PROGRAM ON THE GLOBAL DEMOGRAPHY OF AGING AT HARVARD UNIVERSITY

Working Paper Series

Health and Economic Growth

David E. Bloom, Michael Kuhn, and Klaus Prettner

February 2018

PGDA Working Paper No. 153
http://www.hsph.harvard.edu/pgda/working/

Research reported in this publication was supported by the National Institute on Aging of the National Institutes of Health under Award Number P30AG024409. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Summary

The positive cross-country correlation between health and economic growth is well-established, but the underlying mechanisms are complex and difficult to discern. Three issues are of central concern. First, assessing and disentangling causality between health and economic growth is empirically challenging. Second, the relation between health and economic growth changes over the process of economic development. Third, different dimensions of health (mortality vs. morbidity, children's and women's health, and health at older ages) may have different economic effects.

Keywords

longevity, health, productivity, poverty traps, economic development, economic well-being, living standards, neoclassical and R&D-based growth

Introduction

At the beginning of the 20th century, average global life expectancy at birth was well below 40 years and real per capita gross domestic product (GDP) was less than a sixth of its current value. The economics literature has thoroughly described many of the main forces driving economic growth over this time span (such as technological progress, education, and physical capital accumulation). Likewise, the roles of medical care, individual behaviors, and the environment in influencing health are well understood. However, understanding of the interrelations between health and economic growth remains somewhat limited. The multitude of economic and social pathways through which health affects economic growth and the reverse causal channel by which economic prosperity promotes better health complicate the description of this relationship. In addition, forces such as technological progress and institutional improvements promote both population health and economic growth. All of these aspects pose challenges to tractable theoretical modeling and empirical identification.

The data clearly reveal a strong positive correlation between health and GDP. Countries with better health status tend to have higher incomes than countries with worse health status, a relationship known as the "Preston curve" (see Preston, 1975). Figure 1 shows the Preston curve for all countries for which data on life expectancy at birth (vertical axis) and on real per capita GDP in 2010 US dollars (horizontal axis) were available for 2015 (red points) and 1960 (blue points). The figure shows that health and income are positively correlated across countries in both years and that both life expectancy and income increased between 1960 and 2015. As far as the convergence between poorer and richer countries is concerned, convergence in life expectancy at birth has progressed faster than has per capita GDP (Becker, Philipson, & Soares, 2005; Deaton, 2013; Weil, 2014).

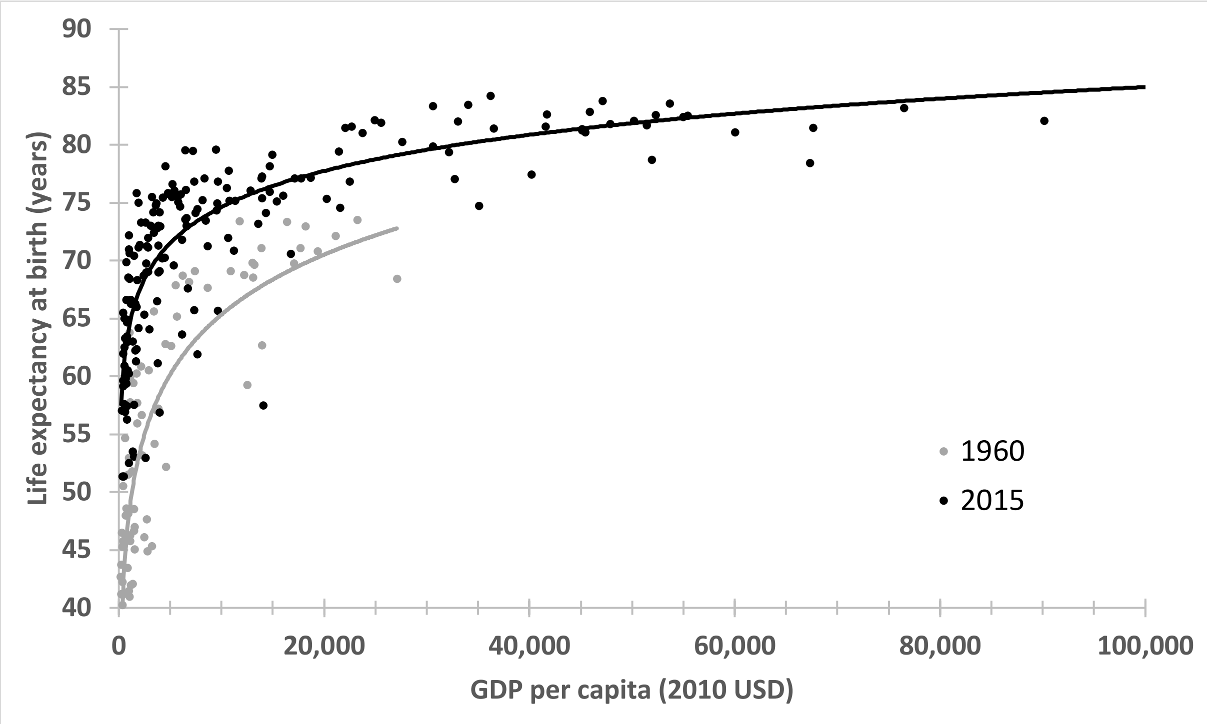

Figure 1. Preston curves for 1960 and 2015. Source: World Bank, 2017.

At least three problems arise in assessing the consequences of health improvements (however measured) for economic growth. First, the nature of the relationship between health and economic growth is unclear, both because of bidirectional causality between these two variables and confounding factors. A growing body of literature seeks to pin down at least partial causal channels: for example, Pritchett and Summers (1996), Bloom and Canning (2000), Bloom, Canning, and Sevilla (2003), and Bloom and Fink (2014) focus on the channel that runs from health to income and growth, while Cutler, Lleras-Muney, and Deaton (2006) and Hall and Jones (2007) describe the reverse channel. Substantial complementarity between health and education further complicates this task (e.g., Becker, 2007), with education exhibiting the same two-way causality in its association with income. This issue is illustrated by Lutz and Kebede (2018), who show that the Preston curve is well explained by education. Further, as Deaton (2013) and Weil (2015) argue, other factors, such as technological progress and increases in institutional quality, which tend to raise per capita incomes and lead to improvements in health, may ultimately drive the health-growth nexus. As far as the statistical analyses are concerned, disentangling these causal channels and quantifying their relative importance is extremely difficult. Most variables suggested as instruments for health in macroeconomic data are unlikely to truly fulfill the exclusion restriction (Bazzi & Clemens, 2013).

Second, the relationship between health and economic growth varies depending on the dimension of health examined (e.g., morbidity vs. mortality) and the affected individual's age, gender, and socioeconomic status. Morbidity reductions translate into a greater labor supply (e.g., Garthwaite,

2012) and raise the productivity of educational investments (e.g., Bleakley, 2007, 2010). Mortality reductions also translate into greater labor supply—predominantly in developing countries—but also encourage greater saving (e.g., Bloom, Canning, & Graham, 2003) and investment in physical capital and raise the return to educational investments (e.g., Boucekkine, de la Croix, & Licandro, 2002). Regarding the affected population, interventions that improve children's and women's health tend to have additional and stronger effects than investments in the health of men and the elderly (Baldanzi, Bucci, & Prettner, 2017; Bloom, Kuhn, & Prettner, 2015; Field, Robles, & Torero, 2009; Miguel & Kremer, 2004). Childhood health interventions have strong positive effects throughout these children's adult lives and positively affect their ability to learn (Bleakley, 2007, 2010; Miguel & Kremer, 2004). Investments in women's health, in turn, tend to have strong intergenerational spillover effects on their children's health (Bhalotra & Rawlings, 2011; Field et al., 2009), and they encourage fertility reductions that spur economic development in high-fertility countries.

Third, a crucial difference exists between the economic effects of health interventions in less developed countries and in developed countries (see Bhargava, Jamison, Lau, & Murray, 2001). Even low-intensity health interventions can have strong positive effects on the working-age population's health in less developed countries where health status is low to begin with (Field et al., 2009; Luca et al., 2018). By contrast, highly developed countries might face the problem of "flat-of-the-curve medicine," with even high-intensity treatments having little impact on the population's health status (Fuchs, 2004). Whatever health improvements do occur mostly accrue to the less economically active population (Poterba & Summer, 1987). Finally, Cervellati and Sunde (2011, 2015a) show that longevity improvements stimulate educational investments and economic growth only if a country has already undergone the demographic transition from high to low rates of fertility and mortality.

The following sections discuss the implications of these nuances, focusing on recent theoretical and empirical literature on the relationship between health and economic growth, without judging the relative strength of the utilitarian and instrumental contributions of health to individual and collective well-being (see Hall & Jones, 2007; Jones, 2016; Jones & Klenow, 2016; Kuhn & Prettner, 2016; Weil, 2014).

Empirical Evidence on the Relationship between Health and Economic Growth

Perhaps surprisingly, few attempts were made to econometrically quantify health's impact on the level and growth of GDP prior to Barro and co-authors' work in the 1990s, which aimed to identify the determinants of long-run economic growth, including longevity (e.g., Barro, 1996; Barro & Lee, 1994; Barro & Sala-i-Martin, 1995). Following in this vein were several studies (e.g., Bloom, Canning, & Sevilla, 2004; Lorentzen, McMillan, & Wacziarg, 2008; Zhang & Zhang, 2005) identifying longevity's positive impact on various measures of GDP and GDP growth, although some studies (e.g., Bhargava et al., 2001) reveal a hump-shaped relationship. Zhang and Zhang (2005) show that an increase in schooling and a decline in fertility accompany life expectancy's positive impact on economic growth, with all effects being subject to decreasing returns. While most of the earlier studies do not address identification issues explicitly, Bhargava et al. (2001) rely on a method developed by Bhargava (1991) that is based on identifying restrictions across time periods, and Bloom, Canning, and Sevilla (2004) use lagged levels and lagged differences as instruments. Lorentzen et al. (2008) arguably employ the strongest identification strategy, relying on malaria ecology, climatic factors, and geographic features as instruments for mortality. They show that reducing adult mortality leads to less risky behavior, lower fertility, greater investments in physical capital, and ultimately increased economic growth.

Shastry and Weil (2003) and Weil (2007) employ an innovative way of identifying the causal effect of health on productivity at the aggregate level. Their method is based on development accounting techniques and follows a two-step procedure. In the first step, the effects of certain health conditions (e.g., anemia) or proxies for health (e.g., height and age at menarche) on individual productivity are obtained from micro-econometric analyses and from randomized controlled trials. These coefficients, which can be estimated rather precisely due to the large number of observations, are then used to infer the macroeconomic effects of health according to the implications of a standard economic production function that accounts for human capital. Because the microeconomic estimates are much less prone to reverse causality issues, Shastry and Weil (2003) and Weil (2007) establish a positive causal effect of health on aggregate labor productivity and therefore on aggregate income. The magnitude of the direct productivity effect of health differences across countries ranges from 10% of all cross-country differences in aggregate income (Weil, 2007) to about one-third (Shastry & Weil, 2003).[1]

By contrast, Acemoglu and Johnson (2007) challenge the view that health causes economic growth. They instrument health by relying on the worldwide epidemiological transition after 1940. Global health interventions and the worldwide introduction of new drugs reduced mortality in almost all countries, irrespective of economic background. Therefore, Acemoglu and Johnson (2007) argue that their instrument fulfills the exclusion restriction. Contrary to the earlier literature's conclusions, they find that health improvements have a negative causal effect on economic growth. Acemoglu and Johnson (2007) explain their findings using a neoclassical growth model in which fertility remains constant as mortality falls and, as a result, the population growth rate increases. The associated capital dilution effect reduces incomes at the steady state, as is well known from Solow (1956).

However, the Acemoglu and Johnson (2007) methodology has been challenged for regressing economic growth on health improvements without including initial health in the model. As such, their finding of a negative correlation between health improvements and economic growth may arise simply because countries that start with better population health grow faster, while experiencing smaller improvements in health than countries with a lower initial health status (see Becker et al., 2005). To address this point, Aghion, Howitt, and Murtin (2011) and Bloom, Canning, and Fink (2014) include initial health in the Acemoglu and Johnson (2007) regressions and find that the negative causal effect vanishes.

The theory underpinning Aghion et al. (2011) and Bloom, Canning, and Fink (2014) assumes decreasing returns to health investments at the macro level. This is consistent with Bhargava et al.'s (2001) finding that an initially positive relationship between adult survival rates and GDP growth reverses into a negative one at high levels of longevity. Indeed, the intuitive expectation is that within countries with high standards of living, large and technically well-equipped health-care systems, and widespread access to (public) health care, further longevity improvements can only be achieved at a resource cost that is so high as to stifle economic performance. Furthermore, declining mortality in these countries disproportionately benefits the older part of the population beyond their retirement age such that the positive economic effects are bound to be lower. Yet, other results from the empirical literature seemingly contradict this theory. Controlling for initial health, Hansen (2014) finds no significant effect of the change or level of longevity on GDP per capita for US states. Furthermore, Hansen and Lönstrup (2015) show that when implementing a three-point panel (with international data from 1900, 1940, and 1980) and controlling for initial health and country fixed effects, increased longevity appears to have a negative influence on GDP per capita.

Cervellati and Sunde (2011) clarify these seemingly contradictory findings by considering the demographic transition in their analyses. Splitting Acemoglu and Johnson's (2007) sample into pre-transition and post-transition countries, Cervellati and Sunde (2011) apply the same methodology and instrument to show that rising life expectancy has a negative but insignificant effect on per capita income in the pre-transition sample but a significantly positive effect in the post-transition sample. In a follow-up paper, Cervellati and Sunde (2015a) show that this is due to the differential impact of longevity on fertility and education decisions across these settings. In pre-transition economies, greater longevity is not associated with greater educational attainment or a reduction in the birth rate. As such, increased survival rates translate into a higher net rate of reproduction. In post-transition economies, greater longevity is associated with increases in various measures of education and consequently reductions in fertility. The Hansen and Lönstrup (2015) results support this theory. They find that the positive relationship between longevity improvements and growth in GDP per capita in post-demographic transition countries remains when considering a three-point panel with country fixed effects. Results from Hansen (2012) and Desbordes (2011) also support a U-shaped relationship between GDP per capita and life expectancy. These findings taken together with those of Bhargava et al. (2001) suggest that health improvements may be detrimental to economic growth in pre-demographic transition societies and beneficial in post-demographic transition societies until very high levels of longevity are reached, at which point the effect becomes negative once again. Further empirical research is needed to test the existence of this trough-then-peak relationship.[2]

The relationship between health and economic growth is further nuanced by distinguishing the influence of specific diseases on GDP per capita from that of aggregate measures of health (such as life expectancy). Indeed, evidence exists that even within developed economies, progress against particular sources of mortality or morbidity may foster better economic performance. Estimation of the parameters of dynamic panel data models using the generalized method of moments (GMM) and employing lagged levels and lagged differences as instruments for current cardiovascular mortality at working age, Suhrcke and Urban (2010) find a negative causal effect of cardiovascular diseases on subsequent economic growth in high-income countries for 1960–2000. Hyclak, Skeels, and Taylor (2016) confirm this same relationship in a subsequent time span, 2000–2012. They also show that across the Organisation for Economic Co-operation and Development (OECD) countries studied, the correlation between cardiovascular mortality and income per capita arises because of Eastern European countries. Again, this aligns with the concept of decreasing returns to health improvements: gains from the cardiac revolution have been mostly exhausted within Western countries and only accrue to countries lagging behind in terms of health and income. China and India, for example, are in favorable economic and demographic positions to reap macroeconomic benefits from health improvements. Bloom, Cafiero-Fonseca, et al. (2014) project that over an 18-year period, five categories of noncommunicable diseases[3] will together reduce labor supply and capital accumulation in China and India enough to result in $27.6 trillion of lost output. Finally, Garthwaite (2012) shows that restricted access to innovative pharmaceutical pain relief has led to a reduction in US labor supply. While these studies indicate significant positive macroeconomic effects of health and health care within specific disease domains, they also suggest that considerable amounts of health-care spending may not be conducive to economic growth. This may be a consequence of less effective treatments (Chandra & Skinner, 2012), inefficiencies in the health-care system (Cutler & Ly, 2011), or the fact that health-care spending is targeted at groups with little potential for productivity gains (e.g., retired adults).

This section concludes with two general observations. First, many studies seeking to establish a causal impact of health on economic growth suffer from a lack of compelling identification. Second, the estimated impacts vary considerably in magnitude and are difficult to compare, reflecting large variations in measurements, econometric methods, and context. Summarizing the findings is therefore difficult, barring the insight that the bulk of research identifies a positive, if often weak, causal link. This is not surprising given the multitude of pathways within the health–income nexus and the relevance of joint drivers, such as institutions. In light of these uncertainties, directing future research toward understanding the role played by health—among many other factors—in the process of economic development would be most useful.

The Channels by Which Health Affects Economic Growth in Less Developed Countries

This section describes how health affects economic growth in less developed countries. The main channel in this context is the demographic transition and thereby the timing of the takeoff from Malthusian stagnation toward sustained long-run economic growth. This section's main focus is therefore on how health investments affect the possibility of escaping from a poverty trap sustained (or at least reinforced) by poor health.

Galor and Weil (2000) were the first to provide an endogenous explanation of the takeoff from Malthusian stagnation toward sustained long-run economic growth. This work pioneered the so-called unified growth theory (see also Galor, 2005, 2011), which explains the growth process over centuries and provides an endogenous explanation for the Industrial Revolution. The unified growth theory explains "the big divergence" between well-developed and less developed economies as a consequence of variation in the timing of the takeoff toward sustained long-run growth. In some countries, the takeoff occurred earlier because they had a head start in some underlying latent variable. As Cervellati and Sunde (2015b) show in a systematic quantitative analysis of a prototype unified growth model, differentials in extrinsic mortality are, indeed, one good candidate for explaining differences in economic takeoff.

When people live longer on average, human capital investments become more likely to pay off because the working life is longer (Ben-Porath, 1967; Cervellati & Sunde, 2013). This implies an increase in the return to human capital investments, whether an individual's human capital or that of his or her children. De la Croix and Licandro (1999), Kalemli-Ozcan, Ryder, and Weil (2000), and Boucekkine et al. (2002, 2003) consider models in which mortality decline triggers greater investments in individual human capital and an increase in economic growth. Chakraborty (2004) extends these works, allowing for longevity to be shaped endogenously by public health investments. Cervellati and Sunde (2005) and Soares (2005) consider models in which a mortality decline encourages parents to have fewer children and to educate those children better, thereby initiating an economic-demographic transition.

Bloom et al. (2015) show that women's health plays a particularly important role in this context. Healthier women are more likely to participate in the formal labor market, and thus they face higher opportunity costs of having children. As a result, investments in women's health lead to a substitution away from having many children toward having fewer, better-educated children. This helps to initiate a transition from stagnation to growth even absent of the Ben-Porath (1967) mechanism.

Ultimately, all these mechanisms revolve around the complementarity among longevity, health, and education, for which ample empirical evidence exists. Jayachandran and Lleras-Muney (2009) directly test one pathway by showing that increases in female adult survival rates lead to differential increases in the education of girls as opposed to boys. Fortson (2011) shows that African regions exposed to higher levels of human immunodeficiency virus (HIV) exhibit lower educational attainment. Oster, Shoulson, and Dorsey (2013) provide micro-level evidence that individuals who learn about their predisposition to Huntington's disease reduce their human capital investment relative to those who remain unaware. Finally, exploiting data from the cardiovascular revolution in the United States, Hansen and Strulik (2017) demonstrate that the Ben-Porath mechanism is operative even for post-retirement increases in life expectancy.

While these studies point to longevity's positive impact on incentives to invest in education, studies by Miguel and Kremer (2004), Bleakley (2007), and Croke, Hicks, Hsu, Kremer, and Miguel (2016) on the eradication of hookworms, by Field et al. (2009) on iodine deficiency, and by Bleakley (2010) and Lucas (2010) on the eradication of malaria all point to a health-related increase in the productivity of education, as Bleakley (2011) forcefully argues. Bleakley and Lange (2009) go on to show that the educational expansion that came with hookworm eradication in the American South was accompanied by declining fertility. Aksan and Chakraborty (2014) highlight the crucial role of morbidity as opposed to mortality, asking why Africa's reduced child mortality has not led to a sustained fertility decline, as was the case in many other countries. As they show, Africa's child mortality was curbed predominantly through medical treatment campaigns rather than through the eradication or prevention of infectious diseases. Even successful treatment would typically leave some physiological limitations through infection-related morbidity. The resulting productivity reduction would then stifle the incentive to invest in education and encourage higher fertility.

The takeoff toward sustained economic growth as described in the unified growth theory is reinforced by the "demographic dividend" (Ashraf, Weil, & Wilde, 2013; Bloom and Freeman, 1988; Bloom & Williamson, 1998; Bloom, Canning, & Sevilla, 2003; Bloom, Kuhn, & Prettner, 2017; Mason, Lee, & Jiang, 2016). As fertility begins to decrease, the overall dependency ratio (youth dependency ratio plus old-age dependency ratio) also drops, which frees resources to be invested in further health improvements, education, and infrastructure. These investments, in turn, foster economic development and hasten the transition toward sustained long-run growth.

Highlighting the role of infectious diseases, which continue to plague many developing countries, is important. Lagerlöf (2003) and Chakraborty, Papageorgiou, and Perez-Sebastian (2010, 2016) provide models that show how recurring epidemics can trap economies in a Malthusian state with high fertility and mortality rates and high volatility of health and survival. With income growth alone unable to push the economy out of the development trap (Chakraborty et al., 2010), the initiation of an epidemiological-economic transition may require a period without major epidemic shocks sufficiently long to allow the population to build up protective human capital (Lagerlöf, 2003).

Of particular concern for sub-Saharan Africa is the high prevalence of HIV/AIDS. Young (2005) argues that, paradoxically, HIV may foster long-run growth by severely curtailing the short-run supply of labor. The resulting boost to wages would increase the opportunity cost of childbearing and thereby trigger a fertility decline and a concomitant increase in child investments. However, recent evidence indicates that such a fertility drop has not materialized (see Fortson, 2009; Juhn, Kalemli-Ozcan, &

Tsuan, 2013; Kalemli-Ozcan, 2012). Azomahou, Boucekkine, and Diene (2016) rather suggest that a modest growth drag, arising from the short-run labor supply reduction, may be followed by a more severe drag due to the drop in human capital investments that come with reduced life expectancy (see Fortson, 2011). Indeed, the HIV tragedy seems to expose the downside of complementarities. In such a case, strong policy interventions aimed at improving both health and education are called for. Bell and Gersbach (2009) study how best to target policy with these objectives when facing resource constraints.

The Channels by Which Health Affects Economic Growth in Developed Countries

Despite some remaining controversy, health improvements are perceived to be an important component of economic development in general and of the takeoff to sustained economic growth in particular. Much more skepticism surrounds the role of health as a driver of economic growth in developed economies. Indeed, many view the high costs of advanced health-care systems as having the potential to deter growth. The debate centers on two main concerns. First, given that longevity improvements in developed countries are concentrated among the elderly (see Breyer, Costa-Font, & Felder, 2010; Eggleston & Fuchs, 2012), further expansions of longevity may lower the economic support ratio (i.e., the ratio of effective labor supply to the dependent population) and thereby lead to a decline in per capita consumption levels. A related concern is that productivity gains insufficiently offset the elderly's high medical costs, which therefore impose a drag on economic growth. Second, with health expenditure shares in many OECD countries approaching or past the 10% mark (OECD, 2017), the absorption of productive resources by "oversized" health-care sectors is feared to compromise economic performance (as debated in Pauly & Saxena, 2012). Particular concerns relate to health insurance as a source of inefficiency and to medical progress as a key cost driver (Chandra & Skinner, 2012).

This section begins by describing how health affects human capital accumulation, overall investment, and R&D-based economic growth in developed countries. The literature, which mostly treats health and longevity improvements as exogenous, also sheds light on whether aging stifles economic growth. Blanchard (1985) undertook the first attempts to model the effects of an increase in life expectancy on economic performance in developed economies, replacing the representative agent assumption of a standard neoclassical growth model with an overlapping generations structure in which individuals face a constant risk of death. An increase in life expectancy raises aggregate savings in this setting and therefore, according to the mechanisms in the neoclassical growth model, raises the economy's growth rate during the transition to the steady state.[4] However, life expectancy itself has no effect on the long-run growth rate at the steady state.[5]

Subsequently, endogenous growth models based on learning-by-doing spillovers (Romer, 1986) replaced the underlying neoclassical framework. Articles utilizing this framework include Reinhart (1999), Heijdra and Mierau (2011), and Mierau and Turnovsky (2014b).[6] The baseline conclusion from this literature is that increasing life expectancy positively affects long-run economic growth: aggregate savings rise with longevity and aggregate returns to capital accumulation are nondiminishing due to knowledge spillovers. Consequently, capital accumulation alone can sustain economic growth. While this effect is derived analytically for age-independent mortality, it can only be illustrated numerically in case of age-dependent mortality.

The argument presented so far refers to the impact of mortality reductions on capital accumulation as a supply-side driver of economic growth. By contrast, Kuhn and Prettner (2018) explore mortality reductions' impact on consumption growth as a demand-side driver. In overlapping generations economies, a reduction in the average death rate leads to greater consumption growth if the average consumption of those who die exceeds per capita consumption across the population (Kuhn & Prettner, 2018). This condition is typically satisfied if consumption increases with age up to age groups that exhibit significant mortality. Kuhn and Prettner (2018) employ data from the National Transfer Accounts to show that this holds for countries such as Finland, Germany, Japan, and the United States.

Models of learning-by-doing spillovers or human capital accumulation as exclusive drivers of long-run growth do not leave room for technological progress to explain economic growth. Prettner (2013) introduces an overlapping generations structure with age-independent mortality into the research and development (R&D)-driven (semi-)endogenous growth models pioneered by Romer (1990) and Jones (1995). Prettner shows that increasing life expectancy has an unambiguously positive effect on technological progress and on long-run economic growth in the cases of both endogenous and semi-endogenous growth. The central mechanism is that increasing life expectancy results in higher aggregate savings, which puts downward pressure on the equilibrium interest rate. This in turn raises the discounted stream of income derived by investing in successful R&D projects. Consequently, the incentive to carry out R&D increases, which boosts technological progress and long-run economic growth.

In another strand of the R&D-based growth literature, Strulik, Prettner, and Prskawetz (2013) show that the aggregate human capital stock, rather than the size of the workforce allocated to R&D, is what matters for long-run economic growth. In older models of this type, lower fertility always implies a lower growth rate of the economy. However, Strulik et al. (2013) show that increased schooling investments accompany lower fertility through the quality-quantity substitution at the household level (see Becker & Lewis, 1973). This effect tends to be strong enough to overturn falling fertility's negative effect on aggregate human capital accumulation such that economic growth rises as fertility falls. Drawing from Bloom and Canning (2005), Prettner, Bloom, and Strulik (2013) show that the human capital dimension in Strulik et al.'s (2013) model consists of both education and the stock of health. Baldanzi et al. (2017) use this insight to construct a fully-fledged dynamic general equilibrium growth model in which parental investments endogenously determine health and education. The complementarity between health and education is crucial to raise the human capital level and therefore the central input into the R&D sector. Consequently, long-run economic growth rises with health investments.

Another important aspect is the impact of health as transmitted through changes in labor supply. Indeed, evidence is mounting that the life years gained with greater longevity are increasingly spent in good health (e.g., Sanderson & Scherbov, 2010), implying that, in principle, working lives can be extended so as to avoid an increase in old-age dependency (e.g., Loichinger & Weber, 2016).[7] The extent to which increases in healthy life span translate into the elderly's higher labor force participation varies strongly across countries, depending on the retirement incentives from the pension scheme, among other factors (Milligan & Wise, 2015). The relationship also varies substantially across subpopulations (Dudel & Myrskylä, 2017).

Theoretical models reflect the mixed empirical evidence: While Prettner and Canning (2014) and Chen and Lau (2016) show that an increase in longevity should lead to an increase in labor supply and savings, caveats arise in the presence of social security and in economies where knowledge spillovers (Romer, 1986) or R&D (Romer, 1990) drive economic growth.[8] Considering the role of a pay-as-you-go pension scheme within a Romer (1986) economy, Heijdra and Mierau (2011) show that declining mortality promotes economic growth due to a sufficient saving response. But this effect is muted under a defined benefits – as opposed to a defined contributions - pension scheme. Surprisingly, the growth-promoting effects are also dampened if the retirement age is raised, due to a reduction in retirement savings (and, thus, capital accumulation) in response to an extended working life. A similar effect is present in Kuhn and Prettner (2016), who consider a Romer (1990) economy: if health improvements lead to a decline in morbidity that dominates the decline in mortality, then labor participation is boosted and retirement savings are reduced. The resulting increase in the interest rate dampens R&D activity and economic growth. While certainly welcome on many grounds, health-related increases in the working life play a surprisingly ambiguous role for economic growth.

The models reviewed so far help allay some of the concerns that aging, in the sense of rising longevity, may undermine economic growth. However, a second important policy concern is that oversized health-care sectors and medical progress may place an undue burden on economic growth.

Kuhn and Prettner (2016) introduce an explicit health-care sector into an overlapping generations version of Romer's (1990) R&D-based growth model. The health-care sector employs labor to raise the population's health level along three dimensions: longer life expectancy, higher worker productivity, and later exit from the labor market. Because providing health care absorbs labor from the production and R&D sectors, and due to diminishing returns of health care in lowering mortality, an interior size of the health-care sector exists that maximizes long-run economic growth.[9] Kuhn and Prettner (2016) show that an increase in the size of the health-care sector beyond its growth-maximizing level constitutes a Pareto improvement that makes all generations, young and old, better off. This result is consistent with rational individuals being willing to spend an increasing fraction of a growing income on health care such that economic development goes hand in hand with an increasing share of the health-care sector in the aggregate economy (Hall & Jones, 2007).

Schneider and Winkler (2016) and Frankovic, Kuhn, and Wrzaczek (2017) study the impact of medical innovations on macroeconomic performance. Comparing balanced growth paths for a Romer (1986) economy, Schneider and Winkler (2016) show that a life-saving technology enhances economic growth as long as the absorption of additional labor into the health-care sector does not lead to reduced spillovers in the production sector. Frankovic et al. (2017) study the impact of life-saving medical innovations within a calibrated overlapping generations model of the US economy.[10] By rendering health care more effective in lowering mortality, especially among the elderly population, medical innovations increase the demand for health care and, thereby, lead to an expansion of the health-care sector (as evidenced, e.g., in Cutler & Huckman, 2003; Roham, Gabrielyan, Archer, Grignon, & Spencer, 2014; Wong, Wouterse, Slobbe, Boshuizen, & Polder, 2012). However, for the following reasons this does not lower per capita GDP at the general equilibrium: the longevity increase that comes with more effective health care and the prospect of purchasing such care in the future trigger a strong increase in saving (as evidenced, e.g., in Bloom, Canning, & Graham, 2003; De Nardi, French, & Jones, 2010). The resulting expansion of the capital stock overcompensates for the decline in the economic support ratio that comes with most survival gains accruing after retirement. Moreover, the sectoral shift toward the relatively labor-intensive production of health care, combined with increasing wages, induces price inflation in the health-care sector. This general equilibrium effect strongly dampens the initial increase in the demand for health care.

While the literature discussed so far treats medical innovations as exogenous, medical R&D is highly resource intensive. Jones (2016) shows that the historic increase in the GDP share of US health care mirrors a similarly drastic increase in the medical R&D share. Considering a model with two rivalrous R&D sectors, one traditional and one "life-saving," Jones (2016) shows that the demand for life-saving innovations may crowd out traditional R&D and lead to a drag on growth. He also shows that such a development may be optimal as long as consumption growth is not reversed. While Jones (2016) assumes that a social planner determines R&D spending, Böhm, Grossmann, and Strulik (2017) and Frankovic and Kuhn (2018a) confirm his findings for decentralized economies with endogenous medical progress.

Health-care institutions, most notably health insurance, shape the demands for health-care and medical innovations. Several recent studies have sought to assess the extent to which the excessive spending that ex post moral hazard generates in the presence of health insurance harms economic performance and ultimately welfare. Simulating the impact of the 2010 US health-care reform, Jung and Tran (2016) show that introducing an insurance mandate and expanding Medicaid stifled both capital accumulation and labor supply, with ambivalent welfare effects. Similarly, Conesa et al. (2017) show that removing Medicare in the United States would foster the welfare of all generations within a new macroeconomic steady state. However, even the cumulative welfare gains would fall short of the welfare loss (due to the abolition of insurance) along the transition path. Frankovic and Kuhn (2018a) provide a separate case for health insurance. They consider the macroeconomic impact of the expansion of US health insurance from 1965 to 2005. Departing from a conjecture by Weisbrod (1991), they consider how the demand expansion triggered by more extensive health insurance coverage will induce additional R&D into new medical technologies (as evidenced, e.g., in Clemens, 2013; Finkelstein, 2004, 2007). According to their simulations, health insurance expansion and the medical innovation it induces can explain a considerable part of health-care expenditure growth. The additional demand generated by health insurance expansion would not yield sizable health improvements for a given state of medical technology and can therefore be considered wasteful. However, the additional gain in life expectancy from induced medical innovation vastly overcompensates for the welfare loss from moral hazard.

Policy Implications and Conclusions

The case for a positive effect of health on economic growth is strongest for less developed, post-demographic transition countries and with respect to children's health and women's health. Health improvements for these populations spur increased investment in human capital (Chakraborty, 2004), increased female labor force participation, and reduced fertility (Bloom, Kuhn, & Prettner, 2015). Together, these forces can help trigger a demographic dividend and initiate a takeoff toward long-run economic growth. Thus, targeted interventions to improve the health conditions of women and children, such as iodine supplementation or vaccination against human papilloma virus (Field et al., 2009; Luca et al., 2018), are likely to yield very high returns in terms of economic growth, well-being, and long-run development.

A somewhat more complex picture emerges for developed economies. While reductions in the burden of chronic diseases yield substantial productivity gains, the improvements disproportionately accrue to older individuals who are less likely to be economically active. The extent to which increasing longevity then translates into additional capital accumulation and productivity growth depends on the particular design of social security schemes and the potentially offsetting impacts of an extended working life. Other concerns relate to the detrimental impact of wasteful health-care spending on economic performance. While scope clearly exists for improving the efficiency of health-care systems throughout, economic growth alone is a poor benchmark for valuing the desirability of health and health care. Indeed, within developed economies, the benefits from even modest health improvements likely far outstrip losses in forgone consumption (Kuhn & Prettner, 2016). The increase in medical innovation spurred by generous provision of health care only compound these positive outcomes. Ultimately, the increasingly unequal distribution of health gains should serve as the primary subject of concern, rather than the level of health expenditure (Case & Deaton, 2017; Chetty et al., 2016; Frankovic & Kuhn, 2018b).

Acknowledgment

The authors are grateful to Alex Khoury, Alyssa Lubet, and Johannes Schwarzer for providing excellent research assistance. They would also like to thank Andrew Jones, David Weil, and an anonymous referee for valuable comments and suggestions. In addition, the authors wish to acknowledge support from the National Institute on Aging of the National Institutes of Health under Award Number P30AG024409. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. Financial support from the Carnegie Corporation of New York is also acknowledged.

Further Reading

For a general introduction at an easy-to-access level, see Deaton (2013). Weil (2014) provides a detailed survey and thorough discussions of the related literature's problems. For the directions of the causal effects between health and income and for strategies of identification, see Shastry and Weil (2003), Weil (2007); Lorentzen et al. (2008), Acemoglu and Johnson (2007), Aghion et al. (2011), Cervellati and Sunde (2011), and Bloom, Canning, and Fink (2014). For the theoretical modeling of the effects of health in less developed countries and the health-related mechanisms by which poverty traps are sustained, see Cervellati and Sunde (2005) and Bloom et al. (2015). For the theoretical mechanisms by which health affects economic growth in developed countries, see Prettner (2013) and Kuhn and Prettner (2016). For an assessment of the interplay between health-related and conventional R&D, see Jones (2016). For an analysis of the (reverse) role of economic growth in the willingness to pay for health and health care, see Hall and Jones (2007), Jones (2016), Jones and Klenow (2016), Kuhn and Prettner (2016), and Frankovic and Kuhn (2018a). For the effects of inequality on health and for recent decreases in life expectancy in the United States, see Chetty et al. (2016), and Case and Deaton (2017).

References

Acemoglu, D., & Johnson, S. (2007). Disease and development: The effect of life expectancy on economic growth. Journal of Political Economy, 115, 925–985.

Aghion, P., Howitt, P., & Murtin F. (2011). The relationship between health and growth: When Lucas meets Nelson-Phelps. Review of Economics and Institutions, 2, 1–24.

Aísa, R., & Pueyo, F. (2006). Government health spending and growth in a model with endogenous longevity. Economics Letters, 90, 249–253.

Aksan, A.-M., & Chakraborty, S. (2014). Mortality versus morbidity in the demographic transition. European Economic Review, 70, 470–492.

Ashraf, Q. H., Lester, A., & Weil, D. N. (2008). When does improving health raise GDP? NBER Macroeconomics Annual, 23, 157–204.

Ashraf, Q. H., Weil, D. N., & Wilde, J. (2013). The effect of fertility reduction on economic growth. Population and Development Review, 39, 97–130.

Azomahou, T. T., Boucekkine, R., & Diene, B. (2016). HIV/AIDS and development: A reappraisal of the productivity and factor accumulation effects. American Economic Review, Papers & Proceedings, 106, 472–477.

Baldanzi, A., Bucci, A., & Prettner, K. (2017). Children's health, human capital accumulation, and R&D-based economic growth. Hohenheim Discussion Papers in Business, Economics and Social Sciences 01–2017, University of Hohenheim, Faculty of Business, Economics and Social Sciences.

Barro, R. (1996). Health and economic growth. Mimeo. Harvard University, Cambridge, MA.

Barro, R., & Lee, J. (1994). Sources of economic growth. Carnegie-Rochester Conference Series on Public Policy, 40, 1–46.

Barro, R., & Sala-i-Martin, X. (1995). Economic growth. New York: McGraw-Hill.

Bazzi, S., & Clemens, M. A. (2013). Blunt instruments: Avoiding common pitfalls in identifying the causes of economic growth. American Economic Journal: Macroeconomics, 5(2), 152–186.

Becker, G. S. (2007). Health as human capital: Synthesis and extensions. Oxford Economic Papers, 59, 379–410.

Becker, G. S., & Lewis, G. H. (1973). On the interaction between the quantity and quality of children. Journal of Political Economy, 81, 279–288.

Becker, G. S., Philipson, T. J., & Soares, R. R. (2005). The quantity and quality of life and the evolution of world inequality. American Economic Review, 95, 277–291.

Bell, C., & Gersbach, H. (2009). The macroeconomics of targeting: The case of an enduring epidemic. Journal of Health Economics, 28, 54–72.

Ben-Porath, Y. (1967). The production of human capital and the life cycle of earnings. Journal of Political Economy, 75, 352–365.

Bhalotra, S., & Rawlings, S. B. (2011). Intergenerational persistence in health in developing countries: The penalty of gender inequality? Journal of Public Economics, 95, 286–299.

Bhargava, A. (1991). Identification and panel data models with endogenous regressors. Review of Economic Studies, 58, 129–140.

Bhargava, A., Jamison, D. T., Lau, L. J., & Murray, C. J. L. (2001). Modeling the effects of health on economic growth. Journal of Health Economics, 20, 423–440.

Blanchard, O. J. (1985). Debt, deficits and finite horizons. Journal of Political Economy, 93, 223–247.

Bleakley, H. (2007). Disease and development: Evidence from hookworm eradication in the American south. Quarterly Journal of Economics, 122, 73–117.

Bleakley, H. (2010). Malaria eradication in the Americas: A retrospective analysis of childhood exposure. American Economic Journal: Applied Economics, 2, 1–45.

Bleakley, H. (2011). Health, human capital, and development. Annual Review of Economics, 2, 280–310.

Bleakley, H., & Lange, F. (2009). Chronic disease burden and the interaction of education, fertility, and growth. Review of Economics and Statistics, 91, 52–65.

Bloom, D. E., Cafiero-Fonseca, E., McGovern, M. E., Prettner, K., Stanciole, A., Weiss, J., Rosenberg L. (2014). The macroeconomic impact of non-communicable diseases in China and India: Estimates, projections, and comparisons. The Journal of the Economics of Ageing, 4, 100–111.

Bloom, D. E., & Canning, D. (2000). The health and wealth of nations. Science, 287, 1207–1209.

Bloom, D. E., & Canning, D. (2005). Health and economic growth: Reconciling the micro and macro evidence. Center on Democracy, Development and the Rule of Law Working Papers, Palo Alto, CA.

Bloom, D., Canning, D., & Fink, G. (2014). Disease and development revisited. The Journal of Political Economy, 122, 1355–1366.

Bloom, D. E., Canning, D., & Graham, B. (2003). Longevity and life-cycle savings. Scandinavian Journal of Economics, 105, 319–338.

Bloom, D. E., Canning, D., Mansfield, R. K., & Moore, M. (2007). Demographic change, social security systems and savings. Journal of Monetary Economics, 54, 92–114.

Bloom, D. E., Canning, D., & Moore, M. (2014). Optimal retirement with increasing longevity. Scandinavian Journal of Economics, 116, 838–858.

Bloom, D. E., Canning, D., & Sevilla, J. P. (2003). The demographic dividend. Population Matters. A RAND Program of Policy-Relevant Research Communication, Santa Monica, California.

Bloom, D. E., Canning, D., & Sevilla, J. (2004). The effect of health on economic growth: A production function approach. World Development, 32, 1–13.

Bloom, D. E., & Fink, G. (2014). The economic case for devoting public resources to health. In J. Farrar, N. White, D. Lalloo, P. Hotez, T. Junghanss, & G. Kang (Eds.), Manson's tropical diseases (23rd ed., pp. 23–30). Philadelphia: Elsevier.

Bloom, D. E., & Freeman, R. B. (1988). Economic Development and the Timing and Components of Population Growth. Journal of Policy Modeling, 10, 57-82.

Bloom, D. E. Kuhn, M., & Prettner, K. (2015). The contribution of female health to economic development. NBER Working Paper 21411, National Bureau of Economic Research, Cambridge, MA.

Bloom, D. E., Kuhn, M., & Prettner, K. (2017). Africa's prospects for enjoying a demographic dividend. Journal of Demographic Economics, 83, 63–76.

Bloom, D. E., & Williamson, J. G. (1998). Demographic transitions and economic miracles in emerging Asia. World Bank Economic Review, 12, 419–456.

Böhm, S., Grossmann, V., & Strulik, H. (2017). R&D-driven medical progress, health care costs, and the future of human longevity. Mimeo. Center for European Governance and Economic Development Research, Göttingen, Germany.

Boucekkine, R., de la Croix, D., & Licandro, O. (2002). Vintage human capital, demographic trends, and endogenous growth. Journal of Economic Theory, 104, 340–375.

Boucekkine, R., de la Croix, D., & Licandro, O. (2003). Early mortality declines at the dawn of modern growth. Scandinavian Journal of Economics, 105, 401–418.

Breyer, F., Costa-Font, J., & Felder, S. (2010). Ageing, health, and health care. Oxford Review of Economic Policy, 26, 674–690.

Buiter, W. H. (1988). Death, birth, productivity growth and debt neutrality. Economic Journal, 98, 179–293

Case, A., & Deaton, A. (2017). Mortality and morbidity in the 21st century. Brookings Papers on Economic Activity, 397–476.

Cervellati, M., & Sunde, U. (2005). Human capital formation, life expectancy, and the process of development. American Economic Review, 95, 1653–1672.

Cervellati, M., & Sunde, U. (2011). Life expectancy and economic growth: The role of the demographic transition. Journal of Economic Growth, 14, 1–35.

Cervellati, M., & Sunde, U. (2013). Life expectancy, schooling, and lifetime labor supply: Theory and evidence revisited. Econometrica, 81, 2055–2086.

Cervellati, M., & Sunde, U. (2015a). The effect of life expectancy on education and population dynamics. Empirical Economics, 48, 1445–1478.

Cervellati, M., & Sunde, U. (2015b). The economic and demographic transition, mortality, and comparative development. American Economic Journal: Macroeconomics, 7, 189–225.

Chakraborty, S. (2004). Endogenous lifetime and economic growth. Journal of Economic Theory, 116, 119–137.

Chakraborty, S., Papageorgiou, C., & Perez-Sebastian, F. (2010). Diseases, infection dynamics, and development. Journal of Monetary Economics, 57, 859–872.

Chakraborty, S., Papageorgiou, C., & Perez-Sebastian, F. (2016). Health cycles and health transitions. Macroeconomic Dynamics, 20, 189–213.

Chandra, A., & Skinner, J. (2012). Technology growth and expenditure growth in health care. Journal of Economic Literature, 50, 645–680.

Chen, Y., & Lau, S.-H.P. (2016). Mortality decline, retirement age, and aggregate savings. Macroeconomic Dynamics, 20, 715–736.

Chetty, R., Stepner, M., Abraham, S., Lin, S., Scuderi, B., Turner, N., A Bergeron, & Cutler, D. (2016). The association between income and life expectancy in the United States, 2001–2014. Journal of the American Medical Association, 315, 1750–1766.

Clemens, J. (2013). The effect of US health insurance expansion on medical innovation. NBER Working Paper 19761. National Bureau of Economic Research, Cambridge, MA.

Conesa, J. C., Costa, D., Kamali, P., Kehoe, T., Nygard, V. M., Raveendranathan, G., & Saxena, A. (2017). Macroeconomic effects of Medicare. Journal of the Economics of Aging, 11, 27–40.

Croke K., Hicks J. H., Hsu E., Kremer M., & Miguel, E. (2016). Does mass deworming affect child nutrition? Meta-analysis, cost-effectiveness, and statistical power. NBER Working Paper 22382. National Bureau of Economic Research, Cambridge, MA.

Cutler, D. M., & Huckman, R. S. (2003). Technological development and medical productivity: The diffusion of angioplasty in New York State. Journal of Health Economics, 22, 187–217.

Cutler, D., Lleras-Muney, A., & Deaton, A. (2006). The determinants of mortality. Journal of Economic Perspectives, 20, 97–120.

Cutler, D. M., & Ly, D. P. (2011). The (paper) work of medicine: Understanding differences in international medical costs. Journal of Economic Perspectives, 25, 3–25.

D'Albis, H., Lau, S.-H. P., & Sánchez-Romero, M. (2012). Mortality transition and differential incentives for early retirement. Journal of Economic Theory, 147, 261–283.

Dalgaard, C.-J., & Strulik, H. (2017). The genesis of the golden age: Accounting for the rise in health and leisure. Review of Economic Dynamics, 24, 132–151.

Deaton, A. (2013). The great escape: Health, wealth, and the origins of inequality. Princeton, NJ: Princeton University Press.

De la Croix, D., & Licandro, O. (1999). Life expectancy and endogenous growth. Economic Letters, 65, 255–263.

De Nardi, M., French, E., & Jones, J. B. (2010). Why do the elderly save? The role of medical expenses. Journal of Political Economy, 118, 39–75.

Desbordes, R. (2011). The non-linear effects of life expectancy on economic growth. Economics Letters, 112, 116–118.

Dudel, C., & Myrskylä, M. (2017). Working life expectancy at age 50 in the United States and the impact of the Great Recession. Demography, 54, 2101–2123.

Eggleston, K. N., & Fuchs, V. R. (2012). The new demographic transition: Most gains in life expectancy now realized late in life. Journal of Economic Perspectives, 26, 137–156.

Field, E., Robles, O., & Torero, M. (2009). Iodine deficiency and schooling attainment in Tanzania. American Economic Journal: Applied Economics, 1, 140–169.

Finkelstein, A. (2004). Static and dynamic effects of health policy: Evidence from the vaccine industry. Quarterly Journal of Economics, 119, 527–564.

Finkelstein, A. (2007). The aggregate effects of health insurance: Evidence from the introduction of Medicare. Quarterly Journal of Economics, 122, 1–35.

Fogel, R. W. (1994). Economic growth, population theory, and physiology: The bearing of long-term processes on the making of economic policy. American Economic Review, 84, 369–395.

Fogel, R. W. (1997). New findings on secular trends in nutrition and mortality: Some implications for population theory. In M. Rosenzweig & O. Stark (Eds.), Handbook of population and family economics (Vol. 1A, 433–481). Amsterdam: Elsevier.

Fortson, J. G. (2009). HIV/AIDS and fertility. American Economic Journal: Applied Economics, 1, 170–194.

Fortson, J. G. (2011). Mortality risk and human capital investment: The impact of HIV/AIDS in sub-Saharan Africa. Review of Economics and Statistics, 93, 1–15.

Frankovic, I., & Kuhn, M. (2018a). Health insurance, endogenous medical progress, and health expenditure growth. ECON Working Paper 01/2018, Technical University of Vienna.

Frankovic, I., & Kuhn, M. (2018b). The impact of medical innovations on longevity inequality. PGDA Working Paper #155.2018, Harvard School of Public Health.

Frankovic, I., Kuhn, M., & Wrzaczek, S. (2017). Medical innovation, demand for health care, and economic performance. ECON Working Paper 08/2017, Technical University of Vienna.

Fuchs, V.R. (2004). *More variation in use of care, more flat-of-the-curve medicine. Why does it occur? What can be done about it? [https://search.proquest.com/openview/5f5f52025733b1274da625a6ff0cd053/1?pq-origsite=gscholar&cbl=36027]* Health Affairs, web exclusive.

Galor, O. (2005). From stagnation to growth: unified growth theory. In P. Aghion & S. Durlauf (Eds.), Handbook of economic growth (Vol. 1A, 171–293) Amsterdam: Elsevier.

Galor, O. (2011). Unified growth theory. Princeton, NJ: Princeton University Press.

Galor, O., & Weil, D. (2000). Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond. American Economic Review, 90, 806–828.

Garthwaite, C. L. (2012). The economic benefits of pharmaceutical innovations: The case of Cox-2 inhibitors. American Economic Journal: Applied Economics, 4, 116–137.

Hall, R. E., & Jones, C. I. (2007). The value of life and the rise in health spending. Quarterly Journal of Economics, 122, 39–72.

Hansen, C. W. (2012). The relation between wealth and health: evidence from a world panel of countries. Economics Letters, 115, 175-176.

Hansen, C. W. (2014). Cause of death and development in the US. Journal of Development Economics, 109, 143–153.

Hansen, C. W., & Lönstrup, L. (2015). The rise in life expectancy and economic growth in the 20th century. Economic Journal, 125, 838–852.

Hansen, C. W., & Strulik, H. (2017). Life expectancy and education: Evidence from the cardiovascular revolution. Journal of Economic Growth, 22, 421–450.

Heijdra, B. J. (2017). Foundations of modern macroeconomics. Oxford: Oxford University Press.

Heijdra, B. J., & Mierau, J. (2011). The individual life cycle and economic growth: An essay on demographic macroeconomics. De Economist, 159, 63–87.

Heijdra, B. J., & Romp, W. (2008). A life-cycle overlapping-generations model of the small open economy. Oxford Economic Papers, 60, 88–121.

Hyclak, T. J., Skeels, C. L., & Taylor, L. W. (2016). The cardiovascular revolution and economic performance in the OECD countries. Journal of Macroeconomics, 50, 114–125.

Jayachandran, S., & Lleras-Muney, A. (2009). Life expectancy and human capital investments: Evidence from maternal mortality declines. The Quarterly Journal of Economics, 124, 349–397.

Jones C. I. (1995). R&D-based models of economic growth. Journal of Political Economy, 103, 759–783.

Jones C. I. (2016). Life and growth. Journal of Political Economy, 124, 539–578.

Jones, C. I., & Klenow, P. (2016). Beyond GDP? Welfare across countries and time. American Economic Review, 106, 2426–2457.

Juhn, C., Kalemli-Ozcan, S., & Tsuan, B. (2013). HIV/AIDS and fertility in Africa: First evidence from population-based surveys. Journal of Population Economics, 26, 835–853.

Jung, J., & Tran, C. (2016). Market inefficiency, insurance mandate and welfare: U.S. health care reform 2010. Review of Economic Dynamics, 20, 132–159.

Kalemli-Ozcan, S. (2012). AIDS, "reversal" of demographic transition and economic development: Evidence from Africa. Journal of Population Economics, 25, 871–897.

Kalemli-Ozcan, S., Ryder H. E., & Weil, D. N. (2000). Mortality decline, human capital investment, and economic growth. Journal of Development Economics, 62, 1–23.

Kelly, M. (2017). Health capital accumulation, health insurance, and aggregate outcomes: A neoclassical approach. Journal of Macroeconomics, 52, 1–22.

Kuhn, M., & Prettner, K. (2016). Growth and welfare effects of health care in knowledge-based economies. Journal of Health Economics, 46, 100–119.

Kuhn, M., & Prettner, K. (2018). Population age structure and consumption growth: Evidence from National Transfer Accounts. Journal of Population Economics, 31, 135–153.

Kuhn, M., Wrzaczek, S., Prskawetz, A., & Feichtinger, G. (2015). Optimal choice of health and retirement in a life-cycle model. Journal of Economic Theory, 158, 186–212.

Lagerlöf, N.-P. (2003). From Malthus to modern growth: Can epidemics explain the three regimes? International Economic Review, 44, 755–777.

Loichinger, E., & Weber, D. (2016). Trends in working life expectancy in Europe. Journal of Aging and Health, 28, 1194–1213.

Lorentzen, P., McMillan, J., & Wacziarg, R. (2008). Death and development. Journal of Economic Growth, 13, 81–124.

Luca, D. L., Iversen, J. H., Lubet, A. S., Mitgang, E., Onarheim, K. H., Prettner, K., and Bloom, D. E. (2018). Benefits and Costs of the Women's Health Targets for the Post-2015 Development Agenda, In

Prioritizing Development: A Cost Benefit Analysis of the United Nations' Sustainable Development Goals, edited by Bjorn Lomborg, Cambridge University Press, 244-254.

Lucas, A. M. (2010). Malaria eradication and educational attainment: Evidence from Paraguay and Sri Lanka. American Economic Journal: Applied Economics, 2, 46–71.

Lutz, W., & Kebede, E. (2018). Education and Health: Redrawing the Preston Curve, Population and Development Review, 44, 343–361.

Mason, A., Lee, R. D., & Jiang J. X. (2016). Demographic dividends, human capital, and saving. The Journal of the Economics of Ageing, 7, 106–122.

Mierau, J., & Turnovsky, S. (2014a). Capital accumulation and the sources of demographic change. Journal of Population Economics, 27, 857–894.

Mierau, J., & Turnovsky, S. (2014b). Demography, growth, and inequality. Economic Theory, 55, 29–68.

Miguel, E., & Kremer, M. (2004). Worms: identifying impacts on education and health in the presence of treatment externalities. Econometrica, 72, 159–217.

Milligan, K., & Wise, D.A. (2015). Health and work at older ages: Using mortality to assess the capacity to work across countries. Journal of Population Ageing, 8, 27–50.

OECD (Organisation of Economic Co-operation and Development). (2017). Health at a glance 2017: OECD health indicators. Paris: OECD Publishing.

Oster, E., Shoulson, I., & Dorsey, E. R. (2013). Limited life-expectancy, human capital and health investments. American Economic Review, 103, 1977–2002.

Pauly, M.V., & Saxena, A. (2012). Health employment, medical spending, and long-term health reform. CES-Ifo Economic Studies, 58, 49–72.

Poterba, J. M., & Summers, L. H. (1987). Public policy implications of declining old-age mortality. NBER Working Paper 934.

Preston, S. H. (1975). The changing relation between mortality and level of economic development. Population Studies, 29, 231–248.

Prettner, K. (2013). Population aging and endogenous economic growth. Journal of Population Economics, 26, 811–834.

Prettner, K., Bloom, D. E., & Strulik, H. (2013). Declining fertility and economic well-being: Do education and health ride to the rescue? Labour Economics, 22, 70–79.

Prettner, K., & Canning, D. (2014). Increasing life expectancy and optimal retirement in general equilibrium. Economic Theory, 56, 191–217.

Pritchett, L., & Summers, L. H. (1996). Wealthier is healthier. Journal of Human Resources, 31, 841–868.

Reinhart, V. R. (1999). Death and taxes: Their implications for endogenous growth. Economics Letters, 62, 339–345.

Roham, M., Gabrielyan, A. R., Archer, N. P., Grignon, M. L., & Spencer, B. G. (2014). The impact of technological intensity of service provision on physician expenditures: An exploratory investigation. Health Economics, 23, 1224–1241.

Romer, P. (1986). Increasing returns and long-run growth. Journal of Political Economy, 94, 1002–1037.

Romer, P. (1990). Endogenous technological change. Journal of Political Economy, 98, 71–102.

Sanderson, W. C., & Scherbov, S. (2010). Remeasuring aging. Science, 329, 1287–1288.

Schneider, M. T., & Winkler, R. (2016). Growth and welfare under endogenous lifetime. Bath Economics Research Papers 47/r16, University of Bath.

Shastry, G. K., & Weil, D. N. (2003). How much of cross-country income variation is explained by health? Journal of the European Economic Association, 1, 387–396.

Soares, R. R. (2005). Mortality reductions, educational attainment, and fertility choice. American Economic Review, 95, 580–601.

Solow, R. M. (1956). A contribution to the theory of economic growth. The Quarterly Journal of Economics, 70, 65–94.

Strulik, H., Prettner, K., & Prskawetz, A. (2013). The past and future of knowledge-based growth. Journal of Economic Growth, 18, 411–437.

Suhrcke, M., & Urban, D. (2010). Are cardiovascular diseases bad for economic growth? Health Economics, 19, 1478–1496.

van Zon, A., & Muysken, J. (2001). Health and endogenous growth. Journal of Health Economics, 20, 169–185.

Weil, D. N. (2007). Accounting for the effect of health on economic growth. The Quarterly Journal of Economics, 122, 1265–1306.

Weil, D. (2014). Health and economic growth. In P. Aghion & S. N. Durlauf (Eds.), Handbook of economic growth (Vol. 2B, pp. 623–682). Amsterdam: Elsevier.

Weil, D. N. (2015). A review of Angus Deaton's "the great escape: health, wealth, and the origins of inequality." Journal of Economic Literature, 53, 102–114.

Weisbrod, B. (1991). The health care quadrilemma: An essay on technological change, insurance, quality of care, and cost containment. Journal of Economic Literature, 29, 523–552.

Wong, A., Wouterse, B., Slobbe, L. C. J., Boshuizen, H. C., & Polder, J. J. (2012). Medical innovation and age-specific trends in health care utilization: Findings and implications. Social Science and Medicine, 74, 263–272.

World Bank. (2017). World development indicators. Washington, DC: World Bank.

Young, A. (2005). Gift of the dying: The tragedy of AIDS and the welfare of future African generations. Quarterly Journal of Economics, 120, 423–466.

Zhang, J., & Zhang, J. (2005). The effect of life expectancy on fertility, saving, schooling and economic growth: Theory and evidence. Scandinavian Journal of Economics, 107, 45–66.

Notes

1. Fogel (1994, 1997) shows the importance of a particular dimension of health - malnutrition - on labor productivity and argues that adequate nutrition could almost double labor productivity from an aggregate perspective in Great Britain over the period 1780–1980.

2. Ashraf et al. (2008) employ a macroeconomic simulation to assess how a mortality decline and the eradication of certain diseases bear on economic development over time, accounting for endogenous responses in terms of fertility and education. They find that the full effects of health improvements take considerable time to unfold.

3. The following disease categories are included: cardiovascular disease, cancer, chronic respiratory disease, diabetes, and mental health disorders.

4. The birth rate equals the death rate in Blanchard (1985) such that population growth is zero by construction. Buiter (1988) confirms Blanchard's (1985) findings for a setting where rising life expectancy boosts population growth.

5. For example, Heijdra and Romp (2008) and Mierau and Turnovsky (2014a), who consider age-specific mortality, subsequently replaced the assumption of constant mortality (and thus the absence of aging) in the original models.

6. Heijdra (2017) provides a nice overview of this literature in Chapter 15.

7. While macro-indicators typically show an increase in healthy life expectancy, micro-level evidence is more mixed (see, e.g., Milligan & Wise, 2015).

8. Bloom et al. (2007), D'Albis et al. (2012), and Bloom, Canning, and Moore (2014) study the individual saving and retirement responses to mortality changes in a partial equilibrium context. Kuhn et al. (2015) and Dalgaard and Strulik (2017) study the endogenous choice of health care, saving, and retirement throughout the life cycle.

9. See van Zon and Muysken (2001), Aísa and Pueyo (2006), and Schneider and Winkler (2016) for similar findings in different settings.

10. While Schneider and Winkler (2016) and Frankovic et al. (2017) consider product-related innovations in medicine (i.e., innovations that raise the life-saving effectiveness of each unit of treatment), Kelly (2017) shows that process-related increases in the productivity of the health-care sector are also conducive to growth.