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Ana Lucia Abeliansky and Holger Strulik

Georg-August-Universität Göttingen

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# How Season of Birth Affects Health and Aging

Ana Lucia Abeliansky*
Holger Strulik**

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**Abstract.** We investigate how the season of birth affects human health and aging. For this purpose, we use five waves of the Survey of Health, Aging, and Retirement in Europe (SHARE) dataset and construct a health deficit index for 21 European countries. Results from log-linear regressions suggest that, on average, elderly European men age faster when they were born in spring and summer (compared to autumn). At given age, they have developed about 3.5 percent more health deficits. The bulk of the season effect is neither mediated through body height nor through education. In a subsample of Southern European countries, where the seasonal variation of sunlight is smaller, the season of birth plays an insignificant role for health in old age. In a subsample of Northern countries, in contrast, the season or birth effect gets larger. At given age, elderly Northern European men born in spring have developed on average 8.7 percent more health deficits than those born in autumn. In non-linear regression we find that the season effect increases with age suggesting that the speed of aging is also influenced by the season of birth.

*Keywords*: health; aging; health deficit index; season of birth.
*JEL:* I10, I19, J13.

* University of Göttingen, Department of Economics, Platz der Göttinger Sieben 3, 37073 Göttingen Germany; email: ana-lucia.abeliansky@wiwi.uni-goettingen.de.
** University of Göttingen, Department of Economics, Platz der Göttinger Sieben 3, 37073 Göttingen, Germany; email: holger.strulik@wiwi.uni-goettingen.de.

## 1. Introduction

The last decades of epidemiological research have provided mounting evidence that environmental conditions early in life, and in particular during the period of gestation, have a significant impact on the development of diseases later in life (for surveys of the literature see Barker, 2004; Vaiserman, 2014, and Langley-Evans, 2015). While the original studies focused on cardiovascular diseases (Barker, 1992, 1995) there is now evidence of "fetal origins" of a wide spectrum of chronic and aging-related diseases, ranging from severe conditions like type-2 diabetes, cancer, and osteoporosis (Calkins and Devaskar, 2011) to relatively mild markers of aging like grip strength, skin thickness, and hearing impairments (Sayer et al., 1998).

A natural way to test the fetal origins hypothesis is to investigate the impact of exposure to shocks in utero on late life outcomes, a literature to which increasingly economists contribute (for surveys see Almond and Currie, 2011; Almond et al., 2017). A particularly mild "shock" is the time of birth itself, which may, for example, impact on fetal development through access to nutrition like fresh fruits and vegetables or the exposure to sunlight and UV-B radiation. The seminal study in this regard is Doblhammer and Vaupel (2001) who show that in Austria and Denmark individuals born in autumn live longer than those born in spring while it is the other way round for individuals born in Australia. Since then, individual country studies for Germany, Greece, Sweden, and the Ukraine found similar patterns with high age at death (lowest mortality) for individuals born October to December and lowest age at death (highest mortality) for those born April to May (Vaiserman, 2002; Lerchl, 2004; Flouris et al., 2009; Ueda et al., 2013).[1]

The prevalence of certain diseases such as diabetes (McKinney, 2001), cardiovascular diseases (Thornhammar et al., 2014), Alzheimer's disease (Philpot et al., 1989), and immune-mediated diseases (Disanto, 2012) has also been shown to be associated with the season of birth. Here, we contribute to this literature by investigating the impact of season of birth to an aggregate, encompassing measure of health and aging, the health deficit index. In contrast to most of the available literature on cross-sections in specific countries, we investigate elderly individuals from a panel of countries observed over time (in up to 5 waves). This allows us to focus on the aging

[1] Conflicting results are provided by Gavrilov and Gavrilova (2004) who find twin peaks of life spans for births in December and May for a sample of female European aristocrats of the 19th century and Sohn (2016) who finds for an U.S. American sample the lowest mortality for autumn births and the highest mortality for winter birth. In the subpopulation of US league baseball players, however the familiar pattern of highest longevity for autumn births and lowest for spring births re-emerges (Abel and Krueger, 2010).

process, understood as the accumulation of new health deficits, and to control for country- and year-of-birth fixed effects.

We follow Mitnitski et al. (2001, 2002) and quantify health and aging by a health deficit index (a frailty index). This index adds the number of health deficits that a person has at a given age relative to the amount of potential health deficits. Health deficits include serious disabilities as well as mild illnesses. The specific choice of deficits is not crucial provided that sufficiently many indicators are present in the index (see Rockwood and Mitnitski, 2006, 2007 for methodological background). The seminal paper by Mitnitski et al. (2002) has generated a very large research program with hundreds of studies applying the methodology.[2]

Measuring aging by the health deficit index has a micro-foundation in the reliability theory of aging. Specifically it has been shown that organisms constructed in parallel from non-aging elements age according to the Gompertz-law of mortality when the number of initially non-functioning elements follows a Poisson distribution (Gavrilov and Gavrilova, 1991). A recent study uses network theory to explain human aging and provides a microfounded explanation for why an *unweighted* health deficit index provides an accurate measure of aging and mortality (Mitnitski et al., 2017).

This theory of aging predicts that small endowment differences early in life (in utero) are preserved and amplified over the lifetime and affect late-life health and mortality (Gavrilov and Gavrilova, 2004). In health economics, it has been criticized that the standard model of health capital accumulation (Grossman, 1972) predicts that health differences in early life are depreciated away and play asymptotically no role for late-life health outcomes (Almond and Currie, 2011). The standard model of health deficit accumulation in contrast, is capable of explaining fetal origins of adult diseases (Dalgaard and Strulik, 2014; Dalgaard et al., 2017).

In this study, we document a significant impact of the season of birth on aging (health deficit accumulation) for elderly European men but not for women. In accordance with most country studies on specific diseases or mortality, men born in spring or summer, at any given age above 55, have accumulated more health deficits than those born in autumn or winter. While we do not consider the causes of this variation, our results are consistent with the notion that mothers

[2]Originally, the methodology was established by Mitnitski, Rockwood, and coauthors as the frailty index. Newer studies also use 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. A handful of studies have 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; Abeliansky and Strulik, 2018a,b).

of children conceived in summer or autumn had less access to fresh fruits and vegetables and less exposure to (vitamin-D-generating) UV-B radiation during critical gestation periods in the winter months (Doblhammer and Vaupel, 2001; Disanto et al., 2012).

The average size of the health effect (of about 3.5 percent more health deficits at any given age above 50) could be regarded as small compared to studies using more severe early-life shocks like exposure to war or famine (Kesternich et al., 2014, 2015; Halmdienst and Winter-Ebmer, 2014, and Akbulut-Yuksel, 2017). This, however, can be expected from relatively mild changes of environmental conditions like seasonal variation in the availability of fresh fruits and UV-B radiation. Interestingly, the season of birth plays an insignificant role in a subsample of Southern European countries where seasonal variation of sunlight is smaller. In a subsample of Northern countries, in contrast, the season or birth effect gets much larger. We find that Northern European men born in spring have accumulated about 8.7 percent on average at any given age. In non-linear regressions we find that this season effect increases from 3 percent at age 50 to 15 percent at age 90, suggesting that the speed of aging itself is influenced by the season of birth.

The result that only male health and aging is significantly affected by the season of birth is consistent with the finding of larger season-of-birth effects for men on life expectancy (Doblhammer and Vaupel, 2001; Lerchl, 2004) and on adult body size (Krenz-Niedbala, 2011) and with the general notion that males are more responsive to adverse environmental conditions in early life (Stinson, 1985). As a potential explanation it has been proposed that boys grow faster than girls in the womb such that the size of the placenta relative to body size of the newborn is smaller for boys and thus provides less buffer capacity to nutritional shocks experienced by the mother (Erikson et al., 2010).

## 2. Data/Methods

We employ the Survey of Health, Aging and Retirement in Europe (SHARE dataset release 6.0.0) for the empirical investigation.[3] We use five waves from SHARE that provide health-related information (wave 1, 2, 4, 5 and 6); 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

[3]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

in 2011 (in 2012 for Germany) wave 5 in 2013, and wave 6 in 2015[4]. We examined individuals aged 50 and above of the 21 countries that participated in the survey: Austria, Belgium, Czech Republic, Croatia, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, and Switzerland. We only took into consideration observations of individuals up to age 85 because a significant fraction of very old people show "super healthy" characteristics, presumably because of selection effects.[5] The participation of each country in the waves can be seen in Figure A in the Appendix. As a robustness check, we also run the same analysis but without the age restriction in the upper-end.

For each person, we constructed a health deficit index following Mitnitski et al. (2002) and Searle et al. (2006). We considered 38 symptoms, signs and disease classifications, as summarized in Table A.1 in the Appendix. We followed Mitnitski et al. (2002) and coded multilevel deficits using a mapping to the Likert scale in the interval 0-1. Details on how each variable was constructed can be found in Table A.2 in the Appendix. We then computed the health deficit index as the ratio of deficits that an individual suffers from. When there were missing information for an individual, we calculated the deficit index based on the available information about potential deficits (i.e. if for a given person information was not available for $x$ potential health deficits, the observed health deficits were divided by $38 - x$). From the surveyed people we retained only those with information on at least 30 health deficits. We first cleaned the data keeping the observations where age and month of birth were reported (at least once if the individual was sampled more than once). From the gross dataset we retained around 73% of the observations. Some observations were lost because individuals drop out of the sample (i.e. passed away) or because they were not interviewed for an unspecified reason. Because of missing information in the creation of the health deficit index or because of the lack of sufficient deficits to achieve the 30-item minimum we lost about 3% of the dataset. We also removed individuals younger than 50 since this was not the targeted population of the survey and this group very likely represented partners of the actual targeted people. We further cleaned the data removing individuals for which the values of the controls seemed implausible (i.e. individuals exhibiting a

[4]Wave 3 was not included given that it does not report health-related variables (it is a retrospective wave).

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

high standard deviation in height measure across waves) and individuals with a health deficit index of zero because we need to apply the logarithms on health deficits.[6] We arrived at a sample of 193,627 observations, which corresponds to 88,567 individuals.

Table 1 shows the amount of observations for each season. There is some variation with regards to the distribution of observations across waves of around 12% between the most and least " popular" seasons of birth for females and 11% for males. This, however, should not be a concern for selection effects since autumn, the season that will turn out to be "healthiest", exhibits the lowest number of observations.

Table 1. Distribution of individuals according to season of birth

| | Females | | Males | |
|---|---|---|---|---|
| Season of birth | Observations | Percent | Observations | Percent |
| Winter | 11,818 | 24.72 | 10,137 | 24.87 |
| Spring | 12,782 | 26.73 | 10,858 | 26.64 |
| Summer | 11,836 | 24.76 | 10,015 | 24.57 |
| Autumn | 11,375 | 23.79 | 9,746 | 23.91 |
| Total | 47,811 | 100 | 40,756 | 100 |

## 3. Results

In this section we estimate a log-linear relationship between age, season of birth, and health deficits with the following equation:

$$\ln D_{iw} = r + \alpha \cdot age_{iw} + \gamma_1 winter_i + \gamma_2 spring_i + \gamma_3 summer_i + \epsilon_{iw} \quad (1)$$

where $D$ is the health deficit index, $i$ represents the individual, and $w$ the wave; age represents the age at the interview, the season corresponds to the season of birth (default category is autumn); and $\epsilon$ is the error term. We estimate (1) separately for men and women. We also include further covariates composed of country dummies and year of birth dummies and as a robustness test we include height and years of education as well.

Equation (1) implies that health deficits grow exponentially with age akin to the Gompertz law of mortality. For individuals born in autumn it reads

$$D_{iw} = R \exp(\alpha \cdot age_{iw}) \quad (2)$$

[6]There were indeed included in the non-linear specifications.

with $R = \exp(r)$. Exponential growth of health deficits can be motivated with a micro-foundation of aging from reliability theory (Gavrilov and Gavrilova, 1991; Dalgaard et al., 2017) and from network theory (Mitnitski et al., 2017). Individuals born in the other seasons also accumulate health deficits exponentially but the speed of aging may differ. Seasonal differences in aging are captured by the $\gamma$-coefficients in equation (1). A positive value of $\gamma_j$, $j \in \{1, 2, 3\}$, for example, implies that individuals born in season $j$ have accumulated more health deficits than those born in autumn.

Since our main variable of interest, season of birth, does not vary with age, we cannot use fixed effects to control for individual-level heterogeneity. Besides OLS, we then use a random effects estimator. In addition, we employ the correlated random effects estimator of Mundlak (1978). The Mundlak (1978) methodology uses the means of the time changing variables in a random effects framework as an alternative approach to fixed effects. When the panel is balanced, the estimates of the coefficients of the time changing variables should be analogous to the one of the within estimator.

To this last specification we then add years of education and body height as additional controls. Education approximates (and controls) for family background (Buckles and Hungerman, 2013) and also influences health behavior and aging of individuals. Height is a health measure that is usually affected by nutritional shocks during early childhood. Next, we study whether the main results are driven by a group of countries: we split the sample in two groups: "Northern Europe" (Sweden, Netherlands, Denmark and Estonia) and "Southern Europe" (Spain, Italy, Greece, and Portugal). Winter is defined as the period from December to (inclusively) February, spring from March to May, summer from June to August, and autumn from September to November. In the Appendix we show the results for the same regressions but without the age restriction (Table A.3), and considering months instead of seasons (Table A.6). For these, we have selected October as the baseline since it is the month in the middle of the autumn season.

Table 2 presents the results of the OLS, random effects, and Mundlak regressions for females and males. All specifications include country dummies as well as year of birth dummies. The baseline country is Austria and the baseline year of birth is 1934.[7] The force of aging is estimated

[7] In extra regressions we have also conducted the same analysis without the year of birth dummies and using 5 year of birth dummies instead. Results remain the same. We have kept this specification since it is the most conservative one.

TABLE 2. Health Deficits and Season of Birth

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01631*** | 0.01742*** | 0.01767*** | 0.01696*** | 0.01829*** | 0.02118*** | 0.02274*** | 0.02159*** |
| | (0.00147) | (0.00187) | (0.00210) | (0.00211) | (0.00198) | (0.00258) | (0.00298) | (0.00299) |
| Winter | 0.00682 | 0.00535 | 0.00612 | 0.00561 | 0.00366 | 0.00028 | 0.00410 | -0.00097 |
| | (0.00862) | (0.00856) | (0.00842) | (0.00775) | (0.00809) | (0.00838) | (0.00860) | (0.00831) |
| Spring | 0.00767 | 0.00685 | 0.00771 | 0.00735 | 0.03122*** | 0.03009*** | 0.03398*** | 0.02971*** |
| | (0.00890) | (0.00842) | (0.00857) | (0.00871) | (0.00929) | (0.00856) | (0.00871) | (0.00871) |
| Summer | 0.01450 | 0.01330 | 0.01366 | 0.01724* | 0.02766*** | 0.02492*** | 0.02644*** | 0.02354*** |
| | (0.01033) | (0.00982) | (0.00986) | (0.00946) | (0.00829) | (0.00776) | (0.00786) | (0.00785) |
| Years of education | | | | -0.03553*** | | | | -0.03291*** |
| | | | | (0.00094) | | | | (0.00121) |
| Height (in cm.) | | | | -0.00332*** | | | | -0.00432*** |
| | | | | (0.00031) | | | | (0.00033) |
| Constant | -2.92902*** | -2.99954*** | -2.87866*** | -2.10847*** | -3.46420*** | -3.65432*** | -3.05189*** | -2.11006*** |
| | (0.11116) | (0.14036) | (0.11384) | (0.13189) | (0.15988) | (0.20542) | (0.11199) | (0.12245) |
| Gender | | | Females | | | | Males | |
| Method | OLS | RE | Mundlak | Mundlak | OLS | RE | Mundlak | Mundlak |
| Observations | 105,868 | 105,868 | 105,868 | 97,169 | 87,759 | 87,759 | 87,759 | 81,251 |
| Individuals | 47,811 | 47,811 | 47,811 | 47,806 | 40,755 | 40,756 | 40,756 | 40,751 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

as between 0.01631 and 0.01767 for females and between 0.01829 and 0.02274 for males, suggesting that women age slightly slower than men. As shown in Abeliansky and Strulik (2018a), attrition by death does not alter the estimated age coefficients. Since the Mundlak estimator models the correlation of the unobserved heterogeneity assuming that the mean at the individual level of the explanatory variables is correlated with the factors that are unobserved (Wooldridge, 2010, Ch. 14.6.3), we consider this as our preferred model. We have refrained from using wave dummies in this setting since they become collinear with age.

Regarding our variables of interest, namely age and season of birth, we find in Table 2 that women age in the same way, irrespective of their season of birth. For men, however, we get a strong and robust seasonal effect. Men born in spring and summer age faster than those born autumn. These effects remain robust and highly significant when we abandon the age restriction of our sample and consider all observations of individuals of age 50 and above (see Table A.3 in the Appendix).

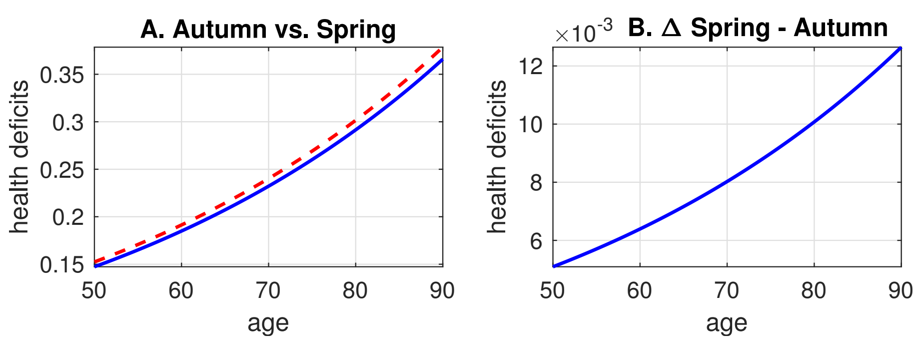
In order to assess the season effect quantitatively, consider for example men born in spring (and in Austria in 1934)[8] and the Mundlak regression. These men, on average, have health

[8]The country dummies do not affect in this setting the statistical signficance of the seasonal effects. Therefore, the effect can be extended to the whole set of countries.

deficits that exceed those of men born in autumn by factor exp(0.03398) = 1.035, i.e. spring-born men have about 3.5 percent more health deficits. In our earlier study, we estimated that the experience of hunger in childhood implied a health deficit factor between 1.15 and 1.35 (Abeliansky and Strulik, 2018b). Childhood hunger episodes during and after World War II (with an average length between 8 and 11 years) could be considered as severe health shocks compared to being born in the "wrong" season is a relatively mild shock. The size of the estimated effect thus appears to be plausible.

In Figure 1, the panel on the left hand side shows the average health deficits by age for autumn born men (solid line) and spring born men (dashed line), based on the estimates of the Mundlak specification (7) of Table 2. One feature that is hard to infer with the naked eye from the left hand side panel is illustrated in the panel at the right hand side: the distance between health deficits of spring-born and autumn-born men gets larger with increasing age. The impact of in utero shocks on adult health thus gets larger as individuals get older.

Figure 1: Season of Birth and Aging of European Men




Panel A shows the health deficits by age; solid (blue) line: birth in autumn, dashed (red) line: birth in spring. Panel B shows the difference in health deficit factor $D(spring) - D(autumn)$. Regression Results from Mundlak estimates.

Columns (4) and (8) of Table 2 introduce our control variables, years of education and adult height. Both control variables are highly significant and have the expected sign. More years of education and tall bodies are associated with better health (less health deficits) at any age. Here, however, it is important that the season of birth effects are robust to the inclusion of these confounders. For men, the effects of age and spring or summer season decline somewhat, suggesting that a very small part of the season-of-birth effect could be mediated through ontogenetic growth or education. Interestingly, however, the bulk of the season effects is apparently *not* mediated through these variables.

Table 3. Health Deficits and Season of Birth - Mediterranean Countries

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01532*** | 0.01787*** | 0.01833*** | 0.01799*** | 0.02436*** | 0.02887*** | 0.03098*** | 0.03045*** |
| | (0.00149) | (0.00159) | (0.00189) | (0.00186) | (0.00194) | (0.00203) | (0.00231) | (0.00228) |
| Winter | -0.02631 | -0.02491 | -0.02375 | -0.02380 | -0.00625 | -0.01160 | -0.00676 | -0.01250 |
| | (0.01973) | (0.01918) | (0.01953) | (0.01881) | (0.01876) | (0.02210) | (0.02211) | (0.02241) |
| Spring | -0.01909 | -0.02271 | -0.02130 | -0.02397 | 0.00591 | -0.00147 | 0.00325 | -0.00452 |
| | (0.01772) | (0.01645) | (0.01676) | (0.01566) | (0.01824) | (0.01981) | (0.01972) | (0.01965) |
| Summer | 0.01829 | 0.01142 | 0.01205 | 0.02168 | -0.02546 | -0.02580 | -0.02373 | -0.02254 |
| | (0.01889) | (0.01630) | (0.01657) | (0.01602) | (0.01720) | (0.01720) | (0.01725) | (0.01724) |
| Years of education | | | | -0.03676*** | | | | -0.03002*** |
| | | | | (0.00144) | | | | (0.00167) |
| Height (in cm.) | | | | -0.00284*** | | | | -0.00408*** |
| | | | | (0.00042) | | | | (0.00051) |
| Constant | -2.57090*** | -2.79026*** | -2.60684*** | -2.10026*** | -3.80255*** | -4.12319*** | -3.41130*** | -2.70432*** |
| | (0.11486) | (0.12278) | (0.18444) | (0.21079) | (0.15443) | (0.15626) | (0.23020) | (0.21900) |
| Gender | | | Females | | | | Males | |
| Method | OLS | RE | Mundlak | Mundlak | OLS | RE | Mundlak | Mundlak |
| Observations | 23,245 | 23,245 | 23,245 | 20,999 | 20,166 | 20,166 | 20,166 | 18,419 |
| Individuals | 10,874 | 10,874 | 10,874 | 10,874 | 9,622 | 9,623 | 9,623 | 9,623 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

We next analyze the effects of the season of birth for different country groups. This is a meaningful exercise since the seasonal variation of sunlight (and fresh fruit availability etc) is more pronounced in Northern European countries than in the South. Specifically, we consider a sample of "Mediterranean countries" including Spain, Italy, Greece and Portugal and a sample of Northern countries including Sweden, Netherlands, Denmark, and Estonia. We expect to find a milder health effect of the season of birth in the first group (or no effect at all), and a stronger one for the second group. Results can be seen in Table 3 and 4, respectively. For the Mediterranean countries we do not observe a significant season of birth effect. Irrespective of the season, the health deficit index increases by 1.8% for woman and 3.0% for men with each extra year of age (according to the Mundlak regressions).

In the Northern countries, in contrast, we observe a strong season of birth effect. As shown in Table 4, men born in spring and summer are unhealthier with regards to the ones born in autumn. These men, on average, have health deficits that exceed those of men born in autumn by factor $\exp(0.08312) = 1.087$, i.e. spring-born men have about 8.7 percent more health deficits. The results are robust to a change of the sample without age restriction, see Tables A.4 and A.5 in the Appendix. Results also remained unchanged when including the control variables. Similar conclusions can also be drawn from a monthly analysis and using October as the baseline (see Tables A.7 and A.8 in the Appendix).

TABLE 4. Health Deficits and Season of Birth - Northern Countries

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01107*** | 0.01390*** | 0.01488*** | 0.01455*** | 0.00993*** | 0.01422*** | 0.01636*** | 0.01525*** |
| | (0.00211) | (0.00209) | (0.00216) | (0.00212) | (0.00252) | (0.00284) | (0.00328) | (0.00337) |
| Winter | 0.01441 | 0.02233 | 0.02591 | 0.03024 | 0.03469 | 0.03173 | 0.03728* | 0.02951 |
| | (0.02150) | (0.02174) | (0.02198) | (0.01892) | (0.02145) | (0.01936) | (0.01978) | (0.01892) |
| Spring | 0.01489 | 0.01907 | 0.02314 | 0.02465 | 0.07800*** | 0.07683*** | 0.08312*** | 0.07585*** |
| | (0.02035) | (0.01988) | (0.02037) | (0.01879) | (0.02167) | (0.02062) | (0.02062) | (0.01924) |
| Summer | 0.00306 | 0.00113 | 0.00250 | 0.00521 | 0.06366*** | 0.06443*** | 0.06711*** | 0.06443*** |
| | (0.01826) | (0.01861) | (0.01873) | (0.01816) | (0.02225) | (0.02066) | (0.02068) | (0.01998) |
| Years of education | | | | -0.03734*** | | | | -0.03200*** |
| | | | | (0.00218) | | | | (0.00245) |
| Height (in cm.) | | | | -0.00443*** | | | | -0.00491*** |
| | | | | (0.00064) | | | | (0.00079) |
| Constant | -2.64696*** | -2.87543*** | -2.27726*** | -1.12562*** | -3.17282*** | -3.47125*** | -2.51705*** | -1.40930*** |
| | (0.15711) | (0.15838) | (0.25647) | (0.29767) | (0.19124) | (0.21654) | (0.30027) | (0.34493) |
| Gender | Females | | | | Males | | | |
| Method | OLS | RE | Mundlak | Mundlak | OLS | RE | Mundlak | Mundlak |
| Observations | 25,046 | 25,046 | 25,046 | 22,918 | 20,404 | 20,404 | 20,404 | 18,678 |
| Individuals | 10,484 | 10,484 | 10,484 | 10,480 | 8,893 | 8,893 | 8,893 | 8,893 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

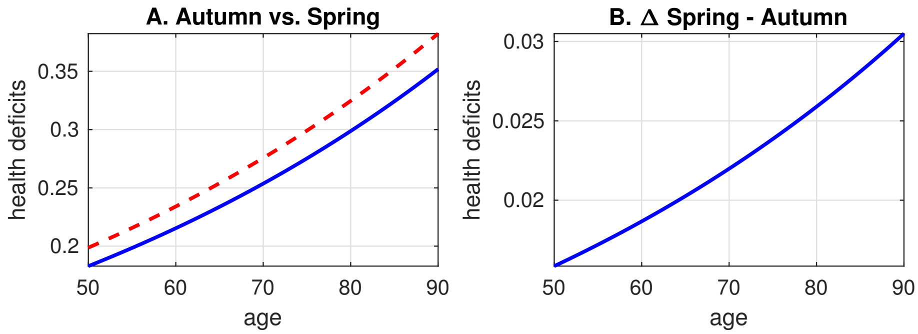
Figure 2 visualizes the season effect on health deficit accumulation. The panel on the left hand side shows the estimated health deficits of men born in autumn (solid line) and men born in spring (dashed line). The increasing difference between the two groups is now clearly visible. The panel on the right hand side shows that the health deficit index of spring born men exceeds that of autumn born men by about 1.5 percentage points at age 50 and by about 3 percentage points at age 90.

The feature that the impact of in utero shocks on adult health gets larger as individuals get older is hard to square with the conventional life cycle model of health economics, the health capital model (based on Grossman, 1972). As pointed out by Almond and Currie (2011), this model predicts that early life health differences are depreciated away as individuals age. A widening gradient for early health shocks is supportive of the health deficit model (Dalgaard and Strulik, 2014), which predicts that small differences in initial health differences lead to large and increasing health differences late in life (Dalgaard et al., 2017).

3.1. **Non-linear Least Squares.** As a final robustness test, we next use a non-linear least squares methodology and estimate the following equation:

$$D_i = A + R \cdot \exp\left(\alpha \cdot age_{iw}\right) \cdot \exp\left(\gamma_1 \cdot winter_i\right) \cdot \exp\left(\gamma_2 \cdot spring_i\right) \cdot \exp\left(\gamma_3 \cdot summer_i\right) + \epsilon_{iw}, \tag{3}$$

Figure 2: Season of Birth and Aging of Northern European Men




Panel A: health deficits by age; solid (blue) line: autumn, dashed (red) line: spring. Panel B: Health deficit factor $D(spring)/D(autumn)$; solid (blue) line: autumn, dashed (red) line: spring. Regression Results from Mundlak estimates.

where $i$ is the individual, $\epsilon$ is the error term; *winter*, *spring*, and *summer* are the respective seasons of birth. We estimate (3) separately for men and women. The non-linear form, akin to the Gompertz-Makeham law of mortality, has been suggested by Mitnitski et al. (2002) and used in our study on convergence of aging in Europe (Abeliansky and Strulik, 2018a). The "Makeham-term" $A$ shifts health deficits up at any age, capturing, for example, environmental factors that influence health deficits unrelated to age. For an insignificant Makeham term, results would collapse to those from linear regression.

Regression results for all countries and the Northern European sample are shown in Table 5. We dropped Southern Europe because the seasons' effects are again insignificant. As shown in Table 5, the Makeham term ($A$) is significantly positive and the point estimate of about 8% is of the same size as in our earlier study (Abeliansky and Strulik, 2018a). Men start out healthier than women (lower estimate of $R$ for men than for women) but age faster (higher estimate of $\alpha$ for men than for women). The force of aging ($\alpha$) increases in magnitude compared to the log-linear specification and is estimated as 0.057 for women and 0.069 for men (for all countries). For men, the season of birth coefficient for spring ($\gamma_1$) and summer ($\gamma_2$) is positive and significantly different from zero. For women, the point estimates for the seasons effects are not statistically significantly different from zero.

The estimates of the age and season coefficients show the same pattern as those of the linear regression. The pooled sample shows that the season effect is strong for males and it gets stronger when we focus on the Northern sample. The non-linear regressions reveal another interesting feature, which – by design – cannot be obtained from log-linear regressions: the season of birth effect increases with age not only absolutely but also in relative terms. To see this more clearly,

Table 5. Season of Birth and Aging: Non-linear Least Squares

| | Female | | Male | |
|---|---|---|---|---|
| | Estimated Coefficient | Standard Error | Estimated Coefficient | Standard Error |
| All countries | | | | |
| A | 0.0836*** | 0.0069 | 0.0764*** | 0.0029 |
| R | 0.0021*** | 0.0007 | 0.0005*** | 0.0001 |
| $\alpha$ | 0.0569*** | 0.0036 | 0.0691*** | 0.0033 |
| $\gamma_1$ | 0.0003 | 0.0159 | 0.0037 | 0.0226 |
| $\gamma_2$ | -0.0168 | 0.0172 | 0.0528** | 0.0235 |
| $\gamma_3$ | 0.0026 | 0.0176 | 0.0700*** | 0.0180 |
| Obs. | 106,689 | | 88,981 | |
| R-squared | 0.1498 | | 0.0918 | |
| Northern countries | | | | |
| A | 0.0992*** | 0.0065 | 0.0761*** | 0.0059 |
| R | 0.0005* | 0.0003 | 0.0003 | 0.0002 |
| $\alpha$ | 0.0715*** | 0.0063 | 0.0725*** | 0.0092 |
| $\gamma_1$ | 0.0330 | 0.0565 | 0.0716 | 0.0627 |
| $\gamma_2$ | 0.0410 | 0.0445 | 0.1925** | 0.0735 |
| $\gamma_3$ | 0.0288 | 0.0437 | 0.1496* | 0.0812 |
| Obs. | 25,427 | | 20,949 | |
| R-squared | 0.1209 | | 0.0678 | |

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.

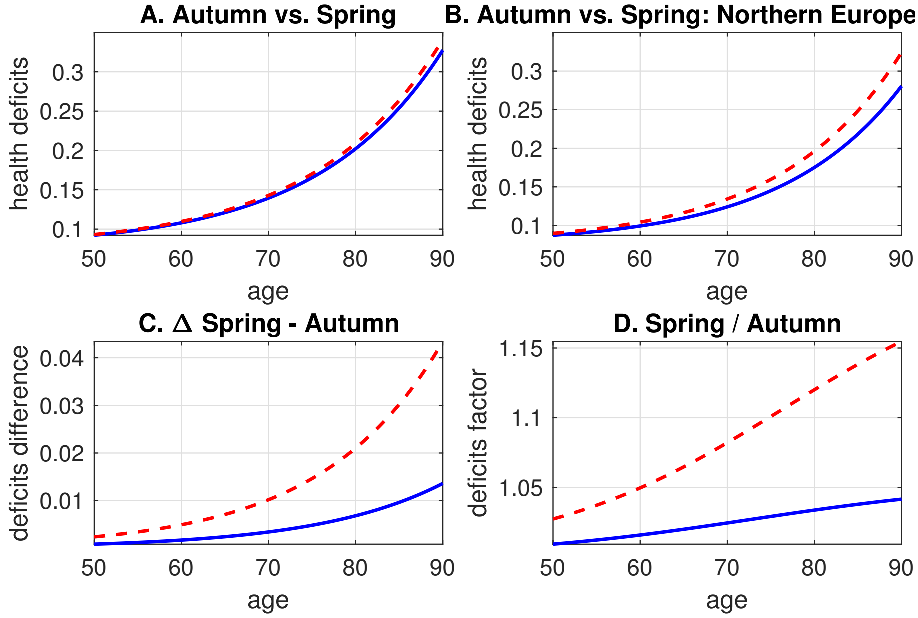
we compute the estimated "deficit factor", implied by (3):

$$\frac{D(spring)}{D(autumn)} = e^{\gamma_2} - \frac{A(\mathrm{e}^{\gamma_2} - 1)}{A + R\mathrm{e}^{\alpha age}}. \tag{4}$$

For $A = 0$, the deficit factor is constant whereas for $A > 0$ and $\gamma_2 > 0$ (and thus $\mathrm{e}^{\gamma_2} > 1$) the deficit factor is increasing with age. This means that spring born men age at a faster speed than autumn born men such that the relative health distance between both groups increases with age.

These results are illustrated in Figure 3. The top panels show the estimated health deficit accumulation for men born in autumn (solid lines) and men born in spring (dashed lines). The top left panel considers the whole sample; the top right panel shows results for the Northern countries. The bottom left panel shows the difference of health deficits between spring born and autumn born men. The solid line shows the difference estimated for the whole sample, the dashed line shows the difference for the Northern countries. Compared to the results from log-linear regression (Figure 1 and 2), the age-gradient of the season of birth effect get steeper, in particular for the Northern countries. The bottom right panel in Figure 3 shows the deficit factor (4). For the whole sample, health deficits of spring born men exceed those of autumn born men by factor 1.01 at age 50 and by factor 1.04 at age 90. For Northern countries the

Figure 3: Season of Birth and Aging in Non-linear Regression




Panel A: health deficits by age; solid (blue) line: autumn, dashed (red) line: spring. Panel B: Health deficit factor $D(spring)/D(autumn)$; solid (blue) line: autumn, dashed (red) line: spring. Panel C: health deficit difference $D(spring) - D(autumn)$; solid (blue) line: all countries, dashed (red) line: Northern countries. Panel D: health deficit factor $D(spring)/D(autumn)$; solid (blue) line: all countries, dashed (red) line: Northern countries.

increase is steeper. Health deficits of spring born men exceed those of autumn born men by factor 1.03 at age 50 and by factor 1.15 at age 90. This means that by the age of 90 spring born men have accumulated 15 percent more health deficits than men born in autumn.

## 4. Conclusion

We investigated how the season of birth influences the speed of aging for elderly men and women from 21 European countries. We found no effect for women but a strong effect for men, which gets even larger when the sample is restricted to Northern European countries where the seasonal variation of sunlight, fresh fruit availability, and the disease environment is more pronounced. Our results are in line with earlier studies focusing on season of birth effects on mortality. Here we show that the season of birth affects health deficits accumulated at any age and the speed at which health deficits accumulate, i.e. the human aging process as such. We thus find further evidence for the health deficit model, which predicts that small initial differences in the state of health are amplified with increasing age (Dalgaard et al., 2017).

Interestingly the season of birth effect is not much mediated through education or body height. This observation further supports the notion that it are in utero conditions through which the season of birth affects the susceptibility to diseases and faster aging in late life. We thus find further evidence for the fetal-origins hypothesis (Barker et al., 1992) and, at the micro-level, for the initial-damage-load hypothesis (Gavrilov and Gavrilova, 1991).

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## References


Abel, E.L., and Kruger, M.L. (2010). Birth month affects longevity. *Death Studies* 34(8), 757-763.

Abeliansky, A. and Strulik, H. (2018a). How we fall apart: Similarities of human aging in 10 European countries, *Demography* 55(1), 341-359.

Abeliansky, A. and Strulik, H. (2018b). Hungry children age faster. *Economics and Human Biology*, forthcoming.

Almond, D. and Currie, J. (2011). Killing me softly: The fetal origins hypothesis. *Journal of Economic Perspectives* 25(3), 153-72.

Almond, D., Currie, J., and Duque, V. (2017). Childhood circumstances and outcomes: Act II. NBER working paper 23017.

Arking, R. (2006). *The Biology of Aging: Observations and Principles*, Oxford University Press, Oxford.

Barker, D.J. (1992). The fetal origins of diseases of old age. *European Journal of Clinical Nutrition* 46, S3-S9.

Barker, D. J. (1995). Fetal origins of coronary heart disease. *British Medical Journal* 311, 171-174.

Barker, D.J. (2004). The developmental origins of adult disease. *Journal of the American College of Nutrition* 23(sup6), 588S-595S.

Börsch-Supan, A., Brandt, M., Hunkler, C., Kneip, T., Korbmacher, J., Malter, F., Schaan, B., Stuck, S., and Zuber, S. (2013). Data Resource Profile: The Survey of Health, Ageing and Retirement in Europe (SHARE). *International Journal of Epidemiology.*

Buckles, K.S., and Hungerman, D.M. (2013). Season of birth and later outcomes: Old questions, new answers. *Review of Economics and Statistics* 95(3), 711-724.

Calkins, K., and Devaskar, S.U. (2011). Fetal origins of adult disease. Current problems in pediatric and adolescent health care, 41(6), 158-176.

Contoyannis, P., Jones, A. M., and Rice, N. (2004). The dynamics of health in the British Household Panel Survey, *Journal of Applied Econometrics* 19(4), 473-503.

Dalgaard, C-J. and Strulik, H. (2014). Optimal aging and death: understanding the Preston curve. *Journal of the European Economic Association* 12(3), 672-701.

Dalgaard, C-J., Hansen, C., and Strulik, H. (2017). Accounting for Fetal Origins: Health Capital vs. Health Deficits, Discussion Paper, University of Copenhagen.

Disanto, G., Chaplin, G., Morahan, J.M., Giovannoni, G., Hyppoenen, E., Ebers, G.C., and Ramagopalan, S.V. (2012). Month of birth, vitamin D and risk of immune-mediated disease: a case control study. *BMC Medicine* 10(1), 69.

Doblhammer, G., and Vaupel, J. W. (2001). Lifespan depends on month of birth. *Proceedings of the National Academy of Sciences* 98(5), 2934-2939.

Eriksson, J.G., Kajantie, E., Osmond, C., Thornburg, K., and Barker, D.J. (2010). Boys live dangerously in the womb. *American Journal of Human Biology* 22(3), 330-335.

Flouris, A. D., Spiropoulos, Y., Sakellariou, G. J., and Koutedakis, Y. (2009). Effect of seasonal programming on fetal development and longevity: links with environmental temperature. *American Journal of Human Biology* 21(2), 214-216.

Gavrilov, L.A. and Gavrilova, N.S. (1991). *The Biology of Human Life Span: A Quantitative Approach*, Harwood Academic Publishers, London.

Gavrilov, L.A. and Gavrilova, N.S. (2004). Early-life programming of aging and longevity: the idea of high initial damage load (the HIDL hypothesis). *Annals of the New York Academy of Sciences* 1019(1), 496-501.

Gluckman, P.D., Hanson, M.A., and Pinal, C. (2005). The developmental origins of adult disease. *Maternal & Child Nutrition* 1(3), 130-141.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy* 80, 223-255.

Gruber, S., Hunkler, C., and Stuck, S. (2014). Generating easySHARE: guidelines, structure, content and programming. *SHARE Working Paper Series: 17-2014*. Munich: MEA, Max Planck Institute for Social Law and Social Policy.

Halmdienst, N., and Winter-Ebmer, R. (2014). Long-run Relations between Childhood Shocks and Health in Late Adulthood. Evidence from the Survey of Health, Ageing, and Retirement in Europe. *CESifo Economic Studies* 60(2), 402-434.

Harttgen, K., Kowal, P., Strulik, H., Chatterji, S., and Vollmer, S. (2013). Patterns of frailty in older adults: comparing results from higher and lower income countries using the Survey of Health, Ageing and Retirement in Europe (SHARE) and the Study on Global AGEing and Adult Health (SAGE). *PLOS One* 8(10), e75847.

Kesternich, I., Siflinger, B., Smith, J.P., and Winter, J.K. (2014). The effects of World War II on economic and health outcomes across Europe. *Review of Economics and Statistics*, 96(1), 103-118.

Kesternich, I., Siflinger, B., Smith, J.P., and Winter, J.K. (2015). Individual behaviour as a pathway between early-life shocks and adult health: Evidence from hunger episodes in post-war Germany. *Economic Journal* 588(125), F372-F393.

Krenz-Niedbala, M., Puch, E.A., and Koscinski, K. (2011). Season of birth and subsequent body size: the potential role of prenatal vitamin D. *American Journal of Human Biology* 23(2), 190-200.

Langley-Evans, S.C. (2015). Nutrition in early life and the programming of adult disease: a review. *Journal of Human Nutrition and Dietetics* 28(s1), 1-14.

Lerchl, A. (2004). Month of birth and life expectancy: role of gender and age in a comparative approach. *Naturwissenschaften* 91(9), 422-425.

McKinney, P. A. (2001). Seasonality of birth in patients with childhood Type I diabetes in 19 European regions. *Diabetologia* 44, B67-B74.

Mitnitski, A.B., Mogilner, A.J., and Rockwood, K. (2001). Accumulation of deficits as a proxy measure of aging. *The Scientific World Journal* 1, 323-336.

Mitnitski, A.B., Mogilner, A.J., MacKnight, C., and Rockwood, K. (2002). The accumulation of deficits with age and possible invariants of aging. *Scientific World* 2, 1816-1822.

Mitnitski, A. and K. Rockwood. (2016). The rate of aging: the rate of deficit accumulation does not change over the adult life span. *Biogerontology*, 17(1), 199–204.

Mitnitski, A. B., Rutenberg, A. D., Farrell, S., and Rockwood, K. (2017). Aging, frailty and complex networks. *Biogerontology* 18, 1-14.

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica* 46(1), 69-85.

Philpot, M., Rottenstein, M., Burns, A., and Der, G. (1989). Season of birth in Alzheimer's disease. *British Journal of Psychiatry* 155(5), 662-666.

Rockwood, K. and Mitnitski, A. (2006). Limits to deficit accumulation in elderly people. *Mechanisms of Ageing and Development* 127(5), 494-496.

Rockwood, K. and Mitnitski, A. (2007). Frailty in relation to the accumulation of deficits. *Journals of Gerontology Series A: Biological and Medical Sciences* 62, 722–727.

Romero-Ortuno, R. and Kenny, R.A. (2012). The frailty index in Europeans: Association with age and mortality. *Age and Ageing* 41(5), 684-689.

Romero-Ortuno, R. (2014). Frailty Index in Europeans: association with determinants of health. *Geriatrics & Gerontology International* 14(2), 420-429.

Sayer, A.A., Cooper, C., Evans, J.R., Rauf, A., WORMALD, R.P. L., Osmond, C., and BARKER, D.J.P. (1998). Are rates of ageing determined in utero? *Age and Ageing* 27(5), 579-583.

Searle, S. D., Mitnitski, A., Gahbauer, E. A., Gill, T. M., and Rockwood, K. (2008). A standard procedure for creating a frailty index. *BMC Geriatrics* 8:24.

Stinson, S. (1985). Sex differences in environmental sensitivity during growth and development. *American Journal of Physical Anthropology* 28(S6), 123-147.

Theou, O., Brothers, T.D., Mitnitski, A., and Rockwood, K. (2013). Operationalization of frailty using eight commonly used scales and comparison of their ability to predict all-cause mortality. *Journal of the American Geriatrics Society* 61(9), 1537-1551.

Tornhammar, P., Ueda, P., Hult, M., Simila, H., Eyles, D., and Norman, M. (2014). Season of birth, neonatal vitamin D status, and cardiovascular disease risk at 35 y of age: a cohort study from Sweden. *American Journal of Clinical Nutrition* 99(3), 472-478.

Ueda, P., Bonamy, A.K.E., Granath, F.,and Cnattingius, S. (2013). Month of birth and mortality in Sweden: a nation-wide population-based cohort study. *PLoS One* 8(2), e56425.

Vaiserman, A., Collinson, A., Koshel, N., Belaja, I., and Voitenko, V. (2002). Seasonal programming of adult longevity in Ukraine. *International Journal of Biometeorology* 47(1), 49-52.

Vaiserman, A. M. (2014). Early-life nutritional programming of longevity. *Journal of Developmental Origins of Health and Disease* 5(5), 325-338.

van den Berg, G.J., Pinger, P.R., and Schoch, J. (2016). Instrumental variable estimation of the causal effect of hunger early in life on health later in life. *Economic Journal*, 126(591), 465-506.

Wooldridge, J.M. (2010). *Econometric Analysis of Cross Section and Panel Data*. MIT press.

## Appendix A

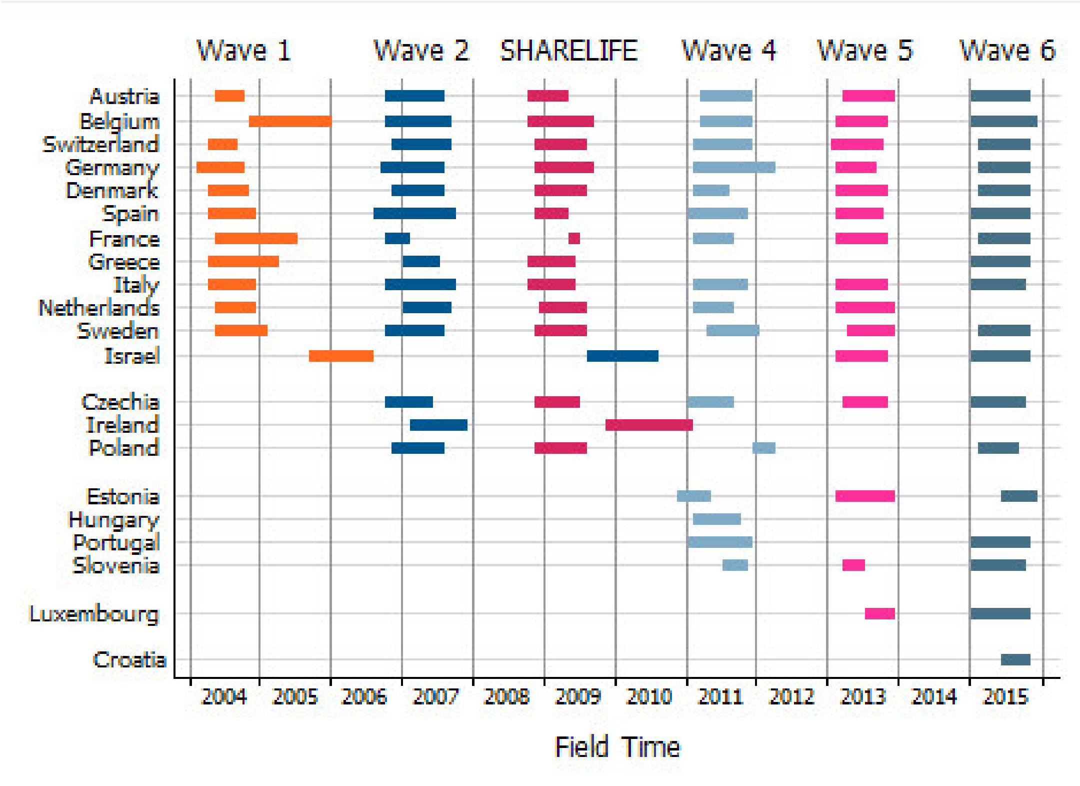


Figure A.1. Participation of countries in different waves of SHARE Survey. Source: SHARE website

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 |
| Depressed | 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 |
| Depressed | 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. Health deficits and season of birth - individuals with no age restriction

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01790*** | 0.01951*** | 0.02000*** | 0.01929*** | 0.01976*** | 0.02348*** | 0.02549*** | 0.02442*** |
| | (0.00153) | (0.00197) | (0.00222) | (0.00221) | (0.00198) | (0.00266) | (0.00312) | (0.00314) |
| Winter | 0.00737 | 0.00428 | 0.00588 | 0.00565 | 0.00319 | 0.00074 | 0.00559 | 0.00098 |
| | (0.00841) | (0.00834) | (0.00820) | (0.00759) | (0.00795) | (0.00817) | (0.00842) | (0.00810) |
| Spring | 0.00922 | 0.00702 | 0.00873 | 0.00833 | 0.03039*** | 0.03021*** | 0.03513*** | 0.03081*** |
| | (0.00861) | (0.00814) | (0.00832) | (0.00847) | (0.00913) | (0.00845) | (0.00866) | (0.00866) |
| Summer | 0.01664* | 0.01535 | 0.01608* | 0.01925** | 0.02798*** | 0.02555*** | 0.02741*** | 0.02459*** |
| | (0.00997) | (0.00958) | (0.00963) | (0.00924) | (0.00834) | (0.00777) | (0.00786) | (0.00790) |
| Years of education | | | | -0.03519*** | | | | -0.03266*** |
| | | | | (0.00094) | | | | (0.00120) |
| Height (in cm.) | | | | -0.00295*** | | | | -0.00413*** |
| | | | | (0.00031) | | | | (0.00034) |
| Constant | -3.04672*** | -3.15718*** | -2.92374*** | -2.22469*** | -3.57817*** | -3.83005*** | -3.07440*** | -2.16802*** |
| | (0.11538) | (0.14771) | (0.11015) | (0.13247) | (0.16007) | (0.21153) | (0.10931) | (0.12286) |
| Gender | | | Females | | | | Males | |
| Observations | 110,392 | 110,392 | 110,392 | 101,406 | 90,486 | 90,486 | 90,486 | 83,828 |
| Individuals | 49,266 | 49,266 | 49,266 | 49,262 | 41,626 | 41,627 | 41,627 | 41,624 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

Table A.4. Health deficits and season of birth - individuals with no age restriction of Mediterrean countries

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01692*** | 0.02001*** | 0.02089*** | 0.02048*** | 0.02598*** | 0.03071*** | 0.03301*** | 0.03248*** |
| | (0.00154) | (0.00175) | (0.00210) | (0.00206) | (0.00195) | (0.00208) | (0.00239) | (0.00238) |
| Winter | -0.02849 | -0.02994 | -0.02771 | -0.02795 | -0.00069 | -0.00792 | -0.00309 | -0.00924 |
| | (0.01897) | (0.01858) | (0.01888) | (0.01821) | (0.01825) | (0.02139) | (0.02142) | (0.02174) |
| Spring | -0.01805 | -0.02412 | -0.02147 | -0.02382 | 0.01019 | 0.00433 | 0.00927 | 0.00124 |
| | (0.01728) | (0.01591) | (0.01621) | (0.01520) | (0.01810) | (0.01976) | (0.01970) | (0.01953) |
| Summer | 0.01844 | 0.01133 | 0.01251 | 0.02221 | -0.02243 | -0.02187 | -0.01991 | -0.01870 |
| | (0.01803) | (0.01563) | (0.01589) | (0.01525) | (0.01729) | (0.01729) | (0.01734) | (0.01747) |
| Years of education | | | | -0.03624*** | | | | -0.02980*** |
| | | | | (0.00141) | | | | (0.00165) |
| Height (in cm.) | | | | -0.00268*** | | | | -0.00381*** |
| | | | | (0.00038) | | | | (0.00051) |
| Constant | -2.69284*** | -2.95259*** | -2.62509*** | -2.18690*** | -3.92942*** | -4.26576*** | -3.51756*** | -2.84280*** |
| | (0.11964) | (0.13507) | (0.17284) | (0.20177) | (0.15545) | (0.16049) | (0.21978) | (0.21305) |
| Gender | | | Females | | | | Males | |
| Observations | 24,419 | 24,419 | 24,419 | 22,115 | 20,889 | 20,889 | 20,889 | 19,109 |
| Individuals | 11,279 | 11,279 | 11,279 | 11,279 | 9,886 | 9,886 | 9,886 | 9,886 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

Table A.5. Health deficits and season of birth - individuals with no age restriction of Northern countries

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01238*** | 0.01598*** | 0.01724*** | 0.01686*** | 0.01211*** | 0.01739*** | 0.02001*** | 0.01910*** |
| | (0.00207) | (0.00215) | (0.00225) | (0.00221) | (0.00259) | (0.00308) | (0.00358) | (0.00369) |
| Winter | 0.01793 | 0.02255 | 0.02776 | 0.03199* | 0.02707 | 0.02682 | 0.03355* | 0.02649 |
| | (0.02102) | (0.02115) | (0.02144) | (0.01865) | (0.02104) | (0.01886) | (0.01928) | (0.01854) |
| Spring | 0.01754 | 0.01830 | 0.02369 | 0.02488 | 0.06989*** | 0.07016*** | 0.07787*** | 0.07079*** |
| | (0.01989) | (0.01954) | (0.01996) | (0.01847) | (0.02157) | (0.02048) | (0.02042) | (0.01910) |
| Summer | 0.00795 | 0.00425 | 0.00639 | 0.00789 | 0.06033*** | 0.06142*** | 0.06444*** | 0.06195*** |
| | (0.01784) | (0.01828) | (0.01842) | (0.01787) | (0.02154) | (0.02002) | (0.02003) | (0.01949) |
| Years of education | | | | -0.03713*** | | | | -0.03211*** |
| | | | | (0.00215) | | | | (0.00241) |
| Height (in cm.) | | | | -0.00334*** | | | | -0.00481*** |
| | | | | (0.00066) | | | | (0.00080) |
| Constant | -2.74911*** | -3.03521*** | -2.28374*** | -1.30759*** | -3.33385*** | -3.71076*** | -2.57720*** | -1.47769*** |
| | (0.15388) | (0.16232) | (0.23893) | (0.28493) | (0.19608) | (0.23502) | (0.29089) | (0.33825) |
| Gender | Females | | | | Males | | | |
| Observations | 26,137 | 26,137 | 26,137 | 23,909 | 21,054 | 21,054 | 21,054 | 19,276 |
| Individuals | 10,780 | 10,780 | 10,780 | 10,777 | 9,068 | 9,068 | 9,068 | 9,068 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

Table A.6. Health deficits and season of birth - October baseline

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01630*** | 0.01742*** | 0.01767*** | 0.01696*** | 0.01828*** | 0.02118*** | 0.02274*** | 0.02159*** |
| | (0.00153) | (0.00188) | (0.00210) | (0.00211) | (0.00202) | (0.00258) | (0.00298) | (0.00299) |
| January | -0.00268 | -0.00296 | -0.00175 | 0.00066 | 0.02022 | 0.01833 | 0.02433 | 0.01900 |
| | (0.01750) | (0.01789) | (0.01803) | (0.01712) | (0.01407) | (0.01518) | (0.01540) | (0.01544) |
| February | 0.01098 | 0.00546 | 0.00664 | 0.00503 | -0.00348 | -0.00763 | -0.00095 | -0.01064 |
| | (0.01705) | (0.01618) | (0.01589) | (0.01495) | (0.01230) | (0.01302) | (0.01316) | (0.01302) |
| March | -0.01029 | -0.01172 | -0.01057 | -0.00856 | 0.02005 | 0.01826 | 0.02329 | 0.01261 |
| | (0.01810) | (0.01629) | (0.01634) | (0.01622) | (0.01434) | (0.01444) | (0.01448) | (0.01437) |
| April | 0.00178 | -0.00041 | 0.00050 | 0.00197 | 0.03500* | 0.03467* | 0.03912** | 0.03250* |
| | (0.01505) | (0.01350) | (0.01376) | (0.01328) | (0.01771) | (0.01880) | (0.01899) | (0.01898) |
| May | 0.01370 | 0.01482 | 0.01544 | 0.01732 | 0.03967** | 0.03836** | 0.04151*** | 0.04194*** |
| | (0.01624) | (0.01716) | (0.01729) | (0.01616) | (0.01519) | (0.01490) | (0.01492) | (0.01383) |
| June | 0.01619 | 0.00872 | 0.00927 | 0.01276 | 0.01022 | 0.00724 | 0.01040 | 0.00356 |
| | (0.01991) | (0.01861) | (0.01872) | (0.01748) | (0.01483) | (0.01350) | (0.01383) | (0.01310) |
| July | -0.00270 | -0.00187 | -0.00152 | 0.00475 | 0.03377* | 0.03251* | 0.03390** | 0.03085* |
| | (0.01923) | (0.01646) | (0.01645) | (0.01564) | (0.01740) | (0.01671) | (0.01670) | (0.01653) |
| August | 0.01106 | 0.01412 | 0.01442 | 0.02197* | 0.04007** | 0.03599** | 0.03687** | 0.03385** |
| | (0.01322) | (0.01210) | (0.01223) | (0.01221) | (0.01517) | (0.01655) | (0.01640) | (0.01615) |
| September | -0.00799 | -0.00737 | -0.00721 | -0.00610 | -0.00586 | -0.00633 | -0.00561 | -0.00722 |
| | (0.01749) | (0.01556) | (0.01557) | (0.01505) | (0.01542) | (0.01684) | (0.01690) | (0.01642) |
| November | -0.01078 | -0.01155 | -0.01158 | -0.00592 | 0.00687 | 0.00725 | 0.00736 | 0.00465 |
| | (0.01662) | (0.01400) | (0.01401) | (0.01418) | (0.01724) | (0.01751) | (0.01743) | (0.01630) |
| December | -0.00680 | -0.00532 | -0.00538 | -0.00104 | -0.00790 | -0.01268 | -0.01354 | -0.01800 |
| | (0.01586) | (0.01632) | (0.01631) | (0.01552) | (0.01863) | (0.01726) | (0.01719) | (0.01640) |
| Years of education | | | | -0.03553*** | | | | -0.03295*** |
| | | | | (0.00094) | | | | (0.00121) |
| Height (in cm.) | | | | -0.00332*** | | | | -0.00431*** |
| | | | | (0.00031) | | | | (0.00033) |
| Constant | -2.78899*** | -2.78216*** | -3.69743*** | -2.74722*** | -3.35210*** | -3.96597*** | -3.56813*** | -2.43728*** |
| | (0.12648) | (0.15574) | (0.07443) | (0.09553) | (0.19027) | (0.13856) | (0.07413) | (0.09063) |
| Gender | Females | | | | Males | | | |
| Observations | 105,868 | 105,868 | 105,868 | 97,169 | 87,759 | 87,759 | 87,759 | 81,251 |
| Individuals | 47,811 | 47,811 | 47,811 | 47,806 | 40,756 | 40,756 | 40,756 | 40,751 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

Table A.7. Health deficits and season of birth - October baseline (Mediterranean)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01512*** | 0.01780*** | 0.01833*** | 0.01798*** | 0.02436*** | 0.02886*** | 0.03097*** | 0.03045*** |
| | (0.00154) | (0.00160) | (0.00189) | (0.00186) | (0.00195) | (0.00203) | (0.00231) | (0.00228) |
| January | -0.02193 | -0.01939 | -0.01728 | -0.01878 | -0.00740 | -0.00007 | 0.00782 | 0.01045 |
| | (0.03283) | (0.02851) | (0.02912) | (0.02939) | (0.03460) | (0.03623) | (0.03613) | (0.03605) |
| February | 0.01246 | 0.01398 | 0.01614 | 0.00486 | -0.00849 | -0.01659 | -0.00789 | -0.02380 |
| | (0.03243) | (0.02679) | (0.02734) | (0.02504) | (0.03476) | (0.03397) | (0.03398) | (0.03453) |
| March | -0.03965 | -0.04147 | -0.03931 | -0.04323 | 0.00442 | -0.00400 | 0.00254 | -0.00270 |
| | (0.02984) | (0.02761) | (0.02797) | (0.02736) | (0.02899) | (0.02776) | (0.02744) | (0.02835) |
| April | 0.00760 | 0.00448 | 0.00640 | 0.01221 | -0.00022 | 0.00319 | 0.00883 | -0.00235 |
| | (0.03290) | (0.02666) | (0.02675) | (0.02581) | (0.03840) | (0.03572) | (0.03615) | (0.03753) |
| May | -0.01734 | -0.02082 | -0.01953 | -0.03436 | -0.00269 | -0.00788 | -0.00309 | 0.00289 |
| | (0.03351) | (0.02845) | (0.02887) | (0.02714) | (0.03414) | (0.03581) | (0.03581) | (0.03597) |
| June | 0.04243 | 0.01753 | 0.01878 | 0.02020 | -0.05922* | -0.04804 | -0.04314 | -0.03619 |
| | (0.03419) | (0.02856) | (0.02854) | (0.02867) | (0.03317) | (0.03283) | (0.03276) | (0.03321) |
| July | 0.01400 | 0.01413 | 0.01496 | 0.03013 | -0.01691 | -0.01988 | -0.01705 | -0.01922 |
| | (0.04229) | (0.03577) | (0.03607) | (0.03350) | (0.03924) | (0.03763) | (0.03778) | (0.03616) |
| August | 0.00503 | 0.01052 | 0.01116 | 0.01879 | -0.01587 | -0.01406 | -0.01279 | -0.00064 |
| | (0.03354) | (0.03068) | (0.03087) | (0.02907) | (0.04072) | (0.04086) | (0.04083) | (0.03953) |
| September | -0.00127 | 0.00246 | 0.00282 | -0.00179 | -0.03470 | -0.02876 | -0.02730 | -0.02140 |
| | (0.02905) | (0.02737) | (0.02743) | (0.02560) | (0.03938) | (0.03893) | (0.03897) | (0.04116) |
| November | 0.00711 | 0.00552 | 0.00570 | 0.00590 | 0.02001 | 0.02566 | 0.02696 | 0.03477 |
| | (0.02971) | (0.02702) | (0.02701) | (0.02646) | (0.03713) | (0.03553) | (0.03551) | (0.03475) |
| December | -0.06841* | -0.06591* | -0.06581* | -0.05669* | -0.02120 | -0.02729 | -0.02837 | -0.01658 |
| | (0.03857) | (0.03440) | (0.03437) | (0.03233) | (0.03579) | (0.03249) | (0.03266) | (0.03078) |
| Years of education | | | | -0.03674*** | | | | -0.03007*** |
| | | | | (0.00143) | | | | (0.00165) |
| Height (in cm.) | | | | -0.00284*** | | | | -0.00408*** |
| | | | | (0.00042) | | | | (0.00050) |
| Constant | -2.28013*** | -2.54194*** | -3.44698*** | -2.67169*** | -3.87212*** | -3.82799*** | -3.35060*** | -2.34380*** |
| | (0.13426) | (0.13804) | (0.11919) | (0.15067) | (0.17292) | (0.11004) | (0.16084) | (0.15075) |
| Gender | Females | | | | Males | | | |
| Observations | 23,245 | 23,245 | 23,245 | 20,999 | 20,166 | 20,166 | 20,166 | 18,419 |
| Individuals | 10,874 | 10,874 | 10,874 | 10,874 | 9,623 | 9,623 | 9,623 | 9,623 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.

Table A.8. Health deficits and season of birth - October baseline (Northern)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Age | 0.01123*** | 0.01395*** | 0.01488*** | 0.01455*** | 0.00997*** | 0.01421*** | 0.01636*** | 0.01526*** |
| | (0.00220) | (0.00210) | (0.00216) | (0.00212) | (0.00259) | (0.00285) | (0.00328) | (0.00337) |
| January | -0.01227 | 0.00715 | 0.01218 | 0.01945 | 0.07484** | 0.07871** | 0.08476** | 0.07671** |
| | (0.04018) | (0.04015) | (0.04079) | (0.03994) | (0.03671) | (0.03333) | (0.03387) | (0.03406) |
| February | -0.02861 | -0.02123 | -0.01663 | -0.01295 | 0.04523 | 0.03340 | 0.04249 | 0.03500 |
| | (0.03395) | (0.03481) | (0.03459) | (0.03368) | (0.03411) | (0.03520) | (0.03563) | (0.03482) |
| March | -0.00325 | 0.00558 | 0.00988 | 0.01357 | 0.06602 | 0.06065 | 0.06624* | 0.05435 |
| | (0.03931) | (0.03596) | (0.03653) | (0.03662) | (0.03958) | (0.03745) | (0.03719) | (0.03513) |
| April | -0.01648 | 0.00574 | 0.00934 | 0.00715 | 0.09830** | 0.09662** | 0.10261*** | 0.10177*** |
| | (0.03174) | (0.03334) | (0.03324) | (0.03447) | (0.03951) | (0.03831) | (0.03872) | (0.03888) |
| May | 0.00210 | 0.01134 | 0.01325 | 0.02152 | 0.13042*** | 0.11441*** | 0.11725*** | 0.11518*** |
| | (0.04035) | (0.03947) | (0.03960) | (0.03740) | (0.03772) | (0.03459) | (0.03461) | (0.03338) |
| June | -0.00141 | 0.01457 | 0.01572 | 0.02234 | 0.07922* | 0.07213* | 0.07402* | 0.07244* |
| | (0.04132) | (0.03911) | (0.03932) | (0.03860) | (0.04151) | (0.03800) | (0.03859) | (0.03783) |
| July | -0.04099 | -0.03705 | -0.03621 | -0.03726 | 0.08148** | 0.08440** | 0.08577** | 0.08699** |
| | (0.03659) | (0.03653) | (0.03666) | (0.03656) | (0.03536) | (0.03465) | (0.03457) | (0.03462) |
| August | -0.00992 | -0.00794 | -0.00785 | 0.00010 | 0.09029** | 0.07538* | 0.07541* | 0.07419* |
| | (0.02967) | (0.03254) | (0.03278) | (0.03347) | (0.04366) | (0.04152) | (0.04172) | (0.04206) |
| September | -0.00634 | 0.00227 | 0.00208 | 0.00035 | 0.02797 | 0.01949 | 0.01768 | 0.02211 |
| | (0.03862) | (0.03770) | (0.03799) | (0.03726) | (0.03736) | (0.03487) | (0.03497) | (0.03443) |
| November | -0.05684 | -0.03851 | -0.04031 | -0.03272 | 0.03201 | 0.01968 | 0.01663 | 0.01859 |
| | (0.03800) | (0.03793) | (0.03806) | (0.03689) | (0.04327) | (0.04314) | (0.04315) | (0.04185) |
| December | 0.02565 | 0.05022 | 0.04853 | 0.05597 | 0.04264 | 0.02054 | 0.01727 | 0.01620 |
| | (0.03884) | (0.03891) | (0.03915) | (0.03876) | (0.03846) | (0.03499) | (0.03503) | (0.03332) |
| Years of education | | | | -0.03736*** | | | | -0.03203*** |
| | | | | (0.00218) | | | | (0.00245) |
| Height (in cm.) | | | | -0.00444*** | | | | -0.00492*** |
| | | | | (0.00064) | | | | (0.00080) |
| Constant | -2.50340*** | -2.75662*** | -3.32781*** | -2.05780*** | -2.68075*** | -3.03198*** | -3.29344*** | -2.00620*** |
| | (0.18781) | (0.17623) | (0.16731) | (0.21695) | (0.21618) | (0.23862) | (0.20098) | (0.25934) |
| Gender | | Females | | | | | Males | |
| Observations | 25,046 | 25,046 | 25,046 | 22,918 | 20,404 | 20,404 | 20,404 | 18,678 |
| Individuals | 10,484 | 10,484 | 10,484 | 10,480 | 8,893 | 8,893 | 8,893 | 8,893 |

Standard errors are clustered at the year of birth level. One asterisk indicates significance at the 10-percent level, two asterisks indicate significance at the 5-percent level, and three asterisks indicate significance at the 1-percent level. The dependent variable is the log of the health deficit index. Year of birth and country dummies are included.