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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 reassess the empirical evidence on the associations among economic growth, changes in age structure, labor force participation and 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 the key to explaining productivity and income growth and that a substantial portion of the demographic dividend is an education dividend.

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1 Introduction

The introduction of the concept of the demographic dividend was an important step forward in untying the Gordian knot of the relationship between demographic change and economic growth. That relationship had been hotly contested for decades (Ehrlich 1968; Ehrlich and Ehrlich 1990; Simon 1982, 1981) and in the end, no strong scientific consensus had emerged from the debate (National Research Council 1986). These early contributions focused primarily on changes in total population size and did not address changes in the composition of the population according to various potentially relevant characteristics of people.

Bloom and Williamson (1998) focused on the relationship between age structure change and economic growth and thus explicitly introduced age as a relevant source of population heterogeneity into the analysis. Other potentially relevant sources of population heterogeneity which play an important role as a potential catalyst of the demographic dividend are labor force participation and the level of educational attainment. While Bloom and Williamson and several other key papers on this issue did include education in their specifications, the now widely used and popularized concept of the demographic dividend only refers to changes in age-dependency ratios (based on fixed intervals of chronological age) whose evolution over the course of demographic transition presumably results in a demographic window that first opens and then closes in a predictable way as the old-age dependency ratio starts to increase (UNFPA 2011). In contrast to this dominant focus on changing age distributions recent studies of the effect of changes in age-specific educational attainment showed that indeed improvements in education seem to be a key driver of economic growth (see Lutz et al. 2008) and have predictive power for future income developments (see Crespo Cuaresma and Mishra 2011). In this paper, we step back to take a fresh look at the question of how the effect of improving education relates to that of changing age structure or, in other words, to what extent the demographic dividend is really an education dividend.

Improving education can impact economic growth through various channels. Higher skill levels of the labor force can directly translate into higher productivity and into better and faster take up of new technologies. In addition, it has been shown that education is an important factor for improving the health status of the population and also tends to contribute to the quality of governance more generally (KC and Lentzer 2010; Lutz et al. 2010; Pamuk et al. 2011). Importantly, female education is one of the key factors – if not the single most important factor – in inducing fertility decline and hence driving the declining young-age dependency ratio, which is the key factor in the demographic dividend argument. There is a vast body of literature documenting and analyzing this pervasive effect of female education on fertility, particularly for societies still in the process of demographic transition (for example Bongaarts 2010; Cochrane 1979; Cochrane et al. 1990; Skirbekk and KC 2012). Lutz and KC (2011) illustrate the major effect of female education on population dynamics by showing that when assuming identical trajectories of education-specific fertility rates, different scenarios on future school enrolment trends can lead to a difference of more than one billion in the projected world population size already by 2050. In this sense, education can be seen as the key trigger of the fertility decline that in consequence kick-starts the demographic dividend. The timing of this effect is such that for a declining proportion of 0-20 year olds – assuming a 30 year average generation length – it is the education of 30-50 year old women that matters. These timing issues are important when it comes to the interpretation of modeling results.

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 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 as in previous studies. Our results indicate that once the (robust) growth effects of educational improvements are conditioned away, the demographic dividend is reduced exclusively to a quantitatively small translation effect.

The paper is structured as follows. In Section 2 we briefly review some of the key contributions to the literature dealing with the demographic dividend, with a specific view of the treatment of education in those models. In Section 3 we revisit the empirics of these associations using improved data as compared to previous studies. In the concluding section we discuss the results and suggest further lines of investigation for the future.

2 Demographic Dividend Models

We can date the modern literature on the demographic dividend as beginning with Bloom and Williamson (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 and was thus quantitatively large. 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 (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 (1993). 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 not discussed in depth in Bloom and Williamson (1998).

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 label 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 call the "translations" effect. They studied per capita economic growth in 86 countries over 4 time periods, 1960-1970, 1970-1980, 1980-1990, and 1990-1995 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. In all their regressions, the coefficient of the education variable was statistically insignificant.

The productivity effect has been studied in detail in more recent contributions. 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 et al. (2000, 2003) 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 (Lutz et al. 2007) to disaggregate education effects by both age and level of educational attainment. These data are more consistent and more detailed than previously existing data sources. Educational attainment distributions for four educational categories have been reconstructed by 5-year age groups and sex using methods of multi-dimensional population dynamics which also incorporate educational mortality differentials. 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.

3 Revisiting the Empirics of Age Structure, Education and Income

3.1 The Modeling Set-Up

We adopt a modeling framework which is in the spirit of the literature on demographic dividend effects, but differs significantly in the details. 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 force 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

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

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 for example Benhabib and Spiegel 1994; Hall and Jones 1999),

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

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 θ 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).

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

3.2 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 (1999) 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, 1999) 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 (1999) 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 (1966). 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 Δs_{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 improvement 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. 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 role that the variable plays as a determinant of labor force participation. It is the increased productivity and technology innovation or adoption capabilities of more educated individuals in the labor force that appear particularly relevant as an explanatory factor of 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]
Δs_{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%
	Δs_{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%
	Δs_{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%
	Δs_{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%
	Δs_{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%
	Δs_{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%
	Δs_{it}	0.058	0.84%
	s_{it}	0.687	0.92%

Although the models estimated and presented here were developed with the intention to roughly resemble the earlier landmark studies on the demographic dividend, there are a few noteworthy differences that should be kept in mind when comparing the results:

a) Our model considers convergence in terms of output per worker, not output per person of working age as is the case in most of the other studies. Since we were able to get access to new data on labor force participation this seemed the more appropriate specification in the spirit of the underlying economic growth model.
b) As a consequence of the availability of these labor force data we explicitly included the labor force participation rate as a variable in the model. To our knowledge this has not been done by earlier studies. This has also implications for what is defined to be the “translation” and “productivity” effect. If the model is only specified in terms of persons in working age an underlying increase in e.g. female labor force participation shows up as an increase in productivity of persons in working age. In our model this effect can be directly measured and is interpreted as part of the translation effect.

c) Unlike earlier studies by Bloom and colleagues we explicitly include data on investment in our models. This was done in order to conform to the current practice in economic growth models.
d) Many of the earlier studies also included life expectancy at birth as an explanatory variable in the equations. We also did this initially but since it consistently turned out to be insignificant we decided to not include it in the table of results presented here.
e) Unlike many of the earlier studies that did include indicators of the level of education in the form of mean years of schooling of the adult population we include both the level of the education variable and its change over time. As the results presented above show, this makes an important difference with respect to the importance of the education variable to economic growth. As described above, our analysis also uses a new and more internally consistent set of education data as provided by the IIASA-VID reconstructions.

Keeping these differences in the estimated models and used data in mind, the significantly different findings that we gain appear to result primarily from three factors:

1. The educational attainment data used here is more consistent across countries and over time than the Barro and Lee (2001) data. These differences are discussed in detail in Lutz et al. (2007), Lutz et al. (2008), and Lutz and KC (2011). The higher consistency is essentially a consequence of the demographic back projections (including consideration of educational mortality differentials) where by definition the education categories stay consistent, unlike in the official data reported by countries to UNESCO where categories tend to be unstable (Lutz et al. 2007).
2. The estimation method used in this study is state of the art. Using dynamic panel GMM methods, we are able to avoid biases in the estimation that originate from the panel structure of the dataset.[1]
3. A key difference seems to lie in the way the education variable is treated. By including only the level or the change in educational attainment previous studies evidently lost relevant information, which we include by adding both to the model in the vein of the endogenous growth literature.

4 Conclusions and Paths of Further Research

Using an improved dataset and state of the art panel methods, we showed that the labor productivity effects which are claimed to accompany the demographic dividend can be explained through the changes in educational attainment level which take place hand in hand with fertility declines. The remaining effect of changes in the age structure on economic growth does not appear statistically different from the standard translation effect due to the changes in dependency ratios during the demographic transition.

[1] This point does not seem to make a decisive difference. Our results are broadly consistent with those in Lutz et al (2008), where standard OLS with fixed effects are used.

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 roughly compatible with the most influential previous models in the demographic dividend literature. The statistical analysis presented above shows that the explicit consideration of both the levels and the changes in educational attainment add significant explanatory power and deserve 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.

A further 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 and Woessmann 2008). 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.

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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