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# WORKFORCE HEALTH AND ECONOMIC GROWTH: EXPLORING THE DYNAMICS FOR MORE THAN HALF A CENTURY*

**Gamze ÖZTÜRK****

**Abstract**

This study contributes to understanding the role of workforce health on output growth and the convergence process in 38 OECD members and 58 low-income countries over a 65-year period. Empirical findings based on system GMM estimations show that (i) year gains in the longevity of the younger workforce at ages 15 to 20 have significant effects on economic growth, (ii) after age 20, the rate of convergence slightly decreases with rising age, (iii) increases in adult mortality adversely affect output growth through the loss of human capital productive ages and the decreases in the incentives to invest in physical capital, and (iv) the growth-enhancing effects of the savings rate considerably rises with increasing age in OECD countries but not in low-income countries. The findings of the study provide valuable insights into the critical role that policy can play in promoting workforce health, ultimately productivity, and long-run economic growth.

**Keywords:** *Economic growth, β-convergence, Workforce health, Human capital, Dynamic panel data.*

**JEL classification:** E24, I10, O47, O57.

# İŞ GÜCÜ SAĞLIĞI VE EKONOMİK BÜYÜME: YARIM YÜZYILDAN DAHA FAZLA BİR SÜREDE DİNAMİKLERİN KEŞFİ

**Öz**

Bu çalışma, iş gücü sağlığının çıktı artışı ve yakınsama süreci üzerindeki rolünün 38 OECD üyesi ve 58 düşük gelirli ülkede 65 yıllık bir dönem için araştırılmasına katkıda bulunmaktadır. Sistem GMM tahminlerine dayanan ampirik bulgular, (i) 15 ila 20 yaş arasındaki genç iş gücünün yaşam beklentisindeki yıllık kazanımların ekonomik büyüme üzerinde anlamlı etkileri olduğunu, (ii) 20 yaşından sonra yakınsama oranının artan yaş ile birlikte gittikçe azaldığını, (iii) yetişkin ölümlerindeki artışların çıktı büyümesini, üretken yaşlardaki beşeri sermaye kaybı ve fiziksel sermayeye yatırım yapma teşviklerindeki düşüşler yoluyla, olumsuz etkilediğini ve (iv) tasarruf oranının büyümeyi arttırıcı etkilerinin OECD ülkelerinde artan yaş ile birlikte önemli ölçüde arttığını, ancak düşük gelirli ülkelerde ise bunun gerçekleşmediğini göstermektedir. Çalışmanın bulguları ayrıca, politikanın iş gücü sağlığını, nihayetinde verimliliği ve uzun vadeli ekonomik büyümeyi teşvik etmede oynayabileceği kritik role ilişkin değerli bilgiler sağlamaktadır.

**Anahtar Kelimeler:** *Ekonomik büyüme, β-yakınsaması, İş gücü sağlığı, İnsan sermayesi, Dinamik panel veri.*

**JEL sınıflandırması:** E24, I10, O47, O57.

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**1.INTRODUCTION**

Health changes the course of economic growth through a number of conceivable pathways. As an essential component of human capital, improvements in the health status of individuals directly boost the supply of human capital (van Zon and Muysken, 2001). On the other hand, as a prerequisite to producing other components of human capital, including education, skills, and learning, better health further enhances the quality and quantity of human capital. Improvements in the health status induce further generation of skill-building activities and raise the returns on investments in other forms of human capital (Behrman, 1996; Becker, 2007; Bleakley, 2010). Moreover, improvements in the health status indirectly trigger investments in physical capital by raising the rate of savings in an economy. In this sense, several studies have shown that better health outcomes induce individuals to save more for retirement and old age (Lee et al., 2000; Bloom et al., 2003). However, the first and foremost effect of health is directly on the labor force of a country. In this context, micro-level evidence has shown that good health directly increases the labor force participation rate and enhances workers' effort (Grossman, 1972; Schultz, 1961; Mushkin, 1962; Becker, 1962). On the other hand, the growth literature has shown that good health significantly enhances workers' productivity and thereby drives long-run economic growth (Muysken et al., 1999; van Zon and Muysken, 2003; Howitt, 2005).

This study aims to explore the effects of workforce health status on long-run output growth and convergence processes using an empirical growth framework. In other words, the main concern of the study is to estimate a conditional convergence equation by highlighting the effects of workforce health specific to age groups. In this sense, the study significantly contributes to the related literature in four ways. First, deviating from related literature, the study directly focuses on the health status of a country's most productive age span by employing age-specific measures of life expectancy and adult mortality. Previous studies have used various health indicators related to the overall population of a country instead of those related to the working-age population. Most of these related works have typically used two crude measures of health, life expectancy at birth and infant or child mortality rates, though they have aimed to examine the productivity implications of health. However, these indicators capture the health level of the entire population, including the dependent population, and therefore are not relevant for productivity measurement (Arora, 2001; Jamison et al., 2005). Differently, this study uses life expectancy at ages from 15 to 60 and adult mortality rates between ages 15 and 60 as proxies for the workforce's health status. Second, the study differs from earlier studies by means of the methodology employed. This study employs a dynamic panel data estimator, the system GMM, to eliminate the shortcomings of the methodological approaches used in the previous studies. As will be explained below, previous approaches are not suitable to the dynamic nature of convergence specification from both an econometric and empirical growth viewpoint. Third, the study includes two separate income groups with different structural characteristics in the analyses: OECD members and low-income countries. Studying the health-growth nexus comparatively within the scope of these country groups provides a significant contribution to the related literature, as (i) earlier studies have mostly focused on a single country group and (ii) for high-income countries, the empirical evidence is still mixed and controversial. Therefore, as stated by Tompa (2002), more research is required in this field by using more appropriate measures of health and more precise methodological approaches to develop better policy responses. Lastly, this study uses more recent data over a relatively longer period of time to explore the dynamics between growth and health.

The main findings of the study are as follows: First, the good health status of the workforce at ages 15 to 40 has a positive, sizeable, and significant impact on aggregate output growth in both country groups. For OECD countries, improvements in the life expectancy at age 20 contribute more to output growth, while this age is falling to 15 in low-income countries, in which employment below age 20 is generally higher than that of high-income countries (ILOSTAT, 2021a). However, for both country groups, year gains in longevity at ages 50 and 60 have a positive but insignificant effect on economic growth. Second, increases in adult mortality between ages 15 and 60 adversely affect the growth rate of per-worker output. These increases in mortality further lead to a decrease in the incentives to save, particularly in OECD countries. Third, the inclusion of age-specific longevity and mortality measures significantly accelerates the convergence process. In each country group, increases in the longevity of the younger workforce aged 15-20 provide the largest contribution to the rate of convergence, but this contribution slightly decreases with increasing age after age 20. Fourth, human capital in the form of education is likely to be important for explaining increases in productivity growth among low-income countries, but it has no significant effect among OECD members. Last but not least, the growth-enhancing effects of the savings rate remarkably rise with increasing age in OECD countries and reach their highest estimated rate for the age group 60. However, in low-income countries, where income is generally allocated to satisfy basic needs, the estimated coefficients on savings rates remain unresponsive to the inclusion of longevity measures. Overall, the findings of the study provide valuable insights into the critical role that policy can play in promoting workforce health through investments in health and, ultimately, productivity and long-run economic growth. The findings of the study indicate that encouraging private savings among those at older ages will significantly promote the long-run growth of OECD countries. The findings of the study further show that for this age group, the growth-enhancing effects of rising savings seem to outweigh the growth-enhancing effects of productivity through year gains. Additionally, given the aging of the workforce in OECD countries (OECD, 2019, 2020), the findings of the study seriously imply that the health status of the workforce will seem to further become an even more important issue among OECD members in the near future.[1] On the other hand, for low-income countries, there is an urgent need for policy action to raise the overall level of savings independent of age to enhance long-run output growth.

The organization of the study is as follows: Section 2 represents a brief review of the related literature. Section 3 explains the empirical methodology and presents the data. Section 4 explains the empirical findings of the study. Section 5 concludes the study and discusses the policy implications.

## 2.LITERATURE REVIEW

Originating from the studies of Solow (1956) and Swan (1956), one of the most attractive research areas revealed by the neoclassical growth theory has been the convergence dynamics across countries. The pioneering models of neoclassical growth have predicted that the growth rate of a country's per capita income tends to be inversely related to its initial income level due to diminishing marginal returns to physical capital. This prediction refers to $\beta$-convergence hypothesis in an absolute sense. It has been the subject of intense controversy and rejected by the empirical growth literature, primarily by the studies of De Long (1988) and Baumol and Wolff (1988). Rather than absolutely, the neoclassical theories of growth actually predict that the per capita income growth rates of the countries will converge conditionally. The conditional $\beta$-convergence hypothesis suggests that the growth rate of a country's per capita income depends on how far the initial level of per capita income is from its long-run equilibrium value, which is further controlled by other determinants of income growth. In other words, considering a group of countries, the differences in the growth rates of countries can be attributed not only to the differences in their initial income levels but also to the differences in their steady-state income levels, which are in turn determined by other fundamental parameters. In this sense, a large number of studies have revealed that the hypothesis on conditional convergence applies for countries or regions that are similar in the fundamental structural characteristics, including technology, population growth, tastes, preferences, and government policies, which shape the long-run equilibrium value of per capita income (Sala-i-Martin, 1996a; 1996b; Barro and Sala-i-Martin, 1990, 1991).

In this context, human capital has appeared as one of the key characteristics that shapes the long-run equilibrium value of the countries' real per capita incomes. It has been primarily emphasized by the several pioneering studies (Schultz, 1960; Arrow, 1962; Uzawa, 1965; Lucas, 1988; Romer, 1990; Rebelo, 1991) and included in the discourse on the convergence argument following the seminal contributions of Barro (1991) and particularly Mankiw et al. (1992). In this sense, Mankiw et al. (1992) were the first to provide a formal theoretical framework for empirical income convergence testing by augmenting the Solow model to include both physical and educational human capital. Following them, a vast body of literature has emerged once the standard neoclassical framework is broadened from physical capital to include human capital in the form of education (Barro and Sala-i-Martin, 1992; Levine and Renelt, 1992; Knight et al., 1993; Benhabib and Spiegel, 1994; Evans and Karras, 1996). However, the notion of human capital broadly refers to the attributes of a country's human resources, by means of which that country is able to boost its productivity and economic growth. These attributes include the knowledge and skills that individuals invest in and accumulate to raise their productivity, but they also include good health as a priority. This health component allows countries to increase their number of human resources and complements other attributes to have better outcomes and increase their returns. Briefly, although being one of the main components of human capital (Schultz, 1961; Becker, 1962; Mushkin, 1962), health has been largely ignored in the discourse on empirical growth studies for a long time. In this respect,

[1] In 2021, the total employment rate of 55- to 64-year-olds in OECD countries was 61.3% of the total number of people in that same age group (OECD, 2022). Additionally, compared to other age groups, the working population over 65 was highest in 38 OECD countries, with an average of about 5546 thousand people over the years between 2010 and 2021 (ILOSTAT, 2021b).

Knowles and Owen (1995, 1997) were the first to include and attract interest in the missing component of human capital in a neoclassical growth framework. They have further expanded the augmented Solow model proposed by Mankiw et al. (1992) by including health capital in addition to education. Ever since, the role of health has been among the major attributes that explain the long-run growth of countries and has become a serious focus of growth inquiry.

Several studies on growth have used a similar theoretical framework provided by Knowles and Owen (1995, 1997) and empirically tested the impact of health on growth and income convergence. In a cross-country framework, these studies have examined the effects of health proxied by total health expenditures (Rivera and Currais, 1999a, 1999b; Heshmati, 2001), life expectancy at birth and infant mortality rates (Knowles and Owen, 1995, 1997; McDonald and Roberts, 2002), and calorie intakes per capita (Webber, 2002). Although these studies have relied on the same theoretical background, their results are erratic depending on the proxy used for health and the country sample employed in the study. For instance, a few of them have shown that health has a positive and significant effect among low-income countries over the 1960-1985 period, but its effects are insignificant for OECD countries (Knowles and Owen, 1995, 1997; McDonald and Roberts, 2002). On the other hand, others have reported positive and significant effects of health among OECD countries (Rivera and Currais, 1999a, 1999b; Heshmati, 2001). By using a large cross-section of countries, Webber (2002) has also found that health in terms of calorie intake per capita has an insignificant effect on economic growth. Furthermore, a few of these studies have included the education component of human capital in their convergence regressions. Some of them have shown that the effect of education is significant and positive for OECD countries (Rivera and Currais, 1999a, 1999b; McDonald and Roberts, 2002), while others have reported insignificant effects (Knowles and Owen, 1995, 1997; Heshmati, 2001). For low-income countries, the evidence has also shown that the coefficient of education is insignificant (Knowles and Owen, 1995, 1997; McDonald and Roberts, 2002).

Another research group examining the health-growth nexus consists of empirical growth studies that originated from similar theoretical backgrounds but made use of the Barro-regression approach. These growth regressions, also named Barro-type regressions after the study of Barro (1991), have been intensively used by the empirical growth studies to examine the alternative determinants of growth. These studies have expanded convergence equations by any variable deemed to be related to income growth, including health, educational attainment, fertility, and economic policy, while simultaneously adding initial income levels to the right-hand side of the growth regressions to control for transitional dynamics (Barro and Lee, 1993, 1994; Barro, 1996).[2] In a cross-country framework, most have confirmed that better health, measured by increases in life expectancy at birth and decreases in infant mortality, is significantly related to higher economic growth. Some of these studies have shown that low initial life expectancy at birth is a strong predictor of slow economic growth in African and Asian countries (Sachs and Warner, 1997; Bloom et al., 1998; Bloom and Williamson, 1998; Bloom et al., 1999). Few of them have reported that the HIV/AIDS epidemic and malaria endemicity are both associated with a reduction in life expectancy at birth, which in turn decreases income growth among low-income African countries (Ainsworth and Over, 1994; Hamoudi and Sachs, 1999; Gallup et al., 1999; Gallup and Sachs, 2000). On the other hand, by providing a methodological debate, Caselli et al. (1996) have re-examined standard growth (Barro-type) regressions by applying a different methodology, the difference GMM, and by using the same sample countries as in Barro and Lee (1993). In their study, they found a negative and insignificant coefficient for life expectancy at birth. Hence, they have argued that the cross-sectional approaches used in the previous studies lead to inconsistency problems that invalidate previous methodological techniques and their estimation results. Following similar methodology, Gyimah-Brempong and Wilson (2004) have examined the growth effects of health, proxied by the life expectancy at birth and infant mortality rates, among OECD and sub-Saharan African countries. They have found that both health status and educational human capital positively and significantly explain the long-run growth of each country group, but the effects of health are much larger in magnitude for African countries with relatively low levels of health capital. Following a different production function approach, Bloom et al. (2004) have found that a one-year improvement in life expectancy at birth leads to about a 4% increase in aggregate output for a panel of 104 countries, even when controlling for schooling and work experience. Chakraborty (2004) has also found that life expectancy at birth and initial income explain 42% of cross-country growth variation among the countries of sub-Saharan Africa over the period 1970-1990 and stated

[2] For a detailed description, please refer to Barro and Sala-i-Martin (2004) and Eq. (18) in Durlauf et al. (2005: 580-581).

that countries that differ in the amounts of human capital in the form of health and education do not converge to similar living standards.

Several studies from a similar tradition have focused on adult survival rates (ASRs) instead of other standard measures of population health. For instance, Bhargava et al. (2001) have shown that a 1% change in ASR is related to about a 0.05% increase in income growth for low-income countries, but the effect of ASR becomes negative for developed countries such as the U.S., France, and Switzerland. Furthermore, Mayer (2001a) has shown that health, as measured by the probability of survival, significantly contributes to the long-run income growth of 18 Latin American countries over the years 1950-1990. Similarly, Jamison et al. (2005) have shown that about 11% of growth during the period 1965-1990 stems from better health as measured by the increases in the ASRs of males between ages 15 and 60. Shastry and Weil (2003) have shown that the change in ASRs is associated with about a 19% change in log income per capita. Weil (2007) has further found that reducing the differences in health proxied by ASRs reduces the variance of log output per worker by 10.6% among 42 countries. Unlike previous studies, Acemoglu and Johnson (2007) have constructed a measure of predicted mortality and investigated whether health improvements since the 1940s have a significant effect on the growth performance of the countries. By using these predicted mortality rates as instruments, they have found that life expectancy has a negative effect on per capita income and output per worker. They have concluded that different factors other than those proposed by the neoclassical growth model may be needed to understand the impact of life expectancy on income levels. However, Bloom et al. (2014) have criticized the findings of Acemoglu and Johnson (2007) due to the exclusion of initial life expectancy and shown that both levels and changes in health status display a positive role in economic growth if initial life expectancy is included in the growth model.[3] More recently, Madsen (2018) has found that health improvements can account for approximately one-third of the productivity advances in 21 OECD countries since 1865. Bane (2018) has found that life expectancy at birth significantly explains the growth process of low-income African countries over the period 1980-2015, but its coefficient is insignificant for middle-income African countries. Lastly, Bucci et al. (2019, 2021) have found that population health, proxied by the life expectancy at birth, and education significantly explain the differences in per capita incomes of both OECD and non-OECD countries.

All in all, although previous studies are all based on the same theoretical background, there is heterogeneity among their empirical results. This heterogeneity is mostly a result of the samples and methodology used, which has some drawbacks as follows: First, the specification of the dependent variable is different across the convergence regressions. That is, the treatment ranges from income to gross product, or from per worker to per capita income, and from growth rates to the log levels of income. Second, although most of these studies aim to explore the productivity implications of health, they have proxied the health status with life expectancy at birth, infant or child mortality rates, health expenditures, and some disease-specific prevalence rates. In this sense, although life expectancy at birth and infant or child mortality rates are among the most frequently used indicators to measure the health status of countries, the use of these indicators is more appropriate for population-level studies. For instance, life expectancy at birth provides an average of mortality rates across all age groups and is not a relevant measure of productivity (Arora, 2001; Jamison et al., 2005). Third, the methodological approaches used in the previous studies raise some serious estimation issues. Most of these studies have used cross-sectional approaches in their empirical analyses. However, these approaches lead to biased and inconsistent estimates on Solow growth variables given the dynamic nature of the convergence equation. They suffer both from the omission of unobservable factors, which include technological differences across countries and other factors related to income growth. Furthermore, these studies have mostly fixed the values of health indicators at the initial or last year of the sample period by biasing the representation of the population's health status during the initial years when infant death rates were usually high (Arora, 2001: 704). On the other hand, other studies using a panel data framework have employed either pooled and static panel methodologies or an Instrumental Variable (IV) approach and Two-Stage Least Squares (2SLS) estimators in their analyses. However, pooled and static panel data methodologies result in a heterogeneity bias resulting from the omission of fixed effects and a serious endogeneity bias due to the simultaneity between growth variables, respectively. On the other hand, the IV approach and 2SLS estimator suffer from a large finite sample bias and

[3] Weil (2014) and Bloom et al. (2019) provide an excellent and recent survey of the literature that analyzes different aspects of the relationship between health and income growth.

the weak instrument problem for short panels (Nickell, 1981; Blundell and Bond, 2000; Mátyás and Sevestre, 2008; Hsiao, 2014).

In this respect, this study examines the effects of workforce health status on economic growth and cross-country output differences. The study directly focuses on the productivity implications of health by using data specific to the working-age population of a country instead of the data what is more typically used previously. In particular, the study uses life expectancy at specific ages ranging from 15 to 60 and adult mortality rates between ages 15 and 60. The study further controls human capital in the form of education, for which the findings of the previous studies were erratic regarding income groups. More importantly, the study employs a more robust and efficient dynamic panel data estimator with its superior features, the system GMM, to overcome the shortcomings of other methodological approaches used in the previous studies. The study further includes both 38 OECD members and 58 low-income countries in the analyses to compare the dynamics at the health-growth nexus in two structurally different country groups. Previous studies have mostly focused on a single income group, while those using both country groups produced controversial results, particularly for OECD countries. Hence, given the above shortcomings of the related literature, it seems highly worthwhile to explore the matter further with more accurate indicators of health and methodological approaches (Tompa, 2002; Caselli, 2005). Finally, compared to previous studies, the study examines out-of-steady-state dynamics of per-worker output over a 65-year period.

## 3. METHODOLOGY AND DATA

Taking its roots from the pioneering studies of Mankiw et al. (1992) and Islam (1995), the following dynamic regression equation was estimated to measure the contribution of workforce health to economic growth and convergence:

$$ln(ROP_{i,t}) - ln(ROP_{i,t-1}) = \gamma_1 ln(ROP_{i,t-1}) + \gamma_2 ln(INVR_{i,t}) + \gamma_3 ln(WGR_{i,t} + DEPR_{i,t} + TECH) + \gamma_4 ln(HEALTH_{i,t}) + Z_{i,t} + \varphi_i + \mu_t + \varepsilon_{it} \quad (1)$$

In Eq. (1), the dependent variable is the log difference of real output per worker $(ROP_{i,t})$ over some $\tau$-years. $\gamma_1$ is the coefficient of the log real output per worker in the previous $\tau$-year span $(ROP_{i,t-1})$ and theoretically expected to be negative to be consistent with the convergence idea. $\gamma_2$ is the coefficient of the savings rate $(INVR_{i,t})$ and expected to be positive. $\gamma_3$ shows the effect of the augmented rate of workforce growth $(AWGR_{i,t})$, which is given by the sum of the workforce growth rate, the depreciation rate, and the growth rate of the technology, $WGR_{i,t} + DEPR_{i,t} + TECH$. In the related literature, a common practice is to assume a constant rate of five percent for the sum of the depreciation rate $(DEPR_{i,t})$ and the growth rate of the technology $(TECH)$. However, this study allows the depreciation rates on physical capital $(DEPR_{i,t})$ to vary across countries and time and keeps technology growth $(TECH)$ constant at two percent following Mankiw et al. (1992). The coefficient $\gamma_4$ measures the effect of workforce health status $(HEALTH_{i,t})$ on output growth. To proxy for the health status of the workforce, two health status indicators were used in the study: life expectancy at ages 15 $(LE15_{i,t})$ to 60 $(LE60_{i,t})$ and adult mortality rates between ages 15 and 60 $(MORT_{i,t})$. It is expected that good (poor) health status, measured by improvements (decreases) in life expectancy and decreases (increases) in adult mortality, enhances (lessens) output growth. In this sense, since a lower $\gamma_1$ (higher $\gamma_1$ in absolute value) indicates the presence of faster convergence, it is expected that the inclusion of health indicators will further increase the estimated value of $\gamma_1$ in absolute terms.[4,5] $Z_{i,t}$ denotes the vector of control variables, which only includes human capital in the form of education $(HC_{i,t})$ in this study. The study includes human capital in the form of education in the analyses (i) to follow and compare the findings with the previous studies and (ii) to partly avoid omitted variable bias in the regressions. Hence, $\gamma_5$ shows the effect of education on output growth and is expected to be positive. Furthermore, $\varphi_i$ corresponds to the country-specific omitted factors and $\mu_t$ captures the impact of macroeconomic shocks occurring during period $t$ on growth that are common to all sample countries. Hence, in the empirical estimations, the study no longer assumes constant technological

[4] Several studies have concluded that the estimated rate of convergence increases with the inclusion of human capital indicators in the model (Mankiw et al., 1992; Islam, 1995; Rivera and Currais, 1999a; McDonald and Roberts, 2002; Hoeffler, 2002).

[5] Since this study does not use a theory-backed convergence equation, the theoretical definition of $\gamma_1$ is unknown. Therefore, the estimated rate of convergence cannot be explicitly calculated in this study. Please refer to Equations (10) and (12) in Islam (1995: 1136-1137) and Equations (6) and (7) in Caselli et al. (1996: 371) for the calculation of the convergence rate using $\gamma_1$ and for its detailed theoretical definition.

progress, which is the case in the previous studies that have employed cross-sectional data approaches. Lastly, $\varepsilon_{it}$ refers to the idiosyncratic shocks, $i$ indicates cross-sectional units, and $t$ denotes time points.

**3.1.Methodology**

This study relies on a panel data framework due to its advantages over time series and cross-sectional data from an empirical growth standpoint, especially in the absence of a suitable proxy for the level of technology (Temple, 1999). In particular, the study employs a dynamic panel data estimator, the system GMM, which has considerable efficiency gains over other panel data estimators. For instance, the OLS levels estimator suffers from a heterogeneity bias resulting from omitting unobserved individual effects, which in turn leads to upwardly biased estimates of the convergence rates in a dynamic panel data framework even when the time dimension is large (Hsiao, 2014). On the other hand, the Within Group (WG) estimator produces downwardly biased estimates of the coefficient on the lagged dependent variable due to a dynamic panel bias caused by the correlation between the lagged dependent variable and the error term when the time dimension is fixed (Nickell, 1981). Therefore, the panel OLS and WG estimates of the coefficient on the lagged dependent variable are considered as approximate upper and lower limits, respectively, while the system GMM estimate of the same coefficient is expected to lie between these upper and lower limits (Bond et al., 2001; Bond, 2002; Hoeffler, 2002). Furthermore, panel OLS and WG approaches strictly require each regressor to be strictly exogenous, which is not the case in empirical growth studies. Therefore, using these approaches further results in a serious endogeneity bias. On the other hand, these inconsistencies caused by static panel estimators have been tried to eliminate by other panel estimators, including the Instrumental Variable (IV) approach of Anderson and Hsiao (1981, 1982), the related Two-Stage Least Squares (2SLS) estimator, and also the difference GMM estimator developed by Arellano-Bond (1991). These estimators have offered a partial solution to the problem of endogeneity through the use of instruments but present a set of problems of their own. In other words, all these estimators suffer from (i) the lack of correlation between the instruments and the regressors, which is known as the weak instruments problem (Mátyás and Sevestre, 2008), and (ii) an inefficiency due to not using all of the available moment conditions (Ahn and Schmidt, 1995, 1997). In other words, these estimators exhibit poor performance, namely, a large finite sample bias and low precision in cases where the individual series are highly persistent, the instruments are weak, and the time dimension is fixed (Blundell and Bond, 1998, 2000; Blundell et al., 2001). Additionally, although designed for the same cases as the system GMM, the difference GMM estimator tends to be downward biased towards the WG estimator if the instruments are weak and the number of observations in the time dimension is small (Bond et al., 2001; Bond, 2002).

The system GMM estimator, which has been proposed by Arellano and Bover (1995) and further improved by Blundell and Bond (1998), is more efficient than the previous estimators since the estimator (i) allows to include more instruments (Roodman, 2009); (ii) does not suffer from a large finite sample bias as does the difference estimator in cases where the series are close to being random walks (Blundell and Bond, 2000; Bond, 2002); and (iii) easily deals with the endogeneity problem. Moreover, the system estimator is based on orthogonal deviation transformation instead of the first difference to remove unobserved individual effects. On the contrary to the first-difference transformation, this transformation does not induce any serial correlation in the disturbances of the transformed model. The estimator further allows to (i) use both the lagged differences and lagged levels of the dependent variable as instruments for the equations in levels and in first differences, respectively; (ii) relate the level restrictions demonstrated by Arellano and Bover (1995) to stationary restrictions on initial conditions, which is exploited by Blundell and Bond (1998) to obtain additional moment conditions; and (iii) include the GMM estimator based on nonlinear moment conditions suggested by Ahn and Schmidt (1995) (Blundell and Bond, 1998; Baltagi and Kao, 2001; Blundell et al., 2001). Therefore, the use of these extra moment conditions dramatically improves the precision of the standard first-difference estimators, especially for the studies using short panels and highly persistent series (Blundell and Bond, 1998; Bond et al., 2001). In this way, the system GMM estimator allows for less restrictive assumptions from an empirical growth standpoint while providing more reliable estimates with superior finite sample properties from an econometric perspective.

Based on the above features, the use of the estimator has become prevalent in empirical growth studies, following the works of Levine et al. (2000), Bond et al. (2001), Hoeffler (2002), and Ding and Knight (2009, 2011), among others. Particularly, from an empirical growth viewpoint, the system GMM estimator simultaneously allows to (i) control for temporal differences in technological change that are assumed to be common to all countries, (ii) include cross-country differences in initial level of productivity and in other unobserved growth-related factors, (iii) address the problem of weak instruments, (iv) enhance the precision for short panels and highly persistent series, and (v) deal with a potential endogeneity originating from unobservable omitted variables, measurement errors, and the simultaneity between Solow growth variables. For instance, a dynamic feedback mechanism may exist between past shocks to GDP and current investment in addition to the simultaneity between current investment and current shocks to GDP (Hoeffler, 2002: 140). Similarly, for the case in this study, not only does better health status stimulate income growth, but also higher income growth improves the health status of the workforce. Furthermore, the relationship between these two variables may be subject to dynamic endogeneity in such a way that the past values of income may affect the current or past investments in health, which in turn may increase the current health status of the workforce.[6,7] Hence, the system GMM estimator helps to deal with any endogeneity issue encountered in the estimation process by instrumenting not only the lagged dependent variable but also all endogenous variables with variables considered uncorrelated with the fixed effects. Additionally, the estimator ensures the consistency of the necessary restrictions on the initial conditions within the standard Solow growth framework (Blundell and Bond, 2000; Bond et al., 2001; Bond, 2002). In short, the system GMM estimator provides a reasonable alternative that combines low bias and high efficiency for short panels. Therefore, the methodology used in this study ensures that more precise and unbiased estimates of the coefficients on Solow convergence variables are obtained compared to those that have been employed in previous studies.

### 3.2.Data

This study uses panel data for 38 OECD and 58 low-income countries over the period 1955-2019.[8] The data on Solow growth variables, including real GDP per worker, the investment rate for physical capital, and the effective depreciation rate, were obtained from the Penn World Table (PWT) database (Feenstra et al., 2015). As the main aim of the study is to explore the productivity implications of workforce health, the output-side definition of real GDP is used in the analyses, which provides a measure of relative productive capacity across countries and over time instead of living standards (Feenstra et al., 2015: 3154). Hence, in the study, the real GDP per worker ($ROP_{i,t}$) is measured as output-side real GDP at chained purchasing power parities (PPPs) (in millions of 2017 US dollars) divided by the total number of persons engaged in a productive activity (in millions). Using per-worker variables is more appropriate for this study (i) to focus exactly on the population contributing to production and (ii) to eliminate the sensitivity of the estimation results to the differences in the shares of countries' dependent populations, which are quite different among high- and low-income country groups. The investment rate for physical capital is measured as the share of gross capital formation at current PPPs and used as a proxy for the savings rate ($INVR_{i,t}$). The annual growth rate of the workforce ($WGR_{i,t}$) is calculated from the data on the number of persons engaged, which includes ages 15 and over. Different from previous studies in the literature, this study further allows the depreciation rates on physical capital ($DEPR_{i,t}$) to vary across countries and time instead of assuming a constant rate of three percent. Hence, the augmented rate of workforce growth ($AWGR_{i,t}$) is obtained as the sum of the workforce growth rate, the depreciation rate, and the rate of technological progress, which is assumed to be constant at two percent following Mankiw et al. (1992). The data on human capital ($HC_{i,t}$) was also obtained from the PWT, which is measured as an index based on years of schooling and returns to education.[9]

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[6] One of the main reasons for using the system GMM is the interrelationship between income and health (Bloom and Canning, 2000; Mayer, 2001a, 2001b; Hartwig, 2010; Swift, 2011).

[7] There exists a significant bilateral relationship between income and health expenditures (Heshmati, 2001; Rivera and Currais, 2003; Erdil and Yetkiner, 2009).

[8] According to the World Bank's income classification, OECD countries include high-income and four upper-middle-income countries (Colombia, Costa Rica, Mexico, and Turkey) that are similar in the sense that they may share the same steady-state characteristics due to their common structural features. The low-income sample includes 58 lower-middle- and low-income countries. Bhutan, Cabo Verde, Chad, Comoros, Djibouti, Guinea, Guinea-Bissau, and Uzbekistan are dropped from this sample due to a lack of data on the human capital index. The list of sample countries is provided in Table A1 in Appendix A.

[9] If one considers the mutual relationship between health and education such that more educated (healthy) people are healthier (better educated) (Groot and van den Brink, 2007; Becker, 2007), the model may be expected to suffer from a collinearity problem that results in biased estimates of the coefficients on both variables. Hence, to avoid any possible multicollinearity issue, the study checks for variance inflation factors (VIFs) as a rule of thumb. The results show that the regression models do not suffer from a serious multicollinearity problem, as the mean VIF value is smaller than or equal to 2.89 in all OECD regressions and is smaller than 3.25 in all regressions, including those for low-income countries.

**Table 1: Descriptive statistics**

| | *Mean* | *Median* | *Std. Dev.* | *Min.* | *Max.* |
|---|---|---|---|---|---|
| ***Panel A*** | **OECD** | | | | |
| $\boldsymbol{GROP_{i,t}}$ *(%)* | 2.46 | 2.46 | 4.08 | -27.76 | 23.71 |
| $\boldsymbol{ROP_{i,t}}$ *(Millions, 2017 US$)* | 53839.62 | 49635.12 | 28330.43 | 4224.84 | 221661.20 |
| $\boldsymbol{INVR_{i,t}}$ *(%)* | 26.23 | 25.83 | 6.91 | 8.09 | 56.99 |
| $\boldsymbol{WGR_{i,t}}$ *(%)* | 1.12 | 1.14 | 2.00 | -13.98 | 7.85 |
| $\boldsymbol{DEPR_{i,t}}$ *(%)* | 3.59 | 3.51 | 0.71 | 2.07 | 7.12 |
| $\boldsymbol{LE15_{i,t}}$ *(years)* | 60.72 | 60.43 | 3.92 | 47.21 | 69.70 |
| $\boldsymbol{LE20_{i,t}}$ *(years)* | 55.92 | 55.60 | 3.83 | 42.93 | 64.77 |
| $\boldsymbol{LE30_{i,t}}$ *(years)* | 46.46 | 46.07 | 3.62 | 34.77 | 55.00 |
| $\boldsymbol{LE40_{i,t}}$ *(years)* | 37.11 | 36.70 | 3.37 | 26.73 | 45.27 |
| $\boldsymbol{LE50_{i,t}}$ *(years)* | 28.16 | 27.71 | 3.04 | 19.03 | 35.79 |
| $\boldsymbol{LE60_{i,t}}$ *(years)* | 19.97 | 19.56 | 2.61 | 11.74 | 26.73 |
| $\boldsymbol{MORT_{i,t}}$ *(rate, per 1000 population)* | 133.84 | 130.00 | 52.65 | 47.00 | 337.00 |
| $\boldsymbol{HC_{i,t}}$ *(index)* | 2.79 | 2.85 | 0.57 | 1.18 | 3.89 |
| ***Panel B*** | **Low-Income** | | | | |
| $\boldsymbol{GROP_{i,t}}$ *(%)* | 1.46 | 1.75 | 8.85 | -73.74 | 57.00 |
| $\boldsymbol{ROP_{i,t}}$ *(Millions, 2017 US$)* | 9733.57 | 6517.69 | 10122.48 | 1192.95 | 80101.05 |
| $\boldsymbol{INVR_{i,t}}$ *(%)* | 16.63 | 14.89 | 10.53 | -10.11 | 95.02 |
| $\boldsymbol{WGR_{i,t}}$ *(%)* | 2.47 | 2.56 | 1.92 | -12.84 | 18.78 |
| $\boldsymbol{DEPR_{i,t}}$ *(%)* | 4.46 | 4.22 | 1.37 | 1.25 | 9.30 |
| $\boldsymbol{LE15_{i,t}}$ *(years)* | 50.21 | 50.13 | 5.76 | 19.43 | 63.81 |
| $\boldsymbol{LE20_{i,t}}$ *(years)* | 46.00 | 45.94 | 5.40 | 20.05 | 58.98 |
| $\boldsymbol{LE30_{i,t}}$ *(years)* | 38.00 | 37.78 | 4.50 | 19.89 | 49.42 |
| $\boldsymbol{LE40_{i,t}}$ *(years)* | 30.20 | 29.92 | 3.50 | 18.38 | 39.95 |
| $\boldsymbol{LE50_{i,t}}$ *(years)* | 22.62 | 22.23 | 2.66 | 14.20 | 30.80 |
| $\boldsymbol{LE60_{i,t}}$ *(years)* | 15.55 | 15.09 | 2.07 | 9.89 | 22.55 |
| $\boldsymbol{MORT_{i,t}}$ *(rate, per 1000 population)* | 318.00 | 310.00 | 117.32 | 68.00 | 871.00 |
| $\boldsymbol{HC_{i,t}}$ *(index)* | 1.59 | 1.44 | 0.51 | 1.01 | 3.61 |

Notes: Std. Dev., Min., and Max. denote the standard deviation, the minimum, and the maximum, respectively. $GROP_{i,t}$ denotes the growth rate of real output per worker.

Deviating from the related literature, this study directly focuses on the health status of the workforce rather than that of the entire population. Therefore, instead of using conventional measures of population health status, including life expectancy at birth and infant or under-five mortality rates, the study uses age-specific measures of life expectancy and adult mortality. Life expectancy at higher ages provides a more appropriate measure to consider the productivity implications of health through the workforce. Similarly, using adult mortality rates helps to better understand the health status of the economically most productive age span. Furthermore, especially for high-income OECD countries, the burdens of non-communicable diseases (NCDs) and aging are relatively higher compared to infant mortality rates (Geppert et al., 2019; OECD, 2019). Therefore, it is more relevant to refer to adult mortality patterns to measure the current health status of the productive population in these countries. Accordingly, life expectancies at ages 15, 20, 30, 40, 50, and 60 are used in the analyses to consider the health status of the workforce. Life expectancy at a particular age refers to the average number of remaining years of life expected by individuals alive at these ages and excludes information on the population below that age. Hence, the measure of life expectancy used in this study covers the population: those just entering the labor market at ages 15 and 20, those in their prime working lives at ages 30, 40, and 50, and those approaching the end of their working lives and retirement at ages 60. Furthermore, adult mortality rates between ages 15 and 60 are used to capture the risk of death between those ages of 15 and 60.[10] The data on life expectancy at specific ages (in years) ($L15_{i,t}$, $L20_{i,t}$, $L30_{i,t}$, $L40_{i,t}$, $L50_{i,t}$, and $L60_{i,t}$) and on adult mortality rates ($MORT_{i,t}$) were obtained from the World Population Prospects (WPP) database of the United Nations (UN) Population Division (2019). The data for these two indicators are already provided at five-year intervals.

Panels A and B of Table 1 present the descriptive statistics of the series for OECD and low-income country groups over the years between 1955 and 2019. The study further uses non-overlapping time intervals that have been widely used in cross-country growth empirics to minimize business cycle effects, which inevitably dominate the short-run variation in growth rates. However, there is no consensus on the determination of the time intervals, even though it is difficult to select an appropriate time interval given the presence of cyclical effects (Temple, 1999). On the other hand, it is more likely to obtain more time series variation with a shorter interval than would be possible with a longer one (Islam, 1995; Bond et al., 2001; Ding and Knight, 2009, 2011). This study opts for non-overlapping 5-year time intervals as in Islam (1995), Bond et al. (2001), and Hoeffler (2002) to avoid modeling cyclical dynamics. For each country group, 13 time points are obtained by using the above setup. Hence, the study includes the following two final samples in the analyses: 38 OECD members and 58 low-income countries were observed over 5-year intervals for the period 1955-2019. All variables were used in their natural logarithms in the analyses.

## 4. EMPIRICAL FINDINGS

Prior to system GMM estimations, the stationarity properties of the series are examined by using first- and second-generation panel unit root tests (PURTs), given the argument that the GMM estimators can be expected to perform poorly in situations where the series are close to being random walks (Bond, 2002: 143).[11] Overall, the results of the PURTs for both log-levels and first differences in logs show that the sample series are free from serious unit root issues.[12] Tables 2 and 3 below report the results of system GMM estimations for OECD and low-income countries, respectively. In all regressions, the left-hand side variable is the log-difference of real output per worker over a 5-year period. The lagged log-level of real output per worker is treated as predetermined, and all independent variables are treated as endogenous regressors in the regressions, i.e., they are assumed to be correlated with the shocks to real output per worker both in the current and in the previous periods. Furthermore, time dummies are included in all regressions to prevent the most likely forms of contemporaneous correlation since the GMM estimators assume that the disturbances are uncorrelated across individuals (Roodman, 2009). Each model is estimated using a one-step system GMM estimator. Most of the studies employing GMM estimators often rely on the results of the one-step estimator, though it is argued that the two-step estimator is always more efficient than the one-step estimator (Bond et al., 2001; Blundell et al., 2001; Hoeffler, 2002; Ding and Knight, 2009). This is because (i) the efficiency gains from using the two-step estimator are very small for the system GMM, (ii) the one-step estimator is more reliable for finite sample inference, even in the presence of non-normality and considerable heteroskedasticity (Blundell and Bond, 1998: 142), and (iii) unlike the two-step estimator, the independence of the one-step weight matrix on estimated parameters makes the approximations of the usual asymptotic distribution more precise (Blundell and Bond, 2000; Bond and Windmeijer, 2002). The results of Monte Carlo studies have further shown that for the two-step estimator, the asymptotic $t$-ratios can be seriously misleading in cases where the equivalent tests based on the one-step estimator are fairly accurate (Bond, 2002: 147).

The consistency of system GMM results depends on the validity of several key conditions. Therefore, the bottom parts of Tables 2 and 3 provide the test statistics to verify the validity of these following conditions. First, the consistency of system GMM depends on the validity of the instrumental variable set, which requires that there be no correlation between the instruments and the error term. This condition is tested by means of the Hansen (1982) test of overidentifying restrictions. Hansen (1982) has suggested the $J$-statistic to test the null hypothesis of the validity of all instruments. Hence, the non-rejection of the null implies that there is no correlation between the instruments and the error term, i.e., the instrument set is valid. Second, system GMM requires that the additional moment restrictions proposed by Blundell and Bond (1998) be valid. The $C$-statistic

[10] Each measure covers the population aged 15-60 instead of 15-64 due to data availability.

[11] The time-series properties of the growth variables are largely ignored in micro-panel regressions due to a belief that time averaging helps to change the order of integration of the series (Phillips and Moon, 2000; Eberhardt and Teal, 2011). However, contrary to this belief, it is argued that time-averaging does not avoid the problem of non-stationarity (Granger, 1988; Granger and Siklos, 1995).

[12] The results and explanations of the PURTs are provided in Table A2 in Appendix A to save space and keep the flow of the paper.

produced by the difference-in-Hansen test is used to test the validity and the exogeneity of instrument subsets, which distinguishes the system GMM from the difference GMM estimator (Blundell and Bond, 2000). The $p$-values of the test statistics given at the bottom of each table show that the instruments and their subsets are all valid in all estimations. Third, the existence of autocorrelation should be checked to avoid using some lags as invalid instruments. In fact, negative first-order serial correlation may be expected in differences, but its evidence is uninformative (Roodman, 2009). To this end, Arellano and Bond (1991) have developed a $z$-test applied to the disturbances in differences to detect autocorrelation aside from the fixed effects in a dynamic panel data model. In general, the test considers the serial correlation of order $AR(k+1)$ in the differences to check for the serial correlation of order $AR(k)$ in levels. Hence, the test detects lagged instruments that become invalid through autocorrelation. The idea of the test lies on the fact that if the disturbances are serially correlated of order $k$, then $y_{i,t-(k+1)}$ is endogenous to the $k^{\text{th}}$ lag of the disturbance term in the error term in differences and thus becomes a potentially invalid instrument (Roodman, 2009: 119). In this case, the instrument set should be restricted to lags $k+2$ and longer of $y_{it}$. The bottom part of Table 2 provides the $p$-values of Arellano-Bond test statistics for first-, second-, and third-order autocorrelation. The results in all columns show that there is no second- or third-order serial correlation. On the other hand, the bottom part of Table 3 shows the $p$-values of the test statistics for first-, second-, third-, and fourth-order autocorrelation. The results in each column of Table 3 indicate that there are serial correlations up to fourth order. Therefore, the instrument set is restricted to lags above four in the estimations of low-income countries since the test results confirm the validity of using these higher lags. Lastly, the number of instruments used in the regressions should be less than or equal to the number of groups to avoid overfitting endogenous variables. This requirement is also met in each estimation.

Table 2 provides the results of system GMM estimations for OECD countries. Column (1) shows the estimation results for absolute convergence, which tests whether there exists a catch-up process among OECD countries independent of their preferences, technology, and workforce health status. According to the results, the coefficient of the lagged real output per worker is significantly negative, showing that 38 OECD members converge in an absolute sense. Column (2) shows the results based on the estimation of the basic Solow model, which neglects the roles of health and education. In line with the findings of growth empirics, the results provide strong support for absolute and faster conditional output convergence among high-income OECD countries (Barro and Sala-i-Martin, 1990; Barro, 1991; Mankiw et al., 1992; Barro and Lee, 1993, 1994; Islam, 1995). Furthermore, the findings show that the savings rate significantly and positively affects the rate of per-worker output growth, while the augmented rate of workforce growth has a significant and negative effect. Columns (3) – (8) show the findings when life expectancy at specific ages is included in the regressions as a proxy for the health status of the workforce. In each column, the results show evidence of significant output convergence conditional on the savings rate, the augmented rate of workforce growth, and the longevity measures. The inclusion of longevity indicators significantly accelerates the convergence process compared to the estimation of the basic Solow model in column (2). In this context, the highest rates are observed for ages 15 and 20, showing that improvements in the life expectancy of this age span allow OECD countries to convergence faster, but the rate of convergence slightly decreases with rising age after age 20. The findings further indicate that a longer life expectancy at each age positively and significantly enhances output growth, except for the life expectancies at ages 50 and 60. The findings indicate that both the magnitude and significance of the coefficients gradually decrease with rising age. In this sense, the largest estimated effects of longevity on output growth are obtained for ages 15 and 20, indicating that a 1% increase in life expectancy at ages 15 and 20 is associated with about a 1.66% and 1.67% increase in the growth rate of real output per worker, respectively. That is, increases in the life expectancy of the younger workforce provide the largest contribution to the rate of output growth. The improvements in life expectancy between ages 30 and 40 have a significant and positive impact on output growth, but this impact is lower compared to those obtained for younger ages. However, the results in columns (7) – (8) indicate that improvements in longevity for ages 50 and 60 have positive but insignificant effects on output growth. The results in columns (3) – (8) further indicate that the magnitude of the coefficient of the savings rate increases with rising age. This finding may also reflect the fact that long-lived people have greater incentives to save for older ages (Lee et al., 2001; Mason and Lee, 2006). In this sense, the highest coefficient of the savings rate is obtained in column (8), in which the effect of life expectancy at age 60 is considered. This finding further indicates that increases in the savings of this age group, who are those approaching the end of their working lives and retirement, play a larger role in the growth process than the increases in their labor productivity through year gains. On the other hand, in each column, the augmented rate of workforce growth has a significantly negative impact on output growth. Lastly, column (9) adds adult mortality rates between ages

15 and 60 to the right-hand side of the regression equation, which practically measure the probability of dying young and are a reasonable inverse proxy for the good health status of the workforce (Caselli, 2005). According to the results, the estimated coefficient on adult mortality is significantly negative, implying that increases in adult mortality lessen per-worker output growth. Compared to the findings for longevity measures in columns (3) – (8), controlling for adult mortality (i) also raises the rate of output convergence among OECD countries, (ii) considerably decreases the positive growth effect of the savings rate, and (iii) lessens the negative growth effect of the augmented rate of workforce growth.

Columns (10) – (16) of Table 2 provide the results of system GMM estimations, which are controlled for human capital in the form of education. In each column, educational human capital has a positive but insignificant effect on output growth among OECD countries. The findings show evidence of significant output convergence in each column, but educational human capital has no significant effect on this process. Similar to the findings in columns (3) – (8), the rate of convergence slightly decreases with increasing age after age 20, and the lowest estimated rate of convergence is found in column (15), in which the regression includes the longevity at age 60. However, after controlling for education, the findings show that longer life expectancy positively and significantly enhances output growth only for the ages 15 and 20. Moreover, the magnitudes and significance of the coefficients of life expectancy at ages 15 and 20 are lower than those obtained in columns (3) – (4) of Table 2. For other age groups, the findings show that year gains have no significant effect on output growth. The results in columns (10) – (16) further indicate that the coefficients of the Solow variables, including the savings rate and the augmented rate of workforce growth, are highly significant. The highest coefficient of the savings rate is again obtained in column (15), in which the effect of life expectancy at age 60 is considered. The results in column (16) also show that adult mortality has a significant and negative effect on output growth, but its effect is larger compared to that in column (9), in which the effect of education is neglected. Once again, compared to longevity measures, controlling adult mortality further decreases the positive effect of the savings rate and the negative effect of workforce growth.

Table 3 gives the results for low-income countries. Similar to the findings of the OECD group, the results in columns (1) and (2) show evidence of absolute and faster conditional output convergence among 58 low-income countries. However, in each column, the estimated rate of convergence is lower than that obtained for OECD countries. Furthermore, the results in column (2) show that both the savings rate and the augmented rate of workforce growth have a significant and positive effect on output growth, but the growth effects of the savings rate are expectedly lower in magnitude than those obtained for OECD countries. Columns (3) – (8) show the findings when life expectancy at specific ages is included in the convergence regressions. In each column, the results show evidence of significant output convergence, whose rate further gains speed with the inclusion of longevity measures compared to column (2) of Table 3. According to the results in columns (3) – (8), longer life expectancy at each age has a significant and positive effect on output growth. However, the younger workforce, ages 15-20, still makes the largest contribution to output growth as in the OECD group. The findings indicate that during the 65-year period, a 1% increase in life expectancy at ages 15 and 20 is associated with about an 0.81% and 0.69% increase in the rate of per-worker output growth among 58 low-income countries, respectively. However, compared to OECD members, the increases in longevity at age 15 contribute more to output growth in low-income countries. This finding reflects different demographic and, hence, working-age dynamics between these two country groups. The magnitude and significance of the coefficients on longevity measures gradually decrease with rising age, as in the case of OECD countries, but the magnitude of this decrease is lower than those found for OECD countries. In other words, in low-income countries, the contributions of year gains to output growth are closer to each other for different age groups compared to OECD members. The improvements in longevity at ages 50 and 60 have a positive but insignificant effect on output growth. The results in columns (3) – (8) further show that the savings rate has a significant and positive effect on output growth. However, contrary to the findings in Table 2, the effects of the savings rate are small in magnitude and do not change noticeably with rising age. This finding indicates that low-level savings in low-income countries are more resilient to improvements in longevity. The findings in column (9) further show that increases in adult mortality significantly decrease per-worker output growth in low-income countries. However, for these countries, controlling for adult mortality does not lead to a considerable decrease in the growth effects of the savings rate.

## Table 2: System GMM estimates: OECD countries

| $\Delta ln(ROP_{i,t})$ | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $ln(ROP_{i,t-1})$ | -0.226***<br>(0.073) | -0.286***<br>(0.070) | -0.379***<br>(0.071) | -0.386***<br>(0.071) | -0.349***<br>(0.066) | -0.337***<br>(0.063) | -0.321***<br>(0.059) | -0.299***<br>(0.051) | -0.360***<br>(0.083) | -0.343***<br>(0.059) | -0.351***<br>(0.061) | -0.324***<br>(0.058) | -0.297***<br>(0.058) | -0.296***<br>(0.057) | -0.276***<br>(0.055) | -0.344***<br>(0.071) |
| $ln(INVR_{i,t})$ | | 0.256***<br>(0.080) | 0.269**<br>(0.103) | 0.261**<br>(0.099) | 0.296***<br>(0.104) | 0.308***<br>(0.104) | 0.314***<br>(0.102) | 0.336***<br>(0.102) | 0.228**<br>(0.088) | 0.278***<br>(0.103) | 0.271***<br>(0.100) | 0.296***<br>(0.103) | 0.286***<br>(0.094) | 0.290***<br>(0.093) | 0.317***<br>(0.100) | 0.248***<br>(0.089) |
| $ln(AWGR_{i,t})$ | | -0.184***<br>(0.066) | -0.274***<br>(0.096) | -0.271***<br>(0.096) | -0.282***<br>(0.100) | -0.283***<br>(0.100) | -0.277***<br>(0.101) | -0.281***<br>(0.104) | -0.196**<br>(0.080) | -0.251**<br>(0.095) | -0.250**<br>(0.094) | -0.259***<br>(0.096) | -0.251***<br>(0.094) | -0.247**<br>(0.094) | -0.275***<br>(0.100) | -0.223**<br>(0.084) |
| $ln(LE15_{i,t})$ | | | 1.662**<br>(0.770) | | | | | | | 1.437*<br>(0.761) | | | | | | |
| $ln(LE20_{i,t})$ | | | | 1.671**<br>(0.754) | | | | | | | 1.470*<br>(0.760) | | | | | |
| $ln(LE30_{i,t})$ | | | | | 1.167*<br>(0.652) | | | | | | | 1.021<br>(0.636) | | | | |
| $ln(LE40_{i,t})$ | | | | | | 0.931*<br>(0.540) | | | | | | | 0.591<br>(0.486) | | | |
| $ln(LE50_{i,t})$ | | | | | | | 0.705<br>(0.460) | | | | | | | 0.506<br>(0.434) | | |
| $ln(LE60_{i,t})$ | | | | | | | | 0.522<br>(0.413) | | | | | | | 0.433<br>(0.416) | |
| $ln(MORT_{i,t})$ | | | | | | | | | -0.172**<br>(0.084) | | | | | | | -0.205**<br>(0.093) |
| $ln(HC_{i,t})$ | | | | | | | | | | 0.052<br>(0.161) | 0.054<br>(0.159) | 0.075<br>(0.145) | 0.100<br>(0.137) | 0.104<br>(0.136) | 0.070<br>(0.135) | 0.084<br>(0.144) |
| Constant | 2.597***<br>(0.824) | 2.818***<br>(0.936) | -2.968<br>(2.826) | -2.781<br>(2.633) | -1.014<br>(2.222) | -0.058<br>(1.769) | 0.743<br>(1.410) | 1.232<br>(1.130) | 4.494***<br>(1.397) | -2.573<br>(2.684) | -2.489<br>(2.544) | -0.853<br>(2.046) | 0.648<br>(1.404) | 1.057<br>(1.113) | 1.227<br>(0.933) | 4.353***<br>(1.330) |
| $AR(1)$ | 0.022 | 0.002 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.006 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 |
| $AR(2)$ | 0.114 | 0.118 | 0.151 | 0.186 | 0.134 | 0.113 | 0.113 | 0.116 | 0.159 | 0.128 | 0.158 | 0.119 | 0.107 | 0.105 | 0.107 | 0.135 |
| $AR(3)$ | 0.780 | 0.583 | 0.537 | 0.540 | 0.515 | 0.500 | 0.510 | 0.543 | 0.583 | 0.547 | 0.550 | 0.527 | 0.553 | 0.550 | 0.565 | 0.583 |
| *Hansen p-value* | 0.209 | 0.297 | 0.156 | 0.182 | 0.141 | 0.106 | 0.143 | 0.112 | 0.115 | 0.121 | 0.125 | 0.117 | 0.156 | 0.161 | 0.186 | 0.128 |
| *Diff. Hansen p-value* | 0.773 | 0.497 | 0.597 | 0.477 | 0.635 | 0.541 | 0.611 | 0.582 | 0.254 | 0.442 | 0.314 | 0.520 | 0.220 | 0.167 | 0.455 | 0.699 |
| *# of instruments* | 17 | 36 | 32 | 32 | 32 | 32 | 32 | 32 | 36 | 37 | 37 | 37 | 38 | 38 | 38 | 37 |
| *# of groups* | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 |

Notes: The dependent variable is $\Delta ln(ROP_{i,t})$ in each case. Heteroskedasticity-consistent standard errors are in the parentheses. In each estimation, the instrument sets are collapsed following Roodman (2009). Hansen $p$-value and Diff. Hansen $p$-value show the $p$-values for the Hansen and difference-in-Hansen test statistics, respectively. The values reported for $AR(1)$, $AR(2)$, and $AR(3)$ are the $p$-values for the $z$-test statistics to check for the serial correlation. The symbol # means the number. The superscripts ***, **, and * denote the significance levels at 1%, 5%, and 10%, respectively.

**Table 3: System GMM estimates: Low-income countries**

| $\Delta ln(ROP_{i,t})$ | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $ln(ROP_{i,t-1})$ | -0.128** | -0.147*** | -0.170*** | -0.168*** | -0.163*** | -0.164*** | -0.165*** | -0.163*** | -0.169*** | -0.172*** | -0.172*** | -0.169*** | -0.172*** | -0.175*** | -0.170*** | -0.172*** |
| | (0.056) | (0.047) | (0.041) | (0.042) | (0.042) | (0.043) | (0.044) | (0.044) | (0.043) | (0.052) | (0.049) | (0.050) | (0.050) | (0.051) | (0.053) | (0.050) |
| $ln(INVR_{i,t})$ | | 0.128** | 0.131** | 0.131** | 0.130*** | 0.129*** | 0.132*** | 0.131*** | 0.133*** | 0.181*** | 0.155** | 0.153** | 0.154** | 0.167** | 0.179*** | 0.159** |
| | | (0.048) | (0.051) | (0.050) | (0.049) | (0.049) | (0.049) | (0.049) | (0.050) | (0.066) | (0.063) | (0.062) | (0.062) | (0.066) | (0.068) | (0.062) |
| $ln(AWGR_{i,t})$ | | 0.330** | 0.014 | 0.054 | 0.112 | 0.151 | 0.188 | 0.227 | 0.138 | 0.037 | 0.019 | 0.059 | 0.084 | 0.080 | 0.112 | 0.067 |
| | | (0.142) | (0.187) | (0.182) | (0.176) | (0.169) | (0.166) | (0.161) | (0.148) | (0.215) | (0.208) | (0.196) | (0.188) | (0.185) | (0.182) | (0.185) |
| $ln(LE15_{i,t})$ | | | 0.809** | | | | | | | 0.678* | | | | | | |
| | | | (0.343) | | | | | | | (0.366) | | | | | | |
| $ln(LE20_{i,t})$ | | | | 0.689** | | | | | | | 0.635* | | | | | |
| | | | | (0.328) | | | | | | | (0.344) | | | | | |
| $ln(LE30_{i,t})$ | | | | | 0.520* | | | | | | | 0.528* | | | | |
| | | | | | (0.287) | | | | | | | (0.295) | | | | |
| $ln(LE40_{i,t})$ | | | | | | 0.510* | | | | | | | 0.558* | | | |
| | | | | | | (0.291) | | | | | | | (0.309) | | | |
| $ln(LE50_{i,t})$ | | | | | | | 0.464 | | | | | | | 0.598* | | |
| | | | | | | | (0.314) | | | | | | | (0.341) | | |
| $ln(LE60_{i,t})$ | | | | | | | | 0.383 | | | | | | | 0.409 | |
| | | | | | | | | (0.332) | | | | | | | (0.337) | |
| $ln(MORT_{i,t})$ | | | | | | | | | -0.172** | | | | | | | -0.183** |
| | | | | | | | | | (0.069) | | | | | | | (0.080) |
| $ln(HC_{i,t})$ | | | | | | | | | | 0.329 | 0.386* | 0.395* | 0.391* | 0.383* | 0.395* | 0.335* |
| | | | | | | | | | | (0.206) | (0.201) | (0.203) | (0.200) | (0.204) | (0.213) | (0.196) |
| **Constant** | 1.235** | 0.317 | -2.041* | -1.602 | -1.007 | -0.926 | -0.717 | -0.420 | 1.842** | -1.916* | -1.607 | -1.201 | -1.221 | -1.182 | -0.583 | 1.772* |
| | (0.513) | (0.506) | (1.040) | (0.981) | (0.854) | (0.835) | (0.809) | (0.796) | (0.820) | (1.074) | (1.001) | (0.842) | (0.816) | (0.822) | (0.742) | (0.931) |
| $AR(1)$ | 0.849 | 0.448 | 0.498 | 0.535 | 0.562 | 0.554 | 0.545 | 0.538 | 0.585 | 0.513 | 0.584 | 0.617 | 0.618 | 0.624 | 0.626 | 0.644 |
| $AR(2)$ | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $AR(3)$ | 0.030 | 0.022 | 0.044 | 0.038 | 0.032 | 0.031 | 0.029 | 0.028 | 0.026 | 0.034 | 0.031 | 0.028 | 0.028 | 0.028 | 0.026 | 0.024 |
| $AR(4)$ | 0.513 | 0.254 | 0.538 | 0.505 | 0.456 | 0.411 | 0.364 | 0.332 | 0.416 | 0.577 | 0.587 | 0.554 | 0.521 | 0.525 | 0.524 | 0.534 |
| ***Hansen p-value*** | 0.331 | 0.531 | 0.177 | 0.227 | 0.262 | 0.235 | 0.205 | 0.245 | 0.217 | 0.290 | 0.446 | 0.488 | 0.456 | 0.484 | 0.565 | 0.281 |
| ***Diff. Hansen p-value*** | 0.283 | 0.246 | 0.363 | 0.520 | 0.482 | 0.381 | 0.233 | 0.164 | 0.243 | 0.165 | 0.224 | 0.285 | 0.352 | 0.373 | 0.375 | 0.330 |
| ***# of instruments*** | 41 | 39 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| ***# of groups*** | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 |

Notes: The dependent variable is $\Delta ln(ROP_{i,t})$ in each case. Heteroskedasticity-consistent standard errors are in the parentheses. In each estimation, the instrument sets are collapsed following Roodman (2009). Hansen $p$-value and Diff. Hansen $p$-value show the $p$-values for the Hansen and difference-in-Hansen test statistics, respectively. The values reported for $AR(1)$, $AR(2)$, $AR(3)$ and $AR(4)$ are the $p$-values for the $z$-test statistics to check for the serial correlation. The symbol # means the number. The superscripts ***, **, and * denote the significance levels at 1%, 5%, and 10%, respectively.

Lastly, columns (10) – (16) give the results of system GMM estimations when the education component of human capital is controlled in the regressions. Unlike the findings of OECD countries, human capital in the form of education has a significant and positive effect on output growth, except for column (10) considering the effects of longevity at age 15. In each column, the results show evidence of significant conditional output convergence among low-income countries. Furthermore, controlling for human capital in the form of education leads to higher rates of convergence for each age group compared to the columns (3) – (8) of Table 3. However, after controlling for educational human capital, the findings show that longer life expectancy only at ages 15-50 positively and significantly enhances output growth. For the age group of 60, the findings show that improvements in longevity have no significant effect on output growth. The results in columns (10) – (16) further indicate that the savings rate has a significant and positive effect on output growth, and its effects become larger in magnitude in each column after controlling for education. The highest coefficient of the savings rate is obtained in column (15), in which the effect of life expectancy at age 60 is considered. The results in column (16) also show that adult mortality has a significant and negative effect on output growth, but its effect becomes larger in magnitude compared to column (9), after controlling for educational human capital. However, excepting for column (2), the augmented rate of workforce growth has no significant impact on output growth among low-income countries.

## 5.CONCLUDING REMARKS AND POLICY IMPLICATIONS

This study aims to examine the role of workforce health status on output growth and the convergence process in OECD and low-income countries over a 65-year period. Particularly, the main aim of the study is to focus exactly on the growth effects of the workforce health status specific to different age groups among two structurally different income groups, for which the empirical evidence is still mixed. In this sense, the study employs two different health indicators, life expectancy at ages 15 to 60 and adult mortality between ages 15 to 60, to proxy for the health status of a country's most productive age span. A dynamic panel data estimator, the system GMM, is used in the analyses due to its superior features over other panel data estimators. It allows for more precise and unbiased estimates of the Solow convergence variables. Although it is not quite accurate to compare the findings of the study with those of the previous studies, mainly due to the differences in the methodology and health proxies used, the overall results of this study reinforce the empirical regularities of economic growth. In other words, the findings of the study (i) provide support for absolute and faster conditional output convergence among structurally similar countries, (ii) show that good health status is an ultimate trigger of the transition to sustained productivity and output growth, and (iii) indicate that the inclusion of health indicators significantly accelerates the convergence process in each country group.

The details of the findings are as follows: First, the findings of the study show that higher longevity at ages 15 to 40 has a positive, sizable, and statistically significant effect on aggregate output growth in OECD and low-income countries. In particular, the increases in the longevity of the younger workforce provide the largest contribution to the rate of output growth. For the OECD group, the increases in longevity at age 20 contribute more to growth, while this age span is falling to 15 in low-income countries. Second, the inclusion of age-specific longevity measures significantly accelerates the convergence process for each age in both country groups. However, after age 20, the rate of convergence slightly decreases with increasing age in each country group. On the other hand, year gains at ages 50 and 60 have no significant effect on output growth in both country groups. Third, for OECD countries, the growth-enhancing effects of the savings rate rise remarkably with the inclusion of health measures and rising age. Especially, controlling the longevity of people at age 60 leads to the highest contribution to the savings rate in OECD countries. However, for low-income countries, where income is generally allocated to satisfy the consumption of basic needs, the estimated rates of savings continue to remain low regardless of age. Fourth, the findings show that increases in adult mortality adversely affect output growth and convergence patterns among both country groups. Its negative effects on growth arise through the loss of human capital at productive ages and decreases in the incentives to invest in physical capital, particularly in OECD countries. Fifth, the augmented rate of workforce growth has a significant and negative effect on output growth among OECD countries, indicating that higher longevity and lower mortality reduce fertility rates and population growth, which further trigger the accumulation of human capital, especially in post-transitional countries (Soares, 2005; Cervellati and Sunde, 2011; Hansen and Lønstrup, 2015). However, the effects of the workforce growth rate are positive but insignificant for low-income country group. Lastly, the findings show that human capital in the form of education has no significant effect on output growth among OECD countries, while it has a significantly positive and larger effect in low-income countries with relatively low levels of human capital. In low-income countries, controlling human capital in the form of education further increases the speed of convergence and raises the coefficients of health indicators in magnitude. However, in OECD countries, the inclusion of educational human capital decreases the significance and magnitude of the coefficients on longevity for each age and lowers the estimated rates of convergence. For OECD countries, the findings indicate that longer life expectancy positively and significantly enhances output growth only for the ages 15 and 20 after controlling for education, but there is no significant effect of longevity on output growth at other ages. However, the negative effects of adult mortality on growth become larger in magnitude in each country group after controlling for educational human capital.

The policy implications of the study are clear. Policies to increase economic growth should favor investments in health, as the findings of the study indicate that the years during which the productive population of a country remains healthy are likely to be important for explaining productivity and output differences between countries. Particularly, raising health investments, providing health care provisions, and promoting healthier lifestyles for those that are between the ages of 15 and 40 will remarkably contribute to the long-run output growth and faster elimination of productivity gaps among both OECD and low-income countries. Policymakers should also be aware that decreasing adult mortality in each income group will remarkably enhance long-run output growth through its benefits on labor productivity and increased savings. Furthermore, the findings of the study show that the growth-enhancing effects of the savings outweigh the growth-enhancing effects of increasing productivity through year gains among the elderly workforce, which is notably high in OECD countries. Therefore, creating an efficient investment environment by means of incentives for private savings for the elderly workforce will remarkably promote long-run output growth in these countries. However, for low-income countries, the overall level of savings should be increased at each age to obtain sustained economic growth in the long run. The findings of the study further show that the simultaneous inclusion of both health and education measures leads to faster convergence rates due to the quick setting of diminishing returns in low-income countries with relatively low levels of health and educational human capital. Therefore, policymakers need to be aware that the ability of low-income countries to remain productive crucially depends on improvements in both the health and education status of the workforce. On the other hand, for OECD countries, the results of the study show that implementing health-enhancing policies seems to be more urgent. However, the results of the study further show that there is a need for future research in OECD countries to further understand the growth effects of health and educational human capital. Lastly, the results of the study contain further implications about the adverse impacts of the COVID-19 pandemic on the country's economies. The pandemic has caused the life expectancy at birth to fall, especially in OECD countries in 2020, with particularly large decreases in the United States (1.6 years) and Spain (1.5 years) (OECD, 2021: 80). Additionally, according to the WHO (2022), 53% of the excess deaths associated with COVID-19 among middle-income countries were concentrated in lower-middle-income countries, while high- and low-income countries accounted for 15% and 4% of the global excess deaths during the last two years. Additionally, according to the report of the OECD (2021), over 1.8 million excess deaths were recorded across OECD countries in 2020, compared to the average number of deaths experienced over the five previous years (OECD, 2021: 84). The findings of this study imply that poor health status of the workforce, through decreases in life expectancy and increases in adult mortality, incurs higher costs to a country in terms of reduced productivity, lower savings, and hence lower long-run output growth. Therefore, given the findings of this study, policymakers need to urgently take serious measures to enhance the health status of the existing workforce to counteract a possible future slowdown in productivity and economic growth among both OECD and low-income countries.

**APPENDIX A**

**Table A1: List of sample countries**

| **OECD Members (38)** | | **Low-Income Countries (58)** | |
|---|---|---|---|
| Australia | Republic of Korea | Algeria | Madagascar |
| Austria | Slovakia | Angola | Mali |
| Belgium | Slovenia | Bangladesh | Mauritania |
| Canada | Spain | Belize | Mongolia |
| Chile | Sweden | Benin | Morocco |
| Colombia | Switzerland | Bolivia | Mozambique |
| Costa Rica | Turkey | Burkina Faso | Myanmar |
| Czechia | United Kingdom | Burundi | Nepal |
| Denmark | United States | Cambodia | Nicaragua |
| Estonia | | Cameroon | Niger |
| Finland | | Central African Republic | Nigeria |
| France | | Congo | Pakistan |
| Germany | | Côte d'Ivoire | Philippines |
| Greece | | Democratic Republic of the Congo | Rwanda |
| Hungary | | Egypt | Senegal |
| Iceland | | El Salvador | Sierra Leone |
| Ireland | | Eswatini | Sri Lanka |
| Israel | | Ethiopia | Sudan |
| Italy | | Gambia | Syrian Arab Republic |
| Japan | | Ghana | Tajikistan |
| Latvia | | Haiti | Togo |
| Lithuania | | Honduras | Tunisia |
| Luxembourg | | India | Tanzania |
| Mexico | | Indonesia | Uganda |
| Netherlands | | Iran | Ukraine |
| New Zealand | | Kenya | Viet Nam |
| Norway | | Kyrgyzstan | Yemen |
| Poland | | Lao People's Democratic Republic | Zambia |
| Portugal | | Lesotho | Zimbabwe |

Notes: According to the World Bank country classification by income, OECD countries include 34 high-income countries that have a GNI per capita (calculated using the World Bank Atlas method) of $12,696 or more in 2020 and also four upper-middle-income countries, Colombia, Costa Rica, Mexico, and Turkey, which have a GNI per capita of $5,790, $11,530, $8,480, and $9,050, respectively, in 2020. Low-income countries include the countries that have a GNI per capita of $4,095 or less in 2020.

**Table A2: The results of PURTs[a]**

| PANEL A | OECD Sample | | | | |
|---|---|---|---|---|---|
| | ***LLC*** **Adjusted** $t^{*}$ | ***IPS*** $W-t$***-stat.*** | ***Fisher ADF*** | ***Pesaran[b] CADF*** $Z(t-bar)$ | ***Pesaran CIPS*** |
| **Log-Level** | | | | | |
| $\boldsymbol{GROP_{i,t}}$ | -31.137*** | -30.431*** | 815.676*** | -8.616*** | -3.393*** |
| $\boldsymbol{ROP_{i,t}}$ | -11.064*** | -2.216** | 138.648*** | 2.901 | -2.531 |
| $\boldsymbol{INVR_{i,t}}$ | -3.848*** | -7.946*** | 208.669*** | -1.924** | -2.701** |
| $\boldsymbol{AWGR_{i,t}}$ | -21.099*** | -19.716*** | 511.562*** | -5.170*** | -2.561 |
| $\boldsymbol{HC_{i,t}}$ | -7.997*** | -0.934 | 108.962*** | -4.479*** | -2.383 |
| **First Differences in Logs** | | | | | |
| $\boldsymbol{GROP_{i,t}}$ | -5.984*** | -36.445*** | 1103.380*** | -9.047*** | -3.646*** |
| $\boldsymbol{ROP_{i,t}}$ | -30.339*** | -30.006*** | 823.657*** | -8.442*** | -3.393*** |
| $\boldsymbol{INVR_{i,t}}$ | -33.890*** | -32.701*** | 925.711*** | -6.217*** | -2.881*** |
| $\boldsymbol{AWGR_{i,t}}$ | -15.766*** | -28.851*** | 795.455*** | -5.506**** | -3.439*** |
| $\boldsymbol{HC_{i,t}}$ | 1.678 | -2.950*** | 109.774*** | -4.599** | -2.625* |
| **PANEL B** | **Low-Income Sample** | | | | |
| **Log-Level** | | | | | |
| $\boldsymbol{GROP_{i,t}}$ | -34.492*** | -31.964*** | 1080.260*** | -7.488*** | -3.781*** |
| $\boldsymbol{ROP_{i,t}}$ | -1.786** | 0.032 | 136.382* | 1.234 | -2.767*** |
| $\boldsymbol{INVR_{i,t}}$ | -2.342*** | -4.554*** | 192.941*** | -1.339 * | -2.644** |
| $\boldsymbol{AWGR_{i,t}}$ | -6.945*** | -14.179*** | 499.457*** | -2.907*** | -2.048 |
| $\boldsymbol{HC_{i,t}}$ | -7.322*** | -1.110 | 181.895*** | 7.411 | -2.008 |
| **First Differences in Logs** | | | | | |
| $\boldsymbol{GROP_{i,t}}$ | -10.470*** | -41.600*** | 1496.180*** | -5.214*** | -4.610*** |
| $\boldsymbol{ROP_{i,t}}$ | -34.629*** | -31.836*** | 1076.960*** | -7.412 *** | -3.781*** |
| $\boldsymbol{INVR_{i,t}}$ | -40.680*** | -41.823*** | 1447.130*** | -3.747*** | -3.835*** |
| $\boldsymbol{AWGR_{i,t}}$ | -18.372*** | -38.475*** | 1409.040*** | -7.971*** | -3.619*** |
| $\boldsymbol{HC_{i,t}}$ | 3.931 | 2.237 | 68.127 | -4.288*** | -2.810*** |

Notes: The null hypothesis is the existence of a unit root for each test. An intercept and a linear time trend are included in each unit root test for each series, as all series exhibit an upward trend for all countries in the panel. The Akaike Information Criterion (AIC) is used to determine the optimal lag lengths in each test. ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively. For the series on health measures, the tests cannot be performed as the data were originally provided at five-year intervals.

[a] Considering the asymptotic properties of the sample series, three first-generation PURTs proposed by Levin, Lin, and Chu (LLC) (2002), Im, Pesaran, and Shin (IPS) (2003), and Maddala and Wu (MW) (1999), as well as a second-generation PURT suggested by Pesaran (2007), are employed to identify the stationarity properties of the annual series since no panel unit root test is free from some statistical shortcomings. The test proposed by LLC (2002) assumes that all panels have the same common autoregressive parameter for the lagged dependent variable, while MW (1999) and IPS (2003) relax this assumption of homogeneity by allowing for a more realistic assumption of heterogeneous autoregressive coefficients in the Dickey-Fuller (DF) regressions.

[b] On the other hand, the test proposed by Pesaran (2007) allows for the presence of cross-sectional dependence. The table above provides both the pooled version of the individual CADF statistics and their averages, known as the cross-sectionally augmented IPS (CIPS) statistic. Furthermore, to test for the presence of cross-sectional dependence (CD), the Breusch-Pagan (1980) Lagrange Multiplier (LM) test, the Pesaran (2004, 2021) CD and scaled LM tests, and the bias-corrected scaled LM test of Baltagi, Feng, and Kao (2012) are implemented in the study. The results show that the null hypothesis of no cross-sectional dependence is rejected in each case. Although the results are not reported to save space, they are available from the author upon request.

**REFERENCES**

Acemoglu, D. and Johnson, S. (2007). “Disease and Development: The Effect of Life Expectancy on Economic Growth”, *Journal of Political Economy*, 115/6, 925-985. https://doi.org/10.1086/529000

Ahn, S. C. and Schmidt, P. (1995). “Efficient Estimation of Models for Dynamic Panel Data”, *Journal of Econometrics*, 68/1, 5-27. https://doi.org/10.1016/0304-4076(94)01641-C

Ahn, S. C. and Schmidt, P. (1997). “Efficient Estimation of Dynamic Panel Data Models: Alternative Assumptions and Simplified Estimation”, *Journal of Econometrics*, 76/1-2, 309-321. https://doi.org/10.1016/0304-4076(95)01793-3

Ainsworth, M. and Over, M. (1994). “AIDS and African Development”, *The World Bank Research Observer*, 9/2, 203-240. https://doi.org/10.1093/wbro/9.2.203

Anderson, T. W. and Hsiao, C. (1981). “Estimation of Dynamic Models with Error Components”, *Journal of the American Statistical Association*, 76/375, 598-606. 10.1080/01621459.1981.10477691

Anderson, T. W. and Hsiao, C. (1982). “Formulation and Estimation of Dynamic Models Using Panel Data”, *Journal of Econometrics*, 18/1, 47-82. https://doi.org/10.1016/0304-4076(82)90095-1

Arellano, M. and Bover, O. (1995). “Another Look at the Instrumental Variable Estimation of Error-Components Models”, *Journal of Econometrics*, 68/1, 29-51. 10.1016/0304-4076(94)01642-D

Arellano, M. and S. Bond. (1991). “Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations”, *The Review of Economic Studies*, 58/2, 277-297. https://doi.org/10.2307/2297968

Arora, S. (2001). “Health, Human Productivity, and Long-Term Economic Growth”, *The Journal of Economic History*, 61/3, 699-749. http://www.jstor.org/stable/2698133

Arrow, K. J. (1962). “The Economic Implications of Learning by Doing”, *The Review of Economic Studies*, 29/3, 155-173. https://doi.org/10.2307/2295952

Baltagi, B. H. and Kao, C. (2001). "Nonstationary Panels, Cointegration in Panels and Dynamic Panels: A Survey", *Nonstationary Panels, Panel Cointegration, and Dynamic Panels* (Advances in Econometrics, 15) (Eds. B. H. Baltagi, T. B. Fomby, and R. Carter Hill), Emerald Group Publishing Limited, Bingley. https://doi.org/10.1016/S0731-9053(00)15002-9

Baltagi, B. H., Feng, Q., and Kao, C. (2012). “A Lagrange Multiplier Test for Cross-Sectional Dependence in a Fixed Effects Panel Data Model”, *Journal of Econometrics*, 170/1, 164-177. https://doi.org/10.1016/j.jeconom.2012.04.004

Bane, J. (2018). “Human Capital and Economic Growth in Developing Countries: Evidences from Low- and Middle-Income African Countries”, *Determinants of Economic Growth in Africa* (Ed. A. Heshmati), Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-76493-1_8

Barro, R. J. (1991). “Economic Growth in a Cross Section of Countries”, *The Quarterly Journal of Economics*, 106/2, 407-443. https://doi.org/10.2307/2937943

Barro, R. J. (1996). “Determinants of Economic Growth: A Cross-Country Empirical Study”, NBER Working Paper Series No. 5698. https://doi.org/10.3386/w5698

Barro, R. J. and Lee, J. W. (1993). “Losers and Winners in Economic Growth”, *The World Bank Economic Review*, 7/supplement 1, 267-298. https://doi.org/10.1093/wber/7.suppl_1.267

Barro, R. J. and Lee, J. W. (1994). “Sources of Economic Growth”, *Carnegie-Rochester Conference Series on Public Policy*, 40, North-Holland, 1-46. https://doi.org/10.1016/0167-2231(94)90002-7

Barro, R. J. and Sala-i-Martin, X. (1990). “Economic Growth and Convergence across the United States”, NBER Working Paper Series No 3419. https://doi.org/10.3386/w3419

Barro, R. J. and Sala-i-Martin, X. (1991). “Convergence across States and Regions”, *Brookings Papers on Economic Activity*, 22/1, 107-182. https://doi.org/10.2307/2534639

Barro, R. J. and Sala-i-Martin, X. (1992). “Convergence”, *Journal of Political Economy*, 100/2, 223-251. https://doi.org/10.1086/261816

Barro, R. J. and Sala-i-Martin, X. (2004). *Economic Growth*, 2nd Edition, MIT Press, Cambridge.

Baumol, W. J. and Wolff, E. N. (1988). “Productivity Growth, Convergence, and Welfare: Reply”, *American Economic Review*, 78/5, 1155-1159.

Becker, G. S. (1962). "Investment in Human Capital: A Theoretical Analysis", *Journal of Political Economy* (Part 2: Investment in Human Beings), 70/5, 9-49. https://doi.org/10.1086/258724

Becker, G. S. (2007). "Health As Human Capital: Synthesis and Extensions", *Oxford Economic Papers*, 59/3, 379-410. https://doi.org/10.1093/oep/gpm020

Behrman, J. R. (1996). "The Impact of Health and Nutrition on Education", *The World Bank Research Observer*, 11/1, 23-37. https://doi.org/10.1093/wbro/11.1.23

Benhabib, J. and Spiegel, M. M. (1994). "The Role of Human Capital in Economic Development Evidence from Aggregate Cross-Country Data", *Journal of Monetary Economics*, 34/2, 143-173. https://doi.org/10.1016/0304-3932(94)90047-7

Bhargava, A., Jamison, D. T., Lau, L. J., and Murray, C. J. L. (2001). "Modeling the Effects of Health on Economic Growth", *Journal of Health Economics*, 20/3, 423-440. https://doi.org/10.1016/S0167-6296(01)00073-X

Bleakley, H. (2010). "Health, Human Capital, and Development", *Annual Review of Economics*, 2, 283-310. https://doi.org/10.1146/annurev.economics.102308.124436

Bloom, D. E. and Canning, D. (2000). "The Health and Wealth of Nations", *Science*, 287/5456, 1207-1209. https://doi.org/10.1126/science.287.5456.1207

Bloom, D. E. and Williamson, J. G. (1998). "Demographic Transitions and Economic Miracles in Emerging Asia", *The World Bank Economic Review*, 12/3, 419-455. https://doi.org/10.1093/wber/12.3.419

Bloom, D. E., Canning, D. and Malaney, P. N. (1999). "Demographic Change and Economic Growth in Asia", *CID Working Paper Series 1999.15*, Harvard University, Cambridge, MA.

Bloom, D. E., Canning, D., and Fink, G. (2014). "Disease and Development Revisited", *Journal of Political Economy*, 122/6, 1355-1366. https://doi.org/10.1086/677189

Bloom, D. E., Canning, D., and Graham, B. (2003). "Longevity and Life-Cycle Savings", *Scandinavian Journal of Economics*, 105/3, 319-338. https://doi.org/10.3386/w8808

Bloom, D. E., Canning, D., and Sevilla, J. (2004). "The Effect of Health on Economic Growth: A Production Function Approach", *World Development*, 32/1, 1-13. https://doi.org/10.1016/j.worlddev.2003.07.002

Bloom, D. E., Canning, D., Kotschy, R., Prettner, K., and Schünemann, J. J. (2019). "Health and Economic Growth: Reconciling the Micro and Macro Evidence", NBER Working Paper Series No. w26003. https://doi.org/10.3386/w26003

Bloom, D. E., Sachs, J. D., Collier, P., and Udry, C. (1998). "Geography, Demography, and Economic Growth in Africa", *Brookings Papers on Economic Activity*, 1998/2, 207-295. https://doi.org/10.2307/2534695

Blundell, R. and S. Bond. (1998). "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models", *Journal of Econometrics*, 87/1, 115-143. https://doi.org/10.1016/S0304-4076(98)00009-8

Blundell, R. and S. Bond. (2000). "GMM Estimation with Persistent Panel Data: An Application to Production Functions", *Econometric Reviews*, 19/3, 321-340. https://doi.org/10.1080/07474930008800475

Blundell, R., S. Bond, and F. Windmeijer. (2001). "Estimation in Dynamic Panel Data Models: Improving on the Performance of the Standard GMM Estimator", *Nonstationary Panels, Panel Cointegration, and Dynamic Panels* (Advances in Econometrics, 15) (Eds. B. H. Baltagi, T. B. Fomby, and R. Carter Hill), Emerald Group Publishing Limited, Bingley. https://doi.org/10.1016/S0731-9053(00)15003-0

Bond, S. R. (2002). "Dynamic Panel Data Models: A Guide to Micro Data Methods and Practice", *Portuguese Economic Journal*, 1/2, 141-162. https://doi.org/10.1007/s10258-002-0009-9

Bond, S. R. and Windmeijer, F. (2002). "Finite Sample Inference for GMM Estimators in Linear Panel Data Models", CeMMAP Working Paper No. CWP04/02. http://dx.doi.org/10.2139/ssrn.311061

Bond, S. R., Hoeffler, A., and Temple, J. R. (2001). "GMM Estimation of Empirical Growth Models", CEPR Discussion Paper No. 3048.

Breusch, T. S., and Pagan, A. R. (1980). "The Lagrange Multiplier Test and Its Applications to Model Specification in Econometrics", *The Review of Economic Studies*, 47/1, 239-253. https://doi.org/10.2307/2297111

Bucci, A., Carbonari, L., and Trovato, G. (2019). "Health and Income: Theory and Evidence for OECD Countries", *Human Capital and Economic Growth,* (Eds. A. Bucci, K. Prettner, and A. Prskawetz), Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-21599-6_6

Bucci, A., Carbonari, L., Ranalli, M., and Trovato, G. (2021). "Health and Economic Development: Evidence from Non-OECD Countries", *Applied Economics*, 53/55, 6348-6375. https://doi.org/10.1080/00036846.2021.1939856

Caselli, F. (2005). "Accounting for Cross-Country Income Differences", *Handbook of Economic Growth* (Vol. 1A), (Eds. P. Aghion and S. Durlauf), Elsevier, North Holland. https://doi.org/10.1016/S1574-0684(05)01009-9

Caselli, F., Esquivel, G., and Lefort, F. (1996). "Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics", *Journal of Economic Growth*, 1/3, 363-389. https://doi.org/10.1007/BF00141044

Cervellati, M. and Sunde, U. (2011). "Life Expectancy and Economic Growth: The Role of The Demographic Transition", *Journal of Economic Growth*, 16/2, 99-133. https://doi.org/10.1007/s10887-011-9065-2

Chakraborty, S. (2004). "Endogenous Lifetime and Economic Growth", *Journal of Economic Theory*, 116/1, 119-137. https://doi.org/10.1016/j.jet.2003.07.005

De Long, J. B. (1988). "Productivity Growth, Convergence, and Welfare: Comment", *American Economic Review*, 78/5, 1138-1154.

Ding, S. and Knight, J. (2009). "Can the Augmented Solow Model Explain China's Remarkable Economic Growth? A Cross-Country Panel Data Analysis", *Journal of Comparative Economics*, 37/3, 432-452. https://doi.org/10.1016/j.jce.2009.04.006

Ding, S. and Knight, J. (2011). "Why Has China Grown So Fast? The Role of Physical and Human Capital Formation", *Oxford Bulletin of Economics and Statistics*, 73/2, 141-174. https://doi.org/10.1111/j.1468-0084.2010.00625.x

Durlauf, S. N., Johnson, P. A., and Temple, J. R. W. (2005). "Growth Econometrics", *Handbook of Economic Growth* (Vol. 1A), (Eds. P. Aghion and S. Durlauf), Elsevier, North Holland. https://doi.org/10.1016/S1574-0684(05)01008-7

Eberhardt, M. and Teal, F. (2011). "Econometrics for Grumblers: A New Look at the Literature on Cross-Country Growth Empirics", *Journal of Economic Surveys*, 25/1, 109-155. https://doi.org/10.1111/j.1467-6419.2010.00624.x

Erdil, E. and Yetkiner, I. H. (2009). "The Granger-Causality Between Health Care Expenditure and Output: A Panel Data Approach", *Applied Economics*, 41/4, 511-518. https://doi.org/10.1080/00036840601019083

Evans, P. and Karras, G. (1996). "Convergence Revisited", *Journal of Monetary Economics*, 37/2, 249-265. https://doi.org/10.1016/S0304-3932(96)90036-7

Feenstra, R. C., Inklaar, R., and Timmer, M. P. (2015). "The Next Generation of the Penn World Table", *American Economic Review*, 105/10, 3150-3182. https://doi.org/10.1257/aer.20130954

Gallup, J. L. and Sachs, J. D. (2000). "The Economic Burden of Malaria", CID Working Paper Series 2000.52, Harvard University, Cambridge, MA.

Gallup, J. L., Sachs, J. D., and Mellinger, A. D. (1999). "Geography and Economic Development", *International Regional Science Review*, 22/2, 179-232. https://doi.org/10.1177/016001799761012334

Geppert, C., Guillemette, Y., Morgavi, H., and Turner, D. (2019). "Labour Supply of Older People in Advanced Economies: The Impact of Changes to Statutory Retirement Ages", OECD Economics Department Working Papers No. 1554, OECD Publishing: Paris. https://doi.org/10.1787/b9f8d292-en

Granger, C. W. (1988). "Aggregation of Time Series Variables-A Survey", Institute for Empirical Macroeconomics Discussion Paper No. 1, Federal Reserve Bank of Minneapolis.

Granger, C. W. J. and Siklos, P. L. (1995). "Systematic Sampling, Temporal Aggregation, Seasonal Adjustment, and Cointegration Theory and Evidence", *Journal of Econometrics*, 66/1-2, 357-369. https://doi.org/10.1016/0304-4076(94)01622-7

Groot, W. and Van Den Brink, H. M. (2007). "The Health Effects of Education", *Economics of Education Review*, 26/2, 186-200. https://doi.org/10.1016/j.econedurev.2005.09.002

Grossman, M. (1972). *The Demand for Health: A Theoretical and Empirical Investigation*, Columbia University Press, New York. https://doi.org/10.7312/gros17900

Gyimah-Brempong, K. and Wilson, M. (2004). "Health Human Capital and Economic Growth in Sub-Saharan African and OECD Countries", *The Quarterly Review of Economics and Finance*, 44/2, 296-320. https://doi.org/10.1016/j.qref.2003.07.002

Hamoudi, A. A. and Sachs, J. D. (1999). "Economic Consequences of Health Status: A Review of the Evidence", CID Working Paper Series 1999.30, Harvard University, Cambridge, MA.

Hansen, C. W. and Lønstrup, L. (2015). "The Rise in Life Expectancy and Economic Growth in the 20th Century", *The Economic Journal*, 125/584, 838-852. https://doi.org/10.1111/ecoj.12261

Hansen, L. P. (1982). "Large Sample Properties of Generalized Method of Moments Estimators", *Econometrica,* 50/4, 1029-1054. https://doi.org/10.2307/1912775

Hartwig, J. (2010). "Is Health Capital Formation Good for Long-Term Economic Growth? Panel Granger-Causality Evidence for OECD Countries", *Journal of Macroeconomics*, 32/1, 314-325. https://doi.org/10.1016/j.jmacro.2009.06.003

Heshmati, A. (2001). "On the Causality Between GDP and Health Care Expenditure in Augmented Solow Growth Model", SSE/EFI Working Paper Series in Economics and Finance No. 423, Stockholm School of Economics.

Hoeffler, A. E. (2002). "The Augmented Solow Model and the African Growth Debate", *Oxford Bulletin of Economics and Statistics*, 64/2, 135-158. https://doi.org/10.1111/1468-0084.00016

Howitt, P. (2005). "Health, Human Capital, and Economic Growth: A Schumpeterian Perspective", *Health and Economic Growth: Findings and Policy Implications*, (Eds. G. López-Casasnovas, B. Rivera, and L. Currais), MIT Press. https://doi.org/10.7551/mitpress/3451.003.0005

Hsiao, C. (2014). *Analysis of Panel Data*, 3rd Edition, Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139839327

ILOSTAT (2021a). Employment-to-population ratio by sex and age-ILO modelled estimates, November 2021. https://ilostat.ilo.org/data/#

ILOSTAT (2021b). Working-age population by sex and age-ILO modelled estimates, November 2021. https://ilostat.ilo.org/data/#

Im, K. S., Pesaran, M. H., and Shin, Y. (2003). "Testing for Unit Roots in Heterogeneous Panels", *Journal of Econometrics*, 115/1, 53-74. https://doi.org/10.1016/S0304-4076(03)00092-7

Islam, N. (1995). "Growth Empirics: A Panel Data Approach", *The Quarterly Journal of Economics*, 110/4, 1127-1170. https://doi.org/10.2307/2946651

Jamison, D. T., Lau, L. J., and Wang, J. (2005). "Health's Contribution to Economic Growth in an Environment of Partially Endogenous Technical Progress", *Health and Economic Growth: Findings and Policy Implications*, (Eds. G. López-Casasnovas, B. Rivera, and L. Currais), MIT Press. https://doi.org/10.7551/mitpress/3451.003.0007

Knight, M., Loayza, N., and Villanueva, D. (1993). "Testing the Neoclassical Theory of Economic Growth: A Panel Data Approach", *International Monetary Fund (Staff Papers)*, 40/3, 512-541. https://doi.org/10.2307/3867446

Knowles, S. and Owen, P. D. (1995). "Health Capital and Cross-Country Variation in Income Per Capita in the Mankiw-Romer-Weil Model", *Economics Letters*, 48/1, 99-106. https://doi.org/10.1016/0165-1765(94)00577-O

Knowles, S. and Owen, P. D. (1997). "Education and Health in an Effective Labour Empirical Growth Model", *The Economic Record*, 73/223, 314- 328. https://doi.org/10.1111/j.1475-4932.1997.tb01005.x

Lee, R., A. Mason, and T. Miller (2001). "Saving, Wealth, and Population", *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World*, (Eds. N. Birdsall, A. C. Kelley, and S. W. Sinding), Oxford University Press, Oxford.

Lee, R., Mason, A., and Miller, T. (2000). "Life Cycle Saving and the Demographic Transition: The Case of Taiwan", *Population and Development Review*, 26/Supplement: Population and Economic Change in East Asia, 194-219.

Levin, A., Lin, C. F., and Chu, C. S. J. (2002). "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties", *Journal of Econometrics*, 108/1, 1-24. https://doi.org/10.1016/S0304-4076(01)00098-7

Levine, R. and Renelt, D. (1992). "A Sensitivity Analysis of Cross-Country Growth Regressions", *American Economic Review*, 82/4, 942-963.

Levine, R., Loayza, N., and Beck, T. (2000). "Financial Intermediation and Growth: Causality and Causes", *Journal of Monetary Economics*, 46/1, 31-77. https://doi.org/10.1016/S0304-3932(00)00017-9

Lucas, R. E. (1988). “On the Mechanics of Economic Development”, *Journal of Monetary Economics*, 22/1, 3-42. https://doi.org/10.1016/0304-3932(88)90168-7

Maddala, G. S. and Wu, S. (1999). “A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test”, *Oxford Bulletin of Economics and Statistics*, 61/S1, 631-652. https://doi.org/10.1111/1468-0084.0610s1631

Madsen, J. B. (2018). “Health-Led Growth since 1800”, *Macroeconomic Dynamics*, 22/4, 961-1000. https://doi.org/10.1017/S1365100516000468

Mankiw, N. G., Romer, D., and Weil, D. N. (1992). “A Contribution to the Empirics of Economic Growth”, *The Quarterly Journal of Economics*, 107/2, 407-437. https://doi.org/10.2307/2118477

Mason, A. and Lee, R. (2006). “Reform and Support Systems for the Elderly in Developing Countries: Capturing the Second Demographic Dividend”, *Genus*, 62/2, 11-35.

Mátyás, L. and Sevestre, P. (2008). *The Econometrics of Panel Data: Fundamentals and Recent Developments in Theory and Practice*, 3rd Edition, Springer, Heidelberg. https://doi.org/10.1007/978-3-540-75892-1

Mayer, D. (2001a). “The Long-Term Impact of Health on Economic Growth in Latin America”, *World Development*, 29/6, 1025-1033. https://doi.org/10.1016/S0305-750X(01)00026-2

Mayer, D. (2001b). “The Long-Term Impact of Health on Economic Growth in Mexico, 1950-1995”, *Journal of International Development*, 13/1, 123-126. https://doi.org/10.1002/jid.764

McDonald, S. and Roberts, J. (2002). “Growth and Multiple Forms of Human Capital in an Augmented Solow Model: A Panel Data Investigation”, *Economics Letters*, 74/2, 271-276. https://doi.org/10.1016/S0165-1765(01)00539-0

Mushkin, S. J. (1962). “Health as an Investment”, *Journal of Political Economy*, 70/5, 129-157. https://doi.org/10.1086/258730

Muysken, J., Ziesemer, T. H. W., and Yetkiner, I. H. (1999). “Health, Labour Productivity and Growth”, Maastricht Economic Research Institute on Innovation and Technology (MERIT) Research Memoranda No. 028. https://doi.org/10.26481/umamer.1999028

Nickell, S. (1981). “Biases in Dynamic Models with Fixed Effects”, *Econometrica*, 49/6, 1417-1426 https://doi.org/10.2307/1911408

OECD (2019). *Working Better with Age, Ageing and Employment Policies*, OECD Publishing, Paris. https://doi.org/10.1787/c4d4f66a-en

OECD (2020). *Promoting an Age-Inclusive Workforce: Living, Learning and Earning Longer*, OECD Publishing, Paris. https://doi.org/10.1787/59752153-en

OECD (2021), *Health at a Glance 2021: OECD Indicators*, OECD Publishing, Paris. https://doi.org/10.1787/ae3016b9-en

OECD (2022). Employment Rate by Age Group (Indicator). (21.4.2022). https://doi.org/10.1787/084f32c7-en

Pesaran, M. H. (2004). “General Diagnostic Test for Cross Section Dependence in Panels”, IZA Discussion Paper No. 1240, https://docs.iza.org/dp1240.pdf

Pesaran, M. H. (2007). “A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence”, *Journal of Applied Econometrics*, 22/2, 265-312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2021). “General Diagnostic Tests for Cross-Sectional Dependence in Panels”, *Empirical Economics*, 60/1, 13-50. https://doi.org/10.1007/s00181-020-01875-7

Phillips, P. C. and Moon, H. R. (2000). “Nonstationary Panel Data Analysis: An Overview of Some Recent Developments”, *Econometric Reviews*, 19/3, 263-286. https://doi.org/10.1080/07474930008800473

Rebelo, S. (1991). “Long-Run Policy Analysis and Long-Run Growth”, *Journal of Political Economy*, 99/3, 500-521. https://doi.org/10.1086/261764

Rivera, B. and Currais, L. (1999a). “Income Variation and Health Expenditure: Evidence for OECD countries”, *Review of Development Economics*, 3/3, 258-267. https://doi.org/10.1111/1467-9361.00066

Rivera, B. and Currais, L. (1999b). “Economic Growth and Health: Direct Impact or Reverse Causation?”, *Applied Economic Letters*, 6/11, 761-764. https://doi.org/10.1080/135048599352367

Rivera, B. and Currais, L. (2003). “The Effect of Health Investment on Growth: A Causality Analysis”, *International Advances in Economic Research*, 9/4, 312-323. https://doi.org/10.1007/BF02296180

Romer, P. M. (1990). "Endogenous Technological Change", *Journal of Political Economy*, 98/5, 71-102. https://doi.org/10.1086/261725

Roodman, D. (2009). "How to Do xtabond2: An Introduction to Difference and System GMM in Stata", *Stata Journal*, 9/1, 86-136. https://doi.org/10.1177/1536867X0900900106

Sachs, J. D. and Warner, A. M. (1997). "Fundamental sources of long-run growth", Papers and Proceedings of the Hundred and Fourth Annual Meeting of the American Economic Association, *American Economic Review*, 87/2, 184-188.

Sala-i-Martin, X. (1996a). "Regional Cohesion: Evidence and Theories of Regional Growth and Convergence", *European Economic Review*, 40/6, 1325-1352. https://doi.org/10.1016/0014-2921(95)00029-1

Sala-i-Martin, X. (1996b). "The Classical Approach to Convergence Analysis", *The Economic Journal*, 106/437, 1019-1036. https://doi.org/10.2307/2235375

Schultz, T. W. (1960). "Capital Formation by Education", *Journal of Political Economy*, 68/6, 571-583. https://doi.org/10.1086/258393

Schultz, T. W. (1961). "Investment in Human Capital", *American Economic Review*, 51/1, 1-17.

Shastry, G. K. and Weil, D. N. (2003). "How much of cross-country income variation is explained by health?", *Journal of the European Economic Association*, 1/2-3, 387-396. https://doi.org/10.1162/154247603322391026

Soares, R. R. (2005). "Mortality Reductions, Educational Attainment, and Fertility Choice", *American Economic Review*, 95/3, 580-601. https://doi.org/10.1257/0002828054201486

Solow, R. M. (1956). "A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, 70/1, 65-94. https://doi.org/10.2307/1884513

Swan, T. W. (1956). "Economic Growth and Capital Accumulation", *Economic Record*, 32/2, 334-361. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x

Swift, R. (2011). "The Relationship between Health and GDP in OECD Countries in the Very Long Run", *Health Economics*, 20/3, 306-322. https://doi.org/10.1002/hec.1590

Temple, J. (1999). "The New Growth Evidence", *Journal of Economic Literature*, 37/1, 112-156. https://doi.org/10.1257/jel.37.1.112

Tompa, E. (2002). "The Impact of Health on Productivity: Empirical Evidence and Policy Implications", *The Review of Economic Performance and Social Progress*, 2/2012, 181-198.

United Nations, World Population Prospects (2019). Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/DataQuery/

Uzawa, H. (1965). "Optimum Technical Change in an Aggregative Model of Economic Growth", *International Economic Review*, 6/1, 18-31. https://doi.org/10.2307/2525621

Van Zon, A. and Muysken, J. (2001). "Health and Endogenous Growth", *Journal of Health Economics*, 20/2, 169-185. https://doi.org/10.1016/S0167-6296(00)00072-2

Van Zon, A. and Muysken, J. (2003). "Health as a Principal Determinant of Economic Growth", Maastricht Economic Research Institute on Innovation and Technology (MERIT), Infonomics Research Memorandum Series No. 021. https://doi.org/10.26481/umamer.2003021

Webber, D. J. (2002). "Policies to Stimulate Growth: Should We Invest in Health or Education?", *Applied Economics*, 34/13, 1633-1643, https://doi.org/10.1080/00036840110115109

Weil, D. N. (2007). "Accounting for the Effect of Health on Economic Growth", *Quarterly Journal of Economics*, 122/3, 1265-1306. https://doi.org/10.1162/qjec.122.3.1265

Weil, D. N. (2014). "Health and Economic Growth", *Handbook of Economic Growth* (Vol. 2), (Eds. P. Aghion and S. Durlauf), Elsevier, North Holland. https://doi.org/10.1016/B978-0-444-53540-5.00003-3

WHO (2022, 5 May). "14.9 million excess deaths associated with the COVID-19 pandemic in 2020 and 2021", News Release. (Accessed on 21 May 2022). https://www.who.int/news/item/05-05-2022-14.9-million-excess-deaths-were-associated-with-the-covid-19-pandemic-in-2020-and-2021

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