# Age Structure, Education and Economic Growth

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## Abstract

The effect of changes in age structure on economic growth has been widely studied in the demography and population economics literature. The beneficial effect of changes in age structure after a decrease in fertility has become known as the demographic dividend. In this paper we first present the motivation for also explicitly addressing changes in education in addition to and age structure and then reassess the empirical evidence on the associations among economic growth, changes in age structure, labor force participation and new data on educational attainment. Using a global panel of countries, we find that once the effect of human capital dynamics is controlled for there is no evidence that changes in age structure affect labor productivity. Our results imply that improvements in educational attainment are not only drivers of fertility decline and hence age structural changes but are also key to explaining productivity and income growth.

## 1. Introduction

This paper tries to bring together two so far rather disjoint fields of scientific inquiry. On the one hand there is the long tradition of studying the macro-economic returns to human capital which is mostly measured in terms of educational attainment of the adult population. This body of literature tends to disregard the changing age structure of the population as a possible driver of economic growth. On the other hand there is the rapidly increasing body of literature on the "Demographic Dividend" in its various forms which is held together by the basic underlying assumption that changes in the age structure of the population are a relevant factor in explaining economic growth. In this paper we will try to bring these two streams of analysis together and empirically estimate the relative effects of changes in age structure, labor force participation and educational attainment on economic growth around the world since 1970.

In the first section of the paper we will step back and more broadly consider the different sources of population heterogeneity – as captured and empirically measured by individual characteristics such as age, sex, level of highest educational attainment, labor force participation, health status, place of residence and others – that for theoretical reasons may be relevant for explaining economic growth. In the following section 3 we will briefly review some of the key contributions to the Demographic Dividend literature with a specific view of the treatment of education in those models. In the main Section 4 we will comprehensively revisit the empirics of these associations by starting from the dominant model specifications and then successively adding human capital indicators. In the concluding section we discuss the results and suggest further lines of investigation for the future.

## 2. Motivation: Adding education to age and sex

When studying the effects of population changes on economic growth we have to consider the fact that human populations are not amorphous masses. They are stratified according to certain characteristics that have significant impact on the behaviors, capabilities and vulnerabilities of the individuals carrying these characteristics. Conventionally, demographers have routinely sub-divided populations according to the age and sex structure. In demography, the sex of a person (or gender in a social and behavioral context) is considered a fundamental characteristic because it is essential for studying the process of reproduction. But mortality and migration also show strong variation by gender. Age is another central characteristic of people because it is the main driver of biological maturation in the young, and age also matters for social institutions such as school attendance, labor force entry, and retirement. Because of distinct patterns of variation of fertility, mortality, and migration with age, and gender those are conventionally considered the two most fundamental demographic dimensions. However, there are many other biological, social, and economic characteristics of people that demographers are taking into account: These include place of residence (and whether urban or rural), citizenship, marital status, educational attainment level, race, migration status, employment status, income group, and health and disability status (Lutz and KC, *Science* 2011).

All these dimensions of analysis have in common that they are characteristics of individual members of the population which are – at least in theory – observable and measurable. They can hence be called observable sources of population heterogeneity. These dimensions are not only interesting in their own right for helping to answer specific questions relating to their past, current or future distributions in the population but to the extent that they are associated with different fertility, mortality and migration intensities, their changing distributions in the total population also impact on the size and age structure of the total population. It is important to note that in addition to these observable sources of population heterogeneity, there is still unobserved heterogeneity in every population which is hard to capture empirically. Theoretical considerations suggest that such unobserved heterogeneity can significantly impact future population dynamics (Vaupel & Yashin 1985), but there is little one can do about it except to be aware of the problem and be cautious about the validity of the conclusions drawn (Lutz and KC, Phil trans 2010). Given this problem associated with hidden heterogeneity, it is even more important to explicitly measure and incorporate the observable sources of population heterogeneity wherever feasible and thus try to minimize the possible biases caused by overall heterogeneity.

It has been argued that among the listed demographic dimensions, educational attainment level is the single most important source of observable population heterogeneity that should be routinely added to population analysis (Lutz et al 1998, Lutz 2010). Under the somewhat provocative heading "Age is not what it used to be, nor is sex" Lutz (2010) discusses one important counterargument to viewing educational attainment as a basic demographic dimension, namely that age and sex would somehow be natural covariates, while education would be merely a social construction. He stresses that our thinking about age is dominated by what is often called "fixed chronological age" which is the time elapsed since birth as measured in years and that today there are already many different ways of looking at age and ageing, referring to biological, mental, economic or social maturity as well as expected remaining life time. Increasingly the many shortcomings of the deeply engrained concept of chronological age as a basic determinant of behavior and socioeconomic organization are being understood which is directly relevant for the notion of "working age population" that is so central for the Demographic Dividend argument. Public policies also start to reflect these changes as is the case in recent anti-age discrimination legislation where it has become illegal to use chronological age as a decisive criterion for many relevant decisions.. It has become a common saying that "40 is the new 30" or "70 is the new 60" implying that people aged 70 today are equivalent in many important dimensions including their health and their level of activity comparable to those aged 60 some time ago. In this paper Lutz (2010) argues that not only chronological age has been losing some of its presumably 'natural' explanatory power but that also the ubiquitous distinction between men and women is starting to forfeit some of its self-evident nature and is increasingly understood to be a social construction.

Demographers are starting to incorporate these ideas about redefining age and ageing in quantitative analyses (Sanderson and Scherbov 2005 and 2010; Lutz et al. 2008b; European Demographic Data Sheet 2012). Already Ryder (1975) and Jacob and Siegel (1993) had made suggestions for adjusting the meaning of age over time. Fuchs (1984) made the more general point that ages should be adjusted routinely for changing life expectancy in the same way that financial variables are adjusted for inflation. Sanderson and Scherbov (2005) and Lutz et al. (2008b) were the first to apply these ideas to recalculating adjusted ageing indicators on a global level and recently Sanderson and Scherbov (2010) also published adjustments based on changes in age-specific disability rates. The conventional almost exclusive reference to dependency ratios based on assumed fixed intervals of productive age such as 15-60 or 20-65 years since birth become highly problematic particularly when used for long time series. The conclusions drawn from them in terms of the consequences on economic growth can be misleading.

At the same time as we understand the shortcoming of the use of conventional chronological age as the single most important indicator of population heterogeneity that matters for economic growth we increasingly understand the importance of educational attainment as an additional source of observable population heterogeneity that greatly matters for economic growth. Based on a new reconstruction of educational attainment distribution by 5-year age groups and sex for more 120 countries back to 1970 which also explicitly considered educational mortality differentials (Lutz et al. VYB) a longstanding puzzle in economic growth could finally be resolved. While economists had assumed for a long time that education has an important positive effect not only on individual earnings but also on aggregate-level economic growth (G. Becker, Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education (Univ. of Chicago Press, Chicago, 1993). R. J. Barro, X. Sala-i-Martin, Economic Growth (MIT Press,Cambridge, MA, ed. 2, 2003)) and the empirical evidence is unambiguous for individual-level earnings, the statistical evidence for economic growth has been ambiguous. In a study using these new age-structured data on human capital it became apparent that economic growth was fastest when the better educated young cohorts enter young adulthood. This pattern is most clearly visible for the Asian tiger states, where the inter-cohort improvements in education were dramatic. At the global level, this study could unambiguously confirm the key role of human capital in economic growth (Lutz, Crespo, Sandrson 2008).

Given this new evidence on the important direct effects of improvements in human capital on economic growth together with the above described problems with using constant age intervals over time as the exclusive indicator that is supposed to capture the effect of a changing population composition on economic growth it is only a logical next step to add the education dimension to the age structure dimension in a common economic growth model that also includes labor force participation, capital accumulation and productivity gains as additional factors. In order to be compatible with the previous literature on economic growth models conventional chronological age will still be used as defining age structure. In terms of terminology, since we consider education to be a core demographic dimension we will also include the benefits of improving human capital under the notion of Demographic Dividend.

## 3. The Demographic Dividend Models

We can date the literature on the Demographic Dividend as beginning with Bloom and Williamson (1997, 1998), who originally called the phase in which age structure change resulted in more rapid economic growth the "demographic gift". The explosion of interest that followed was the result of five factors. First, Bloom and Williamson showed that age structure change accounted for around one-third of the East Asian economic miracle. This is quite a large effect. Second, the econometric approach that they used was the standard conditional convergence framework used in many prior studies of economic growth. This approach was well understood and widely accepted and subsequently has been used in most studies of the demographic dividend. Third, the Demographic Dividend analysis provided a framework in which prior empirical studies of the determinants of economic growth could be consistently integrated. Fourth, the approach lent itself to an interesting comparison of the economic futures of South East Asian and South Asian economics, and finally because many people had strong *a priori* beliefs that demography and economic growth had to be strongly connected, a belief which up to the Bloom and Williamson papers did not have a convincing empirical justification.

Education and the Demographic Dividend were linked from the beginning. Bloom and Williamson (1997, 1998) studied the rate of real GDP per capita growth in 78 countries between 1965 and 1990. One of the independent variables that they used was the level of human capital in 1965, measured as the log of the average years of post-primary schooling of the population 25+ years old, based on data in Barro and Lee (1994). The results for the education variable were only reported for their OLS regressions and not the instrumental variable ones. In all those regressions the education variable always had a positive and statistically significant coefficient. The importance of education changes to the East Asian economic miracle, however, was never discussed.

Kelley and Schmidt (2005) developed the Demographic Dividend model by making a distinction between the demographic determinants of the growth of output per person of working age, which they called the "productivity" effect and the growth of output per capita due to changes in the share of the working age population in the total population, which they called the "translations" effect. They studied per capita economic growth in 86 countries over 4 time periods, 1960-70, 1970-80, 1980-90, and 1990-95 and found that demographic changes worldwide accounted for around 20 percent of economic growth, with a greater impact seen in Asia and Europe. The human capital variable was the log of the average years of post-primary schooling for males 25+ years old and functioned as part of the productivity effect. Mean years of schooling were based on the updated Barro and Lee (2006) data. In all their regressions, the coefficient of the education variable was statistically insignificant.

The productivity effect has now been studied in more detail. Bloom et al. (2009) show, in a panel of countries, that a reduction in fertility increases female labor force participation and thus increases the proportion of the working age population who are in the labor force. Lee and Mason (20xx, 20xx) have introduced the concept of the second Demographic Dividend, which occurs when an aging population accumulates more wealth and that additional wealth is productively invested in the economy.

Lutz et al (2008) extend the Demographic Dividend model in two ways. First, they distinguish two mechanisms for human capital to influence economic growth, through the direct effect of the productivity of workers and indirectly through its effect on the rate of total factor productivity growth. Second, they use the new IIASA-VID education database to disaggregate education effects by both age and level of educational attainment. Using data for 101 countries over six five-year time periods from

1970-2000, they find that the direct productivity effect is particularly strong for older workers with secondary education while younger workers with tertiary education have the greatest effect on the speed of total factor productivity growth.

In this paper, we build on the prior literature by making an explicit distinction between the "productivity" effect and the "translations" effect, by articulating the two avenues through which human capital acquisition operates and measuring their separate contributions to economic growth, and by taking changes in female labor force participation rates and changes in investment into account. For consistency, our empirical strategy here is to use the same conditional convergence model used in most other studies of the demographic dividend and to use the same sort of aggregated human capital variable that is found in those studies.

# 4. Revisiting the empirics of age structure, education and income

## 4.1. The modeling set-up

We adopt a modeling framework which is in the spirit of the most influential empirical contributions to the literature on demographic dividend effects (see for example Kelley and Schmidt, 1995, Bloom and Williamson, 1998, Bloom and Canning, 2001, 2003, Bloom et al. 2000, Bloom et al. 2002 or Bloom and Canning, 2008, just to name a few). The approach used for the statistical evaluation of the effect of demographic dynamics on economic growth is based on simple decompositions of output per capita into output per worker and a variable which captures changes in age structure and labor participation.

We start our analysis by considering an aggregate production function given by

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha}, \tag{1}$$

where $Y_{it}$ is total output in country *i* at time *t*, $A_{it}$ is total factor productivity, $K_{it}$ is the capital stock and $L_{it}$ is total labor input. Considering variables per worker, the production function given by (1) can be written as

$$y_{it} = A_{it} k_{it}^{\alpha}, \tag{2}$$

where $y_{it} = Y_{it}/L_{it}$ is GDP per worker and $k_{it} = K_{it}/L_{it}$ is capital per worker. In growth rates, equation (2) can be written as

$$\Delta \ln y_{it} = \Delta \ln A_{it} + \alpha \Delta \ln k_{it}. \tag{3}$$

Since income per capita instead of income per worker is usually used for growth regressions, the relationship between total population, working age population and labor force needs to be taken into account in order to differentiate pure accounting effects from causal links between employment, age structure and income growth. Notice that

$$y_{it} = \frac{Y_{it}}{L_{it}} = \frac{Y_{it}}{N_{it}} \frac{N_{it}}{L_{it}} = \tilde{y}_{it} \frac{N_{it}}{L_{it}}, \tag{4}$$

where $\tilde{y}_{it}$ denotes GDP per capita and $N_{it}$ refers to total population. Combining (3) and (4) to obtain an expression for income per capita,

$$\Delta \ln \tilde{y}_{it} = \Delta \ln y_{it} + \Delta \ln L_{it} - \Delta \ln N_{it} = \Delta \ln A_{it} + \alpha \Delta \ln k_{it} + \Delta \ln L_{it} - \Delta \ln N_{it}. \tag{5}$$

Assuming that TFP growth is constant over time, the empirical implementation of (5) implies regressing the growth rate of income per capita on the growth rate of capital per worker, the growth rate of the labor force and the growth rate of population. The parameters associated with the last two variables should equal 1 and -1, respectively, if changes in the labor force share do not have productivity effects and only affect income per capita through the accounting channel exposed in (4).

If we assume that, due to technology adoption and income convergence dynamics, the growth rate of TFP depends on the distance to the global technology frontier as proxied by the level of GDP per worker of the country, this specification can be rewritten as

$$\Delta \ln \tilde{y}_{it} = \delta + \mu \ln y_{it-1} + \alpha \Delta \ln k_{it} + \Delta \ln L_{it} - \Delta \ln N_{it}. \quad (6)$$

Using the fact that

$$\ln y_{it} = \ln \tilde{y}_{it} + \ln\left(\frac{N_{it}}{W_{it}}\right) + \ln\left(\frac{W_{it}}{L_{it}}\right) = \ln \tilde{y}_{it} - \ln\left(\frac{W_{it}}{N_{it}}\right) - \ln\left(\frac{L_{it}}{W_{it}}\right),$$

where $W_{it}$ denotes working age population,

$$\Delta \ln \tilde{y}_{it} = \delta + \mu \ln \tilde{y}_{it-1} - \mu \ln\left(\frac{W_{it-1}}{N_{it-1}}\right) - \mu \ln\left(\frac{L_{it-1}}{W_{it-1}}\right) + \alpha \Delta \ln k_{it} + \Delta \ln L_{it} - \Delta \ln N_{it}. \quad (7)$$

This specification implies that the working age share and the participation rate should be added to the economic growth specification in addition to the growth rate of the labor force and total population. Parameter estimates of the same size and opposite sign of that of the initial income level for these two variables imply that changes in the participation rate and the working age share affect economic growth exclusively through the accounting channel described above.

The production function given by (1) does not consider human capital as either an input of production or a determinant of TFP growth. We can easily generalize the production function to include human capital (see Benhabib and Spiegel, 1994 or Hall and Jones, 1999, for some authoritative references which use similar approaches),

$$Y_{it} = A_{it} K_{it}^{\alpha} H_{it}^{1-\alpha},$$

where $H_{it} = h_{it} L_{it}$, and human capital per worker is denoted by $h_{it}$ , which in turn is defined as

$$h_{it} = \exp \theta s_{it},$$

where $\theta$ refers to the returns to schooling and $s_{it}$ are the average years of schooling of the labor force. The corresponding specification for the model with human capital is given by

$$\Delta \ln \tilde{y}_{it} = \Delta \ln A_{it} + \alpha \Delta \ln k_{it} + \Delta \ln L_{it} - \Delta \ln N_{it} + (1-\alpha)\theta \Delta s_{it}. \quad (8)$$

Assuming the dependence of technology growth on the distance to the technology frontier, the specification is then given by

$$\Delta \ln \tilde{y}_{it} =$$

$$\delta + \mu \ln \tilde{y}_{it} - \mu \ln\left(\frac{W_{it-1}}{N_{it-1}}\right) - \mu \ln\left(\frac{L_{it-1}}{W_{it-1}}\right) + \alpha \Delta \ln k_{it} + \Delta \ln L_{it} - \Delta \ln N_{it} + (1-\alpha)\theta \Delta s_{it}, \quad (9)$$

In addition, the overall human capital stock (average years of schooling) is often assumed to affect the growth rate of TFP by acting as a catalyst of technology creation and technology adoption (see for instance Benhabib and Spiegel, 1994, 2005).

$$\Delta \ln \tilde{y}_{it} =$$

$$\delta + \rho s_{it} + \mu \ln \tilde{y}_{it} - \mu \ln\left(\frac{W_{it-1}}{N_{it-1}}\right) - \mu \ln\left(\frac{L_{it-1}}{W_{it-1}}\right) + \alpha \Delta \ln k_{it} + \Delta \ln L_{it} - \Delta \ln N_{it} + (1-\alpha)\theta \Delta s_{it}, \qquad (10)$$

## 4.2. The empirical evidence

We confront the different specifications above with a panel data for 105 countries over the period 1980-2005, divided into periods of five years. The selection of countries was exclusively determined by the availability of the required data. The source of our data and the list of countries included in the analysis are presented in the appendix. All the specifications estimated include country and period fixed effects. The inclusion of the lagged income per capita term on the right hand side of some of the models presented implies that the estimation of panel data models with country fixed effects, so as to obtain inference from within-country dynamics, is not straightforward. Standard OLS estimation methods would lead to biased estimates since we do not take into account the correlation between the error term (which includes a country-specific fixed effect) and the lagged dependent variable. Generalized method of moments (GMM) methods have been proposed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) to overcome the endogeneity problem by using lagged values of first differenced and levels of the explained variable as instruments. In our empirical implementation we use the Blundell-Bond "system" GMM estimator (Blundell and Bond, 1998) for models which include lagged income per capita as an explanatory variable. The Blundell-Bond method has been shown to perform best for highly persistent variables, as is the case of income per capita.

The estimation of the different specifications is presented in Table 1. For the models estimated by GMM (those which include the initial income per capita level as a regressor) we include the usual specification tests related to instrumentation (Sargan test for overidentifying restrictions) and to the characteristics of the residuals (the standard tests for first and second order residual autocorrelation). We account for the potential endogeneity of the growth rate in the labor force and the change in years of schooling using two lags of the variables and their first difference, as is done for the lagged income level in the framework of the Blundell and Bond (1998) method. As theoretically expected, the growth rate of the labor force is significantly and positively related to economic growth, with estimates that range between 0.8 and 2. The growth rate of population, on the other hand, does not enter the model significantly in any of the specifications, although its effect is on average positive. The fourth specification presented in Table 1, which includes the growth rates of the labor force and total population together with the participation rate and the working age share, as well as the change in years of schooling, shows demographic dividend effects which are above the pure translation effects defined by (4). The estimation results of this model would lead us to conclude that the participation and age structure effects which follow fertility declines have direct productivity and economic growth enhancing effects. Furthermore, the effect of education would be deemed to be statistically insignificant and human capital investments would not appear to have a clear return in terms of income growth.

In the fifth column of Table 1 we consider education to affect economic growth not only as an input of the production function through the augmentation of labor income but also as a determinant of total factor productivity in the sense of Nelson and Phelps (1968). The variable measuring average years of schooling has a significant positive effect on economic growth and its inclusion as an extra regressor renders the parameter attached to the change in educational attainment also positive and significant. Furthermore, the returns to education implied by the parameter estimate associated with $\Delta s_{it}$ are approximately 18%, well above those usually found in the microeconometric literature. Theoretically, this is precisely what would be expected from returns to education at the macroeconomic level, where externalities are likely to be quantitatively much larger than at the individual level.

Most importantly, the pure demographic effects (excluding education) implied by the parameters attached to the labor participation and working age share variables are now not significantly different from the pure translation effects resulting from the fact that theoretically the models are built on output per worker but empirically it is income per capita which is used. Column (6) in Table 1 estimates the restricted model, imposing the parameter restrictions implied by the existence of translation effects. Such a regression implies that the estimated effects of the human and physical capital variables are to be interpreted as direct effects on income per worker. The size of the effect of human capital improvements in this specification appears accordingly much larger than in the rest of the regressions.

The relative role of age-structure and labor-force participation versus human capital dynamics assuming that the translation effect is in place can be evaluated by assessing the quantitative effect of typical variations in the corresponding variables. Obtaining the within-country standard deviation of the ratio of the labor force to total population and its growth rate, as well as of mean years of schooling and its change, we can calculate the size of the effect of typical in-sample variations of our variables of interest on income growth. In Table 2 we present the resulting effects of a change by one (within-country) standard deviation of these variables on yearly income per capita growth implied by model (6) in Table 1. The results are presented evaluating the variation of the age-structure/participation and human capital variables in the full sample as well as in subsamples defined by income groups according to the World Bank. As compared to the human capital effects, the size of the translation effects is relatively small in the full sample. In particular, the relative size of the realized human capital effects in low income countries, which present only limited growth effects due to the accounting channel, is particularly large. The group of lower middle income countries appears to have benefitted of both relatively large translation and even larger human capital effects on economic growth in comparison to the rest of the sample, with the exception of the small and heterogeneous group of non-OECD high income countries (formed by Equatorial Guinea, The Bahamas and Singapore).

Summarizing the set of results presented above, we can conclude that not accounting for the role of education as a determinant of economic growth properly would have led us to believe that the beneficial income growth effects took place directly through changes in age structure. Once we control for both the stock and investment in human capital we find that, statistically, it is the change in educational attainment levels that are the primal source of the demographic dividend effects that are present in the data. Empirically, the pure effect of changes in age structure on economic growth appears to take place exclusively through translation effects related to the measurement of income as GDP per capita instead of GDP per worker. It should be noted that, given the fact that our preferred specifications control for both educational attainment and labor force dynamics, the estimated effects of human capital go beyond the increase in participation expected from more educated populations. Since we are not able to reject that participation and age structure effects take place exclusively through the translation mechanism, it is the increased productivity and technology innovation or adoption capabilities of more educated individuals in the labor force that explains growth differences in GDP per worker within countries for our sample.

**Table 1: Panel estimates, economic growth models**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| $\Delta \ln k_{it}$ | 0.419** | 0.582*** | 0.589*** | 0.564*** | 0.559*** | 0.492*** |
| | [0.160] | [0.165] | [0.126] | [0.133] | [0.102] | [0.111] |
| $\Delta \ln L_{it}$ | - | 0.797** | 1.479** | 1.961*** | 1.609*** | 1 |
| | | [0.376] | [0.658] | [0.485] | [0.510] | (imposed) |
| $\Delta \ln N_{it}$ | - | 0.89 | 0.37 | 0.187 | 0.348 | -1 |
| | | [0.997] | [1.052] | [1.081] | [0.979] | (imposed) |
| $\ln \tilde{y}_{it}$ | - | - | -0.043 | -0.064 | -0.110** | -0.178** |
| | | | [0.0479] | [0.0437] | [0.0479] | [0.085] |
| $\ln\left(\frac{L_{it}}{W_{it}}\right)$ | - | - | 0.302 | 0.557** | 0.519* | 0.178** |
| | | | [0.326] | [0.271] | [0.288] | [0.085] |
| $\ln\left(\frac{W_{it}}{N_{it}}\right)$ | - | - | 0.871 | 1.391** | 0.995 | 0.178** |
| | | | [0.790] | [0.623] | [0.619] | [0.085] |
| $\Delta s_{it}$ | - | - | - | 0.131 | 0.400** | 0.717** |
| | | | | [0.170] | [0.177] | [0.306] |
| $s_{it}$ | - | - | - | - | 0.0405*** | 0.0671** |
| | | | | | [0.0128] | [0.0335] |
| Test for accounting effect: growth rates (p-val.) | - | 0.1538 | 0.3767 | 0.0503 | 0.1350 | - |
| Test for accounting effect: Levels (p-val.) | - | - | 0.5035 | 0.0201 | 0.1941 | - |
| Test for accounting effect: growth rates and levels (p-val.) | - | - | 0.7144 | 0.0505 | 0.3918 | - |
| Sargan test (p-val.) | - | - | 0.1323 | 0.2457 | 0.5433 | 0.2665 |
| AR(1) test (p-val.) | - | - | 0.0032 | 0.0017 | 0.0026 | 0.0522 |
| AR(2) test (p-val.) | - | - | 0.1768 | 0.2548 | 0.2918 | 0.1741 |
| Observations | 521 | 521 | 521 | 521 | 521 | 521 |
| Number of countries | 105 | 105 | 105 | 105 | 105 | 105 |

Robust standard errors in brackets. *(**)[***] stands for significance at the 10%(5%)[1%] level. Tests for accounting effects refer to the tests of the restrictions described in the text. "Sargan test" is the p-value of the Sargan test for overidentifying restrictions, "AR($p$) test" is the p-value of the test for $p$-th order autocorrelation of the residuals. All specifications include country and period fixed effects. Variables which are in growth rates or changes are measured over the corresponding period. All other variables are measured at the first year of the period.

**Table 2: Size of effects on economic growth**

| | | Within-country standard deviation | Effect on yearly income growth |
|---|---|---|---|
| Full sample | $(\Delta \ln L_{it} - \Delta \ln N_{it})$ | 2.93% | 0.59% |
| | $\ln(L_{it} / N_{it})$ | 4.98% | 0.18% |
| | $\Delta s_{it}$ | 0.081 | 1.17% |
| | $s_{it}$ | 0.689 | 0.92% |
| High income countries: OECD (N=23) | $(\Delta \ln L_{it} - \Delta \ln N_{it})$ | 2.86% | 0.57% |
| | $\ln(L_{it} / N_{it})$ | 4.31% | 0.15% |
| | $\Delta s_{it}$ | 0.065 | 0.93% |
| | $s_{it}$ | 0.56 | 0.75% |
| High income countries: non OECD (N=3) | $(\Delta \ln L_{it} - \Delta \ln N_{it})$ | 6.56% | 1.31% |
| | $\ln(L_{it} / N_{it})$ | 6.85% | 0.24% |
| | $\Delta s_{it}$ | 0.131 | 1.88% |
| | $s_{it}$ | 0.855 | 1.15% |
| Low income countries (N=30) | $(\Delta \ln L_{it} - \Delta \ln N_{it})$ | 2.10% | 0.42% |
| | $\ln(L_{it} / N_{it})$ | 2.78% | 0.10% |
| | $\Delta s_{it}$ | 0.091 | 1.31% |
| | $s_{it}$ | 0.685 | 0.92% |
| Lower middle income countries (N=32) | $(\Delta \ln L_{it} - \Delta \ln N_{it})$ | 3.33% | 0.67% |
| | $\ln(L_{it} / N_{it})$ | 5.05% | 0.18% |
| | $\Delta s_{it}$ | 0.088 | 1.26% |
| | $s_{it}$ | 0.766 | 1.03% |
| Upper middle income countries (N=17) | $(\Delta \ln L_{it} - \Delta \ln N_{it})$ | 2.51% | 0.50% |
| | $\ln(L_{it} / N_{it})$ | 7.69% | 0.27% |
| | $\Delta s_{it}$ | 0.058 | 0.84% |
| | $s_{it}$ | 0.687 | 0.92% |

## 5. Outlook and Discussions

This paper should only be seen as a first step in a broader assessment of the effects of changes in population composition according to a larger number of relevant individual characteristics on economic growth. Here we only focused on (chronological) age, labor force participation and educational attainment. The models were defined in a way to be compatible with the most influential previous models in the Demographic Dividend literature. The statistical analysis presented above shows that in the context of these models the explicit consideration of educational attainment adds significant explanatory power and deserves to be a key component of any future study on the Demographic Dividend. Since empirically a declining young-age dependency ratio tends to come along with an increasing educational attainment of the adult population, simple models that only consider fixed age intervals and disregard education can thus falsely attribute the productivity enhancing effect of education to a declining young-age dependency ratio and thus the typically preceding fertility decline.

This model actually underestimates the overall longer-term effect of increasing education of economic growth because it assumes the age structure to be a given and does not associate the underlying earlier fertility declines with the increasing female education that in most countries tended to be an important factor contributing to fertility decline. There is no space here for reviewing the extensive literature on female education and fertility but it suffices to say that the effects tend to be very strong particularly in the middle phase of demographic transition (Bongaarts 2010 – VYB, Lutz and KC 2011). If this would be explicitly taken into account the above described "translational" effects of age structure would also be in part attributable to improvements in education. Due to the relative long time lags from improving female education to lower fertility to this being reflected in a changed age structure and the complexity of not all women having their children at the same age such an assessment of this additional effect of education was beyond the scope of this paper. But it is a challenge that should be taken up soon.

Another extension of the analysis should utilize the age, sex and distribution detail of the newly reconstructed human capital data. Since in most countries the younger cohorts are better educated than the older ones, the use of mean years of schooling of the entire adult population above a certain age (as is done in most economic studies) cannot reflect these inter-cohort differences. Also it could be studied to what degree differential expansion rates of the different educational attainment categories effect economic growth and how this interacts with the changing age structure.

Finally, human capital is not only based on formal education and labor force participation but also on skills, cognitive functioning and health. While these dimensions are clearly more difficult to quantify and hardly any time series with consistent data exist, more could be done using existing data for subsets of countries such as the OECD or EU for which more standardized surveys exist (Hanushek). An explicit inclusion of age-specific health and cognition indicators could also help to address the above described problems of using longer time series based on conventional chronological age. While it is interesting and important for setting policy priorities to try to identify the relative contributions of all these different demographic/human capital dimensions on economic growth, the Demographic Dividend should be understood as a comprehensive concept that covers improvement in the human capital base of societies that will impact positively on the wellbeing of their individual members.

5.

## 4. Conclusions

**[TO BE WRITTEN]**

## References

**[TO BE WRITTEN]**

## Appendix: Data and variables

Table A1 presents the list of countries included in the analysis. All countries for which data are available are used, with the exception of oil exporters. Income per capita data are sourced from the Penn World Tables 6.3 (PWT 6.3, Heston et al. 2009). Capital stock data are obtained using the perpetual inventory method based on investment rates from the PWT 6.3. Labor force, working age population and total population are obtained from the World Bank's World Development Indicators. The educational attainment variable is the mean years of schooling for persons aged 15-64, sourced from the IIASA-VID dataset.

**Table A1: Countries in the sample**

| | | | | |
|---|---|---|---|---|
| Angola | Congo, Rep. | Guatemala | Mongolia | Senegal |
| Argentina | Colombia | Honduras | Mozambique | Singapore |
| Australia | Comoros | Haiti | Mauritania | Sierra Leone |
| Austria | Cape Verde | Hungary | Mauritius | El Salvador |
| Burundi | Costa Rica | Indonesia | Malawi | Somalia |
| Belgium | Cuba | India | Malaysia | Sao Tome and Principe |

| | | | | |
|---|---|---|---|---|
| Benin | Djibouti | Ireland | Niger | Sweden |
| Burkina Faso | Denmark | Italy | Nigeria | Syria |
| Bangladesh | Dominican Republic | Jordan | Nicaragua | Chad |
| Bulgaria | Algeria | Japan | Netherlands | Togo |
| Bahamas | Ecuador | Kenya | Norway | Thailand |
| Belize | Egypt | Cambodia | Nepal | Tunisia |
| Bolivia | Spain | Korea | New Zealand | Turkey |
| Brazil | Ethiopia | Lao PDR | Pakistan | Tanzania |
| Cent. Af. Rep. | Finland | Liberia | Panama | Uganda |
| Canada | France | Sri Lanka | Peru | Uruguay |
| Switzerland | United Kingdom | Morocco | Philippines | United States |
| Chile | Ghana | Madagascar | Poland | Vietnam |
| China | Guinea-Bissau | Maldives | Portugal | South Africa |
| Cote d'Ivoire | Equatorial Guinea | Mexico | Paraguay | Zambia |
| Cameroon | Greece | Mali | Rwanda | Zimbabwe |