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Long-Run Improvements in Human Health: Steady But Unequal

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Abstract. There exists a steady trend at which later born cohorts, at the same age, are healthier than earlier born cohorts. We show this trend by computing a health deficit index for a panel of 14 European Countries and six waves of the Survey of Health, Aging, and Retirement in Europe (SHARE). We find that for each year of later birth, health deficits decline by on average 1.4 - 1.5 percent with insignificant differences between men and women, between countries, and over time. We argue that this trend approximates the rate of medical progress, broadly defined. The steady progress implies substantial delays of human aging. For example, the level of health deficits experienced at age 65 by individuals born 1920 is predicted to be experienced at age 85 by individuals born 1945. The potential health gains are not fully appropriated by individuals of low socio-economic status. Their health deficits decline at about the same rate but from a higher level, which means that we find long-run persistence of health inequality.

Keywords: health; aging; health deficit index; medical progress; health inequality.

JEL: I10, I14, I15, I24.

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1. Introduction

As humans get older they develop more health deficits, i.e. they age also in physiological terms. Like mortality, physiological aging can be conceptualized as being stochastic at the individual level while it exhibits strong regularities at the population level (Arking, 2006). On average, humans develop 2 to 4 percent more health deficits from one birthday to the next (Mitnitski, 2002; Abeliansky and Strulik, 2018a,b,c). The aging process, however, is modifiable. It can be postponed by healthy behavior and medical technology. In this paper we show a steady decline of health deficits prevalent in elderly individuals at any given age. For every year of later birth, younger generations experience 1.4-1.5 percent less health deficits than earlier born generations. This trend is remarkably stable across 14 European countries and over time (i.e. over the range of our sample from birth year 1918 to birth year 1965).

An earlier literature has observed similar long-run trends for mortality. Oeppen and Vaupel (2002) show that best-practice life expectancy increased by 3 months per year of birth since 1840, with country trends converging to best practice trend. From this observation they conclude "broken limits to life expectancy". Strulik and Vollmer (2013) show for a sample of developed countries that since the mid 20th century human lifespan increased in sync with life-expectancy. Vaupel (2010) concludes that human senescence has been delayed by a decade in the sense that levels of mortality that used to prevail at age 70 now prevail at age 80, and levels that used to prevail at age 80 now prevail at age 90.

It is not self-evident that declining mortality is associated with, on average, better health. If people were increasingly saved from death without curing or postponing the respective diseases, the prevalence of health deficits would increase. Several studies compiled evidence for increasing prevalence of aging-related (chronic) diseases at the population level (e.g. Crimmins, 2004; Christensen et al., 2009). These trends, however, could be mostly composition effects resulting from an increasing average age of the population. They are compatible with improving health at the individual level, i.e. improving health at *given age*. This notion is supported by several studies using aggregated (macro) data. Crimmins et al. (2016) find that disability-free life expectancy in the U.S. increased since the 1980s. Salomon et al. (2012) show that healthy life expectancy increases in sync with life expectancy (see also Strulik and Werner, 2016). Chatterji et al. (2015) show declining trends of functioning and disability status (using, among other sources, the SHARE data set). Dalgaard et al. (2018) construct aggregate health deficit indices for the working-age population of 191 countries and show that, over the last quarter of century, the workforce did not age in physiological terms, although it got chronologically older. We contribute to this literature by showing a robust and precisely estimated trend at which the health status of humans improves such that later born cohorts display, at the same age, less health deficits than earlier born cohorts.

The measurement of health and aging by the health deficit index has been introduced by Mitnitski and Rockwood (2001, 2002a,b). It is now a well established methodology applied in countless studies in the medical science and, recently, also in the economics of aging (Dalgaard and Strulik, 2014).[1] The index simply records the fraction of a large set of aging-related health conditions that is present in an individual (see Searle et al., 2008, for methodological background). The health deficit index and, in particular its exponential increase with age (akin to the Gompertz law of mortality) has a micro-foundation in the reliability theory of human aging (Gavrilov and Gavrilova , 1991). It is also supported more directly by a network theory of aging (Mitnitski et al., 2017).

We compute the health deficit index for individuals from 14 countries and 6 waves (collected 2004 – 2015) of the Survey of Health, Aging, and Retirement in Europe (SHARE). We built on our earlier work (Abeliansky and Strulik, 2018a,b,c) and exploit the panel and cohort structure of the SHARE data. In previous studies we controlled for year-of-birth fixed effects but here we make them the explicit object of investigation and show the presence of long-run trends of health improvements and their unequal appropriation by individuals from different socioeconomic background.[2]

The steady pace at which health deficits decline from one birth cohort to the next as well as its similarity across countries suggests to associate it with medical progress. To paraphrase Chernew and Newhouse (2011), continuous change is hard to explain with discretionary and irregular changes like policy interventions. Chernew and Newhouse (2011) apply this reasoning to argue that the observed secular growth of health care spending is likely driven by income growth and medical progress. This view is largely accepted in the literature, albeit with disagreement of how

[1]Originally, the methodology was established by Mitnitski, Rockwood, and coauthors as the frailty index. Newer studies use also the term health deficit index (e.g. Mitnitski and Rockwood, 2016), which seems to be a more appropriate term when the investigated population consists to a significant degree of non-frail persons.

[2]A couple of studies investigated the health deficit index (frailty index) using the SHARE data (Romero-Ortuno and Kenny, 2012; Harttgen et al., 2013, Theou et al., 2013; Romero-Ortuno, 2014). In contrast to our work, these studies did not exploit the panel structure of the data for longitudinal analysis.

much technological progress contributes to health expenditure trends (Chernew and Newhouse, 2011).

In our case, considering the reverse causality, income growth and health expenditure growth are a priori also conceivable drivers of health trends. It seems, however, unlikely that large parts of the secular decline in health deficits are driven by growth of income or health expenditure. The reason is that growth of GDP per capita and growth of health care spending vary greatly across the countries of our sample. For example, for 21 OECD countries from Chandra and Skinner (2012, Table 1), average annual GDP capita growth in the period 1980-2006 ranged from 1.0 percent (Switzerland) to 3.8 percent (Ireland). Health expenditure growth ranged from 1.6 percent (Sweden) to 4.5 percent (Spain). The total increase of the health expenditure share of GDP during this period ranged from 0.5 to 7 percentage points with a mean of 2.9 and a standard deviation of 1.5.[3] There is thus a huge variation across countries along these dimensions whereas there is very little variation across countries in the rate at which health deficit decline. We estimate that this rate is not statistically different across countries and that it lies with 95% confidence in the interval $(1.41\%, 1.67\%)$ for women and $(1.23\%, 1.55\%)$ for men. This means that there is little variation left to be explained by the large country differences in income growth and health expenditure growth. Medical progress, broadly defined (including, for example, knowledge about healthy behavior) can be more easily imagined to diffuse across countries and to be the common driving force behind the steady decline of health deficits.

The trend rate of health deficit decline represents an output- or success-oriented measure of medical progress. It provides an alternative to input-oriented measures that interpret technological change as the time-trend of the unexplained part of health expenditure, akin to the Solow-residual in studies of productivity growth (Chernew and Newhouse, 2011). A particularly interesting study in this regard is Smith et al. (2009) who interpret medical technology as the common year-fixed-effects in health expenditure regressions for a panel of 21 OECD countries. The estimates suggests that medical technology increased relatively steadily since the 1980s, at annual rates around 1.2 - 1.5 percent (Smith et al., 2009, Exhibit 2).

The benefits of medical progress, however, are not appropriated equally by everyone. We use information on years of education to approximate own socio-economic status and on books at

[3] If we consider only the 10 countries that are contained in Chandra and Skinner's (2012) sample and in our sample, the range of income growth and health expenditure growth remains unchanged and the expenditure share of GDP ranges from 0.5 to 4.2 percentage points with a mean of 2.5 and a standard deviation of 1.5.

home in childhood (at age 10) to approximate socio-economic family background. We find that lower socio-economic strata experience a similar (yet not exactly equal) rate at which health deficits decline by year of birth but that there are large differences in levels at each year of birth. This means that low socioeconomic status delays the full appropriation of medical progress. For example, at age 75, individuals born in 1945 who obtained 6 years of education display the same health deficit index as individuals born in 1910 with 15 years of education. This delay is about same for both men and women.

We also find differential effects for socioeconomic background. Individuals from families of higher socioeconomic status (more books at home at age 10) exhibit less health deficits at any age. The effect of socioeconomic background is particularly strong for women. For example, at age 75, women born in 1930 with no books at home display the same health status as women born in 1920 with a bookcase of books at home, i.e. they experience a delay in the appropriation of technical progress of about 10 years. For men this difference is just about 2 years.

As mentioned above, we find only a very small time trend for health inequality. Moreover, the direction of the trend depends on whether inequality is measured in absolute or relative terms. In terms of health deficits displayed at a given age, the distance between high and low socioeconomic background declines somewhat over time. In relative terms, in contrast, there is mild divergence. At any age, the ratio of health deficits displayed by individuals of low vs. high socioeconomic status, is mildly higher for later born cohorts. These differences, however, are quantitatively small such that, as a stylized fact, health inequality remains almost constant in the long run.[4]

The paper proceeds as follows. In the next section we describe the data. In Section 3 we estimate the model of human aging and compare long-run trends identified by year-of-birth fixed effects and year-of-birth time trends. In Section 4 we investigate the role of socio-economic background. Section 5 concludes.

[4] In this regard, health deficit trends differ from trends in mortality where the socioeconomic gradient seems to increase over time, not only in the U.S. (Meara et al., 2008) but also in many European countries (Mackenbach, 2006).

2. Data Description

For the empirical analysis we employ the Survey of Health, Aging and Retirement in Europe (SHARE dataset release 6.0.0).[5] We use information from five waves (1, 2, 4, 5 and 6) that include health-related information; for methodological details, see Börsch-Supan et al. (2013) and Gruber et al. (2014). Wave 1 took place in the year 2004, wave 2 in 2006/7, wave 4 in 2011 (in 2012 for Germany), wave 3 in 2008/2009 (except Ireland 2009-2011), wave 5 in 2013, and wave 6 in 2015. Wave 3 does not include health-related variables, since it is a retrospective wave from where we obtain information on the amount of books at home at the age of 10 as a proxy for socioeconomic conditions in early childhood. The number of books is a categorical variable that takes the value of 1 when there were none or very few books at home, 2 when there were enough books to fill one shelf (11-25 books), 3 when there were enough books to fill one bookcase (26-100 books), 4 when there were enough books to fill two bookcases (101-200 books), and 5 for more than 200 books (more than two bookcases). Finally, we also include information about the individual's amount of years of education as a proxy for socioeconomic status.

We consider all countries in the sample for which we have information on socioeconomic status in childhood (only available in Wave 3 of SHARE), so that we can asses the effects of the socioeconomic gradient in childhood and adulthood within the same sample. These countries are: Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Poland, Spain, Sweden, and Switzerland. We include observations of individuals aged 50 to 85. For the regressions presented in the main text we kept only observations of individuals up to age 85 since a significant share of older people show "super healthy" characteristics, presumably because of selection effects. As robustness, in additional regressions in the Appendix we show our main results but now for a sample without an upper bound restriction of age.[6]

We created a health deficit index for each individual, following the methodology developed by Mitnitski et al. (2001), see also Searle et al. (2008) for the general procedure of creating a health deficit index (or frailty index). We took 38 symptoms, signs and disease classifications into account, as summarized in Table A.1 in the Appendix. Our specific selection of health

[5]DOIs: 10.6103/SHARE.w1.600, 10.6103/SHARE.w2.600, 10.6103/SHARE.w3.600, 10.6103/SHARE.w5.600, 10.6103/SHARE.w5.600

[6]Although the main target was to survey adults aged 50 or older (aiming at constructing a dataset that is representative of the non-institutionalized population of age 50+), younger people can also be found in the data since partners were also interviewed. These younger people were removed since they do not belong to the representative sample. People were followed across time when possible but there were also sample refreshments in the different waves.

deficits applies the same assembly of the health deficit index as in Harttgen et al. (2013). This means that we included deficits that are aging-related and not suffering from too many missing values. According to the gerontological literature that we follow, it does not matter which particular health deficits are included in the index as long as there are sufficiently many (30 or more, see Searle et al. 2008). We coded multilevel deficits using a mapping to the Likert scale in the interval 0-1. Details on how each variable was built can be found in Table A.2 in the Appendix. We then computed the health deficit index as the proportion of deficits that an individual suffers from. When there were missing data for an individual, we constructed the deficit index based on the available information about potential deficits (i.e. if for a particular individual data was not available for x potential health deficits, the observed health deficits were divided by $38 - x$). From the surveyed individuals, we conserved only those with information on at least 30 health deficits. Due to missing values in the creation of the health deficit index or because of the lack of sufficient deficits to reach the 30-item minimum, we lost less than 0.47% of the potential dataset. After further data cleaning because of the age we considered (50 to 85 in the main specifications), we kept about 92.5% of the potential dataset for the panel analysis. Close to half of this reduction was due to interviewed individuals being younger than 50 years. A further decrease of about 9% was due to missing information or implausible values of the years of education variable.[7]

Summary statistics are shown in Table 1. We observe that women are on average more frail than men and that they have received slightly less education. In terms of books at home by age 10, the mean for both genders is very similar. One should recall that this variable has less observations since it was only asked in wave 3, restricting the sample to participants present in this wave. Finally, the average age of both genders is the same. In terms of country coverage, the amount of observations by country are included in Table A.3 in the Appendix.

3. Long-run Trends of Human Health

3.1. **Year-of-Birth Effects.** A first approach to identify long-run trends in human aging is inspecting the coefficients of year-of-birth fixed effects. To identify different aging patterns across cohorts we estimate for each gender (female and male) a log-linear relationship between

[7]Since this question was asked in all of the waves we restricted the full sample to the availability of this control. We did not do the same with the number of books at home at age 10 since this question was only asked in wave 3.

Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Females					
Deficit index	86,529	0.1782	0.1376	0.0066	1
Log deficits	86,529	-2.0160	0.8041	-5.0239	0
Age	86,529	65.3059	9.1454	50	85
Year of birth	86,529	1945	9.5035	1918	1965
Years of education	86,529	10.4574	4.2184	0	25
Books at home at age 10	38,727	2.1242	1.2162	1	5
Males					
Deficit index	73,157	0.1303	0.1209	0.0066	0.9531
Log deficits	73,157	-2.3894	0.8574	-5.0239	-0.0480
Age	73,157	65.5354	8.9717	50	85
Year of birth	73,157	1945	9.2852	1918	1965
Years of education	73,157	11.1406	4.4821	0	25
Books at home at age 10	31,772	2.0806	1.2101	1	5

age, year-of-birth fixed effects, and health deficits with the following equation:

$$\ln D_i = r + \alpha \cdot age_i + \sum_{t=1}^{T-1} \gamma \cdot yrbirth_{it} + \epsilon_i, \tag{1}$$

where D is the health deficit index, i represents the individual; age represents the age at the interview, $yrbirth$ is a set of year-of-birth fixed effects; t refers to the year of birth and ϵ is the error term. We also include further covariates composed of mean age for the Mundlak specification and country fixed effects.[8] Since individuals with zero health deficits were omitted from the sample, the health deficits index D is strictly positive.

Equation (1) implies that health deficits grow exponentially with age akin to the Gompertz (1892) law of mortality:

$$D_i = R \cdot \exp(\alpha \cdot age_i) \prod_{t=1}^{T-1} \exp(\gamma_t \cdot yrbirth_{it}), \tag{2}$$

with $R = \exp(r)$. Exponential growth of health deficits is motivated by a micro-foundation of aging from reliability theory (Gavrilov and Gavrilova, 1991; Dalgaard et al., 2017). It is also supported more directly by a network theory of aging (Mitnitski et al., 2017).

Columns (1) and (2) in Tables 1 and 2 present the results of the ordinary least squares (OLS) and random effects (RE) regressions for females and males. All specifications include country

[8]The country fixed effects relate to the countries where the interviews took place. People included in our sample are limited to those born in the country of interview location. Therefore, we had to relinquish 7.6% of the sample given that they were not citizens of the country where they were interviewed.

fixed effects, which show some variation in the health status of countries, which is, however not important in the current context (see Abeliansky and Strulik, 2018a, for a more in depth analysis). For purpose of clarity, the country fixed effects are thus not shown in Tables 2 and 3. Robust standard errors are in parenthesis and are clustered at the year-of-birth level.

Table 2. Health Deficits – Females

	(1)	(2)	(3)	(4)	(5)
Age	0.01721***	0.01849***	0.01876***	0.01876***	0.01876***
	(0.00147)	(0.00183)	(0.00207)	(0.00207)	(0.00207)
Year of birth				-0.01560***	
				(0.00129)	
Austria#Year of birth					-0.01563***
					(0.00129)
Germany#Year of birth					-0.01559***
					(0.00129)
Sweden#Year of birth					-0.01570***
					(0.00129)
Netherlands#Year of birth					-0.01563***
					(0.00129)
Spain#Year of birth					-0.01553***
					(0.00129)
Italy#Year of birth					-0.01554***
					(0.00129)
France#Year of birth					-0.01557***
					(0.00129)
Denmark#Year of birth					-0.01573***
					(0.00129)
Greece#Year of birth					-0.01556***
					(0.00129)
Switzerland#Year of birth					-0.01575***
					(0.00129)
Belgium#Year of birth					-0.01555***
					(0.00129)
Czech Republic#Year of birth					-0.01553***
					(0.00129)
Poland#Year of birth					-0.01537***
					(0.00129)
Ireland#Year of birth					-0.01568***
					(0.00130)
Constant	-3.03311***	-3.09893***	-2.97309***	27.02394***	27.08360***
	(0.11162)	(0.13792)	(0.12073)	(2.60106)	(2.60044)
Mean age			-0.00193	-0.00004	-0.00002
			(0.00237)	(0.00227)	(0.00227)
Method	OLS	RE	Mundlak	Mundlak	Mundlak
Observations	86,529	86,529	86,529	86,529	86,529
Individuals	37,295	37,296	37,296	37,296	37,296

The log of the health deficit index is the dependent variable. Robust standard errors are in parenthesis and clustered at the year-of-birth level. One asterisk indicates significance at the 10-percent level; two asterisks, at the 5-percent level; and three asterisks, at the 1-percent level. Columns (1) to (4) include country fixed effects and columns (1) to (3) include year-of-birth fixed effects.

In our earlier work (Abeliansky and Strulik, 2018a,b,c) we found indications that the OLS and RE approach are misspecified due to unobserved heterogeneity. We thus present in Columns (3) of the same tables results of the Mundlak regressions by gender. The Mundlak estimator accounts for the correlation at the individual level of the unobserved heterogeneity with the time-changing covariates (Wooldridge, 2010, Ch. 14.6.3). The Mundlak estimates for males (from Table 3, columns (3) to (5)) are more reliable since the mean of the age is statistically significant, which suggest that this should be our preferred specification. We keep the same specification for females for completeness, although in this case the Mundlak model provides essentially the same results as the random effects specification. Tables A.4 and A.5 in the Appendix show the same results but without the age restriction. The main results are preserved and the point estimates barely change.

TABLE 3. Health Deficits – Males

	(1)	(2)	(3)	(4)	(5)
Age	0.01958***	0.02244***	0.02387***	0.02387***	0.02387***
	(0.00199)	(0.00250)	(0.00288)	(0.00288)	(0.00288)
Year of birth				-0.01402***	
				(0.00144)	
Austria#Year of birth					-0.01399***
					(0.00144)
Germany#Year of birth					-0.01396***
					(0.00145)
Sweden#Year of birth					-0.01413***
					(0.00144)
Netherlands#Year of birth					-0.01409***
					(0.00145)
Spain#Year of birth					-0.01397***
					(0.00144)
Italy#Year of birth					-0.01397***
					(0.00144)
France#Year of birth					-0.01399***
					(0.00144)
Denmark#Year of birth					-0.01414***
					(0.00145)
Greece#Year of birth					-0.01405***
					(0.00145)
Switzerland#Year of birth					-0.01414***
					(0.00145)
Belgium#Year of birth					-0.01397***
					(0.00145)
Czech Republic#Year of birth					-0.01391***
					(0.00144)
Poland#Year of birth					-0.01377***
					(0.00145)
Ireland#Year of birth					-0.01404***
					(0.00144)
Constant	-3.56684***	-3.76246***	-3.22924***	23.91814***	23.85511***
	(0.15682)	(0.19613)	(0.12334)	(2.88640)	(2.88794)
Mean age			-0.00848***	-0.00853***	-0.00851***
			(0.00277)	(0.00267)	(0.00267)
Method	OLS	RE	Mundlak	Mundlak	Mundlak
Observations	73,157	73,157	73,157	73,157	73,157
Individuals	32,362	32,362	32,362	32,362	32,362

The log of the health deficit index is the dependent variable. Robust standard errors are in parenthesis and clustered at the year-of-birth level. One asterisk indicates significance at the 10-percent level; two asterisks, at the 5-percent level; and three asterisks, at the 1-percent level. Columns (1) to (4) include country fixed effects and columns (1) to (3) include year-of-birth fixed effects.

Columns (1)-(3) from Tables 2 and 3 show that men age faster than women (higher age coefficient) but start out more healthy (lower constant), a result that confirms earlier studies (e.g. Mitnitski et al., 2002; Abeliansky and Strulik, 2018a,b,c). Here, however, we are particularly interested in differences of the aging process across cohorts, i.e. in the year-of-birth fixed effects included in these regression. In Figures 1 and 2 we plot the year-of-birth fixed effects from columns (3) from Tables 2 and 3, since these are our preferred specifications. The reference year is 1934.[9] We see a clear pattern of declining year-of-birth fixed effects, implying that subsequent cohorts, at the same age, display less health deficits than earlier cohorts.

The remarkably monotonous and almost linear decline of the year-of-birth fixed effects suggests a less demanding specification (retaining more degrees of freedom) which replaces the year-of-birth fixed effects by a year of birth trend. Figures 3 and 4 show the regression line of the year-of-birth fixed effect together with the estimated year-of-birth fixed effects, for females and males. As it can be seen, the fit is very good; the associated R-squared is 0.96 and 0.94, respectively. Figures A.1,A.2, A.3, and A.4 in the Appendix show the equivalent figures but for the OLS and RE estimates.

There is some variation at the upper and lower end of the year of birth plots, but this is presumably due to a lower number of observations for these years as Table A.6 in the Appendix shows. The assumption of a year-of-birth trend is thus plausible and convenient for the following analyses of potentially country-specific trends and the role of education and socio-economic background for the secular decline of health deficits.

3.2. **Year-of-Birth Trends.** To investigate year-of-birth trends, we now proceed with estimating the following model:

$$\ln D_i = r + \alpha \cdot age_i + \gamma \cdot yrbirth_i + \epsilon_i, \tag{3}$$

where *yrbirth* is no longer a set of fixed effects but a trend (the equation also includes the mean age as an extra control, as required by the Mundlak approach). Results for the time-trend regression are shown in column (4) from Tables 2 and 3. According to these estimates, women from an earlier cohort have 1.5% less health deficits ($\exp(-0.0156) - 1 = -.015$), compared to women born one year later. In the case of men, the coefficient translates to a 1.4% decline in health deficits per year of birth. The point estimate is moderately smaller than for women, although the difference between genders is not statistically significant.

In columns (5) we report results when we interact the country fixed effects with the year-of-birth trend. The obtained coefficients are remarkably similar and not statistically different from each other. This means that individuals from all countries experience about the same decline

[9]This year was selected because it is somewhere in the middle of the year of birth interval, but results do not rely on the specific choice of the reference year.

Figure 1. Year-of-Birth Fixed Effects

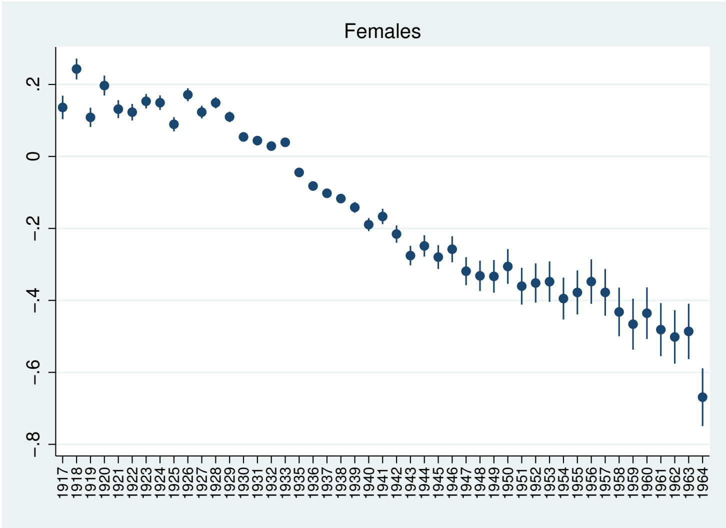
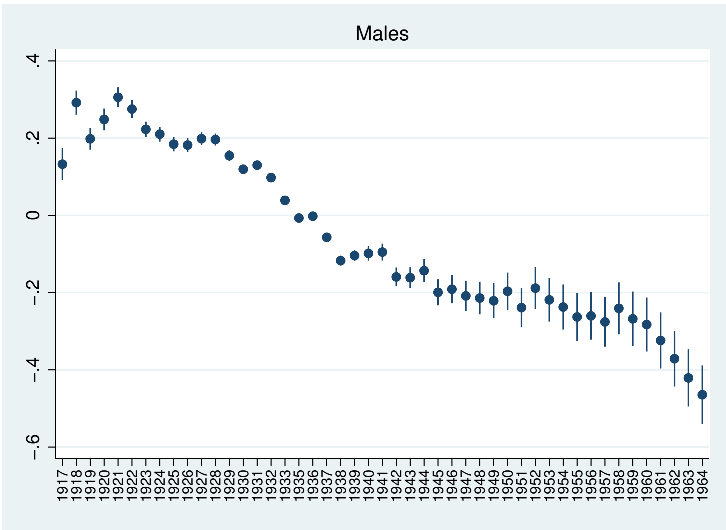


Figure 2. Year-of-Birth Fixed Effects



in health deficits. As argued in the Introduction, this observation suggests to identify the year-of-birth trend with medical progress since the large differences in country income growth and health expenditure growth explain at most a small variation in country-specific health trends.

In order to better assess the quantitative importance of these results, we illustrate by way of example the estimated aging process for two cohorts. In Figure 5, the left panel shows results for women, the right panel for men. Health deficits predicted for the specific age are shown by solid (blue) lines for the cohort born 1930 and by dashed (red) lines for the cohort born 1960. At any age, women display more health deficits but those of men increase at a slightly higher rate. At any age, the later born cohort exhibits substantially fewer health deficits and the difference

Figure 3. Year-of-Birth Fixed Effects and Year-of-Birth-Trend

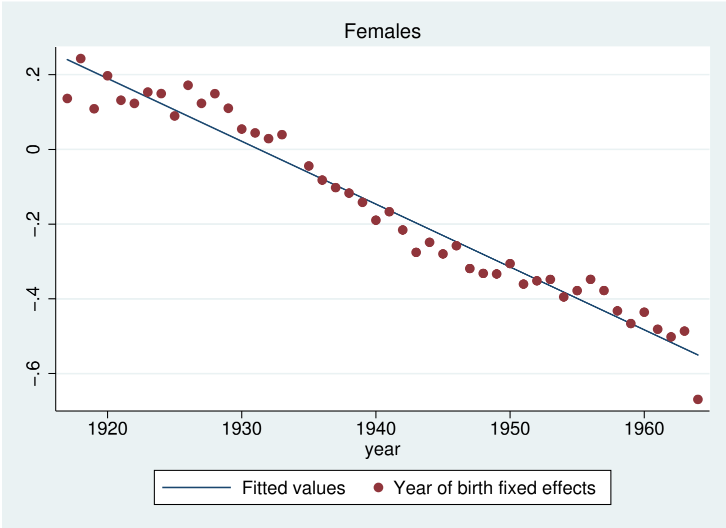
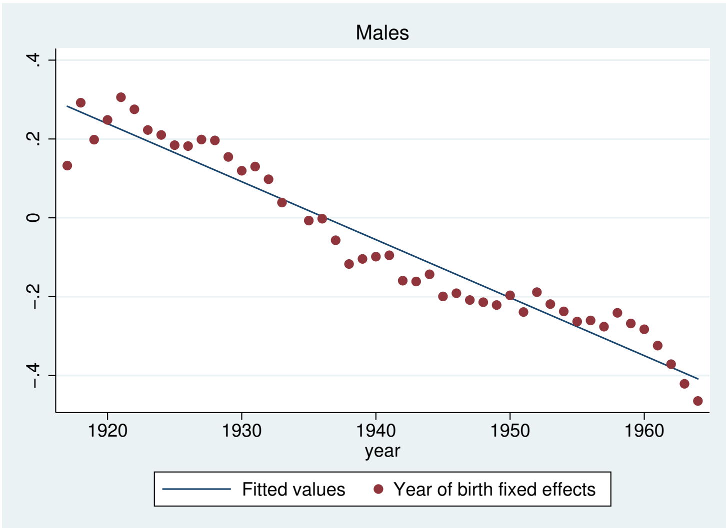


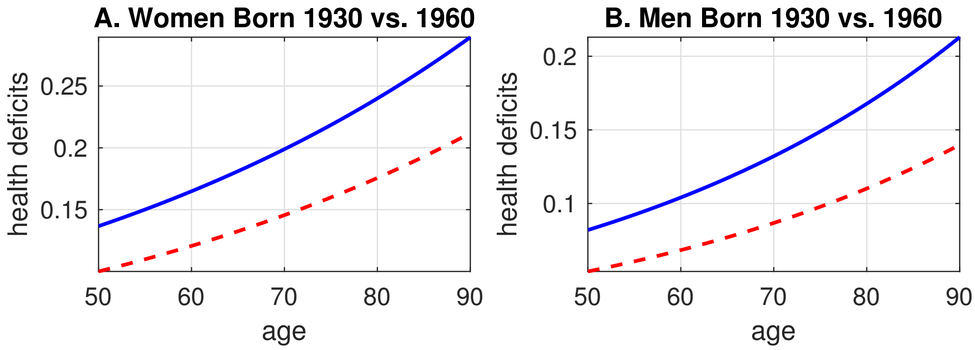
Figure 4. Year-of-Birth Fixed Effects and Year-of-Birth-Trend



is also increasing with age. For women, the later born cohort displays a 3.6 percentage point lower health deficit index at age 50 and a 7.8 percentage points lower health deficit index at age 90. For men, the difference increases from 2.8 at age 50 to 7.3 at age 90.

Figure 6 illustrates the same results in an alternative way. It shows the predicted health deficit at age 65 (solid lines) and age 85 (dashed lines) for cohorts born from 1920 to 1970. The Figure highlights the remarkable delay of aging that humans experienced over fifty years. For example, the health deficit index that women born in 1920 exhibited at age 65 is predicted to be exhibited by women born 1945 at age 85. For men, the delay is somewhat smaller. Health

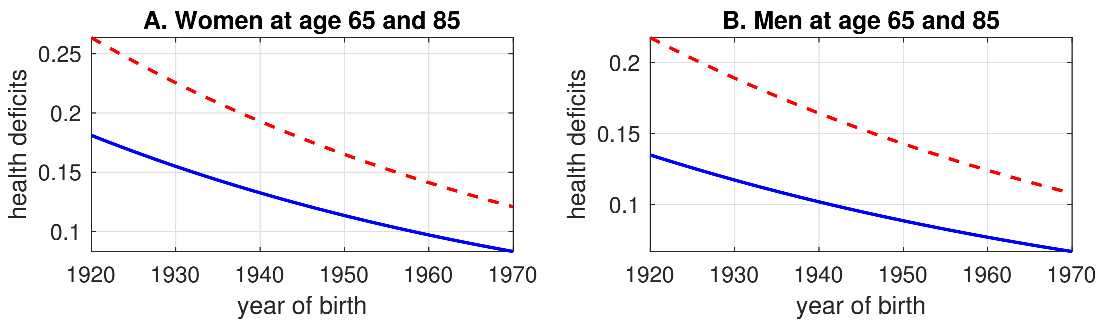
Figure 5. Year of Birth and Aging of Men and Women



Average health deficits by age. Panel A: solid (blue) line: Women born 1930, dashed (red) line: women born 1960. Panel B: solid (blue) line: Men born 1930, dashed (red) line: men born 1960. Regression Results from Mundlak estimates.

deficits of the 1920 cohort at age 65 are predicted for the 1955 cohort at age 85. As stylized fact, a cohort born one generation (30 years) later displays a 6 - 7 percentage points lower health deficit index, which means that it experiences about a quarter less health deficits.

Figure 6. The Health Deficit Index by Year of Birth



Average health deficits by birth cohort. Panel A: solid (blue) line: women at age 65, dashed (red) line: women at age 85. Panel B: solid (blue) line: men at age 65, dashed (red) line: men at age 85. Regression Results from Mundlak estimates.

4. Socioeconomic Status and Socio-Economic Background

We next investigate the evolution of health inequality over time by allowing the year-of-birth trend to vary with socio-economic status and socio-economic family background. As explained in Section 2 we approximate socioeconomic status by years of education (edu_years) and estimate the following equation:

$$\ln D_i = r + \alpha \cdot age_i + \gamma \cdot yrbirth_i + \kappa \cdot yrbirth_i \cdot edu\_years + \epsilon_i. \tag{4}$$

In the next step we address differentials according to socioeconomic background, approximated by the number of books at home in childhood (at age 10) and estimate the following equation:

$$\ln D_i = r + \alpha \cdot age_i + \gamma \cdot yrbirth_i + \delta \cdot \sum_{books=2}^{books=5} books \cdot yrbirth_i + \epsilon_i, \quad (5)$$

in which *books* measures categorically the number of books at home in childhood, as explained in Section 2. As a last step, we try to disentangle whether socioeconomic status in adulthood and childhood are robust when included jointly by estimating the following equation:

$$\ln D_i = r + \alpha \cdot age_i + \gamma \cdot yrbirth_i + \kappa \cdot yrbirth_i \cdot edu\_years + \sum_{books=2}^{books=5} \lambda \cdot yrbirth_i \cdot books + \epsilon_i, \quad (6)$$

Table 4. Trends of Human Health and Socioeconomic Status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age	0.018762***	0.018765***	0.022126***	0.022126***	0.023874***	0.023875***	0.028619***	0.028625***
	(0.002069)	(0.002069)	(0.001886)	(0.001885)	(0.002882)	(0.002883)	(0.002664)	(0.002665)
Year of birth	-0.015599***	-0.011244***	-0.015376***	-0.011255***	-0.014021***	-0.010616***	-0.027046***	-0.023409***
	(0.001290)	(0.001361)	(0.002939)	(0.002883)	(0.001444)	(0.001483)	(0.004316)	(0.004242)
Years of educ.#Year of birth		-0.000017***		-0.000014***		-0.000016***		-0.000015***
		(0.000001)		(0.000001)		(0.000001)		(0.000001)
books_2#Year of birth			-0.000056***	-0.000036***			-0.000055***	-0.000030***
			(0.000008)	(0.000008)			(0.000008)	(0.000008)
books_3#Year of birth			-0.000095***	-0.000058***			-0.000072***	-0.000030***
			(0.000008)	(0.000008)			(0.000009)	(0.000009)
books_4#Year of birth			-0.000109***	-0.000059***			-0.000087***	-0.000029*
			(0.000012)	(0.000012)			(0.000019)	(0.000017)
books_5#Year of birth			-0.000105***	-0.000044***			-0.000083***	-0.000008
			(0.000013)	(0.000013)			(0.000018)	(0.000020)
Constant	27.023943***	18.844520***	26.802477***	18.940694***	23.918142***	17.575203***	50.301796***	43.364199***
	(2.601057)	(2.736299)	(5.907753)	(5.791933)	(2.886396)	(2.962761)	(8.672869)	(8.522385)
Mean age	-0.000040	-0.000031	-0.005215	-0.004157	-0.008533***	-0.008332***	-0.029556***	-0.028242***
	(0.002268)	(0.002187)	(0.004058)	(0.003933)	(0.002673)	(0.002616)	(0.005325)	(0.005347)
Gender	Female	Female	Female	Female	Male	Male	Male	Male
Observations	86,529	86,529	38,727	38,727	73,157	73,157	31,772	31,772
Individuals	37,296	37,296	11,720	11,720	32,362	32,362	9,796	9,796

The log of the health deficit index is the dependent variable. Robust standard errors are in parenthesis and clustered at the year-of-birth level. One asterisk indicates significance at the 10-percent level; two asterisks, at the 5-percent level; and three asterisks, at the 1-percent level. Austria is the default category, as well as "none or very few books (0-10 books)" for the regressions which include books at home at age 10. The second category of the variable is "(books) enough to fill one shelf (11-25 books) "; the third "(books) enough to fill one bookcase (26-100 books)", the fourth "(books) enough to fill two bookcases (101-200 books)", and the fifth "(books) enough to fill two or more bookcases (more than 200 books) ".

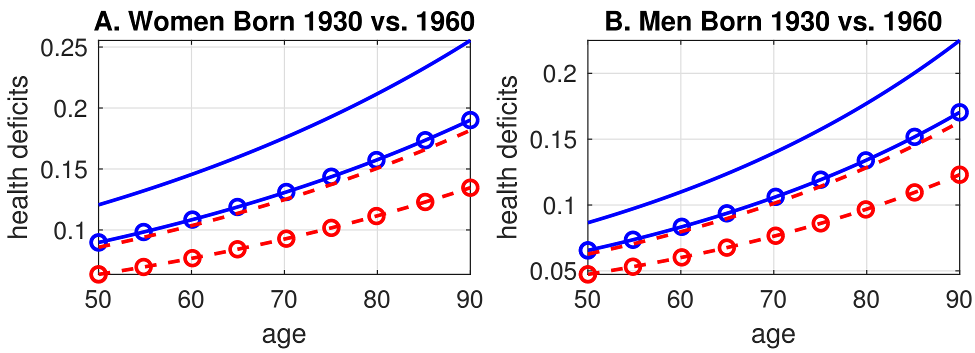
We use the correlated random effects estimator of Mundlak (1978), as it was our preferred specification in Section 3. All equations (4) – (6) include country fixed effects and the mean age as an extra control, as required by the Mundlak approach. Results are shown in Table 4. Columns (1) and (5) replicate columns (5) from Tables 2 and 3 and are presented for comparison. Columns (2) and (6) show how much an extra year of education is associated with the year-of-birth trend.

The estimated coefficients are negative and significant, indicating that the year-of-birth trend advances relatively faster for individuals with more education. This means that the benefits from technological progress are relatively better appropriated by individuals of high socio-economic status.

The feature that part of the "pure effect of medical progress" is mediated through differential appropriation can also be seen in the estimates of the year-of-birth effect, which declines in absolute terms: from -0.0156 to -0.0112 for women and from -0.0140 to -0.0106 for men. The interaction effect means that, for example, for women born 1930 the deficit index will be 3 percent lower for every additional year of education ($\exp(-0.000017 \cdot 1930) = 0.97$). The point estimate for men is slightly lower but not statistically different from that for women.

In Figure 7 we illustrate, by way of example, the aging process of men and women depending on year of birth and socio-economic background. Solid (blue) lines refer to individuals born in 1930 and dashed (red) lines refer to individuals born in 1960. Unmarked lines refer to individuals with 6 years of education while circled lines refer to individuals with 15 years of education. Results are shown in the panel on the left-hand side for woman and in the panel on the right-hand side for men.

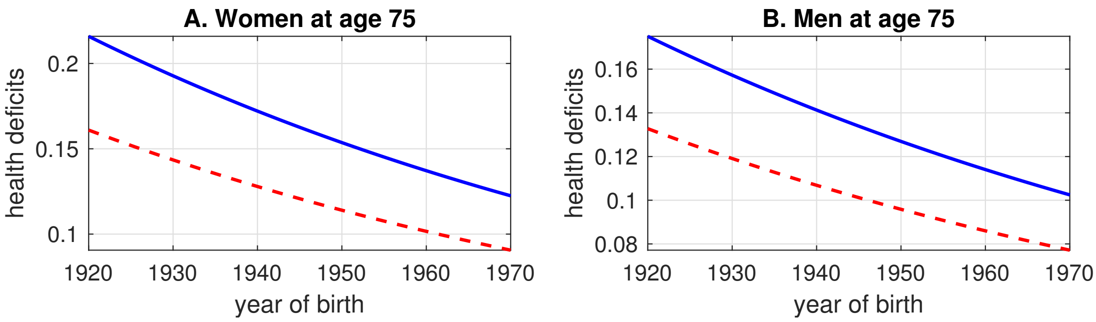
Figure 7. Education, Year of Birth, and Aging of Men and Women



Average health deficits by age. Panel A: solid (blue) lines: individuals born 1930 with 6 years of education, dotted solid (blue) line: individuals born 1930 with 15 years of education; dashed (red) line: individuals born 1960 with 6 years of education, dotted dashed (red) line: individuals born 1960 with 15 education. Regression results from Mundlak estimates.

Figure 7 reveals a strong socio-economic gradient that increases as individuals get older. For women born 1930 (solid lines), the health deficit index with 6 years of education exceeds that with 15 years of education by 3.1 percentage points at age 50 and by 6.5 percentage points at age 90, i.e. the difference doubles from the 50th to the 90th birthday. This absolute increase in social distance results naturally from the fact that health deficits increase as individuals get older. In relative terms, the distance is independent from age and obtained as $\exp(-0.000017 \cdot 1930 \cdot 9) = 0.741$. This means that, at any age, women of low socio-economic status display 26% more health deficits than those of high socio-economic status. For women born 1960 the relative difference in health deficits with respect to socio-economic status is predicted to increase from 2.2 percentage points at age 50 to 4.7 percentage points at age 90, i.e. again a doubling of the distance, albeit at a much lower level than for the cohort from 1930. For men, the aging dynamics are similar, although at a somewhat lower level of health deficits. The most striking impression from Figure 7 is perhaps the closeness of the circled solid line and the dotted line for both men and women. It means that individuals born in 1960 with 6 years of education display about the same health deficits as individuals born 1930 with 15 years of education.

Figure 8. Education and the Health Deficit Index by Year of Birth



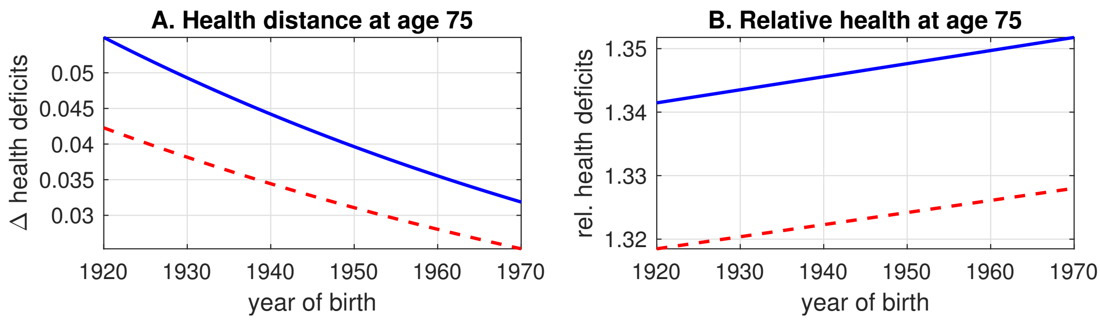
Average health deficits by birth cohort. Panel A: women at age 65; solid (blue) line: 6 years of education, dashed (red) line: 15 years of education. Panel B: men at age 65; solid (blue) line: 6 years of education, dashed (red) line: 15 years of education. Regression Results from Mundlak estimates.

In Figure 8 we illustrate how the socioeconomic gradient of health evolves over time. The Figure shows for women (on the left) and men (on the right) the health deficits exhibited at age 75 by year of birth. Solid lines represent individuals with 6 years of education and dashed lines represent individuals with 15 years of education. Health deficits decline with year of birth for both social strata but from a much higher level for individuals of low socio-economic status. The level of health deficits exhibited by highly educated women born in 1920 is reached by low educated women only in 1945. Men exhibit less health deficits than women of the same cohort and the same years of education but the social distance between high and low educated individuals is about the same as for women.

From Figure 8 a long-run trend for social distance is hardly discernable for the naked eye. However, we know that eventually social distance in absolute terms will disappear. This follows by construction from model (4), which assumes that the impact of year of birth on health deficits that operates through years of education is given by $\exp(\kappa \cdot yrbirth)$. For negative κ, as estimated, this expression converges to zero as the year of birth goes to infinity, implying convergence of social distance in absolute terms. In relative terms, health deficits of low educated persons differ from those of high education from the same cohort by $\exp(-\kappa \cdot yrbirth \cdot \Delta edu\_years)$. Since Δedu_years is negative (because low educated individuals have less education) and κ is negative, relative distance approaches infinity for rising $yrbirth$.

Summarizing, absolute and relative distance evolve in different directions. But how quantitatively important are these trends? We assess this issue with help of Figure 9. Solid lines represent women and dotted lines represent men, both at age 75. The panel on the left-hand side shows absolute distance, i.e. the difference in health deficits between individuals of 6 years of education and individuals of 15 years of education from the same cohort. Absolute distance is slowly declining. It is higher and slightly faster declining for women. The health deficit index differs by 5.5 percentage points for women born 1920 and is predicted to differ by 3.2 percentage points for women born 1970.

Figure 9. Absolute and Relative Health Inequality



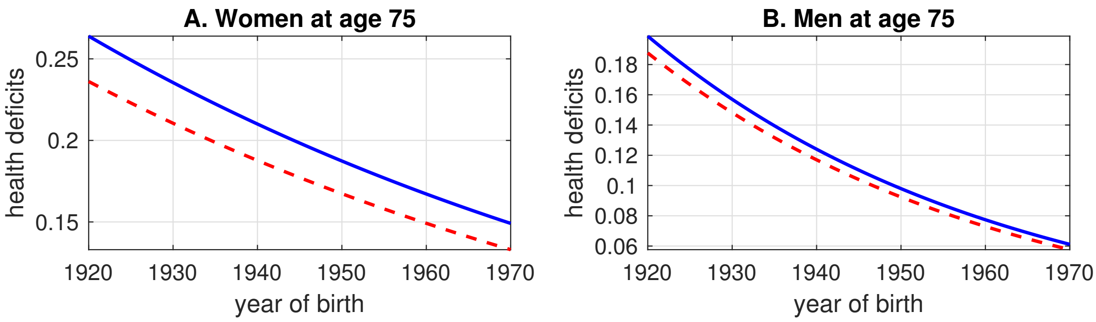
Panel A shows the difference of health deficits accumulated at age 75 between individuals with 6 years of education and individuals of 15 years of education. Panel B shows the health deficits of individuals with 6 years of education relative to individuals with 15 years of education. Solid (blue) line: women; red (dashed) line: men.

The panel on the right-hand side of Figure 9 shows that social distance in relative terms is about the same for men and women and very slowly increasing. The health deficit index of women with low education exceeded that of women with high education by factor 1.34 for the cohort of 1920 and it is predicted to increase to factor 1.35 for the cohort of 1970. As a stylized fact we thus conclude that relative health inequality is very persistent. Irrespective of their year of birth, men and women with 6 years of education display about 1/3 more health deficits than equally aged individuals with 15 years of education.

Finally, we discuss results with respect to socioeconomic family background. Columns (3) and (7) in Table 4 show results for model (5), i.e. when years of schooling are replaced by books at home. The books coefficients are negative and significant and they are increasing in the number of books, indicating that individuals from a more literate family background benefitted relatively more from medical progress. These effects are stronger for women than for men. For women born 1930, for example the health deficit index is 17 percent lower when there were enough books to fill one bookcase (26-100 books) compared to those with no or few books ($0.83 = \exp(-0.000095 \cdot 1930)$). Men from the same cohort and family background benefitted only with a health deficit reduction of 13 percent from their literate family background ($0.87 = \exp(-0.000072 \cdot 1930)$).

As shown in columns (4) and (8), the two measure of socio-economic status have explanatory power, even when entered jointly. Most of the coefficients for the interaction of the year-of-birth trend with books at home become smaller, while the size of coefficients for the interaction with years of education barely changes. Table A.7 in the Appendix shows the same regression results but without the age restriction. Results remain basically the same, although the coefficient for the highest amount of books at home loses statistical significance for males.

Figure 10. Books at Home and the Health Deficit Index by Year of Birth



Panel A: women at age 65; solid (blue) line: no books, dashed (red) line: enough books to fill one bookcase. Panel B: men at age 65; solid (blue) line: no books, dashed (red) line: enough books to fill one bookcase. Regression Results from Mundlak estimates evaluated at 12 years of education.

The implications of these results for the evolution of health deficits and health inequality are illustrated in Figure 10. The figure shows for alternative years of birth the effects of family background by controlling for education, i.e. it illustrates results from column (4) and (8) of Table 4. Specifically, we assume that individuals have 12 years of education and compare health deficits at age 75 when there were no books at home in childhood (solid lines) with the case when there were enough books to fill one bookcase (dashed lines). We see that effects of family background are substantially larger for women (shown on the left-hand side) compared to men (shown on the right-hand side). For women, health deficits differ by about 2.5 percentage points with a mildly declining trend. This means that women with no books at home in childhood display about 12 percent more health deficits at age 75 than women whose family had a bookcase full of books. For men the absolute distance between these social strata is only about 0.7 percentage points and the relative distance is about 6 percent, i.e. men with no books at home in childhood display about 6 percent more health deficits at age 75 than men from the same cohort whose family had a bookcase full of books.

5. Conclusion

In this paper we proposed a new method to investigate long-run health trends. We computed the health deficit index for individuals from 14 countries and 6 waves of the SHARE data set and focused on the year-of-birth fixed effects, i.e. the gain in reduction in health deficits that individuals experience simply because they were born later. Comparing health between individuals (of different age and gender and from different countries) is usually a difficult subject of investigation because health (in contrast to mortality) is a multi-dimensional concept and the various dimensions of health are influenced in a variety of ways and change not necessarily in the same way over time (Crimmins, 1996). Here we exploited the feature of the health deficit index as an encompassing measure of aging and health, which allowed us to clearly reveal long-run trends in human health that were perhaps less clearly visible in previous studies.

In regressions of the health deficit index, we found that the size of the year-of-birth fixed effect declines monotonously at a pace that can be well approximated with a linear trend. This trend of 1.4 to 1.5 percent less health deficits per later year of birth appears to be remarkably uniform across gender, across countries and over time.

The steady reduction of health deficits for later cohorts implies substantial delays of human aging. For example, the level of health deficits experienced at age 65 by individuals born 1920 is predicted to be experienced at age 85 by individuals born 1945. We thus the confirm for health deficits, the postponement of senescence emphasized by Vaupel (2010) in the context of mortality. The confirmation of the postponement hypotheses is not a great surprise from the perspective of the micro-foundation of gerontology. The basic insight from this literature is that death is not explained by chronological age, but by the frail status of the human body (Arking, 2006; Gavrilov and Gavrilova, 1991; Mitnitski et al., 2002b). It thus seems natural that similar secular trends can be observed for mortality and morbidity. Since we found the trend to be very similar for all 14 countries in our sample (which display quite different trends with respect to income and health expenditure growth), we argue that it is likely driven by medical progress. Our (success-oriented) measure of medical progress suggest that progress advances at an annual rate of 1.4 - 1.5 percent.

The potential health gains from medical progress are, however, not fully appropriated by individuals of low socio-economic status. We found that their health deficits decline at about the same rate but from a higher level. The implied socio-economic disparities are quite large. For example, our estimates suggest that men and women with 6 years of education display about one-third more health deficits at any age and irrespective from year of birth than equally aged individuals with 15 years of education. We also found that low socioeconomic background in childhood causes a delay in appropriating the gains from medical progress, which is particular strong for women. Summarizing, we find long-run persistence of health inequality.

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Appendix A

Table A.1. Items of the Health Deficit Index

Arthritis	Difficulties concentrating
Stroke	Difficulties shopping
Parkinson	Difficulties lifting 5kg
Diabetes	Difficulties pulling/pushing object
Cholesterol	Less enjoyment
Asthma	Difficulties managing money
Depression	Difficulties joining activities
High blood pressure	Difficulties bathing
Cataracts	Difficulties dressing
Pain	Difficulties doing housework
Difficulties seeing arm length	Difficulties walking across house
Difficulties seeing across street	Difficulties eating
Difficulties sitting long	Difficulties getting out of bed
Difficulties walking 100mt	Difficulties using the toilet
Difficulties getting out chair	Difficulties using map
Difficulties climbing stairs	Walking speed (only in wave 1 and 2)
Difficulties kneeing	BMI
Difficulties picking an object	Grip strength
Difficulties extending arms	Mobility

Table A.2. Variables from the SHARE Data

Dimension	Variable	Coding in SHARE dataset
Arthritis	ph006d8	yes=1, no=0
Stroke	ph006d4	yes=1, no=0
Parkinson	ph006d12	yes=1, no=0
Diabetes	ph006d5	yes=1, no=0
Cholesterol	ph006d3	yes=1, no=0
Asthma	ph006d7	yes=1, no=0
Depression	mh002_	yes=1, no=1
High blood pressure	ph006d2	yes=1, no=0
Cataracts	ph006d13	yes=1, no=0
Pain	ph010d1	yes=1, no=0
Difficulties seeing arm length	ph044_	none=0, mild=0.25, moderate=0.5, bad=0.75, very bad=1
Difficulties seeing across street	ph043_	none=0, mild=0.25, moderate=0.5, bad=0.75, very bad=1
Difficulties sitting long	ph048d2	yes=1, no=0
Difficulties walking 100mt	ph048d1	yes=1, no=0
Difficulties getting out chair	ph048d3	yes=1, no=0
Difficulties climbing stairs	ph048d5	yes=1, no=0
Difficulties kneeing	ph048d6	yes=1, no=0
Difficulties picking an object	ph048d10	yes=1, no=0
Difficulties extending arms	ph048d7	yes=1, no=0
Difficulties concentrating	mh014_	yes=1, no=0
Difficulties shopping	ph049d9	yes=1, no=0
Difficulties lifting 5kg	ph048d9	yes=1, no=0
Difficulties pulling/pushing object	ph048d8	yes=1, no=0
Less enjoyment	mh016_	yes=1, no=0
Difficulties managing money	ph049d13	yes=1, no=0
Difficulties joining activities (because of health)	ph005_	not limited=0, limited, not severely=0.5, severely limited=1
Difficulties bathing	ph049d3	yes=1, no=0
Difficulties dressing	ph049d1	yes=1, no=0
Difficulties doing housework	ph049d12	yes=1, no=0
Difficulties walking across the house	ph049d2	yes=1, no=0
Difficulties eating	ph049d4	yes=1, no=0
Difficulties getting out of bed	ph049d5	yes=1, no=0
Difficulties using the toilet	ph049d6	yes=1, no=0
Difficulties using map	ph049d7	yes=1, no=0
Walking Speed (only available wave 1 and wave 2)	wspeed and wspeed2	no problem if: aged<75 (by construction);(wspeed>=0.4 or wspeed2==0); problem if: wspeed<=0.4 or wspeed2==1
BMI	bmi	(bmi<=18.5 or bmi>=30) =1; (bmi>=25 and bmi<30)=0.5; bmi>18.5 and bmi<25)=0
Grip strength	maxgrip and bmi	it is recorded as frail for women if (maxgrip<=29 & bmi<=24); (maxgrip<=30 & (bmi>=24.1 & bmi<=28)); (maxgrip<=32 & bmi>28); for men if : (maxgrip<=29 & bmi<=24); (maxgrip<=30 & (bmi>=24.1 & bmi<=28)); (maxgrip<=32 & bmi>28)
Mobility	mobility	(mobility>=3)=1; (1>=mobility<3)=0.5 and mobility=0

Table A.3. Observations by Country

Females				Males			
Country	Freq.	Percent	Cum.	Country	Freq.	Percent	Cum.
Austria	6,208	7.17	7.17	Austria	5,039	6.89	6.89
Germany	6,454	7.46	14.63	Germany	5,874	8.03	14.92
Sweden	6,305	7.29	21.92	Sweden	5,504	7.52	22.44
Netherlands	5,077	5.87	27.79	Netherlands	4,241	5.8	28.24
Spain	8,008	9.25	37.04	Spain	7,083	9.68	37.92
Italy	8,669	10.02	47.06	Italy	7,479	10.22	48.14
France	7,914	9.15	56.21	France	6,329	8.65	56.79
Denmark	6,085	7.03	63.24	Denmark	5,409	7.39	64.19
Greece	4,782	5.53	68.77	Greece	4,141	5.66	69.85
Switzerland	4,350	5.03	73.79	Switzerland	4,019	5.49	75.34
Belgium	9,750	11.27	85.06	Belgium	8,384	11.46	86.8
Czech Republic	9,510	10.99	96.05	Czech Republic	6,937	9.48	96.28
Poland	2,932	3.39	99.44	Poland	2,297	3.14	99.42
Ireland	485	0.56	100	Ireland	421	0.58	100

Figure A.1. Year of Birth Fixed Effects and Time Trend (OLS)

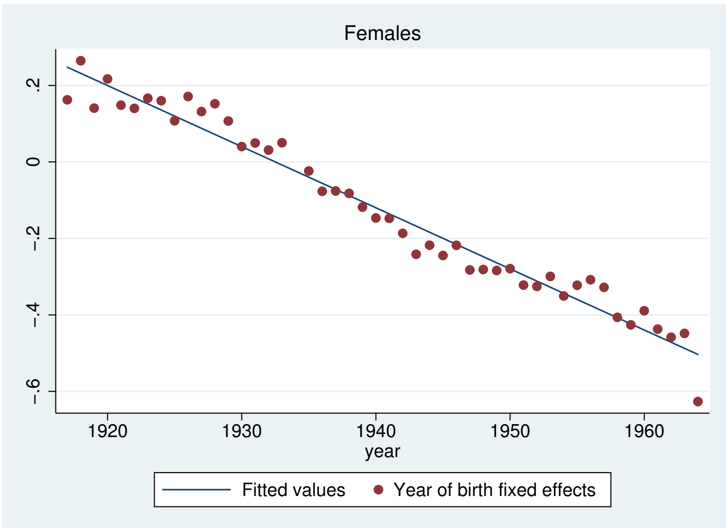

Table A.4. Technological Progress and Aging - Females, no Age Restriction

	(1)	(2)	(3)	(4)	(5)
Age	0.01885***	0.02061***	0.02113***	0.02113***	0.02113***
	(0.00153)	(0.00194)	(0.00220)	(0.00220)	(0.00220)
Year of birth	0.07907***	0.07794***	0.07679***	0.08468***	
	(0.02150)	(0.02160)	(0.02175)	(0.02258)	
Germany	-0.14174***	-0.14293***	-0.14406***	-0.14705***	
	(0.02452)	(0.02341)	(0.02372)	(0.02379)	
Sweden	-0.01732	-0.00078	-0.00609	-0.00113	
	(0.02656)	(0.02614)	(0.02799)	(0.02791)	
Netherlands	0.21618***	0.18230***	0.18347***	0.19133***	
	(0.01941)	(0.01795)	(0.01806)	(0.01825)	
Spain	0.21642***	0.18289***	0.18214***	0.18624***	
	(0.02222)	(0.02216)	(0.02205)	(0.02180)	
Italy	0.10045***	0.10180***	0.09936***	0.10875***	
	(0.02454)	(0.02435)	(0.02493)	(0.02468)	
France	-0.18582***	-0.19445***	-0.19599***	-0.18679***	
	(0.02244)	(0.02158)	(0.02178)	(0.02197)	
Denmark	0.11117***	0.12571***	0.12302***	0.12924***	
	(0.02190)	(0.02009)	(0.01967)	(0.01883)	
Greece	-0.24320***	-0.23905***	-0.24028***	-0.23569***	
	(0.02641)	(0.02588)	(0.02609)	(0.02615)	
Switzerland	0.14191***	0.15554***	0.15390***	0.16495***	
	(0.02072)	(0.02211)	(0.02241)	(0.02210)	
Belgium	0.18945***	0.18588***	0.18589***	0.18482***	
	(0.01736)	(0.01688)	(0.01688)	(0.01669)	
Czech Republic	0.49815***	0.49807***	0.49349***	0.50048***	
	(0.02503)	(0.02336)	(0.02371)	(0.02320)	
Poland	-0.10682***	-0.10444***	-0.11771***	-0.11141***	
	(0.03945)	(0.03927)	(0.04112)	(0.04071)	
Ireland				-0.01608***	
				(0.00131)	
Austria#Year of birth					-0.01611***
					(0.00131)
Germany#Year of birth					-0.01607***
					(0.00131)
Sweden#Year of birth					-0.01619***
					(0.00131)
Netherlands#Year of birth					-0.01611***
					(0.00131)
Spain#Year of birth					-0.01601***
					(0.00130)
Italy#Year of birth					-0.01602***
					(0.00130)
France#Year of birth					-0.01605***
					(0.00131)
Denmark#Year of birth					-0.01621***
					(0.00131)
Greece#Year of birth					-0.01604***
					(0.00131)
Switzerland#Year of birth					-0.01623***
					(0.00131)
Belgium#Year of birth					-0.01603***
					(0.00131)
Czech Republic#Year of birth					-0.01602***
					(0.00131)
Poland#Year of birth					-0.01585***
					(0.00131)
Ireland#Year of birth					-0.01617***
					(0.00131)
Constant	-3.15284***	-3.25736***	-3.02532***	27.93556***	27.98757***
	(0.11586)	(0.14566)	(0.11666)	(2.62732)	(2.62543)
Mean age			-0.00358	-0.00183	-0.00181
			(0.00240)	(0.00238)	(0.00238)
Method	OLS	RE	Mundlak	Mundlak	Mundlak
Observations	90,388	90,388	90,388	90,388	90,388
Individuals	38,440	38,440	38,440	38,440	38,440

The log of the health deficit index is the dependent variable. Robust standard errors are in parenthesis and clustered at the year-of-birth level. One asterisk indicates significance at the 10-percent level; two asterisks, at the 5-percent level; and three asterisks, at the 1-percent level. Columns (1) to (3) also include year of birth dummies and Austria and 1934 are the default categories.

Table A.5. Technological Progress and Aging - Females, no Age Restriction

	(1)	(2)	(3)	(4)	(5)
Age	0.02107***	0.02479***	0.02668***	0.02669***	0.02669***
	(0.00198)	(0.00260)	(0.00304)	(0.00304)	(0.00304)
Year of birth	0.06013***	0.05992***	0.05795***	0.06165***	
	(0.02177)	(0.02218)	(0.02232)	(0.02311)	
Germany	-0.27492***	-0.28110***	-0.28409***	-0.28419***	
	(0.01811)	(0.01892)	(0.01855)	(0.01922)	
Sweden	-0.18568***	-0.17746***	-0.19331***	-0.19072***	
	(0.02417)	(0.02386)	(0.02527)	(0.02515)	
Netherlands	0.05587*	0.03599	0.03972	0.04819	
	(0.02848)	(0.02871)	(0.02950)	(0.03023)	
Spain	0.05592**	0.03555	0.03448	0.03769	
	(0.02574)	(0.02626)	(0.02566)	(0.02627)	
Italy	-0.00725	-0.00109	-0.00903	0.00103	
	(0.02027)	(0.02008)	(0.01939)	(0.02004)	
France	-0.28168***	-0.29383***	-0.29789***	-0.28959***	
	(0.02614)	(0.02495)	(0.02457)	(0.02553)	
Denmark	-0.11127***	-0.10185***	-0.10978***	-0.10702***	
	(0.03507)	(0.03369)	(0.03260)	(0.03255)	
Greece	-0.30303***	-0.30162***	-0.30466***	-0.30240***	
	(0.02368)	(0.02203)	(0.02200)	(0.02146)	
Switzerland	0.00392	0.02342	0.01787	0.02976	
	(0.02203)	(0.02014)	(0.02029)	(0.02026)	
Belgium	0.15004***	0.14566***	0.14493***	0.14329***	
	(0.01673)	(0.01886)	(0.01879)	(0.02005)	
Czech Republic	0.42067***	0.43565***	0.42207***	0.43058***	
	(0.03178)	(0.03002)	(0.02850)	(0.02866)	
Poland	-0.08789**	-0.08471**	-0.12347***	-0.12156***	
	(0.04037)	(0.04062)	(0.03933)	(0.03972)	
Ireland				-0.01505***	
				(0.00158)	
Austria#Year of birth					-0.01502***
					(0.00158)
Germany#Year of birth					-0.01499***
					(0.00159)
Sweden#Year of birth					-0.01516***
					(0.00158)
Netherlands#Year of birth					-0.01511***
					(0.00158)
Spain#Year of birth					-0.01499***
					(0.00158)
Italy#Year of birth					-0.01500***
					(0.00158)
France#Year of birth					-0.01502***
					(0.00158)
Denmark#Year of birth					-0.01517***
					(0.00158)
Greece#Year of birth					-0.01507***
					(0.00158)
Switzerland#Year of birth					-0.01517***
					(0.00158)
Belgium#Year of birth					-0.01500***
					(0.00158)
Czech Republic#Year of birth					-0.01494***
					(0.00158)
Poland#Year of birth					-0.01480***
					(0.00158)
Ireland#Year of birth					-0.01508***
					(0.00158)
Constant	-3.68122***	-3.94018***	-3.25727***	25.86462***	25.79980***
	(0.15677)	(0.20335)	(0.11894)	(3.15103)	(3.15266)
Mean age			-0.01092***	-0.01040***	-0.01038***
			(0.00294)	(0.00291)	(0.00291)
Method	OLS	RE	Mundlak	Mundlak	Mundlak
Observations	75,552	75,552	75,552	75,552	75,552
Individuals	33,092	33,092	33,092	33,092	33,092

The log of the health deficit index is the dependent variable. Robust standard errors are in parenthesis and clustered at the year-of-birth level. One asterisk indicates significance at the 10-percent level; two asterisks, at the 5-percent level; and three asterisks, at the 1-percent level. Columns (1) to (3) also include year of birth dummies and Austria and 1934 are the default categories.

Figure A.2. Year of Birth Fixed Effects and Time Trend (OLS)

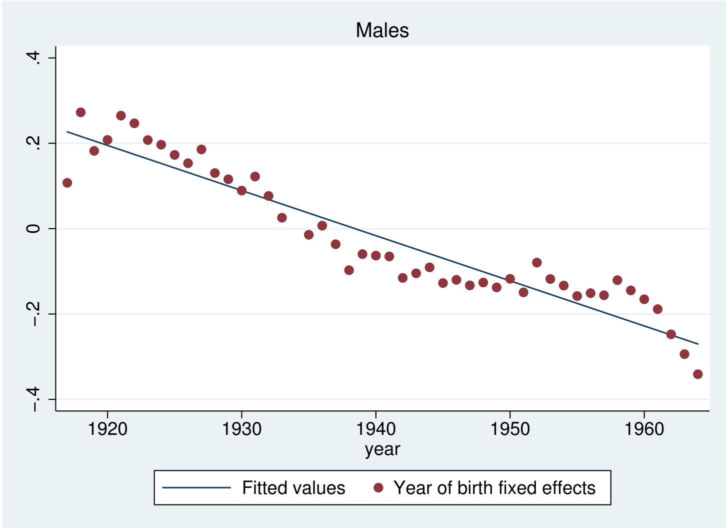

Figure A.3. Year of Birth Fixed Effects and Time Trend (RE)

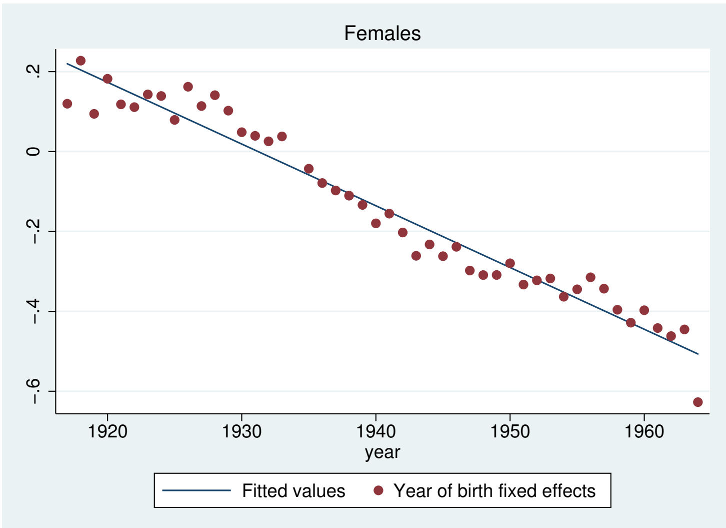

Figure A.4. Year of Birth Fixed Effects and Time Trend (RE)

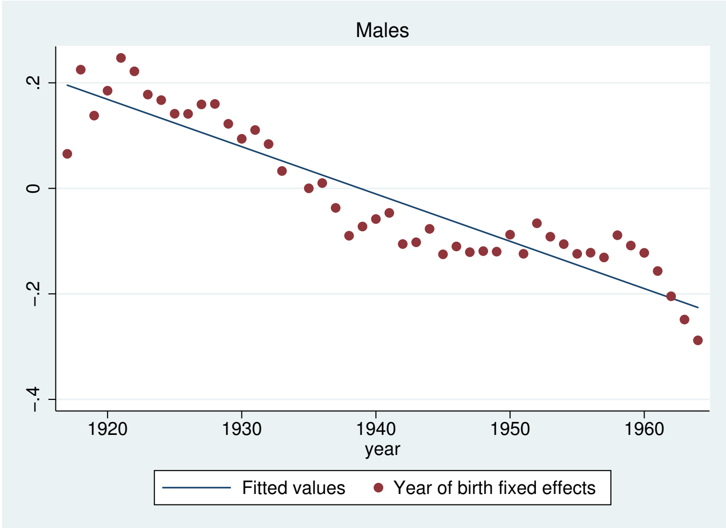

Table A.6. Observations by Year of Birth

Year of birth	Observations	Year of birth	Observations	Year of birth	Observations
1918	29	1934	3,665	1950	6,362
1919	70	1935	3,845	1951	6,229
1920	140	1936	3,691	1952	5,970
1921	311	1937	4,062	1953	6,069
1922	451	1938	4,400	1954	5,486
1923	513	1939	4,623	1955	4,823
1924	576	1940	5,111	1956	4,652
1925	856	1941	4,527	1957	3,452
1926	1,058	1942	4,928	1958	3,166
1927	1,493	1943	5,339	1959	3,291
1928	1,723	1944	5,670	1960	3,342
1929	2,103	1945	5,382	1961	2,122
1930	2,723	1946	6,477	1962	1,679
1931	2,808	1947	6,370	1963	618
1932	3,184	1948	6,488	1964	553
1933	3,086	1949	6,115	1965	55

Table A.7. Technological Progress, Aging and Socioeconomic Conditions, no Age Restriction

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age	0.021126***	0.021129***	0.023926***	0.023926***	0.026685***	0.026686***	0.031254***	0.031261***
	(0.002198)	(0.002197)	(0.001976)	(0.001975)	(0.003036)	(0.003037)	(0.002852)	(0.002852)
Year of birth	-0.016083***	-0.011641***	-0.018025***	-0.013514***	-0.015050***	-0.011621***	-0.032970***	-0.028957***
	(0.001306)	(0.001423)	(0.002960)	(0.002963)	(0.001583)	(0.001637)	(0.004472)	(0.004427)
books_2#Year of birth			-0.000056***	-0.000036***			-0.000052***	-0.000028***
			(0.000008)	(0.000008)			(0.000008)	(0.000008)
books_3#Year of birth			-0.000092***	-0.000056***			-0.000069***	-0.000027***
			(0.000008)	(0.000008)			(0.000009)	(0.000009)
books_4#Year of birth			-0.000110***	-0.000061***			-0.000083***	-0.000025
			(0.000012)	(0.000012)			(0.000019)	(0.000017)
books_5#Year of birth			-0.000103***	-0.000043***			-0.000079***	-0.000004
			(0.000013)	(0.000013)			(0.000018)	(0.000020)
Years of educ.#Year of birth		-0.000017***		-0.000014***		-0.000016***		-0.000015***
		(0.000001)		(0.000001)		(0.000001)		(0.000001)
Constant	27.935563***	19.566802***	32.077733***	23.424285***	25.864621***	19.462242***	62.029511***	54.332275***
	(2.627318)	(2.854240)	(5.944797)	(5.947031)	(3.151030)	(3.257548)	(8.973087)	(8.876915)
Mean age	-0.001827	-0.001530	-0.008823**	-0.007277*	-0.010401***	-0.010036***	-0.035405***	-0.033686***
	(0.002381)	(0.002311)	(0.004081)	(0.003983)	(0.002908)	(0.002831)	(0.005563)	(0.005582)
Gender	Female	Female	Female	Female	Male	Male	Male	Male
Observations	90,388	90,388	40,424	40,424	75,552	75,552	32,757	32,757
Individuals	38,440	38,440	11,904	11,904	33,092	33,092	9,880	9,880

The log of the health deficit index is the dependent variable. Robust standard errors are in parenthesis and clustered at the year-of-birth level. One asterisk indicates significance at the 10-percent level; two asterisks, at the 5-percent level; and three asterisks, at the 1-percent level. Austria is the default category, as well as "none or very few books (0-10 books)" for the regressions which include books at home at age 10. The second category of the variable is "(books) enough to fill one shelf (11-25 books) "; the third "(books) enough to fill one bookcase (26-100 books)", the fourth "(books) enough to fill two bookcases (101-200 books)", and the fifth "(books) enough to fill two or more bookcases (more than 200 books) ".