. This topic is left as an area for future research.

The main part of the paper treats the demographic, educational, and government variables as exogenous explanatory variables in conditional convergence regressions; that is, the focus is on the variation in these variables that is not linked to the level of development. The main result from these panel regressions is that the estimated relation between the age structure and the subsequent growth rate of per capita income when initial per capita income is held constant is hump-shaped and of economic importance. This result is robust to conditioning on variables such as the population growth rate, the net migration rate, educational attainment and government size as well as regional and state dummies, a finding that provides information on the potential mechanisms by which age matter for growth. For example, the hypothesis that the growth effects of age group variables only reflect the capital-dilution effect in the neoclassical growth model, i.e. the effect of population growth, is strongly rejected. The additional empirical results from these panel regressions can be summarized as follows:

(i) A high educational attainment is associated with a high subsequent growth *only* if age structure variables (and/or state-specific effects) are accounted for.

(ii) Using IV estimation, the population growth rate is negatively correlated with growth if age structure variables are not included as regressors, but uncorrelated with growth if age structure variables are included.

(iii) The size of the state and local government sector tends to be positively correlated with subsequent growth if state-specific effects are ignored.

These empirical findings are consistent with the augmented MRW-model of this paper, which allows the different age groups to differ in productivity to e.g. reflect the growth effects of human capital accumulated through experience. Other mechanisms, e.g. via savings, through which the age distribution has growth effects can however not be excluded.

The empirical findings on growth and demographics are robust in the sense that they also apply to the Swedish regions; that is, also for the Swedish regions the estimated partial relation between the age distribution and the subsequent growth rate of per capita income is found to be hump-shaped and of economic importance. (These results are reported in a separate appendix that is available upon request).

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Appendix: The transitional dynamics

To evaluate the dynamics, the system is log-linearized around steady state. I start by substituting the production function into equations (6a) and (6b) and rewrite the dynamic system in terms of the logs of $\hat{k}$ and $\hat{h}$:

$$\frac{d\ln\hat{k}}{dt} = s^k Aq\, e^{-(1-a)\ln\hat{k}} e^{l\ln\hat{h}} - (n+g+d) \tag{A.1a}$$

$$\frac{d\ln\hat{h}}{dt} = s^h Aq\, e^{a\ln\hat{k}} e^{-(1-l)\ln\hat{h}} - (n+g+d) \tag{A.1b}$$

I make a first-order Taylor expansion around the steady state values, $\ln\hat{k}^*$ and $\ln\hat{h}^*$, determined by equations (A.1a) and (A.1b):

$$\frac{d\ln\hat{k}}{dt} = -(1-a)(n+g+d)\ln(\hat{k}/\hat{k}^*) + l(n+g+d)\ln(\hat{h}/\hat{h}^*) \tag{A.2a}$$

$$\frac{d\ln\hat{h}}{dt} = a(n+g+d)\ln(\hat{k}/\hat{k}^*) - (1-l)(n+g+d)\ln(\hat{h}/\hat{h}^*) \tag{A.2b}$$

To substitute away the two types of capital I take the log of the production function:

$$\ln\hat{y} = \ln A + a\ln\hat{k} + l\ln\hat{h} + \ln q \tag{A.3}$$

Differentiating (A.3) with respect to time yields:

$$\frac{d\ln\hat{y}}{dt} = a\frac{d\ln\hat{k}}{dt} + l\frac{d\ln\hat{h}}{dt}$$

(A.4)

Note that $\frac{d\ln q}{dt}$ is assumed to be zero. A sufficient (but not necessary) condition for this term to be zero is that all age groups, N_j, grow at the same rate as *N* grows; i.e. at the rate *n*.

Inserting (A.2a) and (A.2b) into (A.4) and collecting terms:

$$\frac{d\ln\hat{y}}{dt} = -(1-a-l)(n+g+d)[a\ln(\hat{k}/\hat{k}^*) + l\ln(\hat{h}/\hat{h}^*)] \tag{A.5}$$

Subtracting $\ln\hat{y}^*$ from (A.3) yields:

$$\ln(\hat{y}/\hat{y}^*) = a\ln(\hat{k}/\hat{k}^*) + l\ln(\hat{h}/\hat{h}^*) \tag{A.6}$$

Combining (A.5) and (A.6) gives us:

$$\frac{d\ln\hat{y}}{dt} = -b\ln(\hat{y}/\hat{y}^*), \quad \text{where} \quad b = (1-a-l)(n+g+d) \tag{A.7}$$

Table 1. Sample correlation matrix for the 1940s for the US states.

	GR	PCI	0-14	15-24	25-44	45-64	65+	MIG	*n*	GOV
GR, 1940-50	1									
PCI, 1940	-0.83	1								
Ages -14, 1940	0.66	-0.84	1							
Ages 15-24, 1940	0.46	-0.62	0.82	1						
Ages 25-44, 1940	-0.60	0.76	-0.69	-0.51	1					
Ages 45-64, 1940	-0.54	0.76	-0.96	-0.87	0.50	1				
Ages 65+ , 1940	-0.41	0.45	-0.75	-0.80	0.13	0.82	1			
MIG, 1940-50	-0.55	0.62	-0.53	-0.52	0.68	0.44	0.21	1		
n , 1940-50	0.53	-0.61	0.83	0.68	-0.36	-0.83	-0.81	-0.06	1	
GOV, 1940	0.12	0.00	-0.14	-0.40	0.06	0.24	0.18	0.22	0.01	1
SCH , 1940	-0.32	0.56	-0.66	-0.73	0.23	0.78	0.64	0.40	-0.49	0.43

Definitions: GR = growth rate of real per capita income. PCI = real income per capita. The age groups are expressed as ratios to total population. MIG = net migration rate, defined as net migration over a 10-year period as a share of total population at the beginning of the period.
n = average annual population growth rate (net of migration flows). GOV = labor earnings in state and local government as a share of total labor earnings. SCH = average years of schooling per labor force person aged 25-65.

Table 2. Absolute convergence regressions for various variables for the US states. Estimates of b.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	log	log of the age groups (as ratios to population):					log	log	*n*
Period	(PCI)	0 -14	15-24	25-44	45-64	65 +	(GOV)	(SCH)	
1880-1990	.017	.026	.013	.023	.027	.033			
	(6.77)	(2.56)	(2.13)	(5.55)	(3.28)	(2.20)			
1910s-1980s									-1.54
									(3.55)
1930-1990	.017	.024	.019	.024	.041	.039	.031		-1.78
	(9.52)	(8.85)	(3.47)	(4.11)	(3.45)	(2.78)	(2.03)		(4.10)
1940-1990								.040	
								(12.1)	
R^2	.90,.86	.82,.61	.35,.48	.94,.65	.90,.83	.92,.74	.43	.97	.21,.27

Notes: Absolute values of *t*-statistics are in parentheses. Estimation method is nonlinear least squares, except for *n* for which linear methods are used.

Table 3. Panel regressions for 1930-1990. Dependent variable: $(\ln y_t - \ln y_{t-t})/10$.

CRS-assumption	no				yes			
Variables/parameters	1 SUR	2 IV	3 SUR	4 SUR	5 SUR	6 SUR	7 IV	8 SUR
$\hat{b}$, 1930-1940	0.013	0.017	0.013	0.021	0.026	0.024	0.026	0.027
	(4.08)	(4.73)	(4.14)	(5.08)	(6.63)	(6.45)	(6.56)	(6.67)
$\hat{b}$, 1940-1950	0.045	0.054	0.045	0.070	0.057	0.060	0.058	0.057
	(8.08)	(7.72)	(8.21)	(8.48)	(9.96)	(10.5)	(9.92)	(10.0)
$\hat{b}$, 1950-1960	0.015	0.023	0.014	0.037	0.033	0.034	0.034	0.033
	(4.33)	(6.28)	(4.24)	(6.84)	(7.26)	(7.99)	(7.23)	(7.19)
$\hat{b}$, 1960-1970	0.023	0.029	0.023	0.035	0.033	0.032	0.033	0.032
	(6.21)	(7.66)	(5.89)	(6.21)	(6.78)	(7.03)	(6.89)	(6.41)
$\hat{b}$, 1970-1980	0.015	0.017	0.014	0.024	0.027	0.023	0.027	0.025
	(2.81)	(2.95)	(2.73)	(3.34)	(4.17)	(3.81)	(4.02)	(4.12)
$\hat{b}$, 1980-1990	-0.002	-0.002	-0.002	0.015	0.013	0.014	0.011	0.013
	(0.24)	(0.33)	(0.34)	(1.83)	(2.06)	(2.19)	(1.58)	(2.02)
Ages 0-14				-0.045	--	--	--	--
				(3.09)				
Ages 15-24				-0.013	0.007	0.018	0.009	0.009
				(1.09)	(0.97)	(2.42)	(1.18)	(1.22)
Ages 25-44				-0.017	0.015	0.001	0.010	0.013
				(1.19)	(2.02)	(0.18)	(1.32)	(1.78)
Ages 45-64				0.007	0.026	0.029	0.025	0.027
				(0.69)	(4.21)	(4.89)	(4.20)	(4.45)
Ages 65+				-0.018	-0.008	-0.007	-0.009	-0.008
				(3.48)	(2.54)	(2.22)	(2.51)	(2.55)
Ln(n + 0.07)		-0.026				0.001	-0.019	
		(2.71)				(0.09)	(1.02)	
MIG		0.012				0.015	0.008	
		(3.59)				(4.47)	(1.98)	
GOV			0.066					0.088
			(2.47)					(2.93)
R^2, 1930-40, 1940-50	.29,.67	.27,.66	.29,.69	.34,.71	.28,.71	.31,.70	.28,.70	.27,.73
R^2, 1950-60, 1960-70	.40,.48	.55,.59	.39,.39	.59,.62	.56,.64	.61,.69	.60,.67	.57,.56
R^2, 1970-80, 1980-90	.13,.01	.09,.13	.23,.01	.08,.31	.11,.27	.18,.32	.09,.29	.22,.26
P-value for equal coefficients		0.021	0.048	0.003	0.009	0.001	0.000	0.002
P-value for CRS					0.241	0.051	0.215	0.165
Joint $\hat{b}$	0.025	0.027	0.025	0.035	0.035	0.035	0.034	0.036
	(18.3)	(13.0)	(18.1)	(10.1)	(10.1)	(10.1)	(9.13)	(10.1)
P-value for equal coefficients	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: All regressors are measured at time $t-t$, except *n* and MIG that are measured between time $t-t$ and *t*. The coefficients on the conditioning variables are restricted to be the same over the equations, whereas b and the intercept are allowed to vary. In the regressions reported in the last two rows, also b is restricted over time. In the IV estimations (columns 2 and 7) the predetermined variables (dated $t-t$) enter as their own instruments. The instruments for *ln(.)* and MIG are initial per capita income, age structure variables (dated $t-t$) and the lagged values of *ln(.)* and MIG, respectively.

"P-value for equal coefficients" refers to a LR test of the null hypothesis of equality overtime of the coefficients on the conditioning variables. (In the last row of Table 3 also the restriction that b is the same over equations is tested.) (Under the null, the LR statistic is asymptotically distributed as chi-squared with degrees of freedom the number of restrictions, see e.g. equation (15-56) in Green, 1997.) "P-value for CRS" refers to a LR test of the null hypothesis that the assumption of CRS is true.

Table 4. Panel regressions with schooling for 1940-1990. Dependent variable: $(\ln y_t - \ln y_{t-t})/10$.

CRS-assumption	no	Yes			
Variables/parameters	1 SUR	2 SUR	3 SUR	4 IV	5 SUR
$\hat{b}$, 1940-1950	0.046	0.060	0.078	0.078	0.064
	(8.19)	(9.64)	(8.67)	(8.63)	(8.89)
$\hat{b}$, 1950-1960	0.017	0.037	0.056	0.053	0.043
	(4.07)	(7.27)	(6.83)	(6.55)	(6.54)
$\hat{b}$, 1960-1970	0.025	0.037	0.053	0.050	0.042
	(5.53)	(6.91)	(6.73)	(6.31)	(6.29)
$\hat{b}$, 1970-1980	0.016	0.029	0.038	0.035	0.033
	(2.76)	(4.22)	(4.74)	(4.40)	(4.30)
$\hat{b}$, 1980-1990	0.001	0.017	0.030	0.023	0.022
	(0.11)	(2.52)	(3.64)	(2.74)	(2.82)
Ages 15-24		0.005	0.005	0.008	0.008
		(0.67)	(0.57)	(0.90)	(0.93)
Ages 25-44		0.027	0.030	0.025	0.031
		(3.16)	(3.47)	(2.67)	(3.38)
Ages 45-64		0.018	0.018	0.018	0.018
		(2.53)	(2.28)	(2.22)	(2.39)
Ages 65+		-0.004	-0.008	-0.009	-0.004
		(1.00)	(2.03)	(1.99)	(1.11)
Ln(*h*) | $\ln(h/\tilde{n}_m)$	0.004		0.023	0.019	
	(0.61)		(3.09)	(2.34)	
Ln(n + 0.07)				-0.027	
				(1.29)	
MIG				0.008	
				(1.66)	
GOV				0.072	
				(1.88)	
REGIONAL DUMMIES	NO	NO	NO	NO	YES
R^2 , 1940-50, 1950-60	.68,.40	.70,.59	.76,.64	.75,.65	.74,.55
R^2 , 1960-70, 1970-80	.45,.13	.66,.12	.59,.13	.56,.21	.62,.12
R^2 , 1980-90	.01	.27	.27	.27	.26
P-value for equal coefficients	0.000	0.130	0.001	0.000	0.000
P-value for CRS		1.000	1.000	1.000	1.000
Joint $\hat{b}$	0.032	0.047	0.066	0.061	0.057
	(11.5)	(10.2)	(8.80)	(8.14)	(8.67)
P-value for equal coefficients	0.000	0.000	0.000	0.000	0.000

Notes: See Table 3. The educational attainment variable in column 1 is defined by ln(*h*), the log of the average years of schooling per labor force person (aged 25-65), whereas in columns 3-4 it is defined by $\ln(h/\tilde{n}_m)$, i.e. by *ln(h)* minus the log of the proportion of the population below 15 years. The coefficients of the regional dummies (column 5), corresponding to the four main census regions, are constrained to be the same over the equations. The instruments for *ln(.)* and MIG in column 4 are the same as in Table 3 except that here also *lnh* and GOV are added to the set of instruments.

Table 5. Panel regressions with state-specific fixed effects (F.E.). Dependent variable: $(\ln y_t - \ln y_{t-t})/10$

Sample period	1930-1990		1940-1990			
CRS-assumption	no	yes	no	yes	yes	yes
Variables/parameters	1 LSDV	2 LSDV	3 LSDV	4 LSDV	5 LSDV	6 IV
$Ln\ y_{t-t}$	-0.046	-0.053	-0.092	-0.088	-0.095	-0.094
	(10.9)	(10.7)	(18.2)	(16.6)	(17.6)	(16.0)
$ln\ y_{t-t} \cdot D_{1940}$	-0.031	-0.024	--			
	(8.64)	(8.31)				
$ln\ y_{t-t} \cdot D_{1950}$	-0.029	-0.021	-0.004			
	(5.74)	(5.58)	(0.76)			
$ln\ y_{t-t} \cdot D_{1960}$	-0.045	-0.023	-0.015			
	(7.21)	(4.31)	(2.67)			
$ln\ y_{t-t} \cdot D_{1970}$	-0.054	-0.028	-0.021			
	(6.80)	(3.86)	(2.82)			
$ln\ y_{t-t} \cdot D_{1980}$	-0.046	-0.018	-0.011			
	(5.60)	(2.73)	(1.46)			
Ages 15-24		0.007		0.010	0.011	0.009
		(0.53)		(0.90)	(1.03)	(0.79)
Ages 25-44		0.006		0.024	0.010	0.012
		(0.53)		(1.97)	(0.79)	(0.90)
Ages 45-64		0.061		0.068	0.041	0.041
		(5.61)		(6.22)	(3.26)	(3.18)
Ages 65+		-0.010		-0.010	-0.011	-0.010
		(1.44)		(1.43)	(1.65)	(1.35)
ln(h) in column 3			0.084		0.061	0.060
ln($h/\tilde{n}_m$) in columns 5-6			(6.13)		(3.92)	(3.74)
ln(n+0.07)						0.013
						(0.44)
MIG						-0.005
						(0.49)
GOV						0.001
						(0.02)
$\bar{R}^2$	0.773	0.782	0.835	0.835	0.847	0.844
P-value for no F.E.	0.000	0.000	0.000	0.000	0.000	0.000
P-value for joint b	0.000	0.000	0.000	0.626	0.496	0.635
Implied joint $\hat{b}$	--	--	--	0.215	0.292	0.281
Joint $\ln y_{t-t}$	-0.044	-0.059				
	(10.8)	(11.1)				
$\bar{R}^2$	0.675	0.705				
Implied joint $\hat{b}$	0.058	0.089				

Notes: Time and individual effects in all regressions. The coefficient on $\ln y_{t-t}$ is allowed to vary over time by interacting $\ln y_{t-t}$ with time dummies, D_t. In the regressions reported in the last three rows, the coefficient on $\ln y_{t-t}$ is, however, restricted. In columns 2 and 4-6 $\ln y_{t-t}$ is replaced by $\ln(y_{t-t}/\tilde{n}_{m,t-t})$ which means that the assumption of CRS is used. The instruments for *ln(n + 0.07)* and MIG in the IV regression (column 6) are identical to those used in Table 4. "P-value for no F.E." refers to an F-test of the null hypothesis that all state-specific fixed effects are equal to zero. "P-value for joint b" refers to a LR test of the null hypothesis that the coefficient on $\ln y_{t-t}$ is the same over time periods.

Figure 1a: Dispersion of the log of the age groups (expressed as ratios to total population) across the US States for every 10 years, 1880–1990

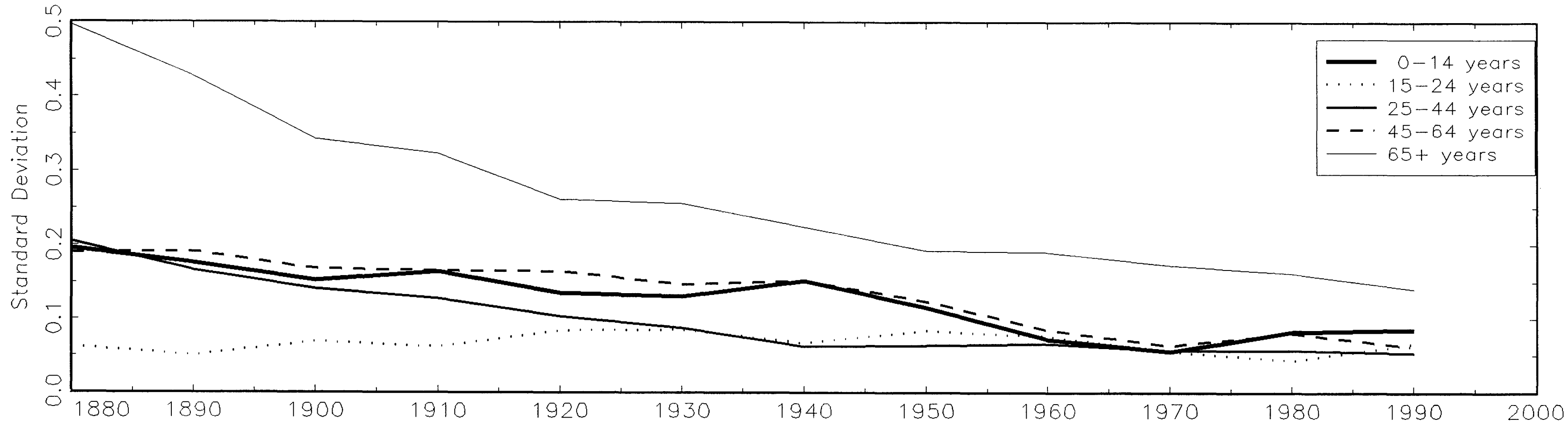

Figure 1b: Dispersion of log per capita income 1880, 1900, 1920, 1929–1990

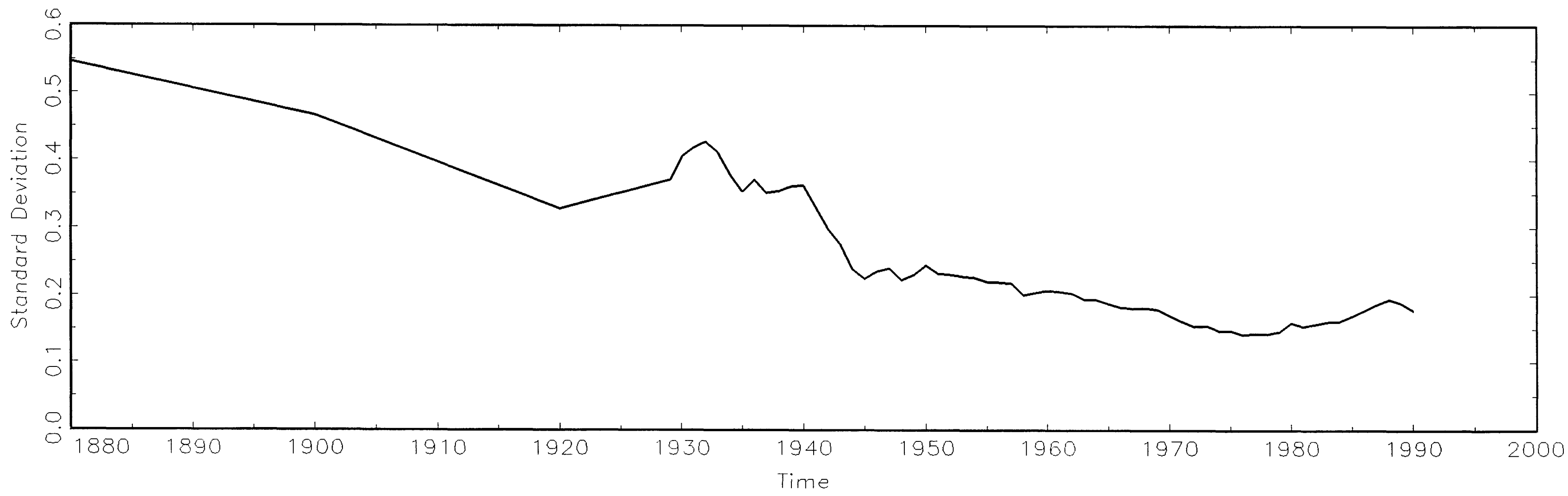

Figure 2a: Dispersion of the log of government size across the US States 1930–90

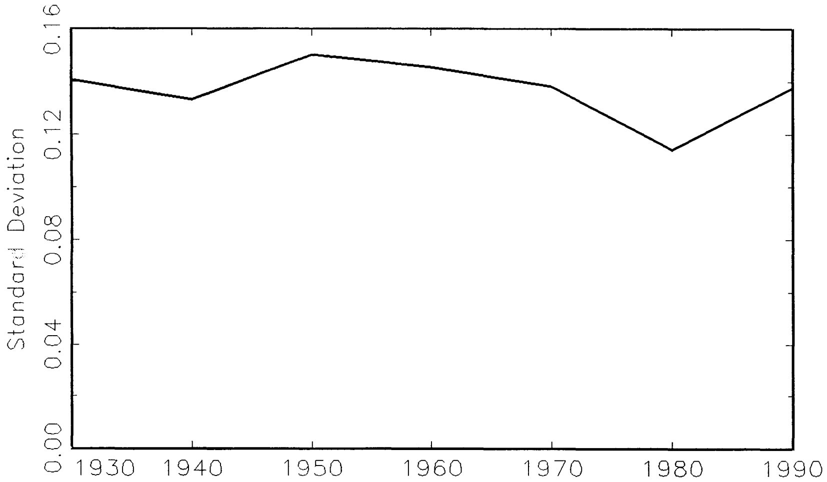

Figure 2b: Dispersion of the log of schooling 1940–1990

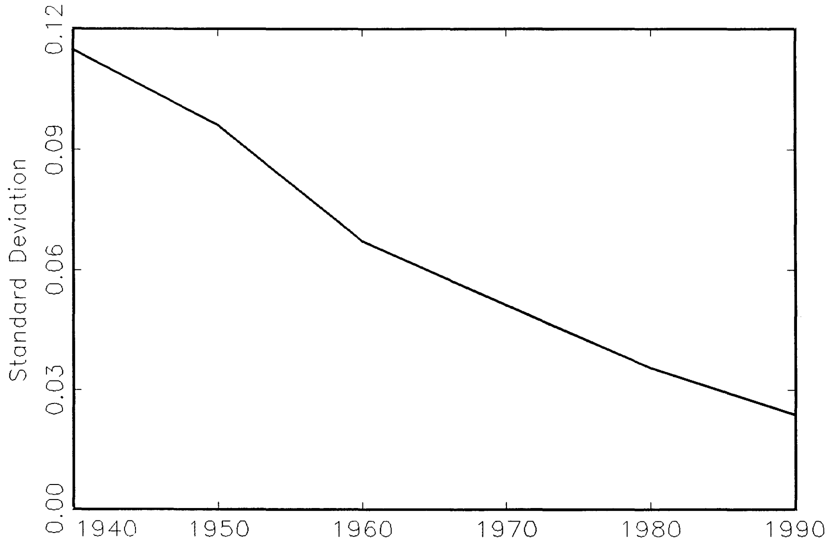

Figure 2c: Dispersion of the average annual population growth rate (net of migration) 1910s–1980s

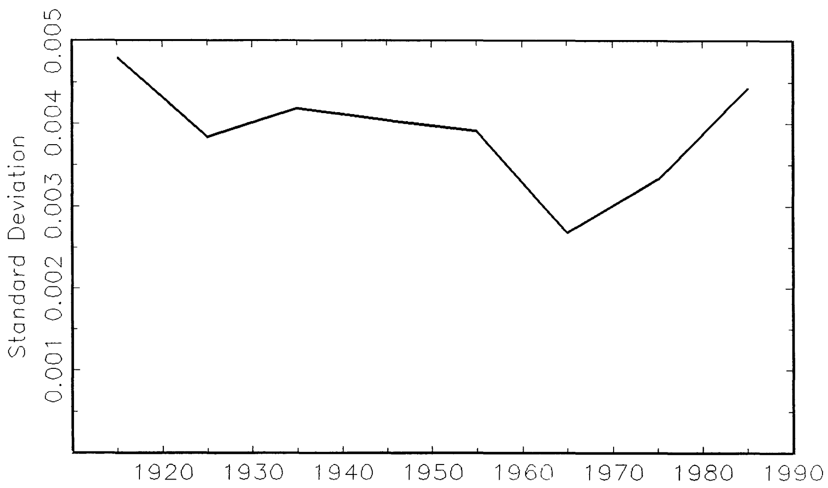

Figure 2d: Dispersion of the net migration rate 1910s–1980s

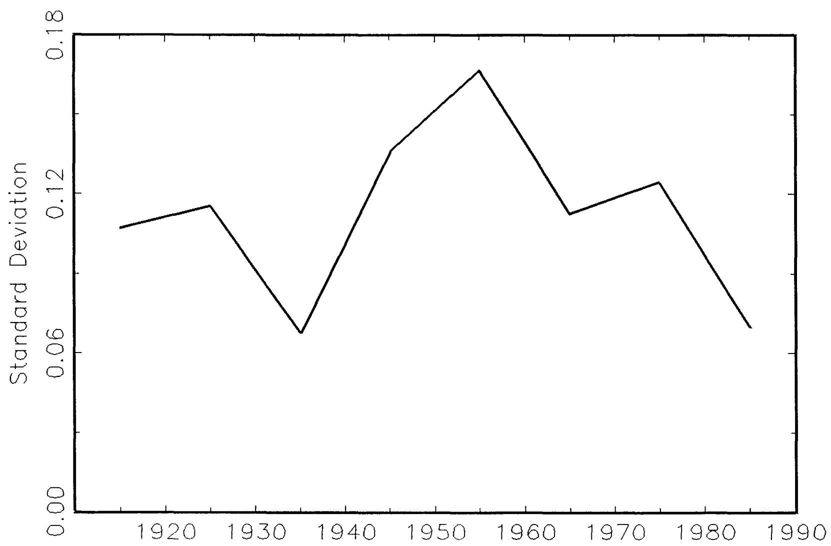

Table A1. Summary statistics, selected series for the US states.

Variables	Mean	StD	Min	Max	Variables	Mean	StD	Min	Max
PCI , 1880	1969	1143	648	6116	Ages 0-14, 1950	0.282	0.033	0.226	0.348
, 1900	2431	1043	853	4936	15-24,	0.150	0.013	0.125	0.178
, 1920	3051	948	1405	5125	25-44,	0.292	0.018	0.261	0.338
, 1930	3213	1217	1186	6119	45-64,	0.195	0.023	0.145	0.238
, 1940	3800	1349	1510	7226	65+ ,	0.081	0.015	0.048	0.109
, 1950	5475	1257	2881	8121	Ages 0-14, 1960	0.320	0.023	0.276	0.380
, 1960	6584	1324	3786	9273	15-24,	0.137	0.011	0.118	0.166
, 1970	8711	1469	5808	11930	25-44,	0.255	0.017	0.218	0.295
, 1980	9775	1534	6806	13154	45-64,	0.195	0.016	0.151	0.232
, 1990	11420	2062	7627	17250	65+ ,	0.092	0.016	0.054	0.119
GR, 1880-1900	0.013	0.008	-0.013	0.030	Ages 0-14, 1970	0.290	0.016	0.258	0.333
, 1900-1920	0.014	0.010	-0.023	0.037	15-24,	0.177	0.010	0.156	0.202
, 1920-1930	0.003	0.014	-0.027	0.036	25-44,	0.232	0.013	0.205	0.275
, 1930-1940	0.018	0.009	-0.000	0.041	45-64,	0.202	0.013	0.167	0.232
, 1940-1950	0.040	0.017	0.010	0.076	65+ ,	0.099	0.017	0.064	0.146
, 1950-1960	0.019	0.007	-0.001	0.033	Ages 0-14, 1980	0.232	0.020	0.193	0.316
, 1960-1970	0.029	0.006	0.018	0.044	15-24,	0.189	0.008	0.167	0.204
, 1970-1980	0.012	0.006	-0.000	0.035	25-44,	0.275	0.016	0.245	0.317
, 1980-1990	0.015	0.009	-0.012	0.029	45-64,	0.192	0.015	0.145	0.223
Ages 0-14, 1880	0.366	0.067	0.242	0.459	65+ ,	0.112	0.018	0.075	0.173
15-24,	0.197	0.012	0.154	0.217	Ages 0-14, 1990	0.263	0.023	0.226	0.363
25-44,	0.281	0.065	0.215	0.452	15-24,	0.104	0.007	0.089	0.118
45-64,	0.124	0.024	0.092	0.184	25-44,	0.321	0.017	0.292	0.358
65+ ,	0.032	0.017	0.010	0.084	45-64,	0.185	0.011	0.141	0.204
Ages 0-14, 1890	0.351	0.060	0.244	0.448	65+ ,	0.127	0.018	0.088	0.183
15-24,	0.200	0.010	0.174	0.214	SCH,1940	8.7	0.9	6.7	10.2
25-44,	0.283	0.049	0.218	0.435	,1950	9.5	0.9	7.6	11.0
45-64,	0.130	0.026	0.093	0.196	,1960	10.6	0.7	9.2	12.0
65+ ,	0.036	0.017	0.015	0.085	,1970	11.4	0.6	10.1	12.4
Ages 0-14, 1900	0.347	0.052	0.259	0.428	,1980	12.6	0.4	11.7	13.4
15-24,	0.194	0.013	0.169	0.221	,1990	13.2	0.3	12.5	13.8
25-44,	0.284	0.040	0.215	0.393	MIG, 1910-20	.0314	.1069	-0.111	0.436
45-64,	0.136	0.024	0.103	0.190	, 1920-30	-.0015	.1153	-0.153	0.513
65+ ,	0.039	0.014	0.019	0.082	, 1930-40	-.0082	.0676	-0.155	0.191
Ages 0-14, 1910	0.323	0.052	0.210	0.416	, 1940-50	.0031	.1355	-0.212	0.382
15-24,	0.196	0.012	0.160	0.214	, 1950-60	.0089	.1667	-0.227	0.575
25-44,	0.295	0.039	0.232	0.420	, 1960-70	.0086	.1124	-0.148	0.495
45-64,	0.145	0.024	0.106	0.193	, 1970-80	.0793	.1244	-0.084	0.525
65+ ,	0.042	0.014	0.021	0.082	, 1980-90	.0158	.0698	-0.091	0.231
Ages 0-14, 1920	0.325	0.044	0.239	0.409	n , 1910-20	.0122	.0048	0.003	0.026
15-24,	0.177	0.015	0.143	0.204	, 1920-30	.0133	.0038	0.007	0.022
25-44,	0.293	0.030	0.240	0.377	, 1930-40	.0083	.0042	0.003	0.019
45-64,	0.159	0.026	0.112	0.206	, 1940-50	.0138	.0040	0.008	0.024
65+ ,	0.046	0.013	0.029	0.085	, 1950-60	.0165	.0039	0.011	0.027
Ages 0-14, 1930	0.304	0.040	0.229	0.385	, 1960-70	.0115	.0027	0.007	0.019
15-24,	0.183	0.016	0.154	0.217	, 1970-80	.0075	.0033	0.003	0.022
25-44,	0.285	0.025	0.236	0.337	, 1980-90	.0067	.0044	-0.002	0.024
45-64,	0.173	0.025	0.129	0.220	GOV, 1930	0.063	0.009	0.043	0.090
65+ ,	0.055	0.014	0.033	0.090	, 1940	0.069	0.009	0.053	0.083
Ages 0-14, 1940	0.263	0.040	0.198	0.346	, 1950	0.057	0.009	0.042	0.093
15-24,	0.184	0.012	0.162	0.220	, 1960	0.079	0.011	0.058	0.107
25-44,	0.292	0.018	0.263	0.335	, 1970	0.107	0.015	0.082	0.154
45-64,	0.193	0.028	0.137	0.233	, 1980	0.111	0.013	0.084	0.155
Ages 65+ , 1940	0.068	0.015	0.043	0.100	, 1990	0.120	0.018	0.095	0.182

Abbreviations and definitions: PCI = real income per capita. GR = growth rate of real income per capita. The age groups are expressed as ratios to total population. SCH = average years of schooling per labor fore person (aged 25-65). MIG = net migration rate, defined as net migration over a ten-year period as a share of total population at the beginning of the period. n = average annual population growth rate net of migration flows. GOV = labor earnings in state and local government as a share of total labor earnings.

Table A2. Sample correlation matrices for subperiods of the period 1880-1990 for the US states.

	GR	PCI	0–14	15-24	25-44	45-64	65+	MIG	*n*	GOV
GR, 1880-1900	1									
PCI, 1880	-0.71	1								
Ages -14, 1880	0.58	-0.86	1							
Ages 15-24, 1880	0.50	-0.45	0.34	1						
Ages 25-44, 1880	-0.67	0.88	-0.83	-0.45	1					
Ages 45-64, 1880	-0.16	0.34	-0.57	-0.25	0.06	1				
Ages 65+ , 1880	0.13	-0.13	-0.24	0.07	-0.31	0.77	1			
GR, 1900-20	1									
PCI, 1900	-0.79	1								
Ages -14, 1900	0.52	-0.81	1							
Ages 15-24, 1900	0.69	-0.77	0.75	1						
Ages 25-44, 1900	-0.77	0.93	-0.80	-0.82	1					
Ages 45-64, 1900	-0.25	0.52	-0.88	-0.59	0.44	1				
Ages 65+ , 1900	0.02	0.18	-0.66	-0.39	0.12	0.85	1			
GR, 1920-30	1									
PCI, 1920	0.36	1								
Ages -14, 1920	-0.54	-0.83	1							
Ages 15-24, 1920	-0.35	-0.80	0.84	1						
Ages 25-44, 1920	0.21	0.89	-0.77	-0.81	1					
Ages 45-64, 1920	0.60	0.69	-0.94	-0.82	0.56	1				
Ages 65+ , 1920	0.54	0.28	-0.66	-0.48	0.07	0.81	1			
MIG, 1920-30	0.31	0.56	-0.54	-0.41	0.54	0.43	0.18	1		
n , 1920-30	-0.52	-0.52	0.79	0.66	-0.45	-0.84	-0.70	-0.01	1	
GR, 1930-40	1									
PCI, 1930	-0.49	1								
Ages -14, 1930	0.50	-0.85	1							
Ages 15-24, 1930	0.53	-0.78	0.88	1						
Ages 25-44, 1930	-0.36	0.82	-0.81	-0.64	1					
Ages 45-64, 1930	-0.48	0.74	-0.93	-0.92	0.57	1				
Ages 65+ , 1930	-0.52	0.50	-0.72	-0.81	0.23	0.85	1			
MIG, 1930-40	0.04	0.51	-0.55	-0.47	0.58	0.47	0.23	1		
n , 1930-40	0.47	-0.67	0.82	0.66	-0.56	-0.77	-0.70	-0.17	1	
GOV, 1930	0.04	0.01	-0.12	-0.06	0.27	0.00	-0.08	0.27	0.00	1
GR, 1950-60	1									
PCI, 1950	-0.61	1								
Ages 0-14, 1950	0.27	-0.77	1							
Ages 15-24, 1950	0.35	-0.79	0.83	1						
Ages 25-44, 1950	-0.18	0.72	-0.59	-0.51	1					
Ages 45-64, 1950	-0.33	0.73	-0.95	-0.89	0.40	1				
Ages 65+ , 1950	-0.15	0.32	-0.69	-0.64	-0.13	0.79	1			
MIG, 1950-60	-0.04	0.50	-0.35	-0.47	0.69	0.24	-0.07	1		
n , 1950-60	0.02	-0.16	0.64	0.41	0.03	-0.66	-0.77	0.39	1	
GOV, 1950	0.11	-0.19	0.38	0.18	-0.19	-0.30	-0.29	0.17	0.49	1
SCH , 1950	-0.48	0.69	-0.55	-0.65	0.26	0.61	0.49	0.32	-0.14	0.14
GR, 1960-70	1									
PCI, 1960	-0.66	1								
Ages -14, 1960	0.10	-0.55	1							
Ages 15-24, 1960	0.54	-0.76	0.71	1						
Ages 25-44, 1960	-0.31	0.74	-0.32	-0.30	1					
Ages 45-64, 1960	-0.11	0.44	-0.92	-0.77	0.07	1				
Ages 65+ , 1960	-0.07	0.08	-0.65	-0.59	-0.43	0.75	1			
MIG, 1960-70	-0.05	0.54	-0.38	-0.28	0.61	0.22	-0.12	1		
n , 1960-70	-0.02	-0.09	0.73	0.54	0.22	-0.77	-0.85	0.24	1	
GOV, 1960	-0.21	-0.20	0.53	0.20	-0.24	-0.41	-0.23	-0.15	0.38	1
SCH , 1960	-0.81	0.68	-0.19	-0.56	0.26	0.16	0.21	0.27	-0.03	0.23
GR, 1970-1980	1									
PCI, 1970	-0.37	1								
Ages -14, 1970	0.16	-0.33	1							
Ages 15-24, 1970	0.29	-0.53	0.54	1						
Ages 25-44, 1970	-0.04	0.62	-0.02	-0.06	1					
Ages 45-64, 1970	-0.27	0.38	-0.85	-0.76	-0.04	1				
Ages 65+ , 1970	-0.09	-0.14	-0.61	-0.49	-0.69	0.54	1			
MIG, 1970-80	0.33	-0.03	0.10	0.02	0.32	-0.19	-0.21	1		
n , 1970-80	0.36	-0.30	0.76	0.60	0.10	-0.77	-0.58	0.47	1	
GOV, 1970	0.43	-0.14	0.36	0.22	-0.08	-0.38	-0.12	0.30	0.48	1
SCH, 1970	-0.12	0.51	0.01	-0.21	0.14	-0.04	0.04	0.12	0.15	0.31
GR, 1980-90	1									
PCI, 1980	-0.07	1								
Ages -14, 1980	-0.44	-0.45	1							
Ages 15-24, 1980	-0.20	-0.20	0.54	1						
Ages 25-44, 1980	-0.15	0.58	-0.10	0.09	1					
Ages 45-64, 1980	0.47	0.32	-0.85	-0.65	-0.16	1				
Ages 65+ , 1980	0.31	-0.19	-0.55	-0.57	-0.67	0.55	1			
MIG, 1980-90	0.21	0.20	-0.31	-0.23	0.34	0.19	-0.02	1		
n , 1980-90	-0.09	0.31	0.18	0.12	0.55	-0.27	-0.50	0.69	1	
GOV, 1980	-0.08	-0.41	0.31	0.33	-0.12	-0.38	-0.07	-0.16	0.02	1
SCH , 1980	-0.15	0.61	-0.02	-0.02	0.39	-0.17	-0.17	0.01	0.40	0.06
PCI, 1990		1								
Ages -14, 1990		-0.53	1							
Ages 15-24, 1990		-0.19	0.13	1						
Ages 25-44, 1990		0.70	-0.38	-0.04	1					
Ages 45-64, 1990		0.28	-0.83	-0.27	0.13	1				
Ages 65+ , 1990		-0.06	-0.51	-0.35	-0.50	0.47	1			
GOV, 1990		-0.49	0.42	-0.10	-0.30	-0.24	-0.10			1
SCH , 1990		0.65	-0.05	-0.32	0.49	-0.17	-0.20			-0.11

Appendix: A comparison between a GMM estimator and the LSDV estimator

Table A3 reports a comparison between the LSDV estimator and the IV estimator developed by Arellano and Bond (1991) based on the sample period 1940-1990. The equation that is estimated is given by writing equation (16) in levels:

$$\ln y_{i,t} \;=\; \overline{m}_i \;+\; \overline{h}_t \;+\; f \cdot \ln y_{i,t-10} \;+\; X_{i,t-10} \cdot \overline{p} \;+\; \overline{u}_{i,t} \qquad (17)$$

where $f = (1 + g \cdot 10)$ and – denotes that the parameter/variable has been multiplied by 10. Columns 1 and 4 show the result from the LSDV estimation of the level equation in (17) without and with age groups included, respectively. (Thus, this column 1 regression corresponds to the growth regression of column 1 reported in the last rows of Table 5.) The age groups are expressed as ratios to total population. Their coefficients are in Table A3 denoted $\overline{p}_j$ where j = 0-14, 15-24, 25-44, 45-64, 65+. The approach behind the IV estimation is to transform the level equation into first differences to eliminate the individual effect, and then use lagged values of the explanatory variables in the level equation as instruments for the right-hand-side variables in the first difference equation (for details see notes to Table A3). Only one period lags (i.e., dated $t - 2t$) are used here; thus, the number of instruments are the same for the different time periods. The results from the IV estimations without and with age groups included are reported in columns 2-3 and in columns 5-6, respectively. Estimates both from the one-step and from the two-step estimator (GMM1 and GMM2) are reported. The GMM2 estimator is robust to heteroskedasticity. However, the hypothesis of groupwise homoskedasticity was typically not rejected for the LSDV regressions.

The consistency of these GMM estimators relies on the assumption that the error term in levels, $\overline{u}_{i,t}$, lacks serial correlation. The error term in the first difference equation should therefore show MA(1) properties; that is, we expect a negative first order serial correlation, but no second order serial correlation. The *mj* statistic of Arellano and Bond (1991), reported in Table A3, indicates also a negative first order serial correlation and rejects second order serial correlation. Another test of specification is the Sargan test for overidentified restrictions. This test do not reject the joint hypothesis that the model is correctly specified and that the instrument variables are uncorrelated with the residuals for the GMM estimations with age groups included (columns 5 and 6).

Table A3 indicates that the LSDV and the GMM estimators produce very similar estimates of f and of the coefficients of the age group variables as well as of their respective t-statistics. An additional result is that the estimated hump-shaped relation between the level of per capita income, y_t, and age (at $t-t$) remains valid also if lagged per capita income, y_{t-t}, is omitted from the LSDV regression (column 7). If, in addition to y_{t-t}, the state dummies are dropped, the hump-shaped relation between y_t and age (at $t-t$) is also maintained. This is shown by the OLS estimation in column 8.

Table A3. Dependent variable: ln y_t. Sample period 1940-1990.

Parameters	1 LSDV	2 GMM1	3 GMM2	4 LSDV	5 GMM1	6 GMM2	7 LSDV	8 OLS
$\hat{f}$	0.304	0.358	0.340	0.120	0.154	0.131	--	--
	(6.58)	(7.35)	(6.14)	(2.30)	(2.20)	(2.21)		
$\hat{p}_{0-14}$				-0.562	-0.621	-0.654	-0.619	-0.782
				(2.43)	(2.33)	(3.76)	(2.66)	(2.35)
$\hat{p}_{15-24}$				-0.295	-0.320	-0.188	-0.259	-0.752
				(1.56)	(1.48)	(1.33)	(1.36)	(3.04)
$\hat{p}_{25-44}$				-0.294	-0.518	-0.276	-0.166	0.835
				(1.21)	(1.71)	(1.53)	(0.69)	(2.43)
$\hat{p}_{45-64}$				0.383	0.438	0.335	0.391	0.439
				(2.37)	(2.38)	(2.16)	(2.39)	(1.71)
$\hat{p}_{65+}$				-0.319	-0.501	-0.363	-0.271	-0.309
				(2.85)	(3.38)	(3.25)	(2.43)	(2.50)
$\bar{R}^2$	0.961			0.970			0.970	0.899
Instruments:		ln y_{t-2t}	ln y_{t-2t}		ln y_{t-2t}, ln $\tilde{n}_{j,t-2t}$	ln y_{t-2t}, ln $\tilde{n}_{j,t-2t}$		
Tests:								
$\hat{}$ [$m1$]	-0.64	[-4.96]	[-2.98]	-0.07	[-4.44]	[-2.42]	0.20	0.72
p-value	0.000	0.000	0.003	0.715	0.000	0.016	0.026	0.000
$m2$	--	-0.173	-0.120	--	1.089	1.342	--	--
p-value		0.863	0.904		0.276	0.180		
Sargan (df)	--	10.47 (3)	12.49 (3)	--	25.47 (18)	25.64 (18)	--	--
p-value		0.015	0.006		0.112	0.108		

Notes: $\bar{p}_j$ is the coefficient of age group j in the level equation in (17). Time effects (not reported in table) are allowed for in all estimations. [$m1$] and $m2$ are test statistics for 1st and 2nd order serial correlation, respectively, which asymptotically follow a standard normal distribution. These statistics apply to the GMM estimations. To test for 1st order serial correlation in the LSDV and OLS estimations, I construct a pooled groupwise version of Durbin's Alternative Test (see e.g. Maddala, 1992, Section 6.7). Thus, the reported serial correlation coefficient, $\hat{}$, is a pooled estimate over the states based on the within residuals. The Sargan statistic tests for overidentified restrictions and it is asymptotically chi-squared distributed. The degrees of freedom are given in parentheses. In the columns 5 and 6 GMM estimations the log of all age groups at time $t-2t$ together with the log of per capita income at time $t-2t$ are used as instruments. The number of observations are 240 in the LSDV and OLS estimations but 192 in the GMM estimations since one time observation is lost due to the first difference transformation.

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