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Youth dependency and total factor productivity

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Abstract

Recent literature shows empirical support for an effect of demographic age structure on economic growth. This literature does not give attention to the possibility that age structure might also have an effect on total factor productivity. Much of the recent literature on economic growth has stressed that an understanding of cross-country differences in output per worker is needed. That literature argues that the most important determinant of international differences in output per worker is differences in total factor productivity. This paper finds empirical evidence in cross-country data for the thesis that the youth dependency ratio (the population below working age divided by the population of working age) reduces 'residual' growth, which measures total factor productivity growth. For this reason, the paper demonstrates that age structure has an effect on the most important determinant of international differences in output per worker.

JEL classification: J11; O40; O47
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1. Introduction

Using cross-country regressions, Mankiw et al. (1992) find that the neoclassical growth model, when augmented by human capital accumulation, explains 78% of the differences among global outputs per worker. Meanwhile, Young (1995) uses growth accounting calculations to determine that input accumulation accounts for most of the East Asian growth miracle. However, there has been recent opposition to these findings. Many believe

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that input accumulation cannot explain the majority of cross-country differences of output per worker. In this thesis, the level of the 'residual' and therefore total factor productivity (TFP) must account for the differences. A 'residual' represents the part of international output differences that input cannot explain.[1]

Prescott (1998) calibrates variants of the neoclassical growth model and shows that no form of capital (physical, human, or intangible) can account for most income differences within the world economy. He concludes that TFP must account for these differences and argues the need for further theorizing on this phenomenon. Hall and Jones (1999) and Klenow and Rodriguez-Clare (1997) both apply recent development accounting methods to global data. Their findings are consistent with Prescott's that differences among the levels of the 'residual' accounts for most of the variation in output per worker by country.

Also consistent with recent literature, Hendricks (2002) shows that only a model wherein cross-county income differences are due to differences in TFP can explain the large gains in earnings observed for immigrants in the United States. Hsieh (2002) recently questioned Young's theory that factor accumulation accounts for most of the East Asian growth miracle (Young, 1995). Hsieh argues that national account statistics (which Young uses) lead to substantial underestimation of TFP growth for East Asia countries, particularly for Singapore. Hsieh instead uses factor prices and finds a much larger contribution of TFP growth to East Asian growth.[2]

A demographic transition accompanied economic growth in East Asia. Following World War II, diffusion of international advances in health care enabled a rise in Asian health standards, including a dramatic reduction in infant mortality (Bloom and Williamson, 1998). A time difference between the reduction in infant mortality and an associated reduction in fertility meant that the age structure of the population underwent a transition. Until the mid-1960s, the growth rate of the total population exceeded the growth rate of the population of working age. Since the mid-1970s, the growth rate of the total population was lower than the growth rate of the working age population (Bloom and Williamson label this latter phase a 'demographic gift' phase). The 'demographic gift' phase coincides significantly with the rise in economic growth throughout East Asia. Bloom and Williamson (1998) and Bloom et al. (2001) argue that the 'demographic gift' was a major contributing factor to this East Asian economic growth miracle.

According to this view, the 'demographic gift' leads to opportunities for growth of output per capita for two reasons. First, there is an accounting effect because a rising ratio of the working age population to the total population increases the ratio of 'producers' to 'consumers' in an economy. Obviously, this contributes positively to growth of output per capita. Second, there might also be 'behavioral' effects on growth of output per worker. Bloom and Williamson stress that, on the one hand, a rising labor force leads to capital dilution, i.e., a reduction of the capital–labor ratio. On the other hand, a rising ratio of the working age population to the total population implies a falling dependency ratio (the population below and above working age divided by the population of working age). In turn, a falling dependency ratio allows the working age population to save a larger

[1] For a demonstration within a single country, see Solow (1957).

[2] However, Young (1998) defended himself imputing Hsieh's results (in the working paper version of Hsieh, 2002) to computational and methodological shortcomings.

percentage of their incomes. This will offset or even reverse the negative effect of labor force growth on the capital–labor ratio. The neoclassical growth model that assumes exogenous TFP growth underlies this hypothesis.

By performing cross-country regressions of the world economy, Bloom and Williamson find support for their hypothesis concerning the effect of age structure on economic growth. These estimations showed a negative and significant effect on growth of output per capita due to growth of the total population, and an opposite, positive and significant effect from the growth of the working age population. The authors used the quantitative results of their cross-country regressions to calculate the contribution of age structure changes to East Asian economic growth. They assert that approximately a third of the growth rate is explainable with a changing age structure. In Bloom et al. (2001), the authors extend these cross-country regressions (i.e., regressions without time-varying data) to pooled time series and cross-country data and find similar results as Bloom and Williamson.

There is also evidence for an impact of a changing dependency ratio on aggregate savings. Horioka (1997) finds such effects in the time series data of Japan, while Kelley and Schmidt (1996) find such effects in pooled time series and cross-country data of the world economy.[3]

However, the aforementioned important recent literature argues that an understanding of international differences in output per worker is needed, because only workers can contribute to production. Moreover, East Asia enjoyed also extraordinary growth of output per worker. The latter phenomenon cannot be explained with the aforementioned pure accounting effect from age structure changes. Furthermore, as mentioned before, the recent literature on economic growth argues that differences in TFP account for the bulk of cross-country differences in output per worker. This paper shows empirical evidence for an effect of the youth dependency ratio (the population below working age divided by the population of working age) on 'residual' growth, which measures TFP growth. Furthermore, the magnitude of this effect is found to be of plausible size. This mitigates any concern that the significant coefficient of the youth dependency ratio reflects reverse causality; that is, it mitigates the relevance of a thesis that rising TFP growth causes a falling youth dependency ratio.

The suggested thesis behind this finding is as follows: countries with a higher youth dependency ratio will have lower aggregate savings. Many developing countries have limited access to international capital markets; for these countries, low savings imply fewer funding opportunities for research and development (possibly, in developing countries funding for imitation of ideas of the industrialized world). In turn, lower research and development (R&D) spending will show up as lower TFP growth.

[3] Further work estimated the macroeconomic effects of the age structure of the labor force (as opposed to dependency ratios) or, more generally, the fraction of various 5-year age groups (i.e., the fraction of the population of age 15–19, 20–24, etc.). Lindh and Malmberg (1999) find an effect of the age composition of the labor force on growth of GDP per worker in OECD countries. Malmberg (1994) finds for Sweden such age structure effects on growth of GDP, on growth of GDP per capita, on growth of TFP, and on aggregate savings, while Feyrer (2002) confirms an effect of the growth rate of such age structure variables on TFP growth in OECD countries. Higgins and Williamson (1997) find an effect of such age structure variables on aggregate savings and the current account in Asia, while Higgins (1998) confirms such age structure effects in the world economy.

This thesis is consistent with recent R&D-based growth models (e.g., Jones, 1995). The paper finds empirical support for this particular mechanism by showing that in cross-country data, the youth dependency ratio reduces the aggregate savings rate. Moreover, the magnitude of this effect is consistent with the life cycle model. This supports the hypothesized channel of causality. Furthermore, savings of the working age population are shown to increase 'residual' growth (which measures TFP growth). This finding is shown to persist even when the growth rate of the labor force is included as a further control variable, a variable which is recently in Bernanke and Gürkaynak (2001), shown to be negatively correlated with TFP growth. This rejects any hypothesis that there may be a significant correlation between TFP growth and the youth dependency ratio only due to the youth dependency ratio picking up the effect of the omitted variable labor force growth.

The next section briefly explains the recent development accounting method, which shows that differences in TFP account for the bulk of differences in output per worker among countries. Furthermore, upon application of this method to growth rates, it is shown that differences in TFP growth account for 87% of cross-country differences in growth of output per worker. Section 3 contains regressions of 'residual' growth on the youth dependency ratio and various control variables and an analysis of the quantitative implications of the results. Section 4 contains tests of the suggested thesis behind the age structure effect and, as in Section 3, an analysis of the quantitative implications of the results. In addition, this section contains a robustness check with the growth rate of the labor force as further control variable. The final section contains the conclusions.

2. Development and growth accounting

As mentioned before, a recent literature on economic growth argues that most cross-country differences in the level of output per worker are due to differences in TFP (Hall and Jones, 1999; Klenow and Rodriguez-Clare, 1997).

The starting point of Hall and Jones (1999) is the following aggregate production function for each country i:

$$Y_i = K_i^{\alpha}(A_iH_i)^{1-\alpha}, \quad \text{with } 0<\alpha<1, \tag{1}$$

where Y_i represents the gross domestic product, K_i denotes the stock of physical capital, H_i denotes the amount of human capital-augmented labor, A_i denotes labor-augmenting TFP, and α is a constant coefficient.

Hall and Jones and Klenow and Rodriguez-Clare calculate human capital upon use of returns to schooling estimated in Mincerian wage regressions (Mincer, 1974). In particular, Hall and Jones calculate human capital-augmented labor from

$$H_i = e^{\phi(E_i)}L_i, \tag{2}$$

with L_i denoting homogenous labor, $\phi(E_i)$ representing the efficiency of a unit of labor with E_i years of schooling, and the derivative $\phi'(E_i)$ representing the Mincerian return to schooling. Hall and Jones calculate H_i by measuring E_i with the average years of school attainment of the population of age 25 and over. The authors assume $\phi(E_i)$ to be piecewise linear. Furthermore, they base their Mincerian returns on a survey of Mincerian returns for countries in the world economy by Psacharopoulos (1994). More specific, for the first 4 years of E_i, they assume a Mincerian return of 13.4%. For the next 4 years, they assume a value of 10.1%. And for any year beyond the eighth year, they assume a value of 6.8%. Finally, Hall and Jones choose in Eq. (1) a value of α=1/3. They argue that this value is broadly consistent with national income accounts data for developed countries.[4]

The earlier growth accounting literature, such as Young (1995), assessed the contributions of TFP growth and input accumulation to economic growth after taking growth rates of Eq. (1). However, the recent development accounting literature stresses that an assessment of the contributions to the level and the growth rate of output per *worker* is needed (i.e., that an assessment is needed after dividing both sides of Eq. (1) by L_i before taking growth rates of this equation). Furthermore, Klenow and Rodriguez-Clare and Hall and Jones argue that in Eq. (1) variation of the term K_i^α captures also variations that are caused by variations in A_i, because higher TFP stimulates capital accumulation by increasing the marginal value product of physical capital. To address both concerns, Hall and Jones argue that it is appropriate to assess the contributions of TFP and inputs to output per worker after rewriting Eq. (1) in the following intensity form:

$$y_i = \left(\frac{K_i}{Y_i}\right)^{\frac{\alpha}{1-\alpha}} h_i A_i, \tag{3}$$

where small letters denote per worker variables. The recent development accounting literature argues that the term $(K_i/Y_i)^{\alpha/(1-\alpha)}$ captures only variations that are not caused by variations in A_i.

Applying development accounting calculations to Eq. (3), Hall and Jones show that differences in TFP account for most of per worker output differences among countries. However, this paper is interested in explaining differences in *growth rates* instead of *levels* of output per worker. For this reason, I apply in this section the recent development accounting method to growth rates. Taking growth rates of Eq. (3) yields

$$\hat{y}_{i,t} = \hat{A}_{i,t} + \hat{X}_{i,t}, \qquad \text{with } \hat{X}_{i,t} = \left(\frac{\alpha}{1-\alpha}\right)\left(\widehat{\frac{K_{i,t}}{Y_{i,t}}}\right) + \hat{h}_{i,t}, \tag{4}$$

where $\hat{\chi}_{i,t}$ denotes the growth rate of a variable $\chi_{i,t}$, and the growth rate of a variable $\chi_{i,t}$ is defined as $\hat{\chi}_{i,t}$=$(1/t)(\ln\chi_{i,t}-\ln\chi_{i,0})$.

After rearranging Eq. (4), I calculated from this equation TFP growth for 70 countries of the world economy from 1965 to 1990 (see the list of countries in Appendix B, I included only countries for which oil production is not the dominant industry). In these

[4] Mankiw, Romer, Weil (1992) estimate the values of the exponents on physical capital and human capital in a similar production function as Eq. (1) econometrically, by regressing output per worker on the savings rate and the schooling rate. However, Hall and Jones argue that these estimates are biased, because TFP, which is in the framework of Mankiw et al. measured with the error in the regression equation, is correlated with the savings rate and the schooling rate. Hence, they argue that the values of the exponents in the production function cannot be determined econometrically.

Table 1
Contributions of TFP growth and input accumulation to differences in growth of output per worker for 1965–1990

$\text{cov}(\hat{y}_{i,t}, \hat{Z}_{i,t})/\text{var}(\hat{y}_{i,t})$	
$\hat{Z}_{i,t}=\hat{A}_{i,t}$	$\hat{Z}_{i,t}=\hat{X}_{i,t}$
87%	12%

calculations, I followed Hall and Jones in assuming $\alpha=1/3$, taking their Mincerian returns and using data as described in Appendix A.[5]

Applying a method of Klenow and Rodriguez-Clare to growth rates, one can decompose the contributions of TFP growth and input accumulation to variation in growth of output per worker by combining Eq. (4) with the identity $\text{var}(\hat{y}_{i,t})=\text{cov}(\hat{y}_{i,t}, \hat{y}_{i,t})$, which yields

$$\begin{aligned} \text{var}(\hat{y}_{i,t}) &= \text{cov}(\hat{y}_{i,t}, \hat{A}_{i,t} + \hat{X}_{i,t}) = \text{cov}(\hat{y}_{i,t}, \hat{A}_{i,t}) + \text{cov}(\hat{y}_{i,t}, \hat{X}_{i,t}) \\ \text{or } 1 &= \frac{\text{cov}(\hat{y}_{i,t}, \hat{A}_{i,t})}{\text{var}(\hat{y}_{i,t})} + \frac{\text{cov}(\hat{y}_{i,t}, \hat{X}_{i,t})}{\text{var}(\hat{y}_{i,t})}. \end{aligned} \tag{5}$$

Using the latter identity, one can calculate the contribution of TFP growth to growth of output per worker as $\text{cov}(\hat{y}_{i,t}, \hat{A}_{i,t})/\text{var}(\hat{y}_{i,t})$ and can calculate the contribution of input accumulation to growth of output per worker as $\text{cov}(\hat{y}_{i,t}, \hat{X}_{i,t})/\text{var}(\hat{y}_{i,t})$ (Table 1). Upon application of this method, Table 1 shows that TFP growth accounts for 87% of cross-country differences in growth of output per worker, while input accumulation accounts for only 12%. This demonstrates that explaining cross-country differences in growth of TFP is also important.

3. Main results

This section contains the results of pooled time series and cross-section regressions. These tests were conducted to find out whether or not the natural logarithm of the youth dependency ratio (defined as the population below age 15 divided by the population of age 15 to 64) has a significant negative effect on TFP growth (as measured with residual

[5] Later, when I define the youth dependency ratio, I define the working age population as the population of age 15 to 64. Therefore, when calculating TFP growth, I measured—because of consistency—E_i as the average years of school attainment of the population age 15 and over instead of age 25 and over as Hall and Jones do. Furthermore, in order to correct for natural resources, Hall and Jones subtract from GDP the value added in the mining industry. Upon use of data of the share of mining in value added in 1988 from Chad Jones' website (see the URL in Appendix A), I calculated the contribution of differences in TFP to cross-country differences in output per worker in 1990 with and without correction for mining. In my sample of countries, the contribution was 62% in case with correction for mining and was 61% in case without correction for mining (i.e., surprisingly even slightly smaller). In light of this small difference, I refrained from correcting for mining in my calculations of TFP growth.

growth). For this purpose, time series and cross-section data of 5-year averages, from 1965–1990, of 70 countries of the world economy were collected and pooled to a balanced panel (the data sources are shown in Appendix A, and the list of countries is shown in Appendix B). As mentioned in the last section, only countries were included for which oil production is not the dominant industry. Residual growth for 5-year averages was calculated according to the aforementioned growth accounting method.

In order to avoid biased coefficients due to the omission of relevant variables, some control variables were included in the regression equations. To capture international technology transfer, I included, as an independent variable, the natural logarithm of TFP in the base year (i.e., the beginning of each 5-year interval) measured by the natural logarithm of the residual. This variable is supposed to capture the idea that countries with a low initial level of TFP have more gains from international technology transfers than do countries with an initially high level of TFP.

In addition, I followed Bloom and Williamson (1998) and Hall and Jones (1999) to control for differences among social infrastructures with the following two variables: (i) an index of government antidiversion policies, which Bloom and Williamson label quality of government institutions and which Hall and Jones (1999) give the abbreviation GADP. This index was assembled by Knack and Keefer (1995) as an index of various policy categories for 1986–1995 and is measured on a [0, 1] scale (see more details to this index in Appendix A). (ii) An index that measures the fraction of years between 1950 and 1994 that a country has been open to trade and which is also measured on a [0, 1] scale. This index was assembled by Sachs and Warner (1995), and each year a country was considered as 'open' if it satisfied five criteria (see more details in Appendix A). I followed Hall and Jones in calculating a single index for social infrastructure as the weighted average of the GADP indexes and the openness index with 0.5 as the weights, and used this single index as a composite index of social infrastructure (abbreviated socinf).[6] As Hall and Jones explain, doing so imposes the restriction that the coefficients for the two policy indicators are the same. Note also that while Hall and Jones argue that social infrastructure explains differences in the level of output per worker, Rodrik (1998) shows that a measure of corruption of Knack and Keefer also explains much of the East Asian economic growth miracle. Since in my sample of countries, this measure of corruption is correlated with the GADP index with a correlation coefficient of 0.89, the index of social infrastructure should also be important for economic growth and TFP growth.[7]

Hall and Jones argue that the index of social infrastructure contains measurement errors. To correct for these measurement errors, I followed Hall and Jones in instrumenting social infrastructure with variables that are correlated with social infrastructure, but uncorrelated with the measurement errors and the residuals of the growth regressions.

[6] Bloom et al. (2001) use 5-year averages of the openness index of Sachs and Warner instead of the average of this index between 1950 and 1994. This allows the authors to exploit the time variation in the data. Contrary to them, I used the average of this index between 1950 and 1994 (that is, I did not use the time dimension in the data). The main reason for this is the fact that the GADP index of Knack and Keefer, i.e., the other element of the composite index for social infrastructure, is not available for different time periods.

[7] The measure of corruption of Knack and Keefer can be found in the data set of Easterly and Levine (1997) at the publication archive of the World Bank Economic Growth Research web page at www.worldbank.org/programs/macroeconomics/.

Following Hall and Jones, I used as instruments the following four variables: (i) the fraction of the population in a country that speaks English as first language (engfrac); (ii) the fraction of the population in a country that speaks English, French, German, Portuguese, or Spanish as first language (eurfrac); (iii) the predicted trade share of an economy taken form Frankel and Romer (1999; lnfrankrom); and, (iv) an index of the distance from the equator (latitude; see for more details Appendix A). In addition, I followed Bockstette et al. (2002) in using an indicator of state antiquity (statehist5) as a further instrument (see Bockstette, Chanda and Putterman, 2002, pp. 351–352 for details of the construction of statehist5). I did so because Bockstette et al. show that the variable statehist5 is a good instrument for Hall and Jones' indicator of social infrastructure. The result of the first stage regression with OLS is (with t-statistics in parentheses):[8,9]

$$\begin{aligned}\text{socinf}_i = 0.131 + \underset{(5.60)}{0.222}\text{engfrac}_i + \underset{(3.46)}{0.091}\text{eurfrac}_i + \underset{(1.70)}{0.025}\text{lnfrankrom}_i \\ + \underset{(1.84)}{0.001}\text{latitude}_i + \underset{(10.82)}{0.606}\text{statehist5}_i, \quad R^2 = 0.50. \qquad (6)\end{aligned}$$

Moreover, to avoid biased coefficients and standard errors because of the omission of time-specific factors in the second stage regressions, I applied a Chow test to test for presence of fixed time effects. It turned out that in all regressions of this paper, an absence of fixed time effects could be rejected. Therefore, all regressions include time dummies (not shown) to capture fixed time effects (with the exception of Eq. (6), because Eq. (6) contains only time-invariant variables).

It is possible that some or all of the variables in this study are difference-stationary; in other words, the mean and the variance are constant over time after first differencing, but not in levels. If true, any significant correlation is potentially spurious. Furthermore, with difference-stationary variables, the t-statistic is not reliable (even if the correlation is 'true'). Because of this possibility, Appendix D contains panel data unit root tests applied to the levels of all variables in this study, with critical values taken from Harris and Tzavalis (1999). These tests revealed that none of the levels of the variables in this study contains a unit root; that is, none is difference-stationary. Therefore, it is appropriate to apply standard inference to the following estimation results.

In Table 2, the second column shows the results of two-stage least squares (2SLS) regression with fixed time effects. In the regressions, the White–Huber procedure was applied to produce heteroscedasticity-consistent t-statistics.[10] It can be seen that the youth

[8] Without the instrument variable statehist5 the coefficient of the instrument variable lnfrankrom had in my first stage regression an extremely low p-value and was negative. This was a further reason for the inclusion of statehist5 as an additional instrument variable.

[9] At this point, a technical note is necessary. In order to exclude from the first-stage regression instruments that are correlated with the measurement errors of social infrastructure, I assumed a triangular system. This means that I assumed social infrastructure to be unaffected from growth of TFP (which seems to be a reasonable realistic assumption). This assumption implies that it is not required to include in the first-stage regression all other independent variables of the following second-stage regression.

[10] Before doing so, I applied a Breusch–Pagan test and a White test to test whether the squared residuals of the 2SLS regressions are jointly independent of the independent variables of the 2SLS regressions (i.e., whether there is homoscedasticity). Both tests rejected homoscedasticity.

Table 2
Explaining total factor productivity (TFP) growth 1965–1990, panel data of 5-year averages

Dependent variable: annual average growth rate of TFP (×100)

Independent variables	2SLS with fixed time effects	Standardized coefficients	2SLS with fixed time effects
Constant	13.33 (4.46)		16.30 (3.26)
Ln of TFP in base year	−1.73 (−4.42)	−0.26	−1.91 (−3.31)
Socinf	3.67 (2.66)	0.17	1.38 (0.79)
Ln of youth dependency ratio	−2.12 (−3.03)	−0.22	−2.10 (−2.59)
Dummy for reg_eap			0.86 (1.20)
Dummy for reg_sa			−0.14 (−0.13)
Dummy for reg_lac			−0.77 (−0.87)
Dummy for reg_ssa			−1.41 (−1.02)
Dummy for reg_mena			1.17 (1.50)
R^2	0.20	0.20	0.22
Number of observations	350	350	350

[a] (White–Huber) heteroscedasticity-consistent *t*-statistics are reported in parentheses behind the coefficient estimates.
[b] Fixed time effects are not shown.
[c] Social infrastructure was instrumented by using the predicted values from the first-stage regression in Eq. (6).

dependency ratio has a negative and significant coefficient. Hence, a high youth dependency not only reduces capital accumulation, as earlier literature argued. Instead, it also reduces TFP growth. For this reason, even if TFP growth accounts for most of the differences in economic growth among countries, the youth dependency ratio is still important for economic growth.

Furthermore, the second column shows that the ln of TFP in the base year has a negative and significant coefficient, indicating presence of a 'catch-up' effect, possibly because countries with a low stock of technical knowledge benefit more from international knowledge transfer. In addition, the coefficient of social infrastructure is positive and significant. The third column shows standardized coefficients of the same regression as in the second column. A standardized coefficient shows the relative importance of a variable.[11] From the table, it can be seen that the youth dependency ratio is about as important for TFP growth as the catch-up effect and social infrastructure. Hence, youth dependency is important for TFP growth in economic terms and should not be ignored.

The fourth column in Table 2 shows the results of an identical regression as in the second column, but with dummy variables for regions of developing countries included to control for fixed regional-specific effects. (In the regressions, reg_eap denotes the region East Asia and Pacific. Furthermore, reg_sa denotes the region South Asia, reg_lac represents the region Latin America and Caribbean, reg_ssa denotes the region Sub-Saharan Africa, and reg_mena represents the region Middle East and North Africa). Dummy variables for the regions of industrialized countries were clearly insignificant and therefore not included. Alternatively, it would have been possible to include country

[11] Technically, a standardized coefficient of an independent variable x is calculated by multiplying the not standardized coefficient with the standard deviation of x and dividing the resulting value by the standard deviation of the dependent variable y.

dummies instead of regional dummies. The reason for including regional dummies is the fact that with regional dummies, it is still possible to include the time-invariant variable social infrastructure as a control variable, a variable that was shown to have a fairly large standardized coefficient and should therefore not be ignored. (Note also that random country effects estimation—not shown—gave exactly identical results as the results in the second column of Table 2. Moreover, also with fixed country effects estimation, i.e., with country dummy variables included—but social infrastructure excluded—the youth dependency ratio remains negative and significant—results not shown). The reader should not be surprised to see that social infrastructure is insignificant once regional dummy variables are included as control variables. This seems to be entirely due to the fact that including many time-invariant variables reduces the significance of other time-invariant variables. The really important result from the fourth column is the fact that the significant effect of the youth dependency ratio is robust towards controlling for fixed regional effects and social infrastructure.

The standardized coefficients in Table 2 established that the youth dependency ratio is about as important for TFP growth as the catch-up effect and social infrastructure. However, a standardized coefficient does not show by how many percentages TFP growth changes from a reduction of the youth dependency ratio from, for example, 0.6 to 0.4.[12] Upon application of an approach of Behrman et al. (1999), the next two tables contain quantitative measures to fill this gap.[13]

The second column in Table 3 shows the average youth dependency ratios of 1965–1990 for various world regions, while the third column shows the difference in the predicted TFP growth rates between a world region and developed countries. To calculate the values of this column, I first calculated the predicted effect of the youth dependency ratio on TFP growth for various world regions. This predicted effect was calculated by multiplying the coefficient of the ln of the youth dependency ratio, which was taken from the second column of Table 2, with the average of the ln of the youth dependency ratios of a particular region. Next, I calculated the difference in the predicted TFP growth rates between a world region and developed countries by substracting the predicted TFP growth rate of developed countries from the predicted TFP growth rate of a world region.

The third and fourth row of Table 3 show in the second column that the youth dependency ratio was in developing countries equal to 0.73 and was in developed countries equal to 0.38. Furthermore, the table shows that this difference in the youth dependency ratios implies a difference in the predicted annual TFP growth rates of −1.39%. That is, the annual growth rate of TFP in developing countries is predicted to have been by 1.39% lower than in developed countries. The next two rows show the developing world region

[12] I am grateful to an anonymous referee for drawing my attention to this limitation.

[13] It is possible to calculate the effect of the youth dependency ratio on TFP growth for a world region, say, East Asia. However, it is difficult to interpret this effect. This is so, because the ln of the youth dependency ratio is negative for most countries of the world. Because its coefficient is negative, the predicted effect of the youth dependency ratio for a world region is positive (which, taken literally, contradicts intuition). Nevertheless, the predicted effect is lower in world regions or time periods with a higher youth dependency ratio. For this reason, one can avoid the problem of interpretation by calculating the difference in the predicted effects of the youth dependency ratios between world regions or between time periods. This is an application of the approach of Behrman et al. (1999).

Table 3
Magnitude of the effect of the youth dependency ratio on annual TFP growth rate, regional differences, average 1965–1990

Cross-country differences between developing countries and developed countries			
World region z	Youth dependency ratio	Difference in predicted TFP growth between world region z and developed countries (%)	Difference in actual TFP growth between world region z and developed countries (%)
Developing countries	0.73	−1.39	−0.60
Developed countries	0.38		
East Asia	0.56	−0.85	2.26
Africa	0.88	−1.78	−1.34

[a] Values are weighted county averages for 1965–1990, where the weights are the shares of the average working age population of each country in the average working age population in its country group.
[b] Cyprus, Israel, and Japan are included into the group of developed countries.
[c] Japan is not included into East Asia, while Cyprus and Israel are not included into Africa.
[d] Predicted refers to predicted from the difference of the youth dependency ratios (more exactly, the ln of it).

with the lowest youth dependency ratio (East Asia with a youth dependency ratio of 0.56) and the world region with the highest youth dependency ratio (Africa with a youth dependency ratio of 0.88). As can be seen, the relatively low youth dependency ratio in East Asia predicts a relatively small difference in TFP growth between East Asia and developed countries (which is −0.85%). In contrast to this, the high youth dependency ratio in Africa implies a relatively large difference in predicted TFP growth between Africa and developed countries (which is −1.78%). The fourth column shows the difference in actual TFP growth between a world region and developed countries. The difference in actual annual TFP growth between developing countries and developed countries was −0.60%. That is, the difference in actual TFP growth was smaller than the predicted difference (most likely because of the catch-up effect). Furthermore, one can see that actual TFP growth in East Asia was much higher than in developed countries (by 2.26%). In contrast, actual annual TFP growth in Africa was much lower than in developed countries (by −1.34%). A comparison of the third and the fourth column demonstrates that the difference in the youth dependency ratios between East Asia and Africa has contributed to the difference in their TFP growth rates. However, one can also see that the difference in the youth dependency ratios predicts only a difference of about 1% in annual TFP growth between these two regions. Because, however, the actual difference in annual TFP growth equals 3.6%, other factors, such as social infrastructure and unobserved factors, must together have been even more important for this difference in actual TFP growth.

The second and third column of Table 4 show that the average youth dependency ratio of developing countries fell from 0.79 in 1965 to 0.66 in 1990. The fourth column shows that upon use of the aforementioned coefficient of the ln of the youth dependency ratio, this change of the youth dependency ratio is predicted to have raised the annual TFP growth rate of developing countries by 0.39%. The fifth column shows that actually annual TFP growth of developing countries fell by 0.60% (some time-specific occurrences must be responsible for this). To conclude: the most important message of Tables 3 and 4 is the fact that the predicted effects of the youth dependency ratio on TFP growth are of

Table 4
Magnitude of the effect of the youth dependency ratio on annual TFP growth, time changes

Time series changes by world region				
	Youth dependency ratio, 1965	Youth dependency ratio, 1990	Predicted change average annual TFP growth	Actual change average annual TFP growth
Developing countries	0.79	0.66	0.39%	−0.60%

[a] Values are weighted county averages for 1965–1990, where the weights are the shares of the average working age population of each country in the average working age population in developing countries.
[b] Cyprus, Israel, and Japan are included into the group of developed countries.
[d] Predicted refers to predicted from changes of the youth dependency ratios (more exactly, the ln of them).

credible magnitude. This mitigates the relevance of a thesis that rising TFP growth caused a falling youth dependency ratio.

Finally, Table 5 checks wether the youth dependency ratio has a similar effect on income growth as it has on TFP growth. Therefore, the table shows the results of 2SLS regressions of growth of output per worker on the natural logarithm of output per worker in the base year and all other variables of Table 2 (again with White–Huber heteroscedasticity-consistent standard errors). These regressions differ from those in Bloom and Williamson (1998) and Bloom et al. (2001) with respect to four important aspects: first, the aforementioned authors test for an effect on growth of output per capita instead of growth of output per worker. However, the recent development accounting literature has stressed that only workers can contribute to production, and therefore an understanding of differences in output per worker is more important than an understanding of differences in output per capita. Second, the aforementioned authors test for effects of growth rates of demographic variables while Table 3 tests for an effect of the level of age

Table 5
Explaining growth of output per worker 1965–1990, panel data of 5-year averages

Dependent variable: annual average growth rate of TFP (×100)			
Independent variables	2SLS with fixed time effects	Standardized coefficients	2SLS with fixed time effects
Constant	8.63 (4.74)		14.82 (4.70)
Ln of output per worker	−0.95 (−4.30)	−0.27	−1.42 (−4.39)
in base year socinf	4.18 (3.99)	0.24	1.12 (0.85)
Ln of youth dependency ratio	−1.97 (−3.23)	−0.25	−2.20 (−3.34)
Dummy for reg_eap			1.32 (2.53)
Dummy for reg_sa			−1.17 (−1.31)
Dummy for reg_lac			−1.05 (−1.62)
Dummy for reg_ssa			−2.47 (−2.33)
Dummy for reg_mena			1.22 (2.16)
R^2	0.25	0.25	0.35
Number of observations	350	350	350

[a] (White–Huber) heteroscedasticity-consistent t-statistics are reported in parentheses behind the coefficient estimates.
[b] Fixed time effects are not shown.
[c] Social infrastructure was instrumented by using the predicted values from the first-stage regression in Eq. (6).

structure. The motivation for doing so is the fact that at least in the transition to a steady state, growth of output per worker is affected by the level of savings. In turn, the level of savings is affected by the level of age structure variables and not their growth rates. Third, the authors do not give attention to the possibility that there might be a difference between the effect from an increase in the youth dependency ratio and the effect from an increase in the elderly dependency ratio (the population above working age divided by the population of working age). However, when I included only developing countries in the sample, then the elderly dependency ratio was insignificant for economic growth (results not shown). Future research might aim to examine possible reasons for the lack of significance of the elderly dependency ratio in developing countries (although probably variation of the elderly dependency ratio is qualitatively rather unimportant for developing countries). However, as this paper is interested in explaining economic growth in developing countries, the regression equations should only contain the youth dependency ratio, and the elderly dependency ratio should clearly be dropped. Fourth, the aforementioned authors included various mainly geographic variables as additional control variables. It turned out that these geographic variables are insignificant (at least for developing countries) once some geographic variables are used as instruments for social infrastructure as in Hall and Jones (1999) and this paper and as described before.[14] Therefore, these control variables were dropped from the regression equations of Tables 2 and 5.

The second column in Table 5 shows qualitatively identical results as the second column in Table 2. Most importantly, it confirms that the coefficient of the youth dependency ratio is negative and significant. The third column shows standardized coefficients of the regression of the second column. The youth dependency ratio turns out to be also about as important for growth of output per worker as social infrastructure and the catch-up effect and/or convergence (due to international technology transfer and/or a diminishing return to capital).

The fourth column shows that the negative effect of the youth dependency ratio on growth of output per worker is also robust concerning the inclusion of dummy variables for regions of developing countries as further control variables. (Note that random effects estimation—results not shown—gave again almost exactly identical results as the second column of Table 5. Furthermore, with fixed country effects estimation—not shown—the coefficient of the youth dependency ratio remains again negative and significant).

4. An explanation, empirical evidence, and robustness

The last section established a negative effect from the youth dependency ratio on TFP growth. However, these results say nothing about the particular way in which the youth dependency ratio affects TFP growth. This section states a possible explanation and provides empirical evidence for the proposed channels by which the youth dependency ratio affects TFP growth. Finally, it is checked whether the magnitude of the coefficients is

[14] This is consistent with a recent literature, which finds insignificant effects of various geographic variables on the level of GDP per capita, once some geographic variables are used as instruments for various measures of quality of institutions (see, e.g., Acemoglu et al., 2001; Easterly and Levine, 2003; Rodrik et al., 2002).

consistent with economic theory and whether the proposed channels are empirically robust.[15]

The starting point for a possible explanation of the last sections' finding is the following 'production' function of technical knowledge of each developing country i:[16]

$$\dot{A}_{i,t} = \delta_i \left(\frac{A_t^*}{A_{i,t}} \right)^{\phi} (R_{I,i,t})^{\lambda}, \qquad \text{with } \phi, \lambda > 0, \tag{7}$$

where, $A_{i,t}$ denotes the stock of domestic knowledge, and $\dot{A}_{i,t}$ denotes the derivative of $A_{i,t}$ with respect to time. Furthermore, δ_i represents a constant productivity parameter (possibly, positively influenced by social infrastructure and therefore different for different countries), A_t^* represents the stock of knowledge of the industrialized world, ϕ and λ are constant coefficients, and $R_{I,i,t}$ denotes the amount of output that is invested in imitation. $(A_t^*/A_{i,t})$ captures the gap between knowledge of the industrialized world and domestic knowledge. The larger this gap, the greater the capability for imitation, because the economy can then benefit more from international knowledge transfer or because simple ideas are imitated first.

Investment in imitation is financed with the savings of the working age population, $S_{i,t}^{\text{wp}}$. Substituting the identity $R_{I,i,t}=S_{i,t}^{\text{wp}}$ in Eq. (7) and dividing by $A_{i,t}$ yields

$$\hat{A}_{i,t} = \frac{\dot{A}_{i,t}}{A_{i,t}} = \delta_i (A_t^*)^{\phi} A_{i,t}^{-(1+\phi)} (S_{i,t}^{\text{wp}})^{\lambda}, \tag{8}$$

where $\hat{A}_{i,t}$ depends negatively on $A_{i,t}$, just as was found in the last section's regressions.[17]

In an overlapping generations model aggregate savings, $S_{i,t}$, are the sum of the savings of the working age population, $S_{i,t}^{\text{wp}}$, and the negative dissavings of the population above working age, $S_{i,t}^{\text{ep}}$ (see, e.g., Obstfeld and Rogoff, 1997, pp. 136–137). This yields after division by aggregate income, $Y_{i,t}$, $(S_{i,t}/Y_{i,t})=(S_{i,t}^{\text{wp}}+S_{i,t}^{\text{ep}})/Y_{i,t}$, where $(S_{i,t}/Y_{i,t})$ represents the aggregate savings rate. Dividing the numerator and the denominator of the fraction on the right-hand side of the aforementioned identity by the working age population yields

$$\frac{S_{i,t}}{Y_{i,t}} = \frac{s_{i,t}^{\text{wp}} + s_{i,t}^{\text{ep}} d_{e,i,t}}{y_{i,t}}, \qquad \text{with } s_{i,t}^{\text{ep}} < 0, \tag{9}$$

where $s_{i,t}^{\text{wp}}$ denotes the savings of each working person, and $s_{i,t}^{\text{ep}}$ denotes the dissavings of each person above working age. Furthermore, $d_{e,i,t}$ denotes the elderly dependency ratio

[15] I am grateful to an anonymous referee for suggesting to me the empirical exercises of this section.

[16] The 'production' function of ideas is taken from Jones (1995) and is adapted to the case of an imitating developing country and to the case with investment in imitation using units of output. See Pérez-Sebastián (2000) for a richer specification which incorporates simultaneous imitation and innovation (that is, 'production' of new ideas).

[17] Contrary to the last section's regressions, in Eq. (8) $\hat{A}_{i,t}$ depends nonlinearly on $A_{i,t}$. However, upon application of a first-order Taylor approximation in the neighborhood of the steady state, one can derive $\hat{A}_{i,t}$ to depend linearly (and negatively) on ln $A_{i,t}$, which was the relation in the last section's regressions. A log–linear approximation is a standard procedure in the growth literature (see its application to the Solow growth model in, e.g., Burda and Wyplosz, 2001, pp. 66–67).

(remember, that the elderly dependency ratio was defined as the population above working age divided by the population of working age), and $y_{i,t}$ denotes aggregate income per working age person.

Most importantly, for my proposed explanation for an effect of the youth dependency ratio on TFP growth, a rising number of children per working age person (and hence a rising youth dependency ratio) leads to falling savings of each working age person due to rising total child-rearing costs. For simplicity, I assume that all noninterest income is income of the working age population (and is approximated with aggregate income), that children only need units of the consumption good and no time of the parents and that children's consumption needs rise proportionally with the consumption level of each working age person, with p_y as this factor of proportionality. Hence, savings of each working person equal

$$s_{i,t}^{\mathrm{wp}} = y_{i,t} - c_{i,t}^{\mathrm{wp}} - p_y c_{i,t}^{\mathrm{wp}} d_{y,i,t}, \tag{10}$$

where $c_{i,t}^{\mathrm{wp}}$ denotes consumption of each working age person, and $d_{y,i,t}$ denotes the youth dependency ratio. Substituting Eq. (10) in Eq. (9) and multiplying with 100 yields

$$\left(\frac{S_{i,t}}{Y_{i,t}}\right)100 = \left[1 - \left(\frac{c_{i,t}^{\mathrm{wp}}}{y_{i,t}}\right)\right]100 - p_y\left(\frac{c_{i,t}^{\mathrm{wp}}}{y_{i,t}}\right)100 d_{y,i,t} - \left(\frac{s_{i,t}^{\mathrm{ep}}}{y_{i,t}}\right)100 d_{e,i,t}. \tag{11}$$

In turn, this gives rise to a first testable channel by which the youth dependency ratio might indirectly influence TFP growth, namely:

Hypothesis 1. The youth dependency ratio has a negative effect on the aggregate savings rate.

Next, after log–linear approximation Eq. (8) gives rise to a second testable channel by which the youth dependency ratio might indirectly influence TFP growth, namely:

Hypothesis 2. TFP growth depends positively on the ln of the savings of the working age population.

When testing Hypothesis 1, I regressed the aggregate savings rate (henceforth savings rate) on the youth and the elderly dependency ratio and time dummy variables. Furthermore, similar to Bloom et al. (2003, specification (4) in Table 1) and Higgins (1998), I included the growth rate of income per working age person as a further control variable.[18] According to various versions of the life cycle model, this growth of income per working age person is supposed to influence $(c_{i,t}^{\mathrm{wp}}/y_{i,t})$ and $(s_{i,t}^{\mathrm{ep}}/y_{i,t})$, two variables

[18] Note however that the aforementioned authors include growth of income per capita instead of per working age person. In addition, Bloom et al. (2003) estimate the effect from the shares of the young and elderly population in the total population from dependency ratios and include further, as the main variable of their interest, the life expectancy. Further, the authors include in their regeressions their age structure variables measured at the beginning of each 5-year interval in their panel regressions. Higgins (1998) estimates the effect of 5-year age groups, i.e., the effects of the shares of the population of age 0–4, 5–9,. . .,65–69, and 70+ in the total population. Moreover, he includes the relative price of investment goods as a further control variable.

Table 6
Explaining the savings rate 1970–1990, panel data of 5-year averages

Dependent variable: savings rate (×100)		
Independent variables	LS with random country and fixed time effects	LS with random country and fixed time effects
Constant	58.42 (6.72)	58.57 (6.73)
Youth dependency ratio	−36.28 (6.37)	−37.50 (6.59)
Elderly dependency ratio	−86.55 (27.04)	85.48 (27.14)
Lagged growth of income per working age person	0.38 (2.44)	0.37 (2.39)
Growth of labor force		0.27 (0.71)
R^2 within	0.20	0.20
Number of observations	275	275

[a] Random country and fixed time effects are not shown.
[b] Income per working age person was measured with GDP per working age person.
[c] 2–statistics are reported in parenthesis behind coefficient estimates.

which are part of Eq. (11) and for which data are not available. Also similar to Bloom et al., I included the growth rate of income per working age person of the previous 5-year period instead of the current 5-year period (Bloom et al., included economic growth of the previous 10 years). This is supposed to avoid problems from possible reverse causality. When calculating the savings rate, I measured aggregate savings with gross domestic savings in constant international dollars (which are calculated from national income accounts data as the difference between the gross domestic product and private and government consumption), and I measured income per working age person with output per working age person. Due to five missing data points for savings, the sample is slightly unbalanced and due to the inclusion of lagged growth of income per working age person, the sample is reduced to 1970–1990. In the regressions, I am following the suggestion of a Breusch and Pagan test to include random country effects and a Hausman test to apply random instead of fixed country effects estimation (the results of both tests are not shown). Furthermore, I included fixed time dummies.

The results of this regression are shown in Table 6. The second column shows that the youth dependency ratio, as well as the elderly dependency ratio have negative and significant coefficients.[19] Furthermore, the coefficient of lagged growth of income per working age person is positive and significant. For reasons that will be clear at the end of this section, the third column shows the same regression as the second column, with the growth rate of the labor force as additional control variable. This variable is, as expected, insignificant with a p-value of 0.48 (not shown), while the coefficient of the youth dependency ratio remains negative and significant.

From the estimation results of Table 6, one can calculate the implied value of p_y in Eq. (11). That is, one can calculate the implied value of the relative consumption needs of each young person in the life cycle model. If the implied value of p_y is of plausible

[19] The table presents z-statistics. However, by and large, a z-statistic is to be interpreted in the same way as a t-statistic.

magnitude, then this supports the hypothesized channel of causality. As Eq. (11) shows, the coefficient of the youth dependency ratio equals in the life cycle model—$p_y(c_{i,t}^{\text{wp}}/y_{i,t})\times 100$. Hence, p_y is calculated by division of the value of the coefficient of the youth dependency ratio by the value of—$(c_{i,t}^{\text{wp}}/y_{i,t})\times 100$. In turn, the value of the coefficient of the youth dependency ratio is in the second column of Table 6, shown to be −36.28. Furthermore, Eq. (11) implies that the average of the constant and all time dummy variables in the regression equation equals $[1-(c_{i,t}^{\text{wp}}/y_{i,t})]\times 100$. In the regression of the second column in Table 6, the average of the constant and the values of the time dummy variables (not shown) equals 54.94. Hence, $(c_{i,t}^{\text{wp}}/y_{i,t})\times 100$ is calculated to be equal to −45.06. As a consequence, we can calculate p_y from dividing −36.28 by −45.06, which gives 0.81. In turn, Weil (1999) argues that a value of p_y of 0.72 would be realistic (admittedly, he defines the young to be of age 0–19 instead of 0–14). Because 0.81 is not very different from 0.72, the coefficient of the youth dependency ratio is within the reasonable range predicted by the life cycle model. This supports the hypothesized channel of causality.

Furthermore, Eq. (11) shows the coefficient of the elderly dependency ratio to equal $(s_{i,t}^{\text{ep}}/y_{i,t})\times 100$. Hence, a plausible size of the estimated coefficient of the elderly dependency ratio requires that the implied value of $(s_{i,t}^{\text{ep}}/y_{i,t})\times 100$ lies within the reasonable range that is predicted by the life cycle model. To calculate the implied value of $(s_{i,t}^{\text{ep}}/y_{i,t})\times 100$, one first has to note that in an overlapping generations model $(s_{i,t}^{\text{ep}}/y_{i,t})\times 100=-(s_{i,t-1}^{\text{wp}}/y_{i,t-1})\times 100$. That is, one has to note that in an overlapping generations model, the dissavings of each person above working age relative to income per working age person equal the average savings of these persons one period before, when they were in working age, relative to the income per working age person one period before. Hence, if we assume an over time constant value of $(s_i^{\text{wp}}/y_i)\times 100$, then in Eq. (11), the coefficient of the elderly dependency ratio must be equal to $-(s_{i,t}^{\text{wp}}/y_{i,t})\times 100$. Next, assume a consumer with intertemporally additive preferences and isoelastic period utility function (see Obstfeld and Rogoff, 1997, pp. 12–14 and pp. 28–31). Upon application of an optimization problem of a consumer with such a utility function, who lives for two periods as person of working age and as person above working age, who needs for child-rearing units of the consumption good only, and who has no bequest motive, one can derive $(s_{i,t}^{\text{wp}}/y_{i,t})\times 100$ as

$$\left(\frac{s_{i,t}^{\text{wp}}}{y_{i,t}}\right)100 = \theta_{i,t}\left[\frac{y_{i,t} - p_y c_{i,t}^{\text{wp}} d_{y,i,t}}{y_{i,t}}\right]100 \text{ or}$$

$$\left(\frac{s_{i,t}^{\text{wp}}}{y_{i,t}}\right)100 = \theta_{i,t}\left[1 - p_y\left(\frac{c_{i,t}^{\text{wp}}}{y_{i,t}}\right)d_{y,i,t}\right]100 \tag{12}$$

where $\theta_{i,t}$ denotes the budget share of consumption of each person above working age, and the terms between squared brackets represent the income of each working age person net of child-rearing costs relative to the income of each working person gross of child-rearing costs. Furthermore, in the second equation of Eq. (12), a glance at the components of the terms between the squared brackets reveals that the terms in front of $d_{y,i,t}$ are equal to the coefficient of the youth dependency ratio in the regression equation in Eq. (11) divided by 100. Hence, dividing the coefficient of the youth dependency ratio in the second column of Table 6 by 100, and multiplying this value with the unweighted country average of $d_{y,i,t}$ (which is 0.64) gives the value of the terms between squared brackets in Eq. (12) as 0.77. As a consequence, the budget share $\theta_{i,t}$ must be larger than one to ensure that the value of $(s_{i,t}^{\mathrm{wp}}/y_{i,t})\times 100$, on the left hand side of Eq. (12), equals 86.55, i.e., equals the absolute value of the coefficient of the elderly dependency ratio in the second column in Table 6.

Because $\theta_{i,t}$ can by definition not exceed one, the value of the coefficient of the elderly dependency ratio in Table 6 is too high to be consistent with the life cycle model without bequests. Nevertheless, the elderly dependency ratio is only a control variable and is not part of my hypothesized explanation for the effect of the youth dependency ratio on TFP growth. Hence, my thesis is not invalidated, no matter whether the coefficient of the elderly dependency ratio is realistic or not.

Next, we turn to a test of Hypothesis 2. Based on a production function for imitation, Hypothesis 2 stated that TFP growth depends positively on the ln of savings of the working age population.[20] As there are no aggregate data of this variable for most of the 70 countries in my sample, I had to calculate this variable upon use of the regression results of Table 6. More precisely, upon use of Eqs. (9) and (11), I first calculated the implied savings of the working age population relative to income per working age person from

$$\frac{S_{i,t}^{\mathrm{wp}}}{Y_{i,t}} = \frac{S_{i,t}}{Y_{i,t}} + 0.8655\ d_{e,i,t},$$

where 0.8655 is the value of the coefficient of the elderly dependency ratio in the second column of Table 6 divided by 100. Next, I calculated the ln of savings of the working age population from

$$\ln S_{i,t}^{\mathrm{wp}} = \ln\left(\frac{S_{i,t}^{\mathrm{wp}}}{Y_{i,t}}\right) + \ln Y_{i,t} + \ln\left(\frac{p_{C,i,t}}{p_{Y,i,t}}\right),$$

where ln $(p_{C,i,t}/p_{Y,i,t})$ denotes the ln of the consumption price level divided by the GDP price level. Adding ln $(p_{C,i,t}/p_{Y,i,t})$ transforms units from 'in terms of the consumption price level' to 'in terms of GDP prices'. A few data points with negative values of $(s_{i,t}^{\mathrm{wp}}/Y_{i,t})$ were dropped from the analysis (because one cannot take the ln of negative values).

Table 7 shows the results of a test of Hypothesis 2. The table contains the same regression equations as Table 2, with the exception that the ln of savings of the working age population replaces the ln of the youth dependency ratio. Hence, TFP growth is regressed on the ln of TFP in the base year, social infrastructure instrumented with all variables of Eq. (6), the ln of savings of the working age population, and time dummies.

[20] If there were no dissavings by the elderly population (which would be contrary to the prediction of the life cycle model), then TFP growth would depend on aggregate savings instead of savings of the working age population. I checked whether there is also an effect from aggregate savings on TFP growth (not shown). The effect is similar to the effect of savings of the working age population.

Table 7
Explaining total factor productivity (TFP) growth 1965–1990, panel data of 5-year averages

Dependent variable: annual average growth rate of TFP (×100)				
Independent variables	2SLS with fixed time effects	Standardized coefficient	2SLS with fixed time effects	2SLS with fixed time effects
Constant	6.08 (3.24)		12.11 (2.15)	6.82 (1.87)
Ln of TFP in base	−1.88 (−4.78)	−0.29	−1.95 (−3.29)	−1.86 (−4.71)
year socinf	4.60 (3.79)	0.22	1.67 (0.96)	4.22 (2.64)
Ln of savings of working age population	0.39 (2.92)	0.20	0.27 (1.67)	0.38 (2.68)
Growth of labor force				−0.14 (−0.43)
Dummy for reg_eap			0.19 (0.27)	
Dummy for reg_sa			−1.31 (−1.21)	
Dummy for reg_lac			−1.67 (−2.04)	
Dummy for reg_ssa			−2.17 (−1.48)	
Dummy for reg_mena			0.37 (0.51)	
R^2	0.21	0.21	0.24	0.23
Number of observations	335	335	335	335

[a] (White–Huber) heteroscedasticity-consistent *t*-statistics are reported in parentheses behind the coefficient estimates.

[b] Fixed time effects are not shown.

[c] Social infrastructure was instrumented by using the predicted values from the first-stage regression in Eq. (6).

[d] Growth of labor force in each 5-year period was instrumented with its value over the previous 5 years and all other independent variables of the second-stage regression.

The second column shows a positive and significant effect from the savings of the working age population. The effects of the other variables are qualitatively identical to Table 2 and quantitatively very similar. The third column shows standardized coefficients of the regression of the second column. The results show that savings are about as important for TFP growth as the catch-up effect and social infrastructure. As in Tables 2 and 5, the fourth column of Table 7 shows the results with dummy variables for regions of developing countries included. In this regression, savings of the working age population remains weakly significant.

Recently, Bernanke and Gürkaynak (2001) have shown that TFP growth is negatively correlated with the growth rate of the labor force. The critical reader might argue that in the earlier regressions of Table 2, the youth dependency ratio might have picked up the effect of the omitted variable labor force growth. If so, then the correlation between TFP growth and the youth dependency ratio was spurious. To check for this possibility, the fifth column in Table 7 shows the results of the same regression as in the second column in Table 7, but with labor force growth included as a further control variable. In this regression, the growth rate of the labor force in each 5-year period was instrumented with its value over the previous 5 years and all other independent variables of the second stage regression. It can be seen from the fifth column that the effect from savings of the working age population remains significant (it remains also significant if in addition to labor force growth regional dummies are included in the regression—results are not shown). Remember that it was shown in Table 6 that the youth dependency ratio has a negative and significant effect on savings per working age person. Thus, Table 7 empirically supports the argument that the negative correlation between TFP growth and the youth dependency ratio was not spurious.[21]

Additionally, the fifth column shows that growth of the labor force is insignificant with respect to TFP growth (this variable is also insignificant if regional dummies are included in the regression—results not shown). Further, if one skims back through the text to Table 6, then one sees that Table 6 showed evidence for an insignificant effect of the growth rate of the labor force on savings per working age person. Hence, Table 7 provides empirical support for absence of any significant effect from labor force growth on TFP growth (directly or indirectly through savings). Appendix C shows that if labor force growth is not instrumented, then it has a significant and negative effect on TFP growth. The fact that labor force growth is significant when it is not instrumented and is insignificant when it is instrumented seems to indicate reverse causation from TFP growth to labor force growth (although an effect from the level of income per capita would be more convincing). Alternatively, the result might show that lagged labor force growth is not a good instrument for labor force growth (nevertheless, a better instrument seems not feasible). However, most important, Appendix C shows that even when growth of the labor force is not instrumented, then savings of the working age population still have a positive and significant effect on TFP growth. Because it was shown that the youth dependency ratio has a negative and significant effect on savings per working age person, this shows that—regardless of whether labor force growth causes a reduction of TFP growth—the negative correlation between TFP growth and the youth dependency ratio is validated.

5. Conclusion

This paper demonstrated empirical support for the thesis that the youth dependency ratio has a negative effect on TFP growth using cross-country data of the world economy. In the regressions, TFP growth was measured with residual growth. In addition, the paper found empirical support for the thesis that a high youth dependency ratio will reduce aggregate savings, and correspondingly, that declining aggregate savings will reduce TFP growth. It is argued that the latter effect is due to reduced funding of research and development or imitation of ideas, as aggregate savings at home declines, while many countries have limited access to the international capital market.

A recent literature shows evidence for age structure effects on growth of output per capita. This literature does not give attention to the possibility that age structure might also affect total factor productivity. Much of the recent literature on economic growth argues that an understanding of international differences in output per worker is needed, because

[21] In principle, it would have been possible to check for a spurious correlation by regressing TFP growth on the youth dependency ratio and labor force growth. Unfortunately, there is strong multicollinearity between the youth dependency ratio and labor force growth. Hence, it would have been impossible to distinguish empirically whether an insignificant coefficient of the youth dependency ratio resulted from absence of a 'true' correlation between TFP growth and the youth dependency ratio or from multicollinarity between the youth dependency ratio and labor force growth.

only workers can contribute to production. That literature shows that most of the international differences in output per worker are explained by differences in TFP. Therefore, by showing empirical evidence for an effect of the youth dependency ratio on TFP growth, the paper demonstrates that age structure has also an effect on the most important determinant of cross-country differences in output per worker.

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Appendix A. The data

A.1. Output per worker (in constant international dollars of 1985)

Source: Global Development Network Growth Database, Easterly and Yu, World Bank (2001; available at http://www.worldbank.org/research/growth/GDNdata.htm).

A.2. Total factor productivity

Definition: The 'residual' calculated according to the recent and earlier growth accounting literature as explained in text.

Source: Output per worker and capital per worker (using aggregate investment in constant international dollars of 1985) were both from Global Development Network Growth Database (2001). Human capital per worker=average years of school attainment of the total population of age above 15 as published in Barro and Lee (2000; available at http://www.cid.harvard.edu/).

A.3. Youth dependency ratio

Definition: Population of age 0–14 divided by population of age 15–64.

Source: World Development Indicators 2000 (CD-ROM).

A.4. Openess

Definition: Fraction of years between 1950 and 1994, in which a country is open to trade. For each year, a country is classified as open if it satisfies all of the following five criteria: (i) Nontariff barriers cover less than 40% of trade, (ii) Average tariff rates of less than 40%; (iii) A black market premium that depreciated by less than 20% relative to the official exchange rate during the 1970s or 1980s; (iv) Country is not a socialist economic system according to the classification of Kornai (1992); and (v) not a state monopolist on major exports.

Source: Index of Sachs and Warner (1995; available at Chad Jones' data archive at http://elsa.berkeley.edu/~chad/datasets.html).

A.5. GADP

Definition: Government antidiversion policies.

Source: International Country Risk Guide, which rated global countries according to 24 categories of risk for international investors. Knack and Keefer (1995) constructed the GADP index as the average of five of these categories (available at Chad Jones' data archive).

A.6. (i) ENGFRAC and (ii) EURFRAC

Definition: Fraction of population in a country that speaks as first language: (i) English or (ii) English, French, German, Portuguese, or Spanish.

Source: Chad Jones' data archive.

A.7. Lnfrankrom

Definition: Predicted trade share of an economy.

Source: Frankel and Romer (1999; available at Chad Jones' data archive).

A.8. Latitude

Definition: Distance from the equator measured as the value of latitude in degrees divided by 90. Location data correspond to the center of the country or the province within a country with the largest number of people.

Source: Global Demography Project at the University of California, Santa Barbara, obtained by Hall and Jones (1999; data available at Chad Jones' data archive).

A.9. Statehist5

Definition: An indicator of state antiquity.

Source: Bockstette et al. (2002).

A.10. Gross domestic savings per working age person in terms of the consumption price level (in constant international dollars of 1985)

Definition: Gross domestic savings in current US dollars divided by the comparative price level of consumption. The resulting data were divided by the consumer price index of the United States with (1985=1) and divided by the population of age 15–64.

Sources: Gross domestic savings in current US dollars, and population of working age was from World Development Indicators 2000 (CD-ROM). The comparative price level of consumption was taken from Penn World Table 6.1 (available at http://pwt.econ.upenn.edu/). The consumer price index of the United States was taken from Global Development Network Growth Database, Easterly and Yu, World Bank (2001).

A.11. GDP price index of 1985

Source: Penn World Table 6.1.

A.12. Elderly dependency ratio

Definition: Population of age above 64 divided by population of age 15–64.
Source: World Development Indicators 2000 (CD-ROM).

A.13. Labor force

Source: Global Development Network Growth Database, Easterly and Yu, World Bank (2001).

Appendix B. List of countries included in data set

Table B.1
List of countries included in data set

Algeria	Guyana	Peru
Argentina	Honduras	Philippines
Australia	Hong Kong	Portugal
Austria	India	Singapore,
Bangladesh	Indonesia	South Africa
Belgium	Ireland	Spain
Bolivia	Israel	Sri Lanka
Brazil	Italy	Sweden
Cameroon	Jamaica	Switzerland
Canada	Japan	Syrian Arab Rep.
Central African Rep.	Jordan	Thailand
Chile	Kenya	Togo
Colombia	Korea, Rep.	Trinidad and Tobago
Costa Rica	Malawi,	Tunisia
Cyprus	Malaysia	Turkey
Denmark	Mali	Uganda
Dominican Rep.	Mauritius	United Kingdom

(continued on next page)

Table B.1 (*continued*)

Ecuador	Mexico	United States
El Salvador	Netherlands	Uruguay
Finland	New Zealand	Venezuela, RB
France	Nicaragua	Zambia
Ghana	Norway	Zimbabwe
Greece	Pakistan	
Guatemala	Paraguay	

Appendix C. Further robustness check

The second column in Table C.1 shows the results of the same regression as in the fifth column of Table 7, but with labor force growth not instrumented. Hence, the column shows results of a regression of TFP growth on the ln of TFP in the base year, on social infrastructure (instrumented according to Eq. (6) in the main text), on the ln of savings of the working age population, on the growth rate of the labor force (not instrumented), and on time dummies.

As anticipated in the main text, the second column shows a significant and negative coefficient of labor force growth when it is not instrumented. Yet still savings of the working age population has a positive and significant coefficient. It was shown in Table 6 that the youth dependency ratio has a negative and significant effect on aggregate savings per working age person. For that reason, the youth dependency ratio has indirectly a negative effect on TFP growth, regardless of whether growth of the labor force is included in the regression and regardless of whether it is instrumented.

Table C.1
Explaining total factor productivity (TFP) growth 1965–1990, panel data of 5-year averages

Dependent variable: annual average growth rate of TFP (×100)		
Independent variables	2SLS with fixed time effects	2SLS with fixed time effects
Constant	9.57 (2.80)	13.54 (2.45)
Ln of TFP in base year socinf	−1.81 (−4.60)	−1.73 (−2.99)
	2.80 (2.15)	0.51 (0.29)
Ln of savings of working age population	0.31 (2.34)	0.19 (1.20)
Growth of labor force	−0.67 (−3.26)	−0.73 (−3.59)
Dummy for reg_eap		1.02 (1.43)
Dummy for reg_sa		−0.61 (−0.56)
Dummy for reg_lac		−1.08 (−1.34)
Dummy for reg_ssa		−1.34 (−1.00)
Dummy for reg_mena		0.95 (1.35)
R^2	0.25	0.28
Number of observations	335	335

[a] (White–Huber) heteroscedasticity-consistent t-statistics are reported in parentheses behind the coefficient estimates.

[b] Fixed time effects are not shown.

[c] Social infrastructure was instrumented by using the predicted values from the first-stage regression in Eq. (6).

The third column shows the same regression as in the second column with dummy variables for regions of developing countries included in the regression. Savings of the working age population remain weakly significant and also growth of the labor force remains significant when it is not instrumented. Hence, this regression shows also some evidence in favor of a 'true' correlation between TFP growth and the youth dependency ratio.

The finding that labor force growth is significant when it is not instrumented and insignificant when it is instrumented might indicate reverse causality from TFR growth to labor force growth. Alternatively, the finding might indicate that lagged labor force growth is not a good instrument for labor force growth. However, a better instrument for labor force growth seems not feasible.

Appendix D. Panel data unit root tests

This appendix shows results of panel data unit root tests for the levels of all time-varying variables that were included in Tables 2, 5–7, and C.1. As explained in the text, if the series contained a unit root, one would have to use cointegration techniques to check whether the relationships are not spurious. In addition, in the case of difference-stationary variables, the *t*-statistics of the regression results would not be reliable. To anticipate the results of the unit root tests: presence of a unit root in the level of a series can be rejected for all variables of Tables 2, 5–7, and C.1. Consequently, this appendix does not contain unit root tests for the first difference of any of the variable. If the level of a series is not difference-stationary, then this must also be true for the first difference of this series.

Harris and Tzavalis (1999) derive critical values for Dickey–Fuller (DF) tests of pooled series with a large (or infinite) cross-section dimension and a small (or finite) time series dimension. They consider the case with fixed country effects and with or without individual deterministic trends. Harris and Tzavalis also derive the critical values for the cases without fixed country effects. Chow test rejected absence of fixed country effects for all variables of this study. Therefore, I included country dummies in all unit root tests. Harris and Tzavalis show that the limiting distribution of the test statistic is normal. This means that one can perform standard DF tests to the pooled series and can use the standard *t*-statistic criteria for inference whether or not the series of consideration contains a unit root.[22] In DF tests, one applies OLS regressions of the first difference of a series on its lagged level. If the lagged level is negative and significant, then presence of a unit root in the level is rejected. The test statistic of the lagged level is often referred to as a DF statistic.

Table D.1 shows the DF test statistics for all time-varying variables of this study (individual trends were included when they were clearly significant according to a Chow test of joint significance). A glance at Table D.1 reveals that the lagged level of all series in

[22] To be more precise: for the case of a limited time dimension the critical values are slightly larger than the *t*-statistic for one-sided tests. However, in case of the variables in this appendix, the small differences did not matter.

Table D.1
Panel data unit root test of levels, panel data of 5-year averages or intervals, 1965–1990

Series	DF	Trend included?
Ln of TFP in base year	−12.77*	Yes
Ln of youth dependency ratio	−8.04*	Yes
Ln of output per worker in base year	−11.37*	Yes
Savings rate	−12.51*	No
Youth dependency ratio	−9.15*	Yes
Elderly dependency ratio	−11.87*	Yes
Growth of labor force	−10.75*	No
Lagged growth of income per working age person	−12.95*	No
Ln of savings of working age population	−9.93*	No

* Significant at 5% level.

this appendix is clearly negative and significant. Hence, none of these variables contains a unit root.

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