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Health and economic development since 1900

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ABSTRACT

The 20th century has brought unprecedented gains in health. While these have improved citizens' lives worldwide, progress has been uneven and have in turn led to substantial cross-country health inequalities. This article looks at the effects of these inequalities on between-country economic inequality since 1900 using a level accounting framework that includes life expectancy as an important part of human capital besides education. The main results show that health has been a historically important source of cross-country income variation. In 1900 and 1955, differences in life expectancy accounted for almost 20 percent and a quarter of between-country income inequality. In addition, I find that the reduction of cross-country health differentials between mid-20th century and 1990 was an important source of income convergence. In a counterfactual exercise, I show that between-country income inequality would have been almost 20 percent higher nowadays, had the process of health convergence after 1955 not taken place. Finally, I find that the relative importance of health for income levels has stayed constant in the last three decades due to a deceleration in the rate of health convergence.

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1. Introduction

The 20th century has brought the most impressive improvement in living standards of all human history. Many parts of the globe have escaped from a regime in which premature death was the norm to a world where sickness and deprivation have become a thing of the past. This 'Great Escape', as it was called by Nobel-prize winner Deaton (2013), has affected citizens in many respects, especially in their levels of income and health.

While these two aspects of countries' development have been extensively analysed in separate literatures,² a growing number of studies have focused on their interaction.³ On one side, a branch of the literature argues that the improvement of a country's health level brings increases in income per capita because a healthier population is more capable of adopting and inventing new technologies, and healthier workers are more productive and

earn higher wages.⁴ On the other side, this view has not been supported by everyone since Acemoglu and Johnson (2007) – and more recently Acemoglu and Johnson (2014) and Hansen and Lønstrup (2015) – have argued that increases in life expectancy have led to rapid population growth, which in turn resulted in capital dilution of reproducible factors of production and, therefore, lower economic growth.

The main contribution of this article is to assess these contrasting views by analysing the impact of health on relative economic performance using development accounting techniques since 1900. This long-term perspective is relevant to enhance our understanding of the effect of health on cross-country income inequality for two reasons. First, it provides a new viewpoint to a literature that has predominantly focused on the second half of the 20th century due to the substantial health improvements that took place worldwide during the international epidemiological transition (Acemoglu and Johnson, 2007). An exclusive focus on this period neglects the first phase

¹ This research was supported by a grant of the Netherlands Organization for Scientific Research (NWO; grant no. 016.130.036).

² On economic growth, see Solow (1956), Romer (1986), Lucas (1988), Galor (1996), Hall and Jones (1999) or Aghion and Durlauf (2005, 2014). On health, see Preston (1975), McKeown (1976), Fogel (2004), Cutler et al. (2006) and Costa (2015).

³ Another aspect of development that has been considered in the context of rising health concerns the welfare of individuals. Becker et al. (2005), Murphy and Topel (2006), Jones and Klenow (2016) and Gallardo-Albarrán (2017) argue that increases in life expectancy are an important source of well-being improvements.

⁴ Some influential studies at the macroeconomic level are Nelson and Phelps (1966), Bloom and Sachs (1999), Gallup et al. (1999), Gallup and Sachs (2001), Sachs (2003), Bloom et al. (2003), Bloom et al. (2004), Weil (2007), Ashraf et al. (2008), Lorentzen et al. (2008), Cervellati and Sunde (2011), Strittmatter and Sunde (2013) and Bloom et al. (2014). At the microeconomic level, see Schultz (2002), Behrman and Rosenzweig (2004), Black et al. (2007) or Case and Paxson (2008).

of the long-term mortality decline and its health-related productivity effects that started in some industrial countries around 1900 (Deaton, 2013; Costa, 2015). The second reason why considering several benchmarks during such a long time span is relevant concerns the analysis of cross-country events on world inequality. While the approach taken by an important part of the literature of considering periods spanning 40 or more years is useful for examining long-term effects, shorter time periods have the potential to unveil the productivity effects of certain health dynamics such as the development of antibiotics during the second quarter of the 20th century or the emergence of HIV during the 1980s (Fogel, 1994; Deaton, 2013; Young, 2005).

To calculate the fraction of income level variation across countries that can be attributed to differences in health since 1900, I extend the health-augmented accounting framework developed by Weil (2007) and further contribute to the literature in two ways. First, I expand Weil's methodology to include a health measure that has been used extensively in the literature and that is widely available across countries and over time: life expectancy at birth.⁵ Second, I extend the benchmarks analysed by Weil (2007) back to the early 20th century using a newly developed dataset on physical capital that contains information on historical capital stocks for 36 countries.

This article presents four findings. The first is that health has been a historically important source of cross-country income variation. In 1900, before the largest declines in mortality took place, health variation accounts for almost 20 percent of income inequality.

Second, the percentage of income inequality accounted for health differences rises up to 26 percent during the first half of the 20th century. This increasing role of health as a divergent force for economic performance can be ascribed to the diffusion of new knowledge stemming from the germ theory of disease among a small group of developed countries (Gwatkin, 1980; Deaton, 2013).

Third, the period spanning from mid-century until 1990 shows an important fall in the role of health as a source of world income inequality due to strong convergence in health levels (Easterlin, 2000; Neumayer, 2003; Acemoglu and Johnson, 2007). More specifically, the percentage of income variance attributed to health differences declines from 26 to 12 percent. A counterfactual exercise derived from the main calculations shows that income inequality across countries would have been almost 20 percent higher, had the process of health convergence after 1955 not taken place. In other words, the reduction of health differences in 1950 was an important source of income convergence until 1990. This finding supports a large number of studies in the literature that have found a positive and significant causal effect of health on economic development. For instance, Lorentzen et al. (2008) argue that high adult mortality causes lower economic growth because it leads to underinvestment due to shorter time horizons and having more offspring. Besides supporting this growth effect, Aghion et al. (2011) find that having a higher initial level of life expectancy is growth enhancing because healthier individuals are more able to create and adapt to new technologies and invest more.

The fourth finding is related to the last part of the analysed period. My calculations show that percentage of income variance attributed to health has been constant in the last decades due to a deceleration in the rate of health convergence because developing countries are now increasingly facing chronic diseases which are much harder to fight against (Deaton, 2004, 2013). This finding

parallels those by Prados de la Escosura (2015) who finds that slower progress in terms of health among non-OECD relative to OECD economies since the 1990s has slowed down convergence in human development.

Besides the studies that analyse the causal effect of health on economic growth, this article also engages with two related bodies of literature accounting for the sources of economic development. The first considers physical capital and human capital in the form of education as basic inputs in the production process to calculate total factor productivity (TFP) differentials. The consensus in this literature is that efficiency plays the largest role in accounting for income differences across countries (Klenow and Rodríguez-Clare, 1997; Hall and Jones, 1999; Caselli, 2005; Easterly and Levine, 2001; Clark and Feenstra, 2003; Hsieh and Klenow, 2010; Jones, 2016). I contribute to this literature showing that health has historically been an important input factor in the production process. Furthermore, the attempt in this article to obtain a better measure of human capital is also related to previous research that has constructed quality-adjusted indicators of human capital using teachers' education, pupil-teacher ratios, test scores or workers' experience (Caselli, 2005; Lagakos et al., 2018).

The second group of accounting studies goes beyond 'traditional' factor inputs to also include health by studying individual mechanisms through which health affects economic growth. Related to the mechanism analysed in this article (i.e. healthier workers are more energetic and productive), two studies stand out. One is the seminal work by Fogel (1994) who estimates that rising nutritional status accounts for 20 to 30 percent of British economic growth since 1790. The improved nutritional status of the population did not only allow beggars and paupers to provide more work, but it also raised the productivity of those already employed. Arora (2001) also investigated the influence of health on growth paths for ten countries and found that changes in health increased their long-term pace between 30 and 40 percent. The main idea of these analyses was brought to the cross-sectional dimension by Weil (2007) who created a development accounting framework including health. This article contributes to this literature combining the long-term perspective by Fogel (1994) with the richer cross-sectional framework of Weil (2007) to consider a large number of countries. Contrary to single-benchmark analyses, taking this long-term multiple-benchmark approach allows for unveiling different dynamics in the role of health on relative economic performance during the 'Great Escape' (Deaton, 2013).⁶

This article is organised as follows. First, I will present the methodology that will be used to include human capital in terms of health in a development accounting framework. Second, I will provide a description of the data I have used. Third I will discuss the main findings of this article and their robustness. And finally, I will conclude.

2. Method

The framework proposed by Weil (2007) begins with a simple Cobb-Douglas aggregate production function:

$$Y_i = A_i K_i^\alpha (H_i)^{1-\alpha}, \quad (1)$$

where Y_i is output, K_i is physical capital, A_i is a productivity term, α is the elasticity of output with respect to capital and i refers to specific countries. H_i is a labour composite determined by:

$$H_i = h_i v_i L_i, \quad (2)$$

⁵ The health measures used by Weil (2007) are adult survival rates and age of menarche.

⁶ It should be noted that (Weil, 2007, 1297–1298) briefly examines the time dimension of its analysis, but only from 1960 onward.

where L_i is the number of workers, h_i is human capital in the form of education and v_i in the form of health. In this framework, v_i (for vitality) refers only to the aspects of individual health that are relevant for the production of output such as energy available for work or mental concentration (Fogel, 1994; Case and Paxson, 2008; Deaton and Arora, 2009; Sánchez, 2017). This is similar to human capital in the form of education in that h_i represents the skills acquired in the educative system which are rewarded in the labour market for their positive impact on productivity (e.g. the ability of solving complex problems).

The health of an individual depends on a number of inputs during her life such as the quality and quantity of nutrition, conditions in the workplace, exposure to pathogens or access to health care (Floud et al., 2011; Costa, 2015). These inputs in turn determine health output, which can be measured with anthropometric indicators (e.g. body height) or mortality measures (e.g. life expectancy or adult survival rates). Weil (2007) assumes that the relationship between health inputs and outputs is mediated by a latent or unobservable measure of health. Formally (and dropping country subscripts), this can be represented as follows:

$$I_j = \text{constant} + \gamma_I z_j + \varepsilon_{Ij}, \quad (3)$$

$$\ln(v_j) = \text{constant} + \gamma_v z_j + \varepsilon_{vj}, \quad (4)$$

where j indexes individuals, I_j is any observable health outcome such as height or life expectancy, z_j is a latent measure of health and v_j is the relevant health outcome for productivity. The two previous equations show how the latent measure of health (z) is relevant for both an observable health outcome and for the effect of health on productivity.

To see how differences in health would translate into different wage levels and health outcomes, an example can be illustrating. Consider two different workers (A and B) with the same human capital in terms of education but with different levels of latent health (z). The expected difference in wages and health outcomes will be:

$$\ln(w_A) - \ln(w_B) = \gamma_v(z_A - z_B), \quad (5)$$

$$I_A - I_B = \gamma_I(z_A - z_B). \quad (6)$$

If we assume that there are no error terms in Eqs. (3) and (4), then we can substitute $(z_A - z_B)$ in Eq. (5) for $\frac{(I_A - I_B)}{\gamma_I}$ from Eq. (6) to obtain:

$$\ln(w_A) - \ln(w_B) = \frac{\gamma_v}{\gamma_I}(I_A - I_B), \quad (7)$$

where the wage differential between two workers with the same characteristics except for their health endowment depends on the extent to which observable health outcomes differ multiplied by the ratio $\frac{\gamma_v}{\gamma_I}$. This ratio is the return to characteristic I , say stature, because it relates changes in health aspects that affect productivity (γ_v) to changes in health that affect health indicators (γ_I). The higher level of latent health affects both body heights and features that are relevant for productivity such as physical effort and mental concentration (Case and Paxson, 2008; Lundborg et al., 2014). Therefore, if we know the return to I , it is possible to obtain an estimate of the differences in human capital in the form of health by employing data on observable health indicators. Formally this can be expressed as:

$$\ln(v_A) - \ln(v_B) = \rho(I_A - I_B), \quad (8)$$

where ρ is the return to characteristic I or the ratio $\frac{\gamma_v}{\gamma_I}$. This equation is the key element for measuring the extent to which human capital in the form of health varies across countries (in the next subsection I will discuss the choices I made for ρ and I). Also, note that Eq. (8) is analogous to the more well-known calculations of the differentials in human capital in the form of education (h), if we consider years of education and schooling returns instead of stature and height returns.

To calculate the percentage of cross-country income inequality accounted for by health differences, I will perform a variance decomposition. As common in the literature, we can decompose Eq. (1) in per-capita and logarithmic terms as follows:

$$\text{var}[\ln(y)] = \text{var}[\ln(y_{KHV})] + \text{var}[\ln(A)] + 2\text{cov}[\ln(A), \ln(y_{KHV})], \quad (9)$$

where $y_{KHV} = k^\alpha h^{1-\alpha} v^{1-\alpha}$. Weil (2007) then creates a measure of the importance of health for cross-country income variance that answers the question: if all cross-country health gaps were eliminated, by which percentage would the variance of (log) income per capita be reduced? Formally:

$$\text{Health}_w = \frac{\text{var}[\ln(v)] + 2(\text{cov}[\ln(v), \ln(k)] + \text{cov}[\ln(v), \ln(h)] + \text{cov}[\ln(v), \ln(A)])}{\text{var}[\ln(y)]} \quad (10)$$

In the robustness tests, I show that the results are consistent to using other measures and functional forms from the development accounting literature.

3. Data

To perform the development accounting exercise outlined in the previous section, I have used data on economic performance, physical capital and human capital in the form of health and education. For income per capita, the most common starting point in the literature is to use GDP per capita from the Maddison Project (Bolt and van Zanden, 2014), which provides long-term income data for a large number of countries.⁷

For physical capital, I have created a dataset containing capital stocks since 1900 for 36 countries.⁸ Similar to previous attempts by Bergeaud et al. (2016), Madsen (2010a,b), Baier et al. (2006), I have created stocks from investment flows using the perpetual inventory method (see the appendix). The dataset used in this paper improves previous attempts in three aspects. First, except for Madsen and Farhadi (2018), the available databases mostly focus on advanced economies. To analyse the sources of the income divergence during the 20th century I need a more complete coverage of the world income distribution. Second, I relax some of the assumptions affecting the accuracy of the historical stocks to obtain long-term investment series by drawing on the work of statistical agencies or scholars for each individual country. And third, when sufficient data are available, I take into account the change in relative prices between structures and machinery and equipment. Since prices for buildings have increased more than for machinery, using constant relative prices from recent years results in an overestimation of historical capital stocks. The resulting data for two selected years, 1900 and 2011, can be found in Fig. 1. As we

⁷ Some recent works in economics and economic history using these data include Baten and Carson (2010), Piketty (2014), Crafts and O'Rourke (2014), Milanovic (2016) and Jones (2016).

⁸ The countries considered are: Sweden, the United Kingdom, Denmark, Finland, Norway, the Netherlands, Germany, Spain, Belgium, Portugal, Italy, France, Canada, the United States, Japan, India, Australia, Austria, Switzerland, New Zealand, Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Honduras, Mexico, Nicaragua, Peru, El Salvador, Uruguay, Venezuela, Korea, Taiwan and Indonesia.

Fig. 1. Physical capital per capita in 1900 and 2011. Source: See the appendix.

can see, there is a positive correlation between economic performance and capital accumulation in both benchmarks, which seems stronger in 2011. Furthermore, the variation of physical capital was larger at the beginning of the 20th century.

For education, I use data on years of education from [Clio Infra \(2017\)](#) and [Barro and Lee \(2016\)](#). In [Fig. 2](#) I provide a snapshot of the evolution of educational attainment throughout the 20th century by region. The first point that stands out is the remarkable increase in education underwent across the board. If an average worker had 3 years of education in 1900, in 2010 this figure had more than tripled. In this process, some parts of the world have made more progress than others, and at different times. For instance, the lead exhibited by Germany in terms of primary school enrolment rates during the 19th century gradually disappeared by the turn of the 20th century, when North America and the European offshoots overtook the old continent ([Lindert, 2004](#)). As a result, educational attainment in 1900 was highest in this region of the world (see [Fig. 2](#)). The leadership of this region was maintained during the first decades of the 20th century as the secondary-school revolution set in. In this respect, the case of the United States is remarkable since it increased the high-school enrolment rate of 18-year olds from 9 to more than 50 percent by 1940 ([Goldin and Katz, 2009](#)). If we look at the European experience, we can conclude that it has been similar to that of North America, although with a lag of several decades. In the remaining regions, most of progress in education over the 20th century has been achieved after 1950 ([Easterlin, 2000](#)). In terms of tertiary education, though, there are still important gaps because industrial economies experienced a longer and more sustained progress than the rest ([Barro and Lee, 2015](#)).⁹

For health, the indicators used in the literature typically consider the number of deaths from a certain disease (e.g. malaria), life expectancy at birth, infant mortality rates or adult mortality rates. The measure chosen for my analysis should reflect as best as possible the mechanism explored in this article: healthier workers are more productive because they can work longer and harder. Examining this mechanism, [Weil \(2007\)](#) uses two different indicators: adult survival rates (ASR) and age of menarche. The advantage of using ASR is that these are widely available for a large number of countries since 1950 and they refer

Fig. 2. Years of education by region. Note: The averages are unweighted. The sources are [Clio Infra \(2017\)](#) and [Barro and Lee \(2016\)](#).

explicitly to the health status of the labour force. The second measure he uses, age of menarche, is also available for many countries, although to a much lower extent than ASR. Given the long-term nature of my approach, these indicators cannot be used for a broad number of countries due to data lack of data. Instead, I will use life expectancy at birth. Besides data availability, another advantage of using this measure is that it makes my analysis comparable to that of other studies in the literature using it such as [Acemoglu and Johnson \(2007\)](#), [Cervellati and Sunde \(2011\)](#) or [Hansen and Lønstrup \(2015\)](#).

The use of this measure is convenient because the availability of data for a large number of countries over a long period allows for performing analyses since 1900 using a comprehensive balanced sample. Moreover, this indicator has the potential to capture the aggregate health component we are interested in for three reasons. First, the prevalence of low levels of life expectancy implies the existence of a hazardous disease environment that not only affects infants and children, but also citizens that live and work in that environment. As shown by [Cutler et al. \(2006, 107\)](#), high-income countries with high levels of life expectancy suffer much less from diseases such as tuberculosis, diarrhoea or respiratory infections than low-income countries nowadays. Second, there is a strong relationship between ASR and life expectancy, the indicator used by [Weil \(2007\)](#) as we can see in [Fig. A1](#) for a sample of 125 countries and three benchmark years (1970, 1990 and 2009). If we look at the correlation coefficient between the two indicators for separate years or pooling them, we obtain values which are very close to one (see [Table A3](#)). Third, and most importantly, there is a large body of literature which argues that individuals exposed to a deadly disease environment characterised by high infant mortality (or low life expectancy) have worse labour market outcomes due to the long-lasting effects of such events ([Barker, 1992](#); [Doblhammer and Vaupel, 2001](#); [Case et al., 2005](#); [Parman, 2015](#); [Saavedra, 2017](#)). In the robustness section, I show that using adult survival rates does not alter the main findings of this article.

In [Fig. 3](#), I present box-and-whisker diagrams drawing on data from [Zijdeman and Ribeira da Silva \(2015\)](#), [United Nations \(2017\)](#) and [World Bank \(2016\)](#).¹⁰ As we can see, the unequal onset of the

⁹ It is important to highlight that all the discussed developments on the basis of my relatively small sample are in line with the world-sample evidence by [Barro and Lee \(2016\)](#). This is very encouraging as it makes us confident that, in terms of education, my sample has a good degree of representativity of the regions analysed.

¹⁰ [Fig. 3](#) shows information on the median value of life expectancy for the whole sample; the interquartile range in which values between the 75th and 25th percentile can be found; and the largest (smallest) observation that is less (higher) or equal than the upper (lower) inner fence.

Fig. 3. The evolution of life expectancy inequality since 1900. Source: Zijdeman and Ribeira da Silva (2015), United Nations (2017) and World Bank (2016).

health transition during the first half of the 20th century had two main consequences. First, median life expectancy moved much closer to the higher levels of the distribution. And second, the regions with the lowest levels of health saw their gaps increase relative to good-performing countries. Consequently, mid-20th century was characterised by enormous health differences between countries that had been steadily adopting knowledge stemming from the germ theory of disease (mostly Western countries) and another set of countries that were lagging behind in this respect (Mokyr, 2000; Deaton, 2013).

By 1945 little progress had been made in developing countries, although considerable improvements were on the way due to a number of international interventions on immunization. UNICEF started vaccinating children against tuberculosis, and in the 1950s its program was extended worldwide to also provide immunization against leprosy, yaws, malaria and trachoma. In 1974, the WHO launched the Expanded Programme on Immunization that promoted immunization against diphtheria, pertussis (whooping cough), tetanus, measles, polio and tuberculosis (Deaton, 2013). These and other factors prompted the international epidemiological transition, as Acemoglu and Johnson (2007) put it, characterised by rapid health gains in countries with lower income levels than observed in developed countries when they experienced them. The effects of this process on the world distribution of life expectancy can be clearly observed in Fig. 3. Not only did the differences between the best- and worst-performing countries decrease between 1950 and 1970, but also the spread in life expectancy in countries within the interquartile range is much smaller (Gwatkin, 1980; Neumayer, 2003; Becker et al., 2005). In the last decades, this convergence has slowed down and some countries may be facing a new wave of widening health gaps (Prados de la Escosura, 2015).

The last element to consider for the analyses are returns to health. In Table 1, I present several estimates from the literature. They seem to be larger in developing than in developed countries which supports the idea that health returns in the past in developed economies are as high as in developing countries nowadays (Floud et al., 2011, 21–23). However, before making this assumption, it is worth considering that such high returns are not found everywhere as LaFave and Thomas (2017) show for Indonesia. In addition, Bleakley et al. (2014) argue that in a developed economy such as the United States height returns in the

Table 1

Returns to body height from the literature.

Returns to height (in %)	Country	Source
9.4	Ghana	Schultz (2002)
8	Colombia	Ribero and Nuñez (2000)
7.8	Brazil	Schultz (2002)
7.3	UK	Fogel (1997)
4.1	Indonesia	LaFave and Thomas (2017)
3.5	Norway	Black et al. (2007)
3.3	US	Behrman and Rosenzweig (2004)

Note: The returns by Fogel (1997), Black et al. (2007) and Behrman and Rosenzweig (2004) are taken from Weil (2007).

past were lower than in developing countries nowadays. Their study suggests that the shift to a 'brain-based' economy and the rise of public schooling increased the marginal benefit of education, thus leading to an increasing importance of cognitive abilities acquired in early childhood. Given the lack of consensus in the literature, I took the health returns from Fogel (1997) since they are in the middle range (see Table 1). Also, this rate of return has been calculated drawing on long-term historical data covering my analysed period.

As highlighted before, I use life expectancy at birth to measure changes in health because it has been applied by the literature discussing the effect of health on economic growth. Given that the returns to health in Table 1 refer to body heights, these have to be converted into returns to life expectancy. For this purpose, I follow the same method that Weil (2007) used for obtaining returns to adult survival rates (Appendix B outlines this procedure in detail).

4. Results

4.1. Main results

Keeping other factors constant, health differences across countries make workers in some countries more productive than others, which in turn affects relative levels of productivity. To analyse the quantitative importance of this mechanism as well as its evolution throughout the 20th and early 21st centuries, Table 2 reports the results of the methodology presented above for six benchmark years since 1900. In the first row, I show the (log) income variation in my 36-country sample, and then the elements from Equation (10) used to compute the percentage of income variance attributable to health differences (last row). Before presenting the results in more depth, it is worth highlighting that the calculated share of income variance accounted for by health differences of up to 12 percent in the later part of the analysed period is in line with Weil (2007). Given the differences in the sample composition and data sources for income, physical capital and health, this should provide enough confidence to examine the results for earlier benchmarks.

Table 2 presents four main findings. First, the importance of health as a source of divergence in economic prosperity is not negligible. At the turn of the 20th century when citizens were still deeply affected by communicable diseases, health differences across countries account for almost 20 percent of income inequality. Furthermore, the effect is larger than in 2008 for any earlier period. This highlights the importance of considering several benchmark years in establishing general conclusions on the magnitude of the effect of health on economic development because it has not remained constant since 1900.

Second, the percentage of income variance accounted for health differences increases substantially up to 1955. Actually,

Table 2

Cross-country income inequality accounted for health differences since 1900.

	1900	1929	1955	1973	1990	2008
var ln (y)	0.527	0.494	0.623	0.684	0.781	0.686
var ln (v) / ln (y)	0.016	0.025	0.028	0.012	0.005	0.005
cov [ln(v), ln(k)] / ln (y)	0.058	0.071	0.059	0.040	0.023	0.024
cov [ln(v), ln(h)] / ln (y)	0.028	0.040	0.037	0.020	0.010	0.009
cov [ln(v), ln(A)] / ln (y)	−0.002	−0.007	0.019	0.023	0.024	0.023
Fraction of variance of ln(y) reduced if all health gaps were eliminated (in %)	18.5	23.3	25.7	17.8	11.8	11.5

Note: See the text for the sources. The results in the last row are calculated following Eq. (10).

eliminating health gaps in that year would reduce income inequality by 25 percent. This increasing role of health as a divergent force for economic performance can be ascribed to the diffusion of new knowledge stemming from the germ theory of disease among a small group of developed countries (Gwatkin, 1980; Deaton, 2013). A relatively immediate outcome of this process was not the creation of drugs to treat the large number of infectious diseases that afflicted citizens, but rather the development of effective preventive measures by public health departments and households (Cutler and Miller, 2005; Alsan and Goldin, 2018; Mokyr and Stein, 1996; Cutler et al., 2006). As a consequence, mid-20th century was characterised by substantial health disparities between countries that had been steadily reducing the incidence of infectious diseases (mostly Western countries) and another set of countries that were lagging behind in this respect.¹¹ According to my calculations, the economic potential of closing the health gap in the sample increased by 40 percent with respect to 1900.

The third finding is the dramatic fall in the role of health as a source of world income inequality between 1955 and 1990 due to the strong health convergence caused by the international epidemiological transition experienced by low-income countries (Easterlin, 2000; Neumayer, 2003; Acemoglu and Johnson, 2007). This decline has its origins in the internationalisation (at least in the intensive sense) of the germ theory of disease. After the Second World War, the knowledge accumulated by Western countries became widely available and citizens across the board benefited from working and living in a much cleaner and safer environment (Easterlin, 2000). Consequently, this finding suggests that the economic potential for catching-up created before mid-century was realised to a large extent by 1990. Actually, the figures for the importance of health for income variation in 1990 are 50 percent of those in 1955.

Before interpreting these findings in the broader context of the literature, it is crucial to highlight two aspects of the nature of the exercise performed in this article. First, the effect I am measuring is the direct role of health on workers' productivity. Therefore, mechanisms such as capital dilution due to

population growth or increased educational attainment as a result of longer time horizons due to health improvements are not taken into account. Second, a development accounting exercise sheds no light on causality. In other words, my analysis does not show whether improving health would lead to higher income, or whether higher income leads to higher health levels. However, the significant share of income variance accounted for health differences in 1955 suggests that the narrowing of these differences had a great catch-up potential. This finding supports a large number of studies that have found a positive and significant causal effect of health on economic development.¹² An example is Lorentzen et al. (2008) who argue that high adult mortality causes lower economic growth because it leads to underinvestment due to shorter time horizons and having more offspring. Aghion et al. (2011) supports this growth effect and finds that having a higher initial level of life expectancy translates into faster growth because a healthier population is more able to create new technologies, adapt to them and invest more. Further support for a causal interpretation comes from the instrument used by Acemoglu and Johnson (2007). They argue that a large part of the increase in life expectancy during this period is due to global interventions (e.g. mass distribution of penicillin, use of DDT against mosquito vectors, etc.) unrelated to the level of economic development in those countries.

The fourth finding is the constant importance of health for relative income levels since the 1990s. The impact of HIV and the increasing challenge of fighting chronic diseases prompted a deceleration in the rate of health convergence (Deaton, 2013). Also, middle-income countries belonging to the former soviet union have experienced an increase in mortality or stagnation. This recent slow down is worrisome from a well-being perspective. Looking at convergence in human development, Prados de la Escosura (2015) finds that slower progress in terms of health among non-OECD relative to OECD economies since the 1990s has contributed to divergence in human development.

Until now, I have focused on the percentage of income variance that can be attributed to differences in life expectancy because it answers a clear question rooted in the literature: which percentage of income variance would be reduced if all countries had the same health status? Another useful way to look at the results is to calculate how income inequality would have evolved, had health differentials stayed constant after (or before) a given benchmark. More specifically, if we take 1955 as a reference year, the counterfactual exercise could be: how much would (log) income

¹¹ If we divide the sample into two groups 'Europe, North America and its offshoots' and 'Latin America and Asia', we can see that most of the variation in life expectancy up to the mid-20th century comes from between-country differences as measured by the Theil index. This supports the idea that, initially, health-enhancing technologies were mostly diffusing among Western countries, thus widening cross-country health differences. After mid-century, the large gains in life expectancy across the world somewhat reduced the between-region component so that by the end of the period this was as important as the within-region component. Moreover, it is worth noting that the development in the within-region component is mostly driven by Latin American and Asian countries. As shown in Table A1, life expectancy dispersion within those regions was substantially higher than in the Western part of the sample throughout the analysed period.

¹² Nelson and Phelps (1966), Bloom and Sachs (1999), Gallup et al. (1999), Gallup and Sachs (2001), Sachs (2003), Bloom et al. (2003), Bloom et al. (2004), Weil (2007), Ashraf et al. (2008), Cervellati and Sunde (2011), Strittmatter and Sunde (2013) and Bloom et al. (2014).

variance increase, if health levels had not converged after 1950?¹³ This counterfactual is useful for looking at a hypothetical scenario after 1955 in which the process of health convergence had not taken place or a situation where the percentage increase in income variance related to health differences in 1900 had not changed throughout the 20th century.

In Fig. 4, I present information on the observed and the predicted log income variance in my sample using 1900 and 1955 as a base year for the effect of health on income inequality. Using 1900 as a benchmark, we can see how keeping constant the effect of health on world income variance in that year results in lower income inequality up to 1973. In such a scenario, the germ theory of disease would not have acted neither as a divergent force for income inequality until mid-20th, nor as a convergent force after 1955. Interestingly, despite income variation would have been lower before 1973, in the later part of the period income inequality would have been nine percent larger than the observed one. Considering health levels had not converged after 1955, then income inequality would be almost 20 percent higher than observed in 2008. All in all, these results reinforce the previous findings that the role of health on economic development in history is not negligible. The international epidemiological transition had a large potential to reduce the differences in material living standards during the second half of the 20th century.

4.2. Robustness tests

The trends and size effects of the role of health on economic development discussed in the previous section may be driven by the composition of the sample. To test the sensitiveness of the main figures to this, I present in Table 3 the results for two alternative samples using data from Penn World Table 9.0 (Feenstra et al., 2015). The first is PWT71 and it consists of 71 countries containing information on income and physical capital from 1955 onward. The second sample, PWT118, has information for 118 countries since 1973. It is worth highlighting that these alternative samples also test the robustness of the results to using different sources for income and physical capital per capita.

The results for PWT71 (Panel A) support previous trends regardless of the indicator we look at. Immediately after mid-century there is a sharp drop in the percentage of income variance accounted for health inequality that continues, although less marked, until 1990. From that year on, this figure remains constant due to the slowdown in mortality convergence. Including 47 countries more with PWT118 (Panel B) further supports these findings. After 1990 though, the results look a bit more optimistic than with the other set of countries because the role of health in accounting for income inequality declines even further.

Fig. 4. Observed and counterfactual evolution of income inequality. Source: the counterfactual figures are based on the percentage increase in income variance attributable to health differences in 1900 and 1955 (see footnote 13 for an explanation on the calculations behind these numbers).

Another element of the main results that can be tested with these samples is the magnitude of the health effect. In general, the values reported in Table 3 indicate that the percentage of income variance accounted for by health are very similar as those in Table 2. Eliminating health gaps in 1955 would reduce cross-country income inequality around 20 and 25 percent. After 1973, the effect of health slightly rises because PWT118 includes more developing economies, although the difference is not substantial.

To test the sensitiveness of my results to changing the health indicator used in the analysis, I present a set of results from 1955 onward for the benchmark sample using adult survival rates in Panel A of Table 4.¹⁴ As we can see, the post-1950 trends discussed previously hold when I use adult survival rates as a measure of health. First, there is a sharp decline in the share of income variance accounted for by health differences between 1955 and 1973, and a further smaller decline until 1990. Then the indicator remains roughly constant. It is worth highlighting that the magnitudes are smaller for the years 1955 and 1973, although still substantial. This can be explained by the fact that life expectancy at birth varies more across countries than adult survival rates because the former are more sensitive to disease and food deprivation.

The second and third robustness tests provide an important check on my main results for two reasons. First, they use different success measures from the development accounting literature. And second, the measure inspired by Klenow and Rodríguez-Clare (1997) uses a different functional form for the production function. More specifically, the contribution of capital to economic growth with this alternative indicator is expressed in capital-output instead of capital per worker terms (see the appendix for a more elaborate explanation of their construction). As we can see, both measures support the main trends discussed earlier as well as the absolute sizes.

In Panel B, I provide a lower- and upper-bound estimate of the contribution of health to world income variance by using the health returns from Table 1. Intuitively, assuming higher (lower) returns to health results in a larger (lower) share of the income variance accounted for by health differences. If we look at the trends, these remain exactly the same as before.

¹³ This question can be answered in three steps. First, I calculate the predicted income variance, if cross-country health gaps did not exist. For this purpose, I subtract from the observed income variance a term consisting of health variance and two times its covariance with physical capital, education and productivity (i.e. the numerator in Eq. (10)). Second, I choose a base year, say, 1955 and look at the factor by which health differences increase log income variance. This step requires dividing the observed income variance by the predicted income variance if all health gaps were eliminated. Third, I multiply this factor by each of the predicted measures of income variation across time without the effect of health. To illustrate this calculation with an example, consider the following counterfactual: what would income dispersion in 2008 be, had health across countries not converged after 1955 so that its contribution to income variation stayed constant? First, I calculate the observed and predicted log income variation for 1955, namely 0.62 and 0.46 respectively. The factor by which health increases income dispersion in 1955 is 1.35 (0.62/0.46). Therefore, we can say that had health levels not converged after 1955, income dispersion would have been 0.82 instead of the observed 0.69 in 2008. This represents an almost 20-percentage increase in world income variance.

¹⁴ The data on ASR were taken from the World Development Indicators (World Bank, 2016) and World Population Prospects (United Nations, 2017).

Table 3
Analyses using alternative samples.

	1955	1973	1990	2008
<i>Panel A: PWT71</i>				
var ln (y)	0.763	0.922	1.240	1.350
var ln (v) / ln(y)	0.023	0.013	0.009	0.009
cov [ln(v), ln(k)] / ln(y)	0.052	0.041	0.033	0.032
cov [ln(v), ln(h)] / ln(y)	0.030	0.020	0.011	0.009
cov [ln(v), ln(A)] / ln(y)	0.014	0.015	0.026	0.033
Accounted income variance if all health gaps were eliminated (in %)	21.4	16.3	14.9	15.6
<i>Panel B: PWT118</i>				
var ln (y)	n.d.	1.184	1.470	1.852
var ln (v) / ln(y)	n.d.	0.016	0.012	0.010
cov [ln(v), ln(k)] / ln(y)	n.d.	0.043	0.038	0.031
cov [ln(v), ln(h)] / ln(y)	n.d.	0.022	0.016	0.010
cov [ln(v), ln(A)] / ln(y)	n.d.	0.018	0.026	0.031
Accounted income variance in ln(y) if all health gaps were eliminated (in %)	n.d.	18.1	17.2	15.6

Note: See Table 2.

Table 4
Accounted income variance in ln(y) if all health gaps were eliminated (in %) (robustness tests).

	1900	1929	1955	1973	1990	2008
<i>Panel A: using different measures</i>						
Using ASR	n.d.	n.d.	21.1	12.1	10.0	10.4
Using measure in Caselli (2005)	19.0	24.7	22.0	13.2	7.0	6.9
Using measure in Klenow and Rodríguez-Clare (1997)	14.5	18.0	19.4	12.6	9.0	9.1
<i>Panel B: changing parameters</i>						
Lower-bound health return	9.0	11.5	12.7	8.6	5.6	5.5
Upper-bound health return	23.3	29.1	32.1	22.5	15.0	14.7
$\alpha = 0.48$	16.6	21.2	22.4	15.7	10.3	10.2

Note: See Table 2.

The last test in Table 4 is aimed at testing the sensitivity of the results to changes in the parameter, α , that measures the relative contribution of capital to aggregate production. Instead of using one third, in Panel D I report the results taking the value suggested in Feenstra et al. (2015): 0.48. Intuitively, the magnitudes of the indicators in this test are smaller than those in Table 2 since the contribution of human capital is now lower. However, we can clearly see that this downward revision is very small and barely affects the main findings.

Although this paper focuses on the analysis of several cross-sections since 1900, it is useful to explore the time dimension by looking at the implications of the model for growth rates of GDP per capita. For this purpose, we can use the increases in life expectancy and their implied effect on productivity (ρ in Eq. (8)). Throughout the 20th century, we can see in Table 5 that the annual contribution of health improvements as a result of the increased

Table 5
Annual contribution to per-capita GDP growth.

	1900–1955	1955–2008
Asia	0.45	0.92
Europe	0.51	0.47
Latin America	0.47	0.78
North America and Offshoots	0.37	0.41

Note: To construct these figures I used the coefficients in Appendix B and the data from Table A1.

productivity of workers ranged between 0.4 and 0.9 percentage points. The experiences of Latin America and Asia are particularly remarkable after mid-century as health improvements contributed to GDP growth much more than in the rest of the sample, thus leading to income convergence. Comparing these figures with those of Cervellati and Sunde (2011), we can regard them as lower-bound estimates.

5. Conclusions

What is the contribution of health to economic development? What has been the effect of the uneven escape from a high-mortality to a low-mortality regime on income inequality throughout the 20th century? In this article I have tackled these questions using a development accounting framework that allows for calculating the share of world income inequality that can be attributed to health differences drawing on Weil (2007). To apply it to a number of benchmarks for more than a century, I have extended it to include life expectancy as a health measure and I have combined it with a new dataset on physical capital.

The findings of this article show that health has been an important source of income variation in the last century. Beginning in 1900, its importance rose substantially due to the unequal spread of the germ theory of disease during the first decades of the 20th century so that the percentage of income variation accounted for by health differences rose up to 25 percent in 1955. This potential for catch-up was largely realised by 1990, thus suggesting that the substantial gains in life expectancy in developing countries during the second half of the 20th century acted as a convergent force for world income inequality. This force has stopped in the last 30 years as some developing countries suffered from HIV, increasingly face diseases affecting the elderly that are much harder to fight against and the one-time improvements of saving the lives of the youngest are petering out. Also, middle-income countries belonging to the former Soviet Union have experienced an increase in mortality or stagnation.

The findings of this article support a body of literature that has emphasised the positive relationship between health and economic development. The large health improvements realised in developing countries after 1950 have contributed to income convergence. Actually, a counterfactual exercise derived from the main calculations suggests that between-country income inequality would have been almost 20 percent higher in the absence of the international epidemiological transition.

To obtain a more precise estimate of the effect of health on economic development, future research could account for other mechanisms than the one examined in this article such as the link between improving health and educational attainment. Such an analysis would be particularly interesting, if it could take into account long-term dynamics as I did in this article because these may change significantly over time.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.ehb.2018.08.009>.

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