Spurring Economic Growth through Human Development: Research Results and Guidance for Policymakers

David E. Bloom, Alex Khoury, Vadim Kufenko
and Klaus Prettner

Education, general health, and reproductive health are key indicators of human development. Investments in these domains can also promote economic growth. This paper argues for human development–related investments based on (1) a theoretical economic growth model with poverty traps, (2) a literature review of evidence that different human development–related investments can promote growth, and (3) own empirical analyses of 1980–2015 data that aim to estimate the relative contribution of different human development indicators to economic growth across heterogeneous growth regimes. Our results suggest the following associations: (1) a one-child decrease in the total fertility rate corresponds to a 2 percentage point (pp) increase in annual per capita gross domestic product (GDP) growth in the short run (five years) and 0.5 pp higher annual growth in the mid-run to long run (35 years), (2) a 10 percent increase in life expectancy at birth corresponds to a 1 pp increase in annual per capita GDP growth in the short run and 0.4 pp higher growth in the mid-run to long run, and (3) a one-year increase in average educational attainment corresponds to a 0.7 pp increase in annual growth in the short run and 0.3 pp higher growth in the mid-run to long run. By contrast, infrastructure proxies are not significantly associated with subsequent growth in any of the models estimated.

David E. Bloom is Clarence James Gamble Professor of Economics and Demography Professor, Department of Global Health and Population, Harvard T.H. Chan School of Public Health, Boston, MA 02115. E-mail: dbloom@hsph.harvard.edu. Alex Khoury is Government Performance Lab Fellow, Harvard Kennedy School of Government, Cambridge, MA, 02138. Vadim Kufenko is a postdoctoral researcher, Institute of Economics, University of Hohenheim, Stuttgart 70593, Germany. Klaus Prettner is Professor of Economics, Department of Economics, Vienna University of Economics and Business (WU), Vienna 1020, Austria; Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), Vienna 1030, Austria.

Introduction

Most countries classified as low income or middle income in the mid-twentieth century experienced substantial economic growth over the last 70 years, but average incomes improved considerably more in some countries than in others. Corresponding differences in human development trajectories accompanied cross-country differences in rates of income growth (see Table T1 in the Supporting Information). The positive association between economic growth and human development outcomes, especially in education, life expectancy, and fertility, is consistent with economic theory and presumably reflects a bicausal relationship: (1) the extent to which increased income allows individuals and governments to invest more heavily in human development and (2) the impact of improvements in general health, reproductive health, and education on economic growth.

Investments in education, general health, and reproductive health can promote economic growth by enhancing worker productivity and labor supply and by inducing higher rates of saving, capital accumulation, and technological progress (Barro 2001; Hanushek 2013; Bloom and Canning 2000; Malecki 1997; Bloom et al. 2000; Lee and Mason 2010). Although substantial evidence supports the impact of human development on economic growth, the literature does not clearly indicate which aspects of human development have the most influence. The literature also fails to clearly compare human development and its components with other drivers of growth, such as those related to institutional quality or the nature and density of infrastructure.

In this paper, we aim to contribute to the literature by assessing the relative extent to which education, health, and fertility reduction can promote economic growth. In addition, we show that other domains that are often mentioned as important, such as infrastructure, are less powerful in promoting economic development. This is done (1) by a theoretical argument based on an economic growth model with poverty traps; (2) by a comparative review of the literature that analyzes the growth effects of education, health, and fertility separately; and (3) by an empirical analysis in which we assess the relative importance of the different associations between education, health, and fertility, on the one hand, and economic growth on the other.

Identification and inference with respect to these effects is performed using cross-country and dynamic panel threshold growth regressions, which allow for heterogeneous growth regimes. Although literature on cross-country threshold growth regressions exists (see Hansen 2000), it does not sufficiently address dynamic threshold panel data growth regressions. This is an important point, because the magnitudes and significance of the effects plausibly differ across growth regimes in a dynamic setting as well. Heterogeneity of economic growth regimes, and thus differences in the effects of growth determinants, poses a new challenge for policymakers, because measures applied in one regime may yield different returns when applied under other conditions.

Bearing in mind the challenges related to reverse causality, we separate the dependent and independent variables at the time of their measurement and obtain the following findings: (1) a one-child decrease in the total fertility rate (TFR) corresponds to a 2 percentage point (pp) increase in annual per capita gross domestic product (GDP) growth in the short run (five years) and 0.5 pp higher annual growth in the mid-run to long run (35 years); (2) a 10 percent increase in life expectancy at birth corresponds to a 1 pp increase in annual per capita GDP growth in the short run and 0.4 pp higher growth in the mid-run to long run; and (3) a one-year increase in average educational attainment, measured in years of schooling, corresponds to a 0.7 pp increase in annual growth in the short run and 0.3 pp higher growth in the mid-run to long run. By contrast, infrastructure proxies are not significantly associated with subsequent growth in any of the models estimated.

Although we acknowledge that all different approaches in the paper are susceptible to idiosyncratic criticisms, the overall picture is remarkably consistent. Human development–focused policies might therefore be the most successful in promoting economic growth.

The paper is organized as follows: "Illustration of the theoretical background" section describes a theoretical framework that shows the importance of human development investments in escaping national poverty traps. "Literature overview of the qualitative and quantitative results of different investments" section reviews the literature on the causal pathways from health, education, and fertility to economic growth and the evidence supporting these mechanisms. "Empirical analysis" section describes this paper's methodological approach in assessing the associations between health, education, and demographic variables and economic growth and presents the results of these analyses. Finally, "Conclusion" section concludes.

Illustration of the theoretical background

This section aims to provide an accessible illustration of the basic model of economic growth and to show how poverty traps can emerge and be sustained (see also Nelson 1956; Solow 1956; Diamond 1965; Acemoglu 2009; and Prettner and Bloom 2020 for more details on the formal derivations). This allows us to isolate the channels through which improvements in education, health, and infrastructure and changes in fertility can affect economic development. The literature review on empirical results and our own analyses in later sections are consistent with the presence of these channels. The fact that the empirical findings are consistent with theoretical mechanisms gives us more confidence in the estimates. However, we acknowledge that definitive causal macroeconomic evidence is difficult to establish because all methods that we apply to address issues such as reverse causality can be criticized for different reasons.

To differentiate the effects of changes in infrastructure, health, education, and fertility from a qualitative point of view, we consider an economy in which time $t = 1, 2 \ldots$ evolves discretely. Aggregate output Y_t depends on the stocks of physical capital K_t and human capital H_t employed in the production process. These two accumulable production factors can be combined to produce aggregate output according to the overall productivity level A_t. The production function that translates factor inputs and productivity into output has the general form:

$$Y_t = F(A_t, K_t, H_t)$$

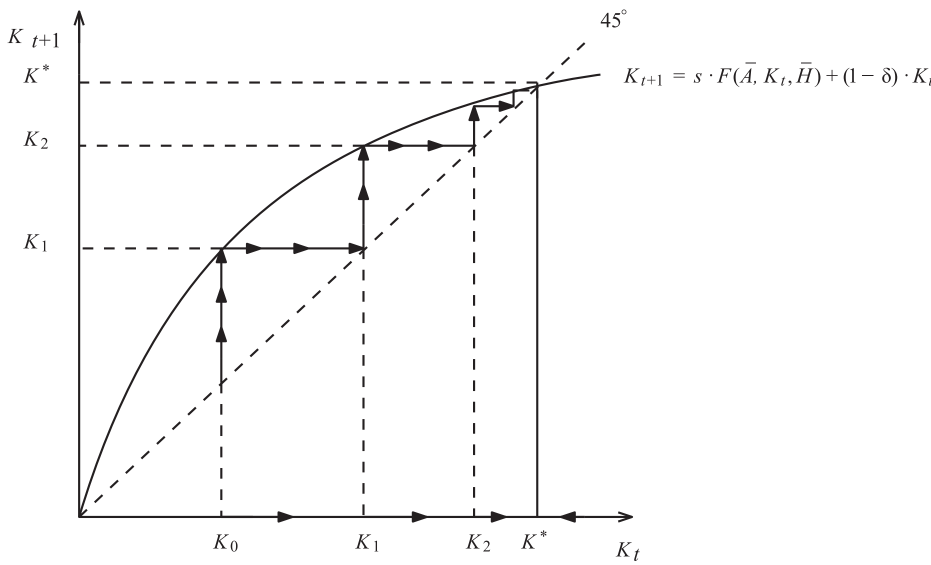
where $F(\ldots)$ has positive first partial derivatives and negative second partial derivatives with respect to the accumulable production factors K_t and H_t. Physical capital comprises private production capital, such as machines, production halls, and office buildings, and public capital, such as railroads, highways, electricity grids, and ports. In contrast to physical capital, human capital is embodied in an economy's workers and is mainly determined by the workforce's average health status and education level. Productivity A_t consists of two parts: the economy's technological state, which determines the location of the production possibility frontier, and the efficiency of input use, which determines whether the economy produces at its production possibility frontier (is efficient) or below its production possibility frontier (is inefficient).

The case of a unique steady-state equilibrium

In a perfectly competitive economy with full information, no externalities, and no overaccumulation of physical capital, all agents' investment decisions are efficient. The private and social rates of return coincide for each investment such that the equilibrium outcome is optimal and does not require governmental intervention. In this case, the economy develops according to the well-known dynamics of standard economic growth models with exogenously increasing technology (Solow 1956; Diamond 1965). Figure 1 illustrates the development process of such an economy. The horizontal axis depicts the physical capital stock at time t, while the vertical axis refers to the physical capital stock at time $t + 1$. The capital stock in each period carries over from the previous period net of the depreciation of old capital, as given by $\delta * K_t$ (where δ is the depreciation rate). The capital stock rises because of gross investment $I_t = s * F(A_t, K_t, H_t)$, where s is the saving rate. These facts are summarized in the capital accumulation equation of the form

$$K_{t+1} = s^* F(A_t, K_t, H_t) + (1 - \delta) K_t$$

FIGURE 1 Economic development based on capital accumulation without a poverty trap. This figure illustrates the growth process as described by a discrete-time version of the Solow (1956) model with a constant human capital stock and constant technology



that pins down the physical capital stock of the next period as a function of, *inter alia*, saving/investment decisions, s, and past levels of human capital, H_t. For the illustration in the figure, we assume that productivity and human capital stay constant at levels $\bar{A}$ and $\bar{H}$ and that the function $F(\bar{A}, K_t, \bar{H})$ is concave in K_t because the marginal product of physical capital is diminishing. Thus, at some point, capital accumulation stops because additional gross investment is only sufficient to replace additional depreciation. When this is the case, the capital stock at time t and the capital stock at time $t+1$ coincide and the economy reaches its steady state. In Figure 1, this point is the intersection of the K_{t+1} curve and the 45° line at the corresponding steady-state capital stock K^*. At this steady state, the economy is comparatively rich. Output growth at the long-run steady state depends mainly on technological progress that shifts the production possibility frontier outward (Romer 1990). In empirical analyses of long-run growth processes in high-income countries, the determinants of technological progress are the main regressors of interest and the specifications of the growth regressions are typically standard linear models of either a cross-country or panel data structure.

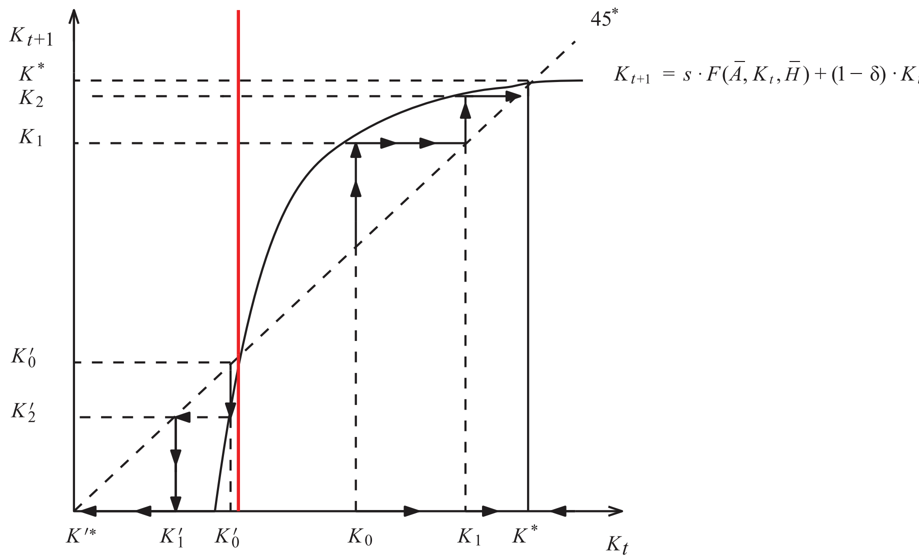
The case of multiple equilibria and poverty traps

In contrast to the case of a unique steady-state equilibrium in high-income countries, market imperfections, externalities, and coordination failures among agents can lead to multiple steady-state equilibria in low-income countries. The multiplicity of equilibria means that some economies will be caught in a poverty trap. In such a poverty trap, income is much lower than at the high-income steady state (described in the previous subsection) because endogenous forces push the economy back into a low-income equilibrium. Usually demographic forces such as high fertility and population growth, poor population health, and low provision and quality of education sustain poverty traps. For an overview of mechanisms that lead to poverty traps see, for example, Leibenstein (1954, 1975), Nelson (1956), Galor and Weil (2000), Bloom Canning, and Sevilla (2003b), de la Croix and Doepke (2003), Azariadis and Stachurski (2005), Galor (2005, 2011), de la Croix and Vander Donckt (2010), Strulik, Prettner, and Prskawetz (2013); Canning, Raja, and Yazbeck (2015); Bloom et al. (2017a, 2020), and Timmer (2020). Demographic variables play a central role in most of these mechanisms, including the following three important channels:

i. Poor health status of the population: The population's general health status could be very low; for example, due to widespread infectious diseases. Consequently, life expectancy might be so low that private investments in education do not pay off (Ben-Porath 1967; Cervellati and Sunde 2005, 2013). Poor population health and its negative consequences for education limit the country's potential for growth, inducing a poverty trap. In this situation, building schools might not be an effective development strategy because the individual return on education and, by extension, education demand is very low.
ii. Population growth: In a country where the majority of the population lives close to the subsistence level, an increase in income (e.g., by a technological improvement or by foreign aid inflows) primarily leads to a higher net rate of reproduction over the subsequent periods. The associated faster population growth additionally strains private and public investments, resulting in declines of physical and human capital whereby the economy remains trapped in the low-income equilibrium (Galor and Weil 2000).
iii. Unaffordable or low-quality education: If relatively high fees are required to attend schools or universities or if these institutions do not broadly provide quality education, then some segments of the population will fall short of their educational and human capital potential. Children in these circumstances are likely to be less productive and earn less, impeding long-term prospects for educational investment in their own children. This could perpetuate poverty across generations and reduce the economy's growth potential (Galor and Zeira 1993).

Straightforward extensions of Solow (1956) and Diamond (1965) allow for a qualitative analysis of the dynamics of poverty traps. This analysis clarifies why physical capital accumulation alone might not lift an economy

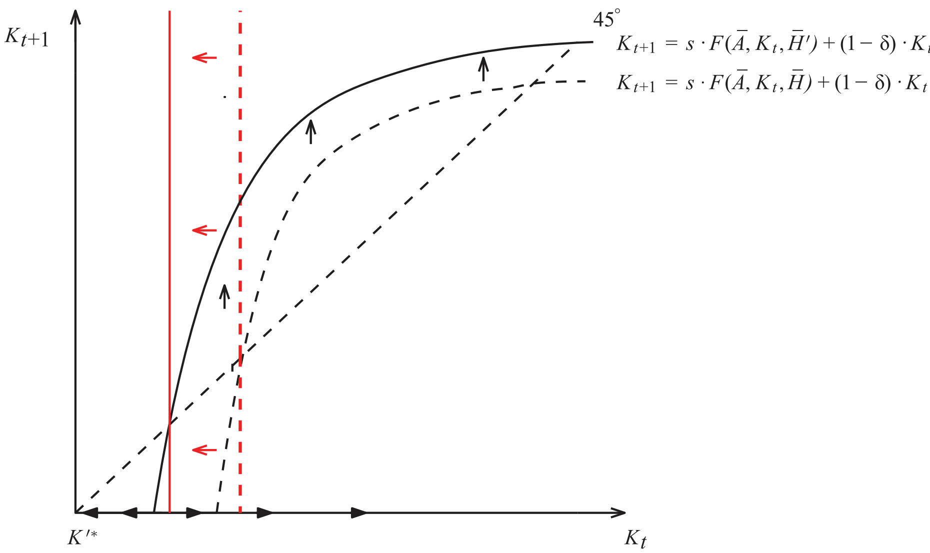
FIGURE 2 Illustration of a possible poverty trap. If the initial capital stock is located to the left of the vertical red line, the capital stock decreases over time and the economy shrinks toward the origin that represents the poverty trap



out of poverty and why investments in human capital and fertility reduction are more promising (which is consistent with our empirical findings later in this paper). Figure 2 shows the canonical case of the dynamics of economic development in the presence of a poverty trap. Three intersections are present between the K_{t+1} curve and the 45° line such that three qualitatively different steady-state equilibria emerge. One steady-state equilibrium is at the origin, where the capital stock K'^* is low and the economy is poor. Another equilibrium is at the capital stock K^*, which corresponds to the prosperity equilibrium shown in Figure 1. In between these two equilibria is an unstable steady-state equilibrium, where the vertical red line intersects the K_{t+1} curve. If the economy starts with a capital stock lower than that corresponding to the level indicated by the vertical red line, the economy is caught in the poverty trap's basin of attraction and converges to the low-income steady state (as indicated by the arrows in the diagram). Any policy that fails to raise the capital stock to a value above the vertical red line cannot catalyze sustained growth.

Two fundamentally different approaches to escaping such a poverty trap exist. The first is to invest massively in accumulating physical capital, whereby the economy ends up with a capital stock to the right of the vertical red line and in the basin of attraction of the high-income steady state. This "big push" strategy has been used as an argument in favor of immense international assistance (aid, subsidized loans, etc.) and expenditures on large infrastructure projects (Murphy, Shleifer, and Vishny 1989).

FIGURE 3 Illustration of the effects of a policy that raises $\bar{H}$ in the case of a poverty trap. The K_{t+1} curve shifts upward such that the poverty trap's basin of attraction shrinks as compared with Figure 2



The second way to overcome the poverty trap is represented by policies targeted at increasing productivity $\bar{A}$ and/or human capital $\bar{H}$ to shift the K_{t+1} curve upward. This shift shrinks the poverty trap's basin of attraction, as Figure 3 illustrates, in which $\bar{H}$ increases to $\overline{H'}$. Investments in education, health, or fertility reduction could cause such an upward shift. To see this dependency of $\bar{H}$ on the underlying demographic variables and therefore the potential of changing demography to hasten an escape from the poverty trap, consider the definition of the aggregate human capital stock in period t as the product of the number of children from the previous generation ($n_{t-1}N_{t-1}$, where n_{t-1} is the fertility rate and N_{t-1} the number of adults), their average education-driven productivity (e_t), and their average health-related productivity (h_t):

$$\overline{H_t} = h_t * e_t * n_{t-1} * N_{t-1}$$

Overall, the economic demography literature has established a quality-quantity tradeoff in the sense that if parents invest more in the number of children (higher n_{t-1}), they invest less in the education and health of their children (lower h_t and lower e_t). The strength of the effect is such that the product of $h_t * e_t * n_{t-1}$ tends to rise with (1) rising average health, (2) rising average education, and (3) decreasing fertility (Galor and Weil 2000; Galor 2005, 2011; Strulik, Prettner, and Prskawetz (2013); Prettner and Strulik 2016; Baldanzi et al. 2021; Bucci and Prettner 2020). This constitutes the theory-based channel through which fertility reductions and increasing health and education investments foster long-run economic growth.

The next section discusses the pathways by which enhancing human capital may foster economic growth based on empirical evidence supporting these mechanisms. In addition, it provides an overview of the quantitative importance of the different effects as found in the literature.

Literature overview of the qualitative and quantitative results of different investments

Pathways and qualitative findings

The literature suggests the following pathways as explanations of the growth effects of education investments: better educated individuals (1) are more productive and therefore contribute more to aggregate output (Psacharopoulos 1994; Hall and Jones 1999; Bils and Klenow 2000; Psacharopoulos and Patrinos 2004, Patrinos and Psacharopoulos 2011), (2) more readily adopt productivity-enhancing technologies from abroad (Nelson and Phelps 1966; Bloom Kuhn, and Prettner 2020), (3) are more likely to establish successful and productive firms (Cabral and Mata 2003; Bhattacharya et al. 2013; Gennaioli et al. 2013), and (4) increase their team members' productivity through spillover effects (Lucas 1988; Battu, Belfield, and Sloane 2003). Overall, a substantial body of macroeconomic literature finds education to be a key determinant of economic growth, suggesting that education's impacts on individual productivity lead to greater total productivity at the country level (see, e.g., Barro 1991; Sala-i-Martin 1997; Hanushek and Kimko 2000; Krueger and Lindahl 2001; Sala-i-Martin et al. 2004; de la Fuente and Doménech 2006; Cohen and Soto 2007; Hanushek and Woessmann 2012, 2015).

Similar pathways suggest that health investments pay off over and above the increases in longevity and reductions in morbidity that are beneficial at the individual level. The literature focuses especially on the following channels: (1) healthier workers are more productive and contribute more to aggregate output (Fogel 1994, 1997; Shastry and Weil 2003; Weil 2007; Kuhn and Prettner 2016; Bloom,Kuhn, and Prettner 2019b); (2) healthier children tend to perform better in school, which enhances their potential for human capital accumulation (Miguel and Kremer 2004; Bleakley and Lange 2009; Field, Robles, and Torero 2009; Bleakley 2010, 2011; Bloom, Kuhn, and Prettner 2017b; Baldanzi et al. 2021); (3) healthier individuals are more inclined to educate themselves and to invest (Ben-Porath 1967; Kalemli-Ozcan et al. 2000; Bloom, Canning, and Graham et al. 2003a; 2007; Bloom, Canning, Moore 2014b; Cervellati and Sunde 2005, 2013; Prettner 2013); and (4) health investments (such as vaccination) that cure or prevent infectious diseases have positive spillovers to other individuals (Luca and Bloom 2018). Here, too, the positive effect found in micro-based studies is consistent with the macro-based evidence that health is an important determinant of economic growth (Barro 1991; Sala-i-Martin 1997; Sala-i-Martin,Doppelhofer, and Miller 2004; Lorentzen et al. 2008; Suhrcke and Urban 2010; Aghion, Howitt, and Murtin 2011; Cervellati and Sunde 2011; Bloom, Canning, and Fink 2014a; Bloom et al. 2019a).

In addition to enhancing productivity, education and health investments facilitate the escape from fertility-induced poverty traps. Poor countries generally have much higher youth dependency rates than wealthier countries. Supporting the basic needs of a relatively large child population imposes a substantial resource burden, necessitating the diversion of resources from other productive investments and ultimately impeding economic growth (see Coale and Hoover, 1958). This high youth dependency is primarily driven by high fertility rates, which, in turn, are partly due to precautionary motives in settings characterized by high infant and child mortality, incomplete insurance markets, and inadequate social protection systems. settings. As women become healthier, more educated, and more empowered, and as their expectations regarding child mortality improve, they tend to have fewer children, which helps in escaping fertility-induced poverty traps and converging onto a development path with low fertility and sustained economic growth (see Becker, Murphy, and Tamura 1990; Galor and Weil 2000; Galor 2005, 2011; Diebolt and Perrin 2013; Prettner and Strulik 2017a; Bloom Kuhn, and Prettner 2020 for the theoretical mechanisms and Brander and Dowrick 1994; Ahituv 2001; Li and Zhang 2007; Herzer, Strulik, and Vollmer 2012; Crespo, Cuaresma Lutz, and Sanderson 2014 for empirical evidence). The economic gains from lowering fertility (known as the "demographic dividend") can be sizable (Bloom and Williamson 1998; Bloom, Canning, and Sevilla 2003c; 2017a; Golley and Tyers 2012; Misra 2015). In addition, published research has revealed a second demographic dividend due to aging (Mason and Lee 2006), wherein persons expecting to live longer accumulate more assets to smooth consumption in old age.

Quantitative results from the literature

Quantitative assessments of the return on investment (ROI) from health, education, and fertility show that their impacts on productivity are sizeable. Psacharopoulos (1994), Hall and Jones (1999), Bils and Klenow (2000), and Montenegro and Patrinos (2014) demonstrate that, across studies of the returns to schooling, income is about 10 percent higher for each additional year of education. Psacharopoulos and Patrinos (2018) estimate even higher returns for low-income countries. In particular, average private rates of return to schooling are highest in Latin America and the Caribbean and for sub-Saharan Africa, and lowest for Europe, the Middle East, and Northern

TABLE 1 Selected prominent studies on the relation between one-year increases in schooling and per capita GDP growth in percentage points

Sources	Relation to per capita GDP growth	Time frame	Coverage
de la Fuente and Doménech (2006, 28)	0.574–1.151% per schooling year	1960–1990	World
Cohen and Soto (2007)	1.05–1.26% per schooling year	1960–1990	World
Lutz, Crespo Cuaresma, and Sanderson (2008, figure S1)	0.2–12.5% per schooling year	1970–2000	World
Hanushek and Woessmann (2012)	0.5% per 25 PISA test score points	1960–1990	World

Africa. Table 1 presents the findings of four prominent studies on education and growth of per capita GDP. The relation between schooling and growth is positive and ranges from 0.2 to 12.5 percent per each additional year of schooling with most of the estimates clustering in the range of 0.5 percent to 1.2 percent. A 25-point improvement in Programme for International Student Assessment (PISA) score, a measure of educational quality, is similarly associated with a 0.5 pp increase in annual per capita GDP growth. These improvements in education may have a positive spillover effect on health as well (Pradhan et al. 2017, 424; Lutz and Kebede 2018).

Fogel (1997), Weil (2007), and Shastry and Weil (2003) quantify the effects of health improvements on economic growth. Fogel (1997) provides historical evidence that improved nutrition (as observed over the period 1780–1980 in Great Britain) raised workforce productivity by 95 percent. Weil (2007) estimates that a 10 percent increase in the adult survival rate leads to a 6.7 percent increase in output per worker (i.e., productivity) and a 4.4 percent increase in GDP per worker. Shastry and Weil's (2003) results imply that differences in adult survival rates can explain as much as one-third of cross-country variation in GDP per worker. Bloom et al.'s (2019a) macroeconomic estimates lie in between the results of Shastry and Weil (2003) and of Weil (2007) based on aggregated microeconomic effects. Bloom et al.'s results indicate that a 10 percent increase in the adult survival rate leads to a 9.1 percent higher productivity per worker. Table 2 includes the results of selected studies on these relations.

Ashraf et al. (2013) simulate output trajectories for different demographic scenarios and show that a TFR decline of 0.5 children per woman raises per capita GDP by 11.9 percent after 50 years. Assuming linearity in the dependence between economic growth and fertility reduction, this implies that reducing the TFR by one child leads to an economic growth rate that is 0.45 pp higher (see also Bloom et al. 2017a). For Asian countries, the results of Bloom and Williamson (1998) and Bloom and Finlay (2009) suggest that one-third of East Asia's "growth miracle" is due to the demographic dividend that followed the strong decline in fertility in

TABLE 2 Selected prominent studies on the relation between increases in life expectancy and per capita GDP (or income) growth

Sources	Effect on growth	Time frame	Region
Bloom, Canning, and Fink 2014a (2014a, 1364)	A one-year increase in life expectancy raises per capita income between 5% and 15% over a 60-year period	1940–2000	World
Bloom et al. (2004)	A one-year increase in life expectancy is associated with a 4% increase in long run per capita output	1960–1990	World
Aghion, Howitt, and Murtin 2011 (2011, table 5)	A 1% increase in life expectancy at birth is associated with 2.88–9.46% higher growth	1960–2000	OECD
Cervellati and Sunde (2011, 130)	A 1% increase in life expectancy at birth in post-demographic transition countries is associated with a 1.94–4.14% higher growth rate	1940–2000	World
Bloom et al. (2019a, 13–14)	A 10% increase in adult survival rates is associated with an increase in labor productivity of 9.1%	1960–2010	World
Weil (2007, 1291)	A 10% increase in adult survival rates is associated with an increase in labor productivity of 6.7% and thus GDP per worker of 4.4%	–	Australia, Denmark, Finland, France, Italy, Japan, the Netherlands, Norway, Sweden, and the UK
Shastry and Weil (2003, 394)	Changes in health can explain 19% of cross-country differences in per capita income	–	World

OECD, Organisation for Economic Co-operation and Development.
NOTE: Studies with a dash in the column of the time frame are cross-sectional.

these countries. This corresponds to an increase in per capita GDP growth of about 0.66 percentage points for each one-child reduction in the TFR. Even small changes in infant mortality, wherein lower fertility rates follow increased survival rates, may lead to a substantial rise in growth (see effects from the selected studies in Table 3). Kelley and Schmidt (2005) examine various methods of modeling the effects of demographic changes on per capita GDP growth present in the literature. They find that demographic change can explain approximately 20 percent of per capita GDP growth across countries, with a larger effect in Asia and Europe than in other regions. These results are broadly in line with Bloom and Freeman (1988), Bloom and Williamson (1998), Bloom and Sachs (1998), and Bloom and Finlay (2009).

TABLE 3 Estimates for demographic dividends

Sources	Effects found	Time frame	Region
Bloom and Williamson (1998, 435–437)	A 1% higher growth rate of the working-age population is associated with an increase of 1.37–1.46% in the per capita GDP growth rate	1960–1990	East and Southeast Asia
Bloom and Finlay (2009, 58)	A 1% higher growth rate of the labor force is associated with an increase of 1.665% in the per capita GDP growth rate	1965–2005	World

We also analyzed literature that studied the relationship between infrastructure spending and economic growth. Influential works by Barro (1990) and Canning and Pedroni (2008) suggest that government spending—and infrastructure spending in particular—may enhance economic development and growth. Other findings (Crafts 2009) suggest that the effect is heterogeneous and that other countereffects may outweigh the positive ones.

Empirical analysis

The previous section's estimates are drawn from sources that use different country samples, time frames, controls, and datasets (of varying quality). Furthermore, these studies utilize different econometric methods and account for different types of costs and benefits. Most importantly, these studies typically focus only on one aspect such as education or health and not on different aspects together. As such, these results are helpful for discerning the general impacts of different types of expenditures but do not allow straightforward comparisons of the relative ROI across sectors.

One main virtue of the original empirical analyses presented in this paper is that they estimate the impacts of health, fertility, education, and infrastructure on per capita GDP simultaneously and under an internally consistent methodological framework. These analyses can better isolate the different relationships of interest and estimate their magnitudes in a fully comparable manner. Our empirical strategy[1] is based on growth regressions in both cross-country and panel data settings. Cross-sectional analyses are used to capture cumulative relationships over a relatively long time horizon. Here, we use initial levels of explanatory variables to explain economic growth over the following time period as a means of addressing issues of reverse causality. However, this does not control for confounding factors that may influence both initial levels of explanatory variables and subsequent growth and thus does not fully address endogeneity concerns. As such, dynamic panel data methods are used to make better inferences about the effects over a five-year interval. Our dynamic panel data specification treats all explanatory variables as endogenous and thus instruments these by their lagged levels and differences. In this way, we try to tackle endogeneity at least in the time dimension.

Although we rely on the growth regression framework both in the cross-section and the panel-data settings, we wish to stress that this method can also identify differences in levels of per capita GDP as present in the theoretical illustration. To see this, consider that the transition periods over which growth rates are higher in one country than in another can be rather long such that discernible differences in growth rates may persist for many decades. If growth rates have discernible differences, then it follows logically that level effects also appear at the end of the observation period. Consequently, we can safely use our methods to assess the effects of health, education, and fertility on long-run income levels as well.

The data for the cross-country and subsequent panel data analysis are taken from different sources, and the number of country observations is restricted by the size of the full set of the explanatory variables. The cross-country regressions explain annual per capita GDP growth rates between 1980 and 2015 as a function of initial income (two time points selected as in Barro 1991, 410), the share of equipment investments, the initial level of life expectancy, mean years of schooling, the TFR, electricity usage per capita (a proxy for infrastructure), the share of the population that is of working age (i.e., age 15–64) to control for the initial demographic structure, and political rights (a proxy for institutions).[2] As for the data sources, per capita GDP, life expectancy, the TFR, electricity usage per capita, and the share of the population that is of working age are taken from the World Development Indicators (World Bank, 2018), whereas the share of equipment investments is taken from DeLong and Summers (1991), the political rights index from Gastil (1987) and Barro (1991), and mean years of schooling from Barro and Lee (2013). The same sources were used for the panel data analysis except for the data on political rights, which were taken from the Freedom House (2018).

To be consistent with the presence of poverty traps based on the theoretical analysis, our data should exhibit multiple equilibria. As such, before we proceed to formulating the empirical strategy, we test the income data for the presence of multiple equilibria, or thresholds. The first step in testing for multiple growth regimes is to conduct a univariate analysis of distributions for the countries in our sample, like that of Quah (1996). Three well-established modality tests are applied using 1960, 1980, and 2015 per capita GDP data for the countries involved in our further analysis: the original Silverman (1981) test; the improved Hall and York (2001) test, specifically tuned for unimodality testing; and the Fisher and Marron (2001) test, which is superior in handling outliers. These tests reveal mixed evidence favoring unimodality for per capita GDP analyses of 1960 data: the Hall and York (2001) test does not reject unimodality, whereas the Fisher

TABLE 4 Testing income modality

log p.c. GDP	Hall and York (2001) / Silverman (1981)	Fisher and Marron (2001)
	H0: Unimodality	
1960	0.080	0.044
1980	0.042	0.039
2015	0.043	0.028
	H0: Bimodality	
1980	0.960	0.662
2015	0.486	0.243

NOTE: for all tests 1,000 bootstrapping rounds are conducted; support is derived from the range of the sample; p.c. = per capita

and Marron test does (see Table 4). However, both tests reject unimodality in favor of bimodality for 1980 and 2015 numbers. Figure 4 indicates that the 1980 modes are located near 8.02 (3,041 international dollars adjusted for purchasing power [INT-$]) and 10.2 (26,903 INT-$), corresponding to the low- and high-income equilibria, respectively. The antimode of 8.8 (6,634 INT-$) for 1980 serves as a virtual borderline between these two regimes. For 2015, the modes are located near 8.21 (3,679 INT-$) and 10.71 (44,802 INT-$). This indicates that the income distribution shifted higher, but maintained bimodality, making the threshold analysis valid throughout the period.

Although bimodality was maintained throughout the period, dispersion increased among low- and middle-income countries (LMICs), reflecting the fact that countries like China, Indonesia, and South Korea moved to upper quartiles within the LMIC group, while other countries experienced very little growth. Strikingly, only South Korea managed the transition from the low-income equilibrium in 1980 to the high-income equilibrium in 2015. Understanding the modality and the implications of the presence of different income regimes is crucial for the estimation strategy because the effects may have different magnitudes for different regimes (and may even offset one another).

To address the problem of poverty traps, we apply single and multiple equilibria empirical strategies. The equation for the single equilibrium approach allows for a single set of coefficients:

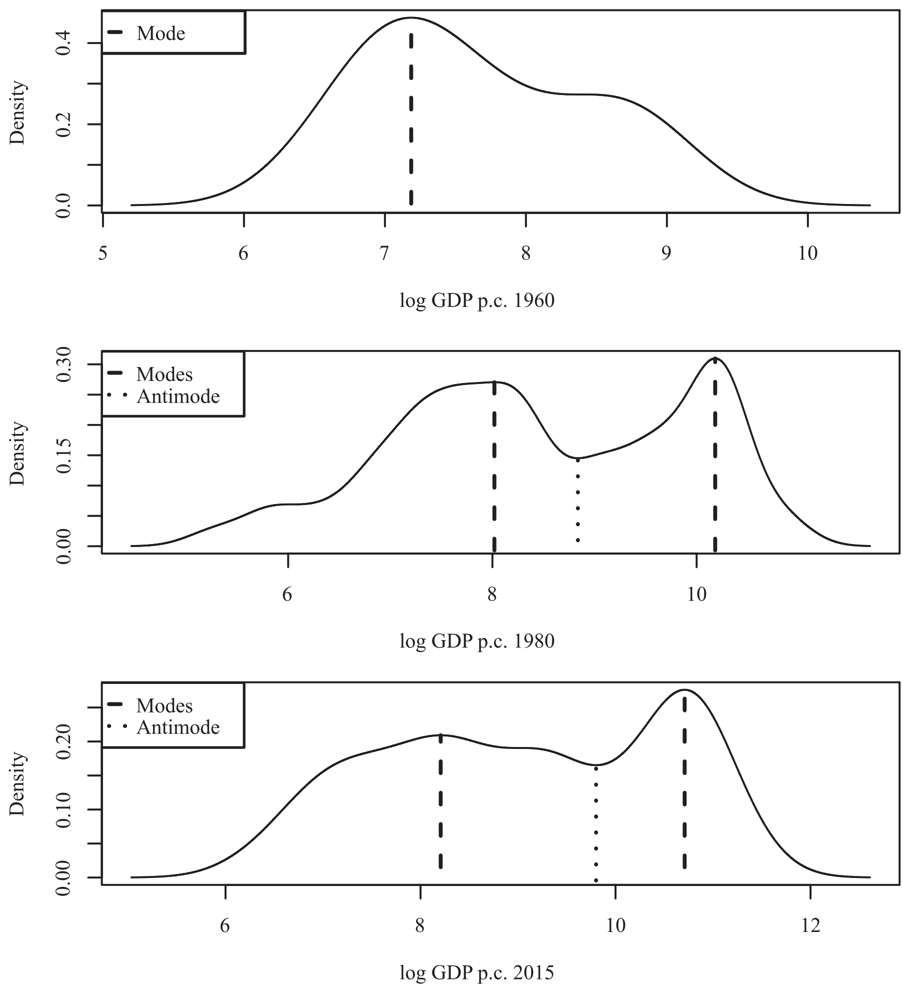
$$\bar{y}_{i,T-t_0} = \beta_0 + \beta_1 y_{i,t_0} + \beta_x X_{i,t_0} + u_{i,T-t_0} \tag{1}$$

whereas the multiple equilibria approach, as in Hansen (2000), allows for two sets of coefficients:

$$\bar{y}_{i,T-t_0} = \begin{cases} \theta_{10} + \theta_{11} y_{i,t_0} + \theta_{1x} X_{i,t_0} + u_{i,T-t_0} & q_i \leq \gamma \\ \theta_{20} + \theta_{21} y_{i,t_0} + \theta_{2x} X_{i,t_0} + u_{i,T-t_0} & q_i > \gamma \end{cases} \tag{2}$$

where $\bar{y}$ is the annual growth rate of per capita GDP between time t_0 and T, y is income at time t_0, X is a matrix of growth determinants at time t_0, u is

FIGURE 4 Evolution of the log of per capita GDP distribution from 1960 to 2015. The same sample of 69 countries is used for the estimation. Critical bandwidths used from 1960, 1980, and 2015 are 0.41, 0.26, and 0.4



the error term, i is the country subscript, β and θ denote the coefficients of interest, and γ and q_i denote the threshold and the threshold variable. We use the initial levels of the selected growth determinants (i.e., their values at t_0) to limit the influence of endogeneity and reverse causality on the estimated coefficients. For the threshold variable, we use the logarithm of initial income to distinguish among countries around the low- and high-income equilibria. This specification is based on those used in Durlauf and Johnson (1995, 368) and Hansen (2000, 587).

In the single equilibrium estimations (Table 5, column 1), fertility was the most powerful predictor of growth. In this specification, the only other significant effects were the convergence effects and the share of

TABLE 5 Single (1) and multiple equilibria (2 and 3) analysis; annual per capita GDP growth rates in 1980–2015

Variables	(1) Overall	Low income (2) $q_i \leq \gamma$	High income (3) $q_i > \gamma$
log of p.c. GDP, 1980	-0.0128***	-0.0169***	-0.0143**
	(0.0028)	(0.0042)	(0.0060)
log of p.c. GDP, 1960	-0.0043	-0.0027	-0.0083
	(0.0032)	(0.0049)	(0.0053)
equipment investment share (DeLong and Summers, 1991)	0.1008*	0.1845*	0.1076
	(0.0505)	(0.0992)	(0.0693)
log of life expectancy, 1980	0.0093	0.0390**	-0.0470
	(0.0176)	(0.0193)	(0.0470)
mean years of schooling, 1980	0.0010	-0.0010	0.0027***
	(0.0007)	(0.0012)	(0.0010)
fertility, 1980	-0.0099***	-0.0052*	-0.0103**
	(0.0023)	(0.0030)	(0.0051)
log of electricity usage p.c., 1980	0.0005	0.0014	0.0036
	(0.0018)	(0.0019)	(0.0044)
working-age population share, 1980	-0.0004	0.0020**	-0.0011
	(0.0006)	(0.0009)	(0.0009)
rural population share, 1980	-0.0000	-0.0003*	0.0000
	(0.0001)	(0.0002)	(0.0001)
political rights (Gastil, 1987; Barro, 1991)	0.0012	0.0018	0.0014
	(0.0010)	(0.0012)	(0.0019)
constant	0.1685*	-0.0752	0.4581*
	(0.0992)	(0.1293)	(0.2492)
countries per regime	69	35	34
R-squared	0.679		
R-squared adj.	0.624		
Breusch-Pagan test (p value)	0.884		
threshold (log of p.c. GDP, 1980)		8.38	

NOTE: Standard errors are in parentheses; three asterisks refer to significance at the 1% level, two asterisks to significance at the 5% level, and one asterisk to significance at the 10% level; p.c. = per capita.

equipment investments. However, the single equilibrium approach may be problematic because effects may vary in magnitude and sign across different data segments; the multiple equilibria analysis in Table 5 (columns 2 and 3) separately estimates effect magnitudes for low- and high-income countries (for the list of countries, see Table T2 in the Supporting Information. The threshold between low- and high-income countries, γ, is determined during the estimation.[3] This reflects income bimodality that persisted during our analysis period (as shown previously).[4] For the countries in the low-income equilibrium, the following variables were significant: initial income, share of equipment investments, life expectancy, fertility, working-age population share, and share of the rural population. It follows that low-income countries exhibit a higher speed of convergence than high-income

TABLE 6 Specification test for the omitted variable bias

Equation	Ramsey RESET test (p-value)
Table 5, Column 1	0.143
Table A5, Column 1	0.210

countries. A 10 percent increase in life expectancy for the low-income countries is linked to a 0.39 pp increase in average annual per capita GDP growth over the following 35 years. Increasing mean years of schooling by one year is in turn linked to a 0.27 pp increase in annual growth. Decreasing TFR by one child per woman is associated with a 0.5 and 1 pp increase in growth for low- and high-income countries, respectively. In Tables 5 and 6 no empirical evidence of heteroskedasticity was found, and normal standard errors were used for both estimation strategies. In cases of heteroskedasticity (robustness checks in Tables T3–T5 in the Supporting Information) robust standard errors were applied.

Table 6 points out the absence of an omitted variable bias according to the Ramsey (1969) test. The inclusion of regional dummies improves the results of the given test slightly. Therefore, we additionally conducted a robustness check with regional dummies for Europe, sub-Saharan Africa, East Asia, landlocked status, and absolute latitude validating our results.

Initial income is an intuitive variable for determining thresholds in the multiple equilibria analysis. However, other variables can be used to delineate thresholds as well: for example, Bloom and Canning (2007) focus on mortality traps and distinguish equilibria using life expectancy data. The state of the country with respect to the demographic transition can also be used to differentiate equilibria. Although correlated with income, the timing of a country's demographic transition can provide additional perspective on variation in economic growth determinants among demographic transition forerunners, followers, trailers, and latecomers (Reher 2004). Bimodality of fertility transitions is plausible (see Figure 5), and the Hall and York (2001)

FIGURE 5 Fertility transition years as in Reher (2004); sample of 58 countries; critical bandwidth: 10.35

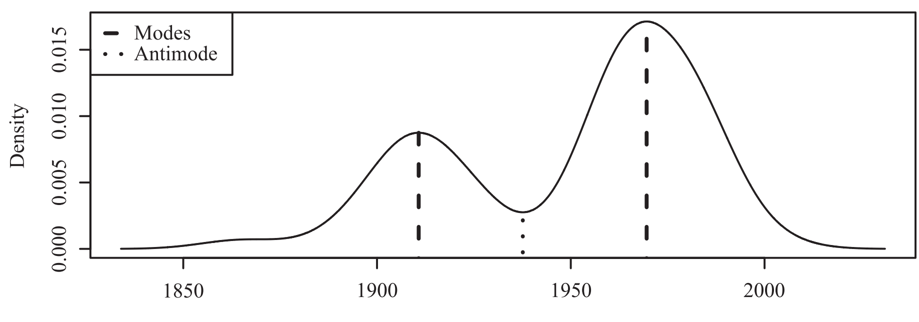


TABLE 7 Multiple equilibria analysis; annual per capita GDP growth rates in 1980–2015

Variables	Forerunners and followers (1) $q_i \leq \gamma$	Trailers and latecomers (2) $q_i > \gamma$
log of p.c. GDP, 1980	-0.0125***	-0.0176***
	(0.0047)	(0.0036)
log of p.c. GDP, 1960	-0.0079*	0.0022
	(0.0046)	(0.0038)
equipment investments share (DeLong and Summers, 1991)	0.0825	0.1863**
	(0.0598)	(0.0886)
log of life expectancy, 1980	-0.1228***	0.0379**
	(0.0410)	(0.0175)
mean years of schooling, 1980	0.0029***	0.0003
	(0.0008)	(0.0010)
fertility, 1980	-0.0192***	-0.0082***
	(0.0047)	(0.0024)
log of electricity p.c. usage, 1980	0.0011	-0.0000
	(0.0033)	(0.0017)
working-age population share, 1980	-0.0009	0.0004
	(0.0008)	(0.0008)
rural population share, 1980	-0.0001	-0.0002
	(0.0001)	(0.0001)
political rights (Gastil, 1987; Barro, 1991)	0.0022	0.0013
	(0.0015)	(0.0010)
constant	0.7880***	-0.0011
	(0.1986)	(0.1087)
countries per regime	28	30
threshold (fertility transition)	1960	

NOTE: Standard errors are in parentheses; three asterisks refer to significance at the 1% level, two asterisks to significance at the 5% level, and one asterisk to significance at the 10% level; p.c. = per capita.

and Fisher and Marron (2001) tests both reject unimodality, with p-values of 0.022 and 0.0002, respectively. According to the threshold analysis, forerunners and followers belong to one regime, whereas trailers and latecomers belong to the other. Table 7 shows that using thresholds based on the timing of the demographic transition produces effect estimates that correspond reasonably well to those produced using initial income: for trailers and latecomers life expectancy is significant and positive and for forerunners and followers mean years of schooling is the most significant determinant. Once again, fertility is significant and negative for both regimes, whereas life expectancy shows a negative effect for forerunners and followers. The fact that increases in life expectancy in forerunners and followers are mainly due to mortality reductions beyond the retirement age could explain the latter because the positive effects of increasing life expectancy on economic growth that would occur through increases in labor productivity of workers cannot play out for this group (Bloom,Kuhn, and Prettner 2019b). Another interesting finding is that forerunners of the demographic transition exhibit slower convergence, whereas the followers exhibit faster convergence: this finding is intuitive, because many of the followers are countries with relatively low income. Controlling for regional dummies, sub-Saharan Africa and South-East Asia did not change our results substantially (see Table T3 in the Supporting Information).

We conduct an additional robustness check with respect to (1) controlling for physical capital, (2) controlling for trade, (3) longer timeframes, and (4) interaction terms. The additional data on physical capital per capita are taken from the Penn World tables (see Feenstra, Inklaar, and Timmer 2015), whereas the trade volume as a fraction of GDP is taken from the World Development Indicators (World Bank 2018). Tables T3 and T4 in the Supporting Information incorporate robustness checks for Tables 5 and 6 with respect to further controls and time frames, whereas Table T5 contains an estimation with an interaction term, based on the specification from Table 5. Considering the effects in Tables T3 and T4 in the Supporting Information, the magnitude and the significance largely resemble those reported in Tables 5 and 6: life expectancy, fertility, and working-age population share are significant for the low-income countries, whereas schooling remains significant for the high-income countries. Demographic transition trailers and followers exhibit significant effects of life expectancy and fertility. In both cases, the proxy for trade is a significant positive growth determinant, which is consistent with findings from the literature (see Singh 2010; Vamvakidis 2002). In addition, we investigate the interaction between electrification and schooling, which combined becomes a powerful determinant of economic growth (see Table A5 in the Supporting Information): Electrification improves quality of education, as Shafiq (2007), Tsaurai and Ndou (2019), and Sovacool and Vera (2014) outline. The key benefits of electrification in education include lighting and extended studying hours, enhanced staff retention and teacher training, and improved school performance. In addition, Ajakaiye and Ncube (2010) and Piętak (2014) argue that infrastructure enhances the economic impact of human capital by improving worker productivity. Although no empirical evidence was found for the significant impact of infrastructure alone, the findings do suggest a positive impact through the channel of human capital.

Although the cross-section analysis provides long- and medium-run inferences, the effects of health, education, and infrastructure can be analyzed in the short run as well. This complementary analysis can be performed using dynamic panel data threshold growth regressions. To conduct a short-run dynamic inference and further minimize endogeneity bias and overcome other problems typical of cross-country growth regressions, we construct a strongly balanced panel dataset encompassing 55 countries for 1990–2015. In this estimation, we include the lag of per capita GDP to control for the convergence process and use five-year averages of the explanatory variables to smooth out business-cycle fluctuations,[5] alleviate measurement errors, and focus on short-run effects. Panel data growth equations are estimated using the system-generalized method of moments (SGMM) estimator (Blundell and Bond, 1998) and treating all explanatory variables as endogenous with their moments as instrumental variables (IV). All explanatory variables are lagged by one five-year time period, and time fixed effects are included.[6] The dynamic threshold panel model from Dang, Kim, and Shin (2012) is used to apply the single and multiple equilibria approach to the panel data. This model is superior to nondynamic threshold panel models, such as Hansen (1999), because it enables the use of dynamic instruments for potentially endogenous variables, including the autoregressive term (which is a crucial control for the convergence effect). We use the same set of variables as in the cross-country regressions, except for the fixed capital investments share, which is not available for the given time span and country sample. Controlling for lagged income should at least partly account for the stock of physical capital and therefore the absence of the latter control should not pose a major issue. The dynamic threshold panel model from Dang, Kim, and Shin (2012) takes the following form:

$$y_{i,t} = \left(\rho_1 y_{i,t-1} + \pi_1 X_{i,t-1}\right) I_{\left\{q_{i,t} \leq c\right\}} + \left(\rho_2 y_{i,t-1} + \pi_2 X_{i,t-1}\right) I_{\left\{q_{i,t} > c\right\}} + v_{i,t} \qquad (3)$$

where i and t are country and time indices with five-year periods, y is the log of per capita GDP, X is a matrix of determinants and controls, I is the indicator function for the regime attribution below or above the threshold, c is a country indicator variable (1 for low income and 2 for high income), ρ and π are coefficients, and $v_{i,t}$ is the composite error term. The data for the dynamic panel data analysis were taken from the World Bank (2018), Barro and Lee (2013), and Freedom House (2018). In the given specification the explanatory variables are instrumented by their lagged levels and differences to address the temporal endogeneity. This approach raises the number of instruments but is necessary to disentangle the temporal interdependencies among the variables. The overidentification tests[7] in Table 8 suggest that the instruments used are valid.

Note that because the dependent variable, per capita GDP, is given in logarithms, the marginal effects represent the change of income in pp. In the single equilibrium dynamic panel data estimation (see Table 8), fertility is the only significant predictor of economic growth: a one-unit decrease in the TFR in the current five-year period is associated with a 4.46 percent increase in per capita GDP in the next. Thus, the annualized effect of fertility is to increase per capita GDP growth by roughly 0.89 pp. Under the multiple equilibria specification, the dynamic threshold panel model estimates significant effects for multiple variables: for the low-income equilibrium, the annualized effects of TFR, schooling, and life expectancy are

TABLE 8 Single (1) and multiple (2 and 3) equilibria SGMM estimation; five-year log per capita GDP levels, 1990–2015

Variables	(1) Overall	(2) $q_{i,t} \leq c$	(3) $q_{i,t} > c$
log p.c. GDP (*t*-1)	0.9387***	0.9127***	0.8601***
	(0.0329)	(0.2295)	(0.0629)
log life expectancy (*t*-1)	0.1113	0.5834*	0.1255
	(0.1074)	(0.3171)	(0.1202)
mean years of schooling (*t*-1)	0.0034	0.0360**	-0.0026
	(0.0050)	(0.0179)	(0.0105)
fertility (*t*-1)	-0.0446*	-0.1028***	-0.0312
	(0.0250)	(0.0369)	(0.0345)
working-age population share (*t*-1)	0.0076	0.0004	0.0079
	(0.0063)	(0.0154)	(0.0074)
log of electricity p.c. usage (*t*-1)	-0.0203	-0.1986	0.0647
	(0.0371)	(0.2351)	(0.0813)
rural population share (*t*-1)	-0.0001	-0.0070	0.0004
	(0.0014)	(0.0047)	(0.0012)
political rights (*t*-1)	-0.0100	-0.0205	-0.0164
	(0.0088)	(0.0229)	(0.0186)
time dummies	yes	yes	
observations	275	275	
countries	55	55	
Arellano-Bond test for AR(2)	0.117	0.838	
Hansen test p-value	0.999	0.999	
threshold (log of p.c. GDP)		7.142	
Difference-in-Hansen tests			
GMM levels, exclusion	0.978	0.997	
GMM levels, difference	0.999	0.888	
IV instruments, exclusion	0.999	0.999	
IV instruments, difference	0.999	0.188	

NOTE: Robust standard errors are in parentheses; three asterisks refer to significance at the 1% level, two asterisks to significance at the 5% level, and one asterisk to significance at the 10% level; p.c. = per capita; GMM: generalized method of moments; IV: instrumental variables.

all significant. A one-child decrease in the TFR is associated with a 2.1 pp increase in per capita GDP growth, an additional year of schooling with a 0.7 pp increase, and a 10 percent increase in life expectancy with a 1.1 pp increase. Notably, the threshold for the given estimation lies close to 7.142 (1,264 INT-$),[8] which is lower than in the cross-section threshold growth regressions, and therefore these effects can be interpreted as best applying to very low-income cases.[9] In general, the short-run effects using the dynamic threshold panel model confirm the importance of fertility reduction, education, and health in these settings.[10]

To summarize, health and demography are again the most powerful predictors of economic growth and thus should be considered priorities in policymaking. Schooling follows in terms of magnitude and robustness.

Altogether, these results are consistent with the theoretical model suggesting that policies to reduce fertility, increase health, and bolster education are effective in helping an economy to escape from a poverty trap. The results are also consistent with the literature discussed in "Literature overview of the qualitative and quantitative results of different investments" section.

Conclusion

In the last 70 years, many LMICs underwent transformational economic growth, while others experienced moderate to nonexistent development gains. Governments of developing countries that made substantial progress can take advantage of the resource expansion that accompanied their past growth experiences and invest in health, education, and fertility reduction to promote further economic growth. Countries that made only modest improvements can draw lessons from these disparate growth outcomes to improve their growth trajectory going forward.

Using an intuitively accessible growth model in discrete time with multiple equilibria, we show that (1) investments in physical capital (e.g., infrastructure investments) could help a country escape a poverty trap and develop along a balanced growth trajectory only in the case of a "big push" scenario, while (2) investments in health and human capital would change the dynamic system and lift the balanced growth trajectory upward, reducing the poverty trap's basin of attraction and easing the transition to sustained growth.

Our empirical analysis is based on cross-sectional and dynamic panel data threshold regressions of 1980–2015 data.[11] While conducting cross-sectional and panel data analysis, we addressed the issue of temporal reverse causality by separating the measurement of the dependent and independent variables in the cross-section framework and instrumenting the dependent variables with their lagged levels and differences in the panel data framework. Empirical analyses across multiple datasets, time frames, controls, and econometric estimators yield four main associations relevant to policymakers in LMIC settings:[12]

(1) A one-child decrease in the TFR corresponds to a 2 pp increase in annual per capita GDP growth in the short run (five years) and 0.5 pp higher annual growth in the mid-run to long run (35 years).
(2) A 10 percent increase in life expectancy at birth corresponds to a 1 pp increase in annual per capita GDP growth in the short run and 0.4 pp higher growth in the mid-run to long run.
(3) A one-year increase in average educational attainment, measured in years of schooling, corresponds to a 0.7 pp increase in annual growth in the short run and 0.3 pp higher growth in the mid-run to long run.

(4) Infrastructure proxies were not significantly associated with subsequent growth in any of the models estimated.

Given that per capita GDP growth in LMICs generally averages between 2 and 4 percent, these estimated changes in annual growth are appreciable.[13] The findings of these analyses are generally consistent with the theoretical and empirical literature.

In prioritizing governmental expenditures for economic growth, decision makers should consider several factors alongside the average effects of the outcome variables on growth: the effectiveness of spending in improving the outcome variables, the timeline over which the spending effects will be realized, and validation using context-specific findings. Applying these metrics, reproductive health and fertility reduction tend to predominate as growth determinants. Policy measures related to this area are most effective in the short- and medium-term time domains (5–15 years). Improving general health can be particularly effective in the medium term as well;[14] however, most of the returns would be expected in the long run. Education features a longer maturity horizon, although for low-income countries, some effects are evident even in the medium term. Infrastructure projects have the broadest range in terms of findings and time domain. Our analyses suggest that this category has less transformative potential than the others, but this does not suggest that a positive relationship between infrastructure spending and economic growth should be ruled out entirely.

Priority setting within sectors is equally important. The Copenhagen Consensus Center's Post-2015 Consensus informs this task for developing countries by ranking more than 100 development targets proposed by the United Nations' Open Working Group according to the social returns to each dollar spent meeting each goal. The results of this aggregated research suggest that investments in decreasing the burden of diseases, HIV and AIDS treatment and prevention, and preschool and primary education (especially for low-income countries) have the most potential for promoting growth (Lomborg, 2018). Other meta-analyses show that investments in primary education tend to offer higher social returns than such investments in secondary education, which, in turn, are higher than returns from tertiary education (Psacharopoulos and Patrinos, 2018). Furthermore, investments in improving gender equality across various domains also promote sustained economic growth very effectively by reducing fertility, increasing the stock of human capital, and improving women's and children's health (Klasen, 2002, 2018; Abu-Ghaida and Klasen, 2004; Bhalotra and Rawlings, 2011; Albanesi and Olivetti, 2016; Prettner and Strulik, 2017a; Bloom Kuhn, and Prettner 2020).

Recognizing that the results presented in this paper represent the average benefits of interventions and improvements in outcomes across countries, with the original empirical results excluding costs altogether, is important. In reality, both the costs and benefits of achieving improvements in outcomes will vary substantially across settings and within the context of different programs. For example, a program to expand access to birth control may be highly successful in reducing fertility where unmet need for contraceptives is high, but completely ineffective in another environment where individuals desire more offspring (Prettner and Strulik, 2017b). As such, policymakers must consider the specific constraints on development in their settings and the relative cost of the options available for achieving improvements in health, education, fertility, and infrastructure to make sound assessments of their relative ROIs. Ultimately, determining which interventions will best promote economic growth remains highly contextual, but well-informed decision makers should benchmark their expectations relative to the cross-country development experience of the last several decades.

Data availability

Datasets and replication files are available upon request. Please contact Vadim Kufenko for further information: vadim.kufenko@uni-hohenheim.de

Notes

The authors would like to thank the editor, three anonymous referees, and David Canning for helpful comments and suggestions and Martin Weese for excellent research assistance. Vadim Kufenko and Klaus Prettner are grateful for the funding provided by the Faculty of Business, Economics, and Social Sciences at the University of Hohenheim within its research focus “Inequality and Economic Policy Analysis (INEPA).” This research was made possible with the support of the Harvard Ministerial Leadership Program. Research findings and conclusions are those of the authors and do not necessarily reflect the views of the Ministerial Program or its funders, or Harvard University.

1 An alternative strategy is a microsimulation using a general equilibrium model as in Kabajulizi et al. (2017) and Mohammed (2018), where the causal impact of expenditures is modeled for Uganda and Algeria, respectively. However, due to calibration issues, these simulations are generally better suited for specific countries, rather than for large cross-country samples. Thus, to provide a broader analysis we base our empirical approach on the well-established growth regression framework.

2 One could assume nonlinearities in these relationships (e.g., the diminishing returns to education) and interaction terms between variables (e.g., that investments in education may increase productivity to a greater extent when a population is healthy). However, inclusion of these extra terms did not improve the predictive power of the models developed in this paper, possibly due to the relatively small sample of countries.

3 The multiple equilibria analysis presented in Table 5 assumes two regimes, reflecting the bimodal income distribution evidenced previously.

4 Implementing these analyses assuming a larger number of regimes would be problematic due to the sample size.

5 As Durlauf et al. (2005) note, five-year aggregation is a well-established practice in dynamic panel data estimation of growth regressions.

6 To avoid perfect collinearity, we leave out the 2010–2015 period.

7 Please note that the Hansen test for overidentifying restrictions may be weakened by the number of instruments.

8 The Hansen (1999) model estimates similar threshold values, validating these results.

9 At least 12 countries from our sample would fall in this category at different time periods: Bangladesh, Benin, Cameroon, China, Congo (Dem. Rep.), Côte d'Ivoire, Ghana, India, Kenya, Myanmar, Nicaragua, and Nigeria. For the list of countries, see Table T2 in the Supporting Information.t

10 In addition, we conducted an impulse–response analysis (see Figures T1 and T2 in the Supporting Information) using panel vector autoregressions based on three-year periods to cross-validate the effects in the short run and explicitly address the impact of health and education expenditures on economic growth. The orthogonal cumulative impulse–response functions with bootstrapped confidence intervals as in Lütkepohl (2005, 126–129) suggest that after five periods (15 years) the impact of health expenditures would prevail over the one of education expenditures.

11 Additional robustness checks are conducted for the timeframes between 1970 and 2015.

12 The relationships among these variables likely vary with contextual factors. As such, the results presented should be understood as average, at-the-margin estimates. Additionally, as discussed previously, different methodologies are used to estimate short-run and mid- to long-run effects, so conclusions about the timeline of the return on benefits should be made cautiously.

13 In interpreting these results, considering the compounding effect of a persistent change in growth over several years is important. For example, a 1 pp increase in average annual economic growth from 3 to 4 percent accumulates to 3.9 times higher per capita GDP after a period of 35 years rather than 2.8 times higher.

14 See Table 8 for the panel data results and the related medium-term effects.

References

Abu-Ghaida, Dina, and Stephan Klasen. 2004. "The Costs of Missing the Millennium Development Goal on Gender Equity." *World Development* 32 (7): 1075–1107. https://doi.org/10.1016/j.worlddev.2004.02.003.

Acemoglu, Daron. 2009. *Introduction to Modern Economic Growth*. Princeton, NJ: Princeton University Press.

Aghion, Philippe, Peter Howitt, and Fabrice Murtin. 2011. "The Relationship between Health and Growth: When Lucas Meets Nelson-Phelps." *Review of Economics and Institutions* 2 (1): 1–24.

Ahituv, Avner. 2001. "Be Fruitful or Multiply: On the Interplay between Fertility and Economic Development." *Journal of Population Economics* 14(1): 51–71. https://doi.org/10.1007/s001480050159.

Ajakaiye, Olu, and Mthuli Ncube. 2010. "Infrastructure and Economic Development in Africa: An Overview." *Journal of African Economies* 19(Suppl. 1): i3–i12. https://doi.org/10.1093/jae/ejq003.

Albanesi, Stefania, and Claudia Olivetti. 2016. "Gender Roles and Medical Progress." *Journal of Political Economy* 124(3): 650–695. https://doi.org/10.1086/686035.

Ashraf, Quamrul H., David N. Weil, and Joshua Wilde. 2013. "The Effect of Fertility Reduction on Economic Growth." *Population and Development Review* 39(1): 97–130. https://doi.org/10.1111/j.1728-4457.2013.00575.x.

Azariadis, Costas, and John Stachurski. 2005. "Poverty Traps Aghion, eds. Philippe and Durlauf, Steven, *Handbook of Economic Growth*. 1, Amsterdam: Elsevier, 295–384. https://doi.org/10.1016/s1574-0684(05)01005-1.

Baldanzi, Annarita, Alberto Bucci, and Klaus Prettner. 2021. "Children's Health, Human Capital Accumulation, and R&D-Based Economic Growth." *Macroeconomic Dynamics* (forthcoming).

Barro, Robert J. 1990. "Government Spending in a Simple Model of Endogeneous Growth." *Journal of Political Economy* 98(5, Pt. 2): S103–S125. https://doi.org/10.1086/261726.

——— 1991. "Economic Growth in a Cross Section of Countries." *The Quarterly Journal of Economics* 106(2): 407. https://doi.org/10.2307/2937943.

——— 2001. "Human Capital and Growth." *American Economic Review* 91 (2): 12–17. https://doi.org/10.1257/aer.91.2.12.

Barro, Robert J., and Jong Wha Lee. 2013. "A New Data Set of Educational Attainment in the World, 1950–2010." *Journal of Development Economics* 104(September): 184–198. https://doi.org/10.1016/j.jdeveco.2012.10.001.

Battu, Harminder, Clive R. Belfield, and Peter J. Sloane. 2003. "Human Capital Spillovers within the Workplace: Evidence for Great Britain." *Oxford Bulletin of Economics and Statistics* 65(5): 575–594. https://doi.org/10.1111/j.1468-0084.2003.00062.x.

Becker, Gary S., Kevin M. Murphy, and Robert Tamura. 1990. "Human Capital, Fertility, and Economic Growth." *Journal of Political Economy* 98(5, Pt. 2): S12–S37. https://doi.org/10.1086/261723.

Ben-Porath, Yoram. 1967. "The Production of Human Capital and the Life Cycle of Earnings." *Journal of Political Economy* 75(4): 352–365. https://doi.org/10.1086/259291.

Bhalotra, Sonia, and Samantha B. Rawlings. 2011. "Intergenerational Persistence in Health in Developing Countries: The Penalty of Gender Inequality?" *Journal of Public Economics* 95(3–4): 286–299. https://doi.org/10.1016/j.jpubeco.2010.10.016.

Bhattacharya, Dhritiman, Nezih Guner, and Gustavo Ventura. 2013. "Distortions, Endogenous Managerial Skills and Productivity Differences." *Review of Economic Dynamics* 16(1): 11–25. https://doi.org/10.1016/j.red.2012.10.001.

Bils, Mark, and Peter J. Klenow. 2000. "Does Schooling Cause Growth?" *American Economic Review* 90(5): 1160–1183. https://doi.org/10.1257/aer.90.5.1160.

Bleakley, Hoyt. 2010. "Malaria Eradication in the Americas: A Retrospective Analysis of Childhood Exposure." *American Economic Journal. Applied Economics* 2(2). https://doi.org/10.1257/app.2.2.1.

——— 2011. "Health, Human Capital, and Development." *Annual Review of Economics* 2(September): 283–310. https://doi.org/10.1146/annurev.economics.102308.124436.

Bleakley, Hoyt, and Fabian Lange. 2009. "Chronic Disease Burden and the Interaction of Education, Fertility, and Growth." *The Review of Economics and Statistics* 91(1): 52–65. https://doi.org/10.1162/rest.91.1.52.

——— and ———. 2000. "The Health and Wealth of Nations." *Science* 287(5456): 1207–1209. https://doi.org/10.1126/science.287.5456.1207.

——— and ———. 2007. "Mortality Traps and the Dynamics of Health Transitions." *Proceedings of the National Academy of Sciences of the United States of America* 104(41): 16044–16049. https://doi.org/10.1073/pnas.0702012104.

———, ———, and Günther Fink. 2014a. "Disease and Development Revisited." *Journal of Political Economy* 122(6): 1355–1366. https://doi.org/10.1086/677189.

———, ———, and Bryan Graham. 2003a. "Longevity and Life-Cycle Savings." *Scandinavian Journal of Economics* 105(3): 319–338. https://doi.org/10.1111/1467-9442.t01-1-00001.

———, David Canning, Rainer Kotschy, Klaus Prettner, and Johannes Schünemann. 2019a. "Health and Economic Growth: Reconciling the Micro and Macro Evidence." *National Bureau of Economic Research*. https://doi.org/10.3386/w26003.

———, David Canning, and Pia N. Malaney. 2000. "Population Dynamics and Economic Growth in Asia." *Population and Development Review* 26(2000): 257–290.

———, David Canning, Richard K Mansfield, and Michael Moore. 2007. "Demographic Change, Social Security Systems, and Savings." *Journal of Monetary Economics* 54(1): 92–114. https://doi.org/10.1016/j.jmoneco.2006.12.004.

Bloom, David E., David Canning, and Michael Moore. 2014b. "Optimal Retirement with Increasing Longevity." *The Scandinavian Journal of Economics* 116(3): 838–858. https://doi.org/10.1111/sjoe.12060.

Bloom, David E., David Canning, and ———. 2003b. "Geography and Poverty Traps." *Journal of Economic Growth* 8(4): 355–378. https://doi.org/10.1023/a:1026294316581.

Bloom, David E., David Canning, and ———. 2003c. "." *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*. Population Matters. Santa Monica, CA: RAND.

———, ———, and ——— 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, David E., and Jocelyn E. Finlay. 2009. "Demographic Change and Economic Growth in Asia." *Asian Economic Policy Review* 4(1): 45–64. https://doi.org/10.1111/j.1748-3131.2009.01106.x.

Bloom, David E., and Richard B. Freeman. 1988. "Economic Development and the Timing and Components of Population Growth." *Journal of Policy Modeling* 10(1): 57–81. https://doi.org/10.1016/0161-8938(88)90035-x.

Bloom, David E., ———, and ———. 2017a. "Africa's Prospects for Enjoying a Demographic Dividend." *Journal of Demographic Economics* 83(1): 63–76. https://doi.org/10.1017/dem.2016.19.

———, ———, and ———. 2017b. "Invest in Women and Prosper." *Finance & Development* 54(3): 50–55.

———, ———, and ———. 2019b. "Health and Economic Growth." In Hamilton, Jonathan K., Dixit, Avinash, Edwards, Sebastian & Judd, Kenneth, *Oxford Research Encyclopedia of Economics and Finance*. Oxford: Oxford University Press. https://doi.org/10.1093/acrefore/9780190625979.013.36.

———, Michael Kuhn, and ———. 2020. "The Contribution of Female Health to Economic Development." *The Economic Journal* 130(630): 1650–1677. https://doi.org/10.1093/ej/ueaa061.

Bloom, David E. and Jeffrey D. Sachs. 1998. "Geography, Demography, and Economic Growth in Africa." *Brookings Papers on Economic Activity* 2: 207. https://doi.org/10.2307/2534695.

Bloom, David E., and Jeffrey G. Williamson. 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.

Blundell, Richard, and Stephen 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.

Brander, James A., and Steve Dowrick. 1994. "The Role of Fertility and Population in Economic Growth." *Journal of Population Economics* 7(1): 1–25. https://doi.org/10.1007/bf00160435.

Bucci, Alberto, and Klaus Prettner. 2020. "Endogenous Education and the Reversal in the Relationship between Fertility and Economic Growth." *Journal of Population Economics* 33(3): 1025–1068. https://doi.org/10.1007/s00148-019-00762-5.

Cabral, Luís M.B., and José Mata. 2003. "On the Evolution of the Firm Size Distribution: Facts and Theory." *American Economic Review* 93(4): 1075–1090. https://doi.org/10.1257/000282803769206205.

Canning, David, and Peter Pedroni. 2008. "Infrastructure, Long-Run Economic Growth and Causality Tests for Cointegrated Panels." *Manchester School* 76(5): 504–527. https://doi.org/10.1111/j.1467-9957.2008.01073.x.

Canning, David, Sangeeta Raja, and Abdo S. Yazbeck, eds. 2015. *Africa's Demographic Transition: Dividend or Disaster*. ? Washington, DC: The World Bank.

Cervellati, Matteo, and ———. 2005. "Human Capital Formation, Life Expectancy, and the Process of Development." *American Economic Review* 95(5): 1653–1672. https://doi.org/10.1257/000282805775014380.

——— and ———. 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.

——— and ——— 2013. "Life Expectancy, Schooling, and Lifetime Labor Supply: Theory and Evidence Revisited." *Econometrica* 81(5): 2055–2086. https://doi.org/10.3982/ecta11169.

Coale, Ansley Johnson, and Hoover, Edgar Malone. 1958. *Population Growth and Economic Development in Low-Income Countries*. Princeton, NJ: Princeton University Press.

Cohen, Daniel, and Marcelo Soto. 2007. "Growth and Human Capital: Good Data, Good Results." *Journal of Economic Growth* 12(1): 51–76. https://doi.org/10.1007/s10887-007-9011-5.

Crafts, Nicholas. 2009. "Transport Infrastructure Investment: Implications for Growth and Productivity." *Oxford Review of Economic Policy* 25(3): 327–343. https://doi.org/10.1093/oxrep/grp021.

Crespo Cuaresma Jesús, Wolfgang Lutz, and Warren Sanderson. 2014. "Is the Demographic Dividend an Education Dividend?" *Demography* 51(1): 299–315. https://doi.org/10.1007/s13524-013-0245-x.

Dang, Viet Anh, Minjoo Kim, and Yongcheol Shin. 2012. "Asymmetric Capital Structure Adjustments: New Evidence from Dynamic Panel Threshold Models." *Journal of Empirical Finance* 19(4): 465–482. https://doi.org/10.1016/j.jempfin.2012.04.004.

de la Croix, David, and Matthias Doepke. 2003. "Inequality and Growth: Why Differential Fertility Matters." *American Economic Review* 93(4): 1091–1113. https://doi.org/10.1257/000282803769206214.

de la Croix, David, and Marie Vander Donckt. 2010. "Would Empowering Women Initiate the Demographic Transition in Least Developed Countries?" *Journal of Human Capital* 4(2): 85–129. https://doi.org/10.1086/657081.

de la Fuente, Angel, and Rafael Doménech. 2006. "Human Capital in Growth Regressions: How Much Difference Does Data Quality Make?" *Journal of the European Economic Association* 4(1): 1–36. https://doi.org/10.1162/jeea.2006.4.1.1.

DeLong, J. Bradford, and Lawrence H. Summers. 1991. "Equipment Investment and Economic Growth." *The Quarterly Journal of Economics* 106 (2): 445. https://doi.org/10.2307/2937944.

Diamond, Peter A. 1965. "National Debt in a Neoclassical Growth Model." *American Economic Review* 55(5): 1126–1150.

Diebolt, Claude, and Faustine Perrin. 2013. "From Stagnation to Sustained Growth: The Role of Female Empowerment." *American Economic Review* 103(3): 545–549. https://doi.org/10.1257/aer.103.3.545.

Durlauf, Steven N., and Paul A. Johnson. 1995. "Multiple Regimes and Cross-Country Growth Behaviour." *Journal of Applied Econometrics* 10(4): 365–384. https://doi.org/10.1002/jae.3950100404.

Durlauf, Steven N., Paul A. Johnson, and Jonathan R.W. Temple. 2005. "Growth Econometrics." Aghion, Philippe & Durlauf, Steven, *Handbook of Economic Growth*, 1(1), Amsterdam: Elsevier, 555–677. https://doi.org/10.1016/s1574-0684(05)01008-7.

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

Field, Erica, Omar Robles, and Maximo Torero. 2009. "Iodine Deficiency and Schooling Attainment in Tanzania." *American Economic Journal: Applied Economics* 1(4): 140–169. https://doi.org/10.1257/app.1.4.140.

Fisher, Nicholas I. and Marron, J. Stephen 2001. "Mode testing via the excess mass estimate." *Biometrika* 88(2): 499–517. https://doi.org/10.1093/biomet/88.2.499N.

Fogel, Robert. 1994. "Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy." *National Bureau of Economic Research* Working Paper No. 4638. https://doi.org/10.3386/w4638.

Fogel, Robert William. 1997. "New Findings on Secular Trends in Nutrition and Mortality: Some Implications for Population Theory." Rosenzweig, Mark & Stark, Oded, *Handbook of Population and Family Economics*, 1 A, Amsterdam: Elsevier, 433–481. https://doi.org/10.1016/s1574-003x(97)80026-8.

Freedom House. 2018. *Freedom in the World*. Washington, DC: Rowman & Littlefield Publishers.

Galor, Oded. 2005. "From Stagnation to Growth: Unified Growth Theory." Aghion, Philippe & Durlauf, Steven, *Handbook of Economic Growth*, 1 A, Amsterdam: Elsevier, 171–293. https://doi.org/10.1016/s1574-0684(05)01004-x.

———. 2011. *Unified Growth Theory*. Princeton, NJ: Princeton University Press.

Galor, Oded, and David N. Weil. 2000. "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond." *American Economic Review* 90(4): 806–828. https://doi.org/10.1257/aer.90.4.806.

Galor, Oded, and Joseph Zeira. 1993. "Income Distribution and Macroeconomics." *The Review of Economic Studies* 60(1): 35. https://doi.org/10.2307/2297811.

Gastil, Raymond D. 1987. *Freedom in the World*. Westport, CT: Greenwood Press.

Gennaioli, Nicola, La Porta, Rafael, Lopez-de-Silanes, Florencio, and Shleifer, Andrei. 2013. "Human Capital and Regional Development." *Quarterly Journal of Economics* 128(1), 105–164.

Golley, Jane, and Rod Tyers. 2012. "Demographic Dividends, Dependencies, and Economic Growth in China and India." *Asian Economic Papers* 11(3): 1–26. https://doi.org/10.1162/asep_a_00156.

Hall, Peter and Matthew York. 2001. "On the Calibration of Silverman's Test for Multimodality." *Statistica Sinica* 11(2), 515–536.

Hall, Robert E., and Charles I. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker than Others?" *The Quarterly Journal of Economics* 114(1): 83–116. https://doi.org/10.1162/003355399555954.

Hansen, Bruce E. 1999. "Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference." *Journal of Econometrics* 93(2): 345–368. https://doi.org/10.1016/s0304-4076(99)00025-1.

——— 2000. "Sample Splitting and Threshold Estimation." *Econometrica* 68(3): 575–603. https://doi.org/10.1111/1468-0262.00124.

Hanushek, Eric A. 2013. "Economic Growth in Developing Countries: The Role of Human Capital." *Economics of Education Review* 37: 204–212. https://doi.org/10.1016/j.econedurev.2013.04.005.

Hanushek, Eric A, and Dennis D Kimko. 2000. "Schooling, Labor-Force Quality, and the Growth of Nations." *American Economic Review* 90(5): 1184–1208. https://doi.org/10.1257/aer.90.5.1184.

———, and ———. 2012. "Do Better Schools Lead to More Growth? Cognitive Skills, Economic Outcomes, and Causation." *Journal of Economic Growth* 17(4): 267–321. https://doi.org/10.1007/s10887-012-9081-x.

———, and ———. 2015. *The Knowledge Capital of Nations: Education and the Economics of Growth*. Cambridge, MA: MIT Press.

Herzer, Dierk, Holger Strulik, and Sebastian Vollmer. 2012. "The Long-Run Determinants of Fertility: One Century of Demographic Change 1900–1999." *Journal of Economic Growth* 17(4): 357–385. https://doi.org/10.1007/s10887-012-9085-6.

Kabajulizi, Judith, Marcus R Keogh-Brown, and Richard D Smith. 2017. "The Welfare Implications of Public Healthcare Financing: A Macro–Micro Simulation Analysis of Uganda." *Health Policy and Planning* 32(10): 1437–1448. https://doi.org/10.1093/heapol/czx125.

Kalemli-Ozcan, Sebnem, Harl E. Ryder, and David N. Weil. 2000. "Mortality Decline, Human Capital Investment, and Economic Growth." *Journal of Development Economics* 62(1): 1–23. https://doi.org/10.1016/s0304-3878(00)00073-0.

Kelley, Allen C., and Robert M. Schmidt. 2005. "Evolution of Recent Economic-Demographic Modeling: A Synthesis." *Journal of Population Economics* 18(2): 275–300. https://doi.org/10.1007/s00148-005-0222-9.

Klasen, Stephan. 2002. "Low Schooling for Girls, Slower Growth for All? Cross-Country Evidence on the Effect of Gender Inequality in Education on Economic Development." *The World Bank Economic Review* 16(3): 345–373. https://doi.org/10.1093/wber/lhf004.

——— 2018. "The Impact of Gender Inequality on Economic Performance in Developing Countries." *Annual Review of Resource Economics* 10(1): 279–298. https://doi.org/10.1146/annurev-resource-100517-023429.

Krueger, Alan B., and Mikael Lindahl. 2001. "Education for Growth: Why and for Whom?" *Journal of Economic Literature* 39(4): 1101–1136. https://doi.org/10.1257/jel.39.4.1101.

Kuhn, Michael, and Klaus Prettner. 2016. "Growth and Welfare Effects of Health Care in Knowledge-Based Economies." *Journal of Health Economics* 46: 100–119. https://doi.org/10.1016/j.jhealeco.2016.01.009.

Lee, Ronald, and Andrew Mason. 2010. "Fertility, Human Capital, and Economic Growth over the Demographic Transition." *European Journal of Population = Revue Europeenne de Demographie* 26(2): 159–182. https://doi.org/10.1007/s10680-009-9186-x.

Leibenstein, Harvey. 1954. *A Theory of Economic Demographic Development*. Princeton, NJ: Princeton University Press.

———. 1975. "The Economic Theory of Fertility Decline." *The Quarterly Journal of Economics* 89(1): 1. https://doi.org/10.2307/1881706.

Li, Hongbin, and Junsen Zhang. 2007. "Do High Birth Rates Hamper Economic Growth?" *Review of Economics and Statistics* 89(1): 110–117. https://doi.org/10.1162/rest.89.1.110.

Lomborg, Bjorn, ed. 2018. *Prioritizing Development: A Cost Benefit Analysis of the United Nations' Sustainable Development Goals*. Cambridge: Cambridge University Press.

Lorentzen, Peter, John McMillan, and Romain Wacziarg. 2008. "Death and Development." *Journal of Economic Growth* 13 (2): 81–124. https://doi.org/10.1007/s10887-008-9029-3.

Luca, Dara Lee, and David E. Bloom. 2018. "The Returns to Parental Health: Evidence from Indonesia." *National Bureau of Economic Research Working Paper 25304*. https://doi.org/10.3386/w25304.

Lucas, Robert 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.

Lütkepohl, Helmut. 2005. *New Introduction to Multiple Time Series Analysis*. Heidelberg: Springer.

Lutz, Wolfgang, Jesus Crespo Cuaresma, and Warren Sanderson. 2008. "The Demography of Educational Attainment and Economic Growth." *Science* 319(5866): 1047–1048. https://doi.org/10.1126/science.1151753.

Lutz, Wolfgang, and Endale Kebede. 2018. "Education and Health: Redrawing the Preston Curve." *Population and Development Review* 44(2): 343–361. https://doi.org/10.1111/padr.12141.

Malecki, Edward J. 1997. "Technology and Economic Development: The Dynamics of Local, Regional, and National Change." *Economic Geography* 69(1): 94–98.

Mason, Andrew, and Ronald Lee. 2006. "Reform and Support Systems for the Elderly in Developing Countries: Capturing the Second Demographic Dividend." *Genus* 62(2): 11–35.

Miguel, Edward, and Michael Kremer. 2004. "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities." *Econometrica* 72(1): 159–217. https://doi.org/10.1111/j.1468-0262.2004.00481.x.

Misra, Roli. 2015. "Impact of Demographic Dividend on Economic Growth." *International Studies* 52(1–4): 99–117. https://doi.org/10.1177/0020881717714685.

Mohammed, Touitou. 2018. "Simulation of the Impact of Economic Policies on Poverty and Inequality: GEM in Micro-Simulation for the Algerian Economy." *International Review of Applied Economics* 32(3): 308–330. https://doi.org/10.1080/02692171.2017.1342778.

Montenegro, Claudio E., and ———. 2014. "Comparable Estimates of Returns to Schooling around the World." *Policy Research Working Paper Series 7020, The World Bank.* https://doi.org/10.1596/1813-9450-7020.

Murphy, Kevin M., Andrei Shleifer, and Robert W. Vishny. 1989. "Industrialization and the Big Push." *Journal of Political Economy* 97(5): 1003–1026. https://doi.org/10.1086/261641.

Nelson, Richard R. 1956. "A Theory of the Low-Level Equilibrium Trap in Underdeveloped Economies." *American Economic Review*, 46(5): 894–908.

Nelson, Richard R., and Edmund Phelps. 1966. "Investment in Humans, Technological Diffusion, and Economic Growth." *American Economic Review* 61(1–2): 69–75.

Patrinos, Harry Anthony, and George Psacharopoulos. 2011. "Education: Past, Present and Future Global Challenges." *World Bank Policy Research Working Paper No. 5616*. https://doi.org/10.1596/1813-9450-5616.

Piętak, Łukasz. 2014. "Review of Theories and Models of Economic Growth." *Comparative Economic Research. Central and Eastern Europe* 17(1): 45–60. https://doi.org/10.2478/cer-2014-0003.

Pradhan, Elina, Elina M. Suzuki, Sebastián Martínez, Marco Schäferhoff, and Dean T. Jamison. 2017. "The Effects of Education Quantity and Quality on Child and Adult Mortality: Their Magnitude and Their Value." *Disease Control Priorities: Child and Adolescent Health and Development* 3(8): 423–440. https://doi.org/10.1596/978-1-4648-0423-6_ch30.

Prettner, Klaus. 2013. "Population Aging and Endogenous Economic Growth." *Journal of Population Economics* 26(2): 811–834. https://doi.org/10.1007/s00148-012-0441-9.

———, and David E. Bloom. 2020. *Automation and its Macroeconomic Consequences*. Cambridge, MA: Academic Press. https://doi.org/10.1016/b978-0-12-818028-0.00001-6.

———, and ———. 2016. "Technology, Trade, and Growth: The Role of Education." *Macroeconomic Dynamics* 20(5): 1381–1394. https://doi.org/10.1017/s1365100514000856.

———, and ——— 2017a. "Gender Equity and the Escape from Poverty." *Oxford Economic Papers* 69(1): 55–74. https://doi.org/10.1093/oep/gpw043.

———, and ——— 2017b. "It's a Sin-Contraceptive Use, Religious Beliefs, and Long-Run Economic Development." *Review of Development Economics* 21(3): 543–566. https://doi.org/10.1111/rode.12280.

Psacharopoulos, George. 1994. "Returns to Investment in Education: A Global Update." *World Development* 22(9): 1325–1343. https://doi.org/10.1016/0305-750x(94)90007-8.

———, and Harry Anthony Patrinos. 2004. "Returns to Investment in Education: A Further Update." *Education Economics* 12(2): 111–134. https://doi.org/10.1080/0964529042000239140.

———, and ———. 2018. "Returns to Investment in Education: A Decennial Review of the Global Literature." *Education Economics* 26(5): 445–458. https://doi.org/10.1080/09645292.2018.1484426.

Quah, Danny T. 1996. "Twin Peaks: Growth and Convergence in Models of Distribution Dynamics." *The Economic Journal* 106(437): 1045. https://doi.org/10.2307/2235377.

Ramsey, James B. 1969. "Tests for Specification Errors in Classical Linear Least-Squares Regression Analysis." *Journal of the Royal Statistical Society: Series B (Methodological)* 31(2): 350–371. https://doi.org/10.1111/j.2517-6161.1969.tb00796.x.

Reher, David S. 2004. "The Demographic Transition Revisited as a Global Process." *Population, Space and Place* 10(1): 19–41. https://doi.org/10.1002/psp.313.

Romer, Paul M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98(5): S71–S102. https://doi.org/10.1086/261725.

Sala-i-Martin, Xavier. 1997. "I Just Ran Two Million Regressions." *American Economic Review* 87(2): 178–183.

Sala-i-Martin, Xavier, Gernot Doppelhofer, and Ronald I. Miller. 2004. "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach." *American Economic Review* 94(4): 813–835. https://doi.org/10.1257/0002828042002570.

Shafiq, M. Najeeb. 2007. "Household Schooling and Child Labor Decisions in Rural Bangladesh." *Journal of Asian Economics* 18(6): 946–966. https://doi.org/10.1016/j.asieco.2007.07.003.

Shastry, Gauri Kartini, and David N. Weil. 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.

Silverman, Bernard W. 1981. "Using Kernel Density Estimates to Investigate Multimodality." *Journal of the Royal Statistical Society* 43(1): 97–99. https://doi.org/10.1111/j.2517-6161.1981.tb01155.x.

Singh, Tarlok. 2010. "Does International Trade Cause Economic Growth? A Survey." *The World Economy* 33(11): 1517–1564. https://doi.org/10.1111/j.1467-9701.2010.01243.x.

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

Sovacool, Benjamin and Ivan Vera. 2014. "Electricity and Education: The Benefits, Barriers, and Recommendations for Achieving the Electrification of Primary and Secondary Schools." *Energy and Education*, 1–36.

Strulik, Holger, Klaus Prettner, and Alexia Prskawetz. 2013. "The Past and Future of Knowledge-Based Growth." *Journal of Economic Growth* 18(4): 411–437. https://doi.org/10.1007/s10887-013-9098-9.

Suhrcke, Marc, and Dieter Urban. 2010. "Are Cardiovascular Diseases Bad for Economic Growth?" *Health Economics* 19(12): 1478–1496. https://doi.org/10.1002/hec.1565.

Timmer, C. Peter. 2020. "Asia's Journey to Prosperity." *The Developing Economies* 58(3): 254–257.

Tsaurai, Kunofiwa, and Adam Ndou. 2019. “Infrastructure, Human Capital Development and Economic Growth in Transitional Countries.” *Comparative Economic Research* 22(1): 33–52. https://doi.org/10.2478/cer-2019-0003.

Vamvakidis, Athanasios. 2002. “How Robust is the Growth-Openness Connection? Historical Evidence.” *Journal of Economic Growth* 7(1): 57–80. https://doi.org/10.1023/a:1013418610712.

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

World Bank. 2018. *World Development Indicators*. Washington, DC: World Bank.