OXFORD BULLETIN OF ECONOMICS AND STATISTICS, 81, 1 (2019) 0305–9049
doi: 10.1111/obes.12257

What Do Wages Add to the Health-Employment Nexus? Evidence from Older European Workers*

Manuel Flores† and Adriaan Kalwij‡

†*Directorate for Employment, Labour and Social Affairs, OECD, France (e-mail: manuel.flores@oecd.org)*
‡*Utrecht University School of Economics, Utrecht, The Netherlands (e-mail: a.s.kalwij@uu.nl)*

Abstract

The role of wages in the health-employment nexus can be important for designing employment policies aimed at older workers with health limitations. We, therefore, estimate the direct effect of health on employment and hours worked and its indirect effect that is mediated through wages using individual-level panel data from SHARE. The endogeneity of self-reported health is controlled for by instrumenting it with severe health conditions in a correlated random effects model. For men, we find that the direct effects of health deterioration, as measured by a reduction in health from the 75th to the 50th percentile of the health distribution, are about a 20% point lower employment probability and about 171 fewer hours worked per year. The indirect health effects through wages work in the opposite directions as health positively affects wages and wages negatively affect employment and hours worked. The total effects of this health deterioration amount to a 12% point lower employment probability and 95 fewer hours worked per year. In particular our finding of a large direct health effect on employment suggests an instrumental role for policy aimed at accommodating workers with health limitations to keep them employed at older ages.

JEL Classification numbers: D00, I10, J14, J20, J30.
*This paper uses data from SHARE, waves 1 and 2, release 2.6.0, as of November 29, 2013. The SHARE data collection has been primarily funded by the European Commission through the 5th Framework Program (project QLK6-CT-2001-00360 in the thematic program Quality of Life), through the 6th Framework Program (projects SHARE-I3, RII-CT-2006-062193, COMPARE, CIT5- CT-2005-028857, and SHARELIFE, CIT4-CT-2006-028812), and through the 7th Framework Program (SHARE-PREP, No. 211909, SHARE-LEAP, No. 227822 and SHARE M4, No. 261982). Additional funding is also gratefully acknowledged from the U.S. National Institute on Aging (U01 AG09740-13S2, P01 AG005842, P01 AG08291, P30 AG12815, R21 AG025169, Y1-AG-4553-01, IAG BSR06-11 and OGHA 04-064) and the German Ministry of Education and Research, as well as from various national sources (see www.share-project.org for a full list of funding institutions). We also thank the Editor, three anonymous referees, Rob Alessie, Anna Choi, Pilar García-Gómez, Marloes de Graaf-Zijl, Herwig Immervoll, Sergi Jiménez, Jochen Mierau, Giacomo Pasini, Hilda Ralsmark, Arthur van Soest, Judit Vall-Castelló, and the seminar participants at OECD, Amsterdam Institute for Advanced Labour Studies, CPB Netherlands Bureau for Economic Policy Analysis, University Pompeu Fabra (CRES), Utrecht University, University of Valencia, the AES Conference 2012 in Bilbao, the Italian SHARE User's Conference 2012 in Venice, the Center for Research on Pensions and Welfare policies in Turin (CeRP's annual conference 2012), the 2012 Netspar Pension Day in Utrecht, and the January 2013 Netspar International Pension Workshop for valuable comments and discussions. Responsibility for the contents lies with the authors and does not necessarily represent the views of the OECD or the Governments of OECD member countries.

I. Introduction

The fact that employed men and women aged 50–64 in 15 European countries report better health than their non-employed peers (see Figures 1 and 2) suggests that, as empirically supported in the literature (e.g. Currie and Madrian, 1999; Kalwij and Vermeulen, 2008), health plays an important role in explaining employment at older ages. In this paper, we add to this research by quantifying the role of individual wages in the health-employment nexus, an issue that, although previously highlighted by Cai (2009, 2010) and Disney, Emmerson and Wakefield (2006), has received virtually no attention in the empirical literature with the exceptions of the earlier studies of Chirikos and Nestel (1985) and Haveman *et al.* (1994). Yet quantifying the mediating role of wages in the health–employment nexus is important for both understanding individuals' labour market behaviour and designing employment policies that support older workers with health limitations to stay employed. The direct effect of health on employment is related to the ability to work, which can be affected by, for instance, better accommodating workers with health impairments through reduced job demands or a change of tasks (Daly and Bound, 1996; Currie and Madrian, 1999; Autor and Duggan, 2010; Burkhauser and Daly, 2011). Its indirect effect through wages, in contrast, indicates the degree to which it is financially worthwhile to remain employed, a decision that may be influenced by such initiatives as wage subsidies for workers with health impairments (see e.g. Burkhauser, Glenn and Wittenburg, 1997; Datta Gupta, Larsen and Stage Thomsen, 2015).

According to economic theoretical models such as Grossman (1972, 2001), the stock of health is a component of human capital that determines wages (Becker, 1964) and the amount of time an individual can spend in the labour market. This latter effect on labour supply operates as well through wages.[1] In addition, and perhaps more importantly, an individual in bad health may have an increased disutility of work (Gordon and Blinder, 1980) and an increased value of leisure time to attend to her own health (Cai, 2009; Brown, Roberts and Taylor, 2010).[2] An important implication of these theoretical considerations in the context of our paper is that one may misestimate the direct effect of health on employment if wages are not controlled for in an employment equation. And, consequently, one would incorrectly assess the importance of policies aimed at helping employers to accommodate workers with health limitations to keep them employed at older ages.

Nevertheless, although the theoretical literature suggests that health, wages, and employment are interrelated, most previous studies have analysed the health–employment and health–wage relations separately. As regards the first, previous studies have usually identified a positive effect of health on employment (see e.g. Bound *et al.*, 1999, for the U.S.; Disney *et al.*, 2006, and García-Gómez, Jones and Rice, 2010, for Great Britain). Yet, as Cai (2009, 2010) and Disney *et al.* (2006) argue and, e.g. Bound's (1991) model suggests,

[1] See also Lazear (1986) for a theoretical model on the retirement–health nexus.

[2] Alternatively, Contoyannis and Rice (2001) argue that the (positive) relation between poor health and low wages may stem from employers' beliefs that poor health correlates with unobserved characteristics that are negatively related with productivity or from discrimination against individuals perceived to be in poor health (see also Currie and Madrian, 1999, pp. 3332–3333, and references therein). In addition, when in bad health, other options may become relevant to the employment decision, such as eligibility for disability insurance benefits (Layard, Nickell and Jackman, 1994).

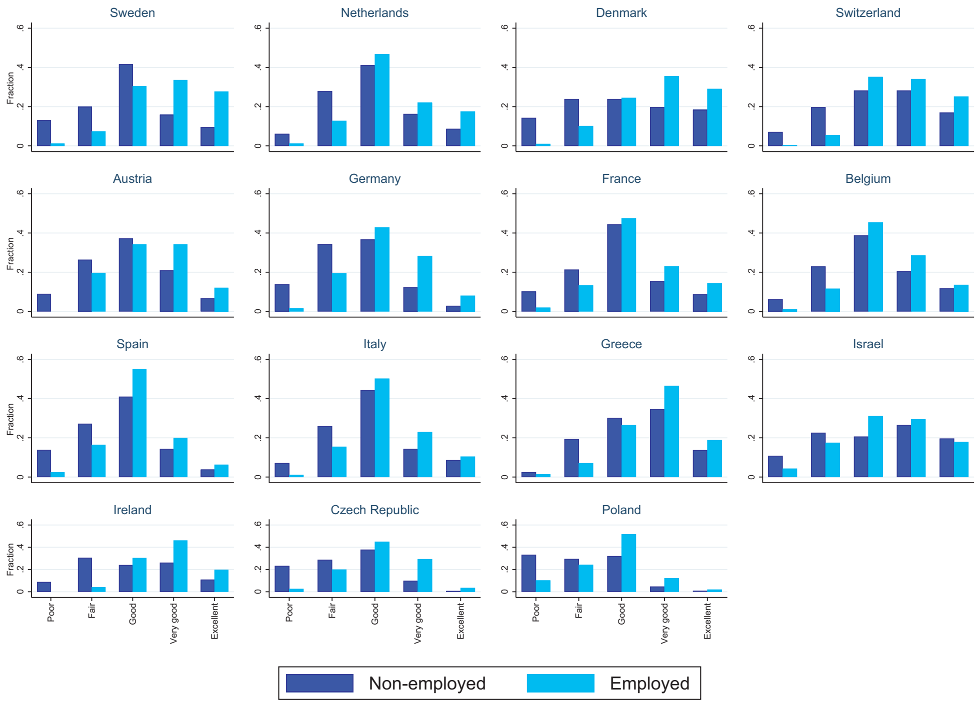

Figure 1. Distribution of self-reported health (SRH) by employment status for men aged 50–64 years in Europe
Source: Author calculations based on waves 1 and 2 of SHARE. The figure shows the distribution of self-reported health by employment status for men aged 50–64 years in 15 European countries. SRH is measured on a 5-point scale from poor to excellent health. Differently from the final estimation sample (see section II), the figure also includes countries and individuals particpating in only one of the two waves.

labour force participation equations which do not consider the wage rate should be interpreted as reduced forms. Moreover, because wages may also be affected directly by health, the estimate on the health variable in such equations should be interpreted as the sum of a direct effect of health on labor supply and an indirect effect operating through wages. This indirect effect can go from positive to negative as it depends on the sign and significance of two effects: the wage effect on labor supply – which can be positive if there is a dominating substitution effect, that is workers substitute leisure with work, and negative if there is a dominating income effect, that is workers substitute work with leisure[3] – and the health effect on wages. The evidence on the health-wage relation is mixed. Brown *et al.* (2010), for example, find no effect of health on both men's (observed) wages and reservation wages in Britain, and Jäckle and Himmler (2010), using data for Germany, find a positive effect of health on wages for men but not for women.[4] For the U.S., Chirikos and Nestel (1985) simultaneously analyse work-time and wages and show that past health problems adversely affect current earnings and hours worked. The only study we know of that simultaneously

[3] See, e.g. Blundell and MaCurdy (1999).

[4] The studies discussed here which investigate wages usually refer to individual's observed wages. When sample selection is taken into account (e.g. Brown *et al.*, 2010; Jäckle and Himmler, 2010 and our model in section III), the observed wage equals the offered wage (Gronau, 1974).

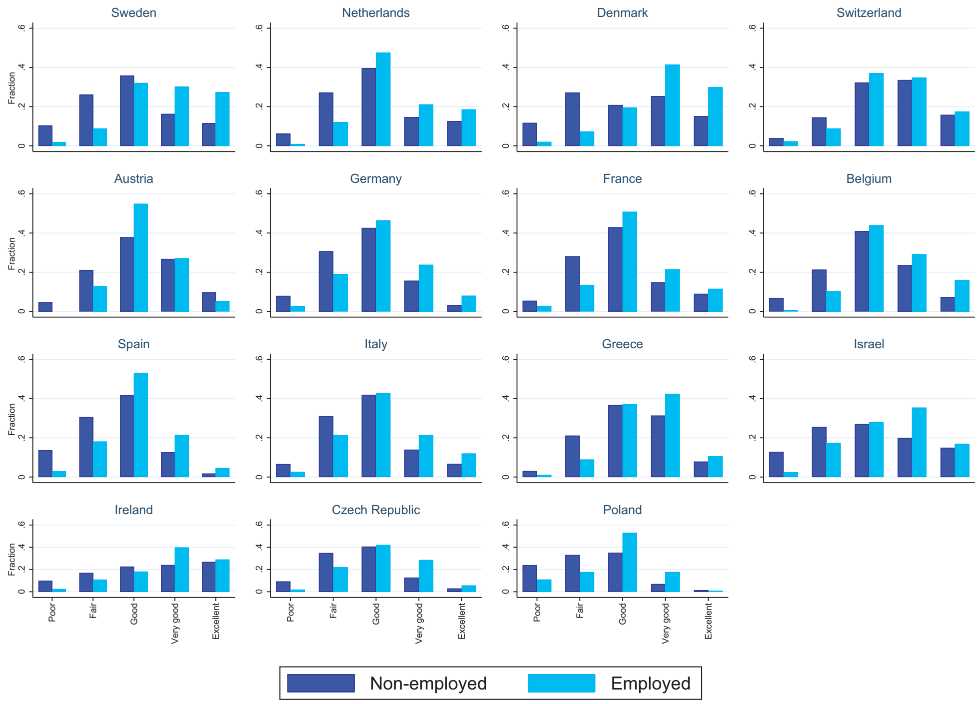

Figure 2. Distribution of self-reported health by employment status for women aged 50–64 years in Europe
Source: Author calculations based on waves 1 and 2 of SHARE. The figure shows the distribution of SRH by employment status for women aged 50–64 years in 15 European countries. SRH is measured on a 5-point scale from poor to excellent health. Differently from the final estimation sample (see section II), the figure also includes countries and individuals particpating in only one of the two waves.

analyses work-time, wages, and health is Haveman *et al.* (1994). Based on data for U.S. men, they report that poor health does affect both wages and work-time negatively, but also that wages do not affect work-time. While they do not estimate this indirect effect of health on work-time through wages, their findings suggest it is insignificant.[5]

In this study, we analyse the relations between health, wages, employment and hours worked using individual-level panel data from the Survey of Health, Ageing and Retirement in Europe (SHARE). Our main contribution to the literature is to estimate for men and women in Europe, both health's direct effects on employment and hours worked and its indirect effects through wages. The adopted empirical framework is similar to the one of Haveman *et al.* (1994) in which health is an endogenous explanatory variable in a system of wage, hours and employment equations. We extend Haveman *et al.*'s (1994) model by accounting for the possible endogeneity of the health variable. As in most of the aforementioned studies, heath is measured by self-reported health (SRH)[6] and is likely to

[5] Bound (1991) also considers a labour supply model of older men that includes both health and annual earnings and, using a similar approach to Stern (1989), uses mortality information to instrument two different self-reported health measures. Nevertheless, the earnings variable is taken as exogenous, and no estimation is made of the indirect effect of health on employment mediated through earnings.

[6] Haveman *et al.* (1994) use a subjective health variable which is constructed from two questions on whether the individual is work limited by health, and by how much.

be an endogenous explanatory variable. A possible reason for this is that SRH is subject to measurement error due to, e.g. justification bias (i.e. those not employed may report worse than actual health to justify not working) and *pure* measurement error (Bound, 1991). Empirical evidence for the justification bias is provided by Lindeboom and Kerkhofs (2009), whose study of older Dutch men shows that failing to account for it leads to overestimation of the effect of health for disability recipients. Cai (2010), however, using Australian data, concludes that there may be a justification bias for women but not for men. The likelihood that SRH is also subject to a dominant *pure* measurement error is indicated by both Crossley and Kennedy (2002) and Jäckle and Himmler (2010) based on the finding that there is an attenuation bias in the effects of health on employment and wages when SRH is treated as an exogenous regressor. In this paper, we follow Bound *et al.* (1999) and correct for measurement error in SRH by using a Health Index (HI) based on self-assessed objective health indicators.

Another possible reason for health being an endogenous explanatory variable in our model is reverse causality as employment, hours worked and wages may affect health (Currie and Madrian, 1999; Grossman, 2001). The empirical evidence on this is rather mixed. For instance, Haveman *et al.* (1994) report an insignificant effect of work-time on health and Stern (1989) and Cai (2010) find a negative effect of employment on health. Snyder and Evans (2006), using U.S. data, suggest that post-retirement (part-time) work may have a health-preserving effect, and, similarly, Rohwedder and Willis (2010) find that early retirement negatively affects the cognitive ability of people in their early 60s, while Coe and Zamarro (2011) find for Europe that retirement has a health-preserving effect on overall general health. Lee (1982) and Cai (2009), for their part, report a positive effect of wages on health for men in the U.S. but no effect for men in Australia. We take reverse causality into account by using a more restricted set of health limitations as instruments for SRH than, for instance, Bound *et al.* (1999), Coe and Zamarro (2011), Disney *et al.* (2006) and García-Gómez *et al.* (2010) do. Our restricted set is based on findings in previous studies. For instance, based on the findings of Rohwedder and Willis (2010) mental health is unlikely to be a valid instrument for health in our model. Studies such as Trevisan and Zantomio (2016), Westerlund *et al.* (2010) and Wu (2003) argue that severe health conditions (such as strokes, cancer or diabetes) are likely to be exogenous variables and, therefore, valid instruments in their models. Likewise, García-Gómez (2011) uses as an alternative for SRH the onset of a chronic health condition to explain transitions across labour market outcomes in European countries. In line with these latter studies, we use severe health conditions as an instrument for SRH which in our panel data models (see below) requires the assumption of strict exogeneity.

Another potentially important source of endogeneity of health in our model is unobserved time-invariant heterogeneity. Only few of the previously cited studies (e.g. Disney *et al.*, 2006; Jäckle and Himmler, 2010) take *correlated* unobserved individual effects into account (cf. Wooldridge, 1995). Unobserved factors such as personality treats (e.g. motivation and diligence) and individuals' circumstances early in life (see e.g. Flores and Kalwij, 2014) may drive to some extent the associations between health, wages and employment. As explained in more detail in the next two sections, while our micro dataset is longitudinal, our empirical model is nonlinear. To control for unobserved time-invariant heterogeneity we therefore use a correlated random effects model similar to Semykina and Wooldridge (2010).

Finally, our model as well extends on Haveman *et al.*'s (1994) model as it takes endogenous sample selection into account when estimating the wage equation.

Our primary empirical findings support the theoretical predictions of health's direct effects on wages, employment and hours worked; that is, we show that individuals in better health have a higher wage rate, are more likely to be employed and work more hours. We, furthermore, show that the indirect effects of health on employment or hours worked through wages are negative. Overall, the direct health effects on employment and hours worked are–in absolute terms–more than twice as large as the indirect effects, such that the total health effects on employment and hours worked remain large and positive. Finally, concerning methodological issues, we provide strong empirical evidence that it is important to control for the endogeneity of self-reported health (SRH) in our wage, employment and hours equations using a more restricted set of health limitations than previously used in the literature and allowing for correlated random effects.

The remainder of the paper is organized as follows. Section II describes the data and the main variables. Section III outlines the empirical model and discuses econometric issues related to the identification of the effects of wages on employment and hours worked and to the endogeneity of SRH. Section IV reports the estimation results and analyses their robustness. Section V summarizes the main findings and concludes.

II. Data and descriptive statistics

Our data set comprises individual-level data from the first and second waves of the Survey of Health, Ageing and Retirement in Europe (SHARE), a multidisciplinary and representative cross-national panel of the European population aged 50 and over. Currently, six waves of SHARE data are available. We do not use the third wave (SHARELIFE) as it does not belong to the standard longitudinal panel of SHARE and contains retrospective information on life-histories instead, nor the fourth to sixth waves as there is no information on wage rates. The first and second waves, conducted in 2004/5 and 2006/7, respectively, include information on socioeconomic status (e.g. employment, earnings, hours worked and education), health (e.g. self-reported subjective health and doctor diagnosed conditions, physical and cognitive functioning, and health behaviours), psychological conditions (e.g. mental health, well-being, and life satisfaction) and social support (e.g. social networks and volunteer activities).[7]

Our empirical analysis is based on data for respondents aged 50–64 from countries who participated in waves 1 and 2. This selection yields 28,546 observations for 20,100 respondents from the following countries: Austria, Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Spain, Sweden and Switzerland. We drop those individuals with missing information on hours worked and wages (4,021 observations)[8] and with

[7] For more information on SHARE waves 1 and 2, see Börsch-Supan and Jürges (2005).

[8] This includes the self-employed for which it is inherently difficult to construct hourly wage rates (see e.g. Cai, 2009; Lindeboom and Kerkhofs, 2009; Jäckle and Himmler, 2010). Re-estimating the model with the self-employed included does not change our main empirical findings and conclusions.

TABLE 1

Summary statistics

	Men		*Women*	
	Mean	*SD*	*Mean*	*SD*
Dependent variables				
Self-reported health (1–5)	3.26	1.05	3.23	1.03
Hourly net wage rate[a]	15.78	18.28	12.72	12.49
Employment	0.57	0.49	0.48	0.50
Annual hours	1,088	1,016	756	871
Health limitations				
1 + severe chronic diseases	0.22	0.42	0.19	0.39
Grip strength (0–100)	47.74	9.67	29.34	7.61
Missing grip strength	0.01	0.07	0.01	0.10
1 + mild chronic diseases	0.59	0.49	0.63	0.48
1 + limitations with ADL	0.05	0.22	0.05	0.22
1 + limitations with IADL	0.06	0.24	0.09	0.29
Socio-economic characteristics				
Job tenure (current or past job)	21.68	12.50	15.36	12.12
Age (50–64)	57.16	3.86	57.05	3.79
Educational attainment				
ISCED 0–2	0.36	0.48	0.42	0.49
ISCED 3–4	0.38	0.49	0.34	0.47
ISCED 5–6	0.26	0.44	0.24	0.42
Living with spouse/partner	0.85	0.36	0.76	0.43
Household size	2.44	1.05	2.18	0.90
Number of grandchildren	1.26	1.98	1.70	2.36
Monthly income from non-employment (wave 1)[b]	2,540	2,321	3,050	2,698
Monthly income from non-employment (wave 2)[b]	3,986	7,960	3,997	7,848
Homeownership	0.79	0.41	0.77	0.42
Country representation				
Austria	0.06	0.24	0.06	0.24
Germany	0.09	0.28	0.08	0.27
Sweden	0.14	0.34	0.16	0.36
Netherlands	0.11	0.31	0.11	0.31
Spain	0.04	0.18	0.04	0.20
Italy	0.09	0.28	0.09	0.28
France	0.12	0.33	0.12	0.33
Denmark	0.09	0.29	0.09	0.29
Greece	0.05	0.21	0.04	0.19
Switzerland	0.03	0.17	0.03	0.17
Belgium	0.18	0.39	0.18	0.38
Observations (N)	3,790		4,606	

Notes: [a]Defined for wage-earners only. In PPP-adjusted 2005 US$. N = 2,169 for men and N = 2,215 for women. [b]The amounts are in nominal € and in gross terms in wave 1, and in net terms in wave 2. For the best possible comparability across waves, in the empirical analysis, we use quintile dummies (see Table A1 for more information).

extreme values in their hourly net wages and their non-labour income.[9] We also exclude male and female respondents with missing values in the health variables (704 observations), non-labour income (1,263 observations) and socio-economic characteristics (295 observations). Since we use tenure from the last job to predict a wage for individuals not working (see section III), we also exclude 3,367 observations corresponding mainly to female homemakers who never worked and 101 observations with implausible values of tenure. Finally, because we control for correlated unobserved individual effects in some of our specifications (see section III), we restrict the sample to respondents who are present in both waves.[10] Our final sample is thus a balanced panel comprising 8,396 total observations for 1,895 male and 2,303 female respondents. Most of our empirical analysis relies on the sample of men, which we believe is less selective, as virtually no observations are lost because of missing job tenure. Nevertheless, for our final specification, we also show the results for women.

Self-reported health (SRH) status is rated on a five-point scale (from 1 to 5: poor, fair, good, very good, and excellent). Employment is defined as working a positive number of hours per week. The hourly net wage rate–measured in PPP-adjusted 2005 US$–is obtained by dividing the amount of net wage earnings by the number of hours worked. Detailed information on health limitations for both men and women is reported in Table 1 together with the summary statistics for other demographic and socio-economic characteristics used in the empirical analysis. The definitions of all variables are provided in the online Appendix Table A1.

III. Empirical model and estimation procedure

Empirical model

Our empirical model builds on the ones of the studies discussed in the introduction. It is considered a partial-equilibrium model of the supply side of the labour market (see e.g. Schultz and Tansel, 1997).[11]

We use the following two equations to estimate the effects of health on wages and employment:

$$E_{it}^{*} = \gamma_0 + \gamma_1 H_{it}^{*} + \gamma_2 w_{it}^{*} + \mathbf{Z}_{it}'\gamma_3 + \mu_i^E + \nu_{it}^E \quad (1)$$

$$w_{it}^{*} = \beta_0 + \beta_1 H_{it}^{*} + \beta_2 Ten_{it} + \beta_3 Ten_{it}^2 + \mathbf{X}_{it}'\boldsymbol{\beta}_4 + \mu_i^w + \nu_{it}^w \quad (2)$$

Equation (1) is an employment equation and equation (2) is a Mincerian type of wage equation (Mincer, 1974). Variables superscripted with an asterisk are latent variables. E_{it}^{*}

[9] Hourly net wages below 1 or above 300 PPP-US$ (141 observations) and the top and bottom 1% of non-labour income (443 observations). Wages are computed based on earnings from employment and hours worked.

[10] In an earlier version using an unbalanced panel of SHARE waves 1 and 2, we tested for possible selectivity bias in our empirical Model 1 of section III due to panel attrition using a test proposed by Verbeek and Nijman (1992). The test results showed no significant sample selection effects due to attrition in our system of equations for health, wages and employment for men. For women, however, we found a significant selection effect in the employment equation.

[11] Given our sample period covers the years 2004–07, we believe this is a reasonable approach as this period corresponds to a 'normal' or boom period. Usually, during such times employment is more driven by individuals' labour supply decisions, which is what we model.

represents an individual i's propensity to be employed at time t and we observe whether or not an individual is employed, $E_{it} = 1[E_{it}^{*} > 0]$, w_{it}^{*} is the logarithm of the hourly net market wage which we observe only for employees, and H_{it}^{*} is individual i's health at time t which is measured by the ordered categorical variable SRH_{it} (self-reported health).

$\mathbf{X}_{it}$ is a vector containing variables that affect employment and wages (dummy variables for educational attainment, age groups, survey year, and country), and $\mathbf{Z}_{it}$ contains the variables included in $\mathbf{X}_{it}$, as well as the variables non-labour income, homeownership (a proxy for wealth) and household composition variables (log household size, marital status and number of grandchildren) that are assumed to affect employment but not wages. Ten_{it} and Ten_{it}^{2} stand for current job tenure and its square and are meant to proxy for the investments in job-specific skills. In line with Grossman's (1972) model, we use educational attainment as a proxy for an individual's general stock of knowledge or human capital exclusive of health capital (see also, Currie and Madrian, 1999, p. 3312; Jäckle and Himmler, 2010).[12] Random individual-specific effects are denoted by μ_i^E and μ_i^w, v_{it}^E and v_{it}^w are idiosyncratic error terms, and they are all assumed to be normally distributed. Equation (1) is estimated as a probit model and equation (2) as a linear model. As discussed in the introduction, we are especially interested in the direct effect of health on employment, determined here by the coefficient γ_1, and the indirect effect of health on employment through wages, determined here by the coefficients γ_2 and β_1.

To gain insights into the effects on the intensive margin, we estimate an equation for hours worked and include the same explanatory variables as in the employment equation:

$$h_{it}^{*} = \delta_0 + \delta_1 H_{it}^{*} + \delta_2 w_{it}^{*} + Z_{it}'\delta_3 + \mu_i^h + v_{it}^h \qquad (3)$$

where h_{it}^{*} are annual hours worked which are left-censored at zero, μ_i^h denotes a normally distributed random individual-specific effect and v_{it}^h is a normally distributed error term. Equation (3) is estimated as a tobit model. Under the assumption of no model misspecification, adding an hours equation to the model may as well increase precision of the estimated effects and we return to this issue in section 'Robustness of results to an alternative hours equation specification'.[13]

When estimating the model that consists of equations (1)–(3), we must deal with five econometric issues: the identification of the relation between wages and employment, sample selection as we only observe the wage rate for employees, possible measurement error in the health variable (SRH), reverse causality and unobserved time-invariant heterogeneity. To address the first, we assume that there are no direct effects of tenure on employment and hours worked once wages and other variables including education and–as discussed below–correlated random effects are controlled for. This assumption of tenure as an exclusion restriction in the employment and hours worked equations is, arguably, less restrictive than the one in Chirikos and Nestel (1985) and Haveman *et al.* (1994) who assume that education has no direct effect on employment once wages is controlled for. In particular, as the more educated people may have a stronger preference for working irrespective of their wage rate.

[12] Since we examine individual behaviour after completion of schooling, *Educ* is taken as a predetermined variable throughout the analysis.

[13] Wooldridge (1995) specifies as well a selection correction term based on a first-stage Tobit model.

To address the second econometric issue, like Brown *et al.* (2010) and Jäckle and Himmler (2010) we use a procedure similar to the one proposed by Heckman (1979) and estimate equations (1)–(3) jointly. We identify the model, as mentioned above, by excluding from the wage equation non-labour income, homeownership and household composition variables (which are included in $\mathbf{Z}_{it}$ but not in $\mathbf{X}_{it}$). Empirical support for these exclusion restrictions can be found in Mroz (1987) who provides compelling lack of evidence for the rejection of the exogeneity assumption on the non-labour income and children variables in a (wife's) labour supply equation that includes the wage rate as an additional regressor.[14]

The third econometric issue stems from possible measurement error in the SRH variable from three sources: *pure* measurement error (see Bound, Brown and Mathiowetz, 2001; Crossley and Kennedy, 2002), the justification bias (see Stern, 1989; Bound, 1991), or the basing of SRH on subjective judgment, which may hinder comparison across individuals (Kapteyn, Smith and Van Soest, 2007; Meijer, Kapteyn and Andreyeva, 2011).[15] It is also worth noting that the *pure* measurement error and the reporting differences are likely to attenuate the effects of SRH on employment and wages, whereas the justification bias will most probably exaggerate its effects (Bound, 1991; Brown *et al.*, 2010; Blundell, French and Tetlow, 2016, pp. 485–487). Nevertheless, all these issues require that SRH be instrumented during estimation of the employment, hours and wage equations. In line with Bound *et al.* (1999), our model thus includes not only the tenure variables and a vector $\mathbf{Z}_{it}$ containing other assumed exogenous socio-economic characteristics (e.g. educational attainment), but also a set of objective health limitations (HL_{it}) as predictors of health (H^*_{it}). We implement this health index (HI) approach, using the following equation:

$$H^*_{it} = \alpha_0 + \mathrm{HL}'_{it}\alpha_1 + \alpha_2\mathrm{Ten}_{it} + \alpha_3\mathrm{Ten}^2_{it} + \mathbf{Z}'_{it}\alpha_4 + \mu^H_i + v^H_{it} \quad (4)$$

where μ^H_i is a normally distributed random individual-specific effect and v^H_{it} is a normally distributed error term. We do not observe H^*_{it} but instead use an ordered categorization variable SRH^*_{it} which takes the values $j = 1, 2, 3, 4, 5$, representing *poor*, *fair*, *good*, *very good*, and *excellent* health, respectively. The resulting ordered probit model is estimated simultaneously with equations (1)–(3). The health limitations are assumed to be exogenous. We assume no systematic differences in reporting on these health limitations across countries and empirical support for this assumption can be found in Kapteyn *et al.* (2007, p. 471, table 5). The health limitations included are severe chronic diseases and grip strength (GS) (see online Appendix Table A1 for details). We do, for instance, not use the health limitations of depression (or mental health) and the Global Activity Limitation Indicator (GALI), because they are likely to be correlated with measurement error in SRH (Meijer *et al.*, 2011).

The fourth econometric issue of reverse causality (Currie and Madrian, 1999; Grossman, 2001) is related to the above-mentioned assumed exogeneity of health limitations. This assumption implies that these limitations are not directly affected by employment and wages, once controlled for observed characteristics and other potentially unobserved

[14] These exclusion restrictions would not hold if, for instance, individuals with low non-labour income are more likely to have a high wage job than individuals with high non-labour income (*ceteris paribus*).

[15] In addition to reporting bias *and* justification bias, Bound (1991) and Bound *et al.* (1999) identify one problem of state-dependence in self-reported subjective health answers to labour market outcomes and a second one of financial incentives for individuals to identify themselves as disabled (see also Stern, 1989).

time-invariant characteristics (see below). As discussed in the introduction, recent studies provide support for two of our methodological choices to address the issue of reverse causality. First, we include only severe chronic diseases and GS as health limitations in equation (4) as these can be considered exogenous. For instance, Westerlund *et al.* (2010) shows that in France, retirement does not change the risk of major chronic diseases, and Wu (2003) argues that severe health conditions (such as strokes, cancer or diabetes) can be interpreted as exogenous health shocks.[16] Second, in contrast to previous studies, we do not include variables such as mental health and GALI as a health limitation in equation (4). The belief that including such health variables in the health equation would violate the exogeneity assumption is supported by, for instance, Bonsang, Adam and Perelman (2012), Rohwedder and Willis (2010), and Llena-Nozal, Lindeboom and Portrait (2004), who all find that non-employment affects mental health. We neither include BMI among the set of health limitations, as for instance Chung, Domino and Stearns (2009)'s study finds that retirement increases the BMI among individuals aged 62–71 in the U.S. which would invalidate the use of BMI in equation (4). To find further validation for our choice of health limitations, we perform sensitivity tests in section 'The exogeneity of health limitations'.

The fifth econometric issue of unobserved heterogeneity stems from assumed time-invariant unobserved individual characteristics, such as personality traits (e.g. motivation and diligence) or early life circumstances (see e.g. Flores and Kalwij, 2014) that affect both health and labour market outcomes later in life. That is, the individual specific error terms may be correlated with health limitations. To take such correlations into account we model all random effects of equations (1)-(4) as time-invariant functions of all time-varying exogenous variables in our model plus individual specific random terms that are assumed uncorrelated with all exogenous variables (cf. Semykina and Wooldridge, 2010). In particular, we use Chamberlain's (1984) device and model the unobserved individual effects as linear projections onto the time-varying exogenous variables for the two periods plus individual specific random terms.[17]

Nevertheless, as in most previous studies discussed in the introduction, a cautionary remark is in place that any causal conclusions are based on the validity of the selected health limitations as instruments for SRH and that the identification of the effects of health on employment, hours and wages in equations (1)–(3) comes from excluding the health limitations ($\mathbf{HL}_{it}$) from the wage, employment and hours equations and from assuming away any time-varying correlated unobserved individual characteristics.

Finally, as in our sample non-employed women are mostly homemakers, while non-employed men are mostly retirees, we estimate the model outlined above separately for men and women. But, as explained further below, most of our analyses focus on men.

Estimation procedure

The four idiosyncratic error terms in equations (1)–(4) are allowed to correlate with each other and are assumed to follow a multivariate normal distribution. In addition,

[16] Similar evidence is provided by Trevisan and Zantomio (2016).

[17] This approach, mostly developed by Wooldridge and coauthors, is often referred to as a correlated random effects model. The list of time-varying exogenous variables includes the health limitations (HL) of equation (4), but not H^* (i.e. SRH). It does neither include time-constant variables such as educational attainment and country dummies.

homoscedasticity of the error terms is assumed. The random effects are as well assumed to be normally distributed. Given these assumptions, our model can be estimated by full information maximum likelihood (FIML). For practical reasons, however, we estimate our model in two stages.

The first stage estimation makes use of the Stata module CMP developed by Roodman (2011). This module estimates a triangular system of equations. To obtain a triangular system, we substitute the wage equation in the employment and hours equations.[18] This triangular reduced form system is estimated by FIML. The estimation requires the computation of multidimensional integrals for which the Geweke–Hajivassiliou–Keane (GHK) simulator is used with 401 or more draws per observation (Geweke, 1989; Keane, 1994; Hajivassiliou and McFadden, 1998).

In the second stage, we use an optimally weighted minimum distance estimator (MDE; also called asymptotic least squares estimator; see Kodde, Palm and Pfann, 1990) to retrieve estimates of the coefficients of equations (1)–(4) from the reduced form estimates that are obtained in the first stage.

IV. Estimation results

This section presents various models that account to different extents for the aforementioned econometric issues of measurement error in SRH, reverse causality and unobserved heterogeneity. This requires having valid instruments for SRH. Table 2 (panel A) reports on the statistical significance of the health limitation in the health equation and for all models it is shown that our instruments are relevant, i.e. they significantly affect SRH. Unlike for linear models, one cannot test for overidentifying restrictions in a nonlinear model such as ours. Instead, we rely on the arguments put forward in the literature for the plausibility (or not) of exogeneity of the various instruments we use (see section I) and on sensitivity checks of our results to the inclusion of different sets of health limitations as instruments. Related to this are the test results in section ‘Unobserved time-invariant heterogeneity’ on the importance of allowing for correlations between the random effect (time-invariant unobserved heterogeneity) and the explanatory variables.

We start with a model with a specification as outlined in section III where we only take measurement error in SRH into account and refer to it as Model 1. This model is similar to that of Haveman *et al.* (1994). Also like these authors, we focus most of our analyses on men but provide results for women for our final specification. For the comparison of the estimated health effects across models, we present results in terms of one-standard deviation (SD) increases in health which turns out to be about equal to a shift from the median to the 75th percentile of the health distribution, a 10% increase in wages and a one-unit increase in case of discrete variables such as dummy variables. Table 2 reports selected coefficient estimates for the various specifications.[19]

[18] We note that for individuals not working we use job tenure from the previous or from the last job–if retired–to predict their offered wage. To take depreciation of these job-skills into account, we assume an annual depreciation rate of 3% since the person stopped working (cf. Haley, 1976; Heckman, 1976). Allowing for education-specific deprecations rates does not change our empirical results (results available upon request).

[19] The full set of results is available upon request from the authors.

TABLE 2

Selected estimated coefficients in the equations for health, wages, employment and hours worked[a]

	Men							*Women*
	Health Index (HI)	*SRH exogenous*	*Restricted HI*	*Extended HI*	*HI & CRE*	*Restricted HI & CRE*	*Extended HI & CRE*	*HI & CRE*
	(Model 1)	*(Model 2)*	*(Model 3)*	*(Model 4)*	*(Model 5)*	*(Model 6)*	*(Model 7)*	*(Model 5)*
Panel A: Health equation (ordered probit model)								
1 + severe chronic conditions (0–1)	−0.8674***		−0.9042***	−0.7979***	−0.4579***	−0.4596***	−0.5019***	−0.3493***
	(0.0520)		(0.0524)	(0.0529)	(0.0682)	(0.0669)	(0.0734)	(0.0742)
Grip Strength	0.0165***			0.0148***	0.0082**		0.0087**	0.0056
	(0.0023)			(0.0023)	(0.0033)		(0.0036)	(0.0041)
Missing Grip Strength (0–1)	−1.0470**			−0.6335*	−0.4660		−0.2970	0.1278
	(0.4337)			(0.3827)	(0.4237)		(0.4666)	(0.2413)
1 + mild chronic conditions (0–1)				−0.6232***			−0.3192***	
				(0.0399)			(0.0531)	
1 + limitations with ADL (0–1)				−0.7901***			−0.2472**	
				(0.1019)			(0.1151)	
1 + limitations with IADL (0–1)				−0.7013***			−0.3299***	
				(0.0892)			(0.1072)	
Joint significance of health indicators (χ^2(df), *P*-value)	381.6(3), 0.0000	–	298.0(1), 0.0000	824.1(6), 0.0000	54.5(3), 0.0000	47.3(1), 0.0000	110.3(6), 0.0000	25.7(3), 0.0000
Joint significance of CRE (χ^2(df), *P*-value)	–	–	–	–	99.2(36), 0.0000	81.8(32), 0.0000	154.5(42), 0.0000	181.8(36), 0.0000
Panel B: Wage equation (linear model)								
Health (+1 SD)	0.0817***	−0.0087	0.0402***	0.0336***	0.0378***	0.0382***	0.0328***	0.0163*
	(0.0101)	(0.0136)	(0.0100)	(0.0091)	(0.0097)	(0.0101)	(0.0093)	(0.0086)
Medium educ. (0–1)	0.0995***	0.1037***	0.1077***	0.1090***	0.1173***	0.1116***	0.1199***	0.1203***
	(0.0300)	(0.0315)	(0.0298)	(0.0298)	(0.0289)	(0.0290)	(0.0291)	(0.0264)
High educ. (0–1)	0.2390***	0.2200***	0.2536***	0.2557***	0.2433***	0.2394***	0.2518***	0.3155***
	(0.0299)	(0.0349)	(0.0296)	(0.0296)	(0.0295)	(0.0297)	(0.0294)	(0.0267)

(*continued*)

TABLE 2
(Continued)

	Men							*Women*
	Health Index (HI)	*SRH exogenous*	*Restricted HI*	*Extended HI*	*HI & CRE*	*Restricted HI & CRE*	*Extended HI & CRE*	*HI & CRE*
	(Model 1)	*(Model 2)*	*(Model 3)*	*(Model 4)*	*(Model 5)*	*(Model 6)*	*(Model 7)*	*(Model 5)*
Tenure	0.0162***	0.0271***	0.0159***	0.0163***	0.0181***	0.0176***	0.0177***	0.0057
	(0.0034)	(0.0041)	(0.0034)	(0.0034)	(0.0064)	(0.0064)	(0.0064)	(0.0067)
$Tenure^2/100$	−0.0236***	−0.0480***	−0.0224***	−0.0232***	−0.0356**	−0.0335**	−0.0346**	−0.0195
	(0.0078)	(0.0101)	(0.0078)	(0.0078)	(0.0149)	(0.0149)	(0.0149)	(0.0163)
Joint significance of tenure variables (χ^2(df), P-value)	61.3(2), 0.0000	86.7(2), 0.0000	65.1(2), 0.0000	66.6(2), 0.0000	8.3(2), 0.0156	8.1(2), 0.0172	8.1(2), 0.0172	1.9(2), 0.3849
Joint significance of CRE (χ^2(df), P-value)	–	–	–	–	85.1(36), 0.0000	66.0(32), 0.0000	99.3(42), 0.0000	114.1(36), 0.0000
Panel C: Employment equation (probit model)								
Health (+1 SD)	0.3825***	0.2024***	0.3389***	0.3310***	0.5188***	0.5447***	0.4272***	0.3550***
	(0.0316)	(0.0214)	(0.0234)	(0.0212)	(0.0414)	(0.0431)	(0.0362)	(0.0354)
Wages (+10%)	−0.0486	−0.1325***	−0.0462	−0.0418	−0.5174***	−0.5365***	−0.5234***	−0.5157***
	(0.0301)	(0.0244)	(0.0293)	(0.0292)	(0.0966)	(0.0991)	(0.0935)	(0.1772)
Medium educ. (0–1)	0.1981***	0.2920***	0.2071***	0.1875**	0.7884***	0.7825***	0.8271***	0.7141***
	(0.0732)	(0.0696)	(0.0742)	(0.0740)	(0.1315)	(0.1296)	(0.1310)	(0.2228)
High educ. (0–1)	0.3743***	0.5980***	0.3918***	0.3692***	1.6006***	1.6215***	1.6448***	1.9179***
	(0.1058)	(0.0914)	(0.1080)	(0.1081)	(0.2478)	(0.2491)	(0.2469)	(0.5672)
Joint significance of CRE (χ^2(df), P-value)	–	–	–	–	484.3(36), 0.0000	479.4(32), 0.0000	611.7(42), 0.0000	433.8(36), 0.0000

(*continued*)

TABLE 2

(Continued)

	Men							*Women*
	Health Index (HI)	*SRH exogenous*	*Restricted HI*	*Extended HI*	*HI & CRE*	*Restricted HI & CRE*	*Extended HI & CRE*	*HI & CRE*
	(Model 1)	*(Model 2)*	*(Model 3)*	*(Model 4)*	*(Model 5)*	*(Model 6)*	*(Model 7)*	*(Model 5)*
Panel D: Hours equation (tobit model)								
Health (+1SD)	279***	234***	260***	260***	238***	287***	209***	231***
	(35)	(25)	(26)	(23)	(39)	(40)	(34)	(38)
Wages (+10%)	−14	−154***	−6	−4	−279***	−276***	−277***	−577***
	(34)	(28)	(33)	(33)	(87)	(87)	(86)	(190)
Medium educ. (0–1)	174**	340***	165**	159*	526***	514***	505***	858***
	(84)	(81)	(84)	(84)	(123)	(121)	(125)	(238)
High educ. (0–1)	321***	692***	305**	290**	1,050***	1,018***	1,019***	2,237***
	(119)	(106)	(121)	(120)	(225)	(222)	(228)	(606)
Joint significance of CRE (χ^2(df), *P*-value)	–	–	–	–	613.4(36), 0.0000	588.6(32), 0.0000	636.1(42), 0.0000	586.0(36), 0.0000
Observations	3,790	3,790	3,790	3,790	3,790	3,790	3,790	4,606

Notes: HI = health index; CRE = correlated random effects; SD = standard deviation.[a] Selected estimated coefficients for equations (1)–(4) obtained from minimum distance estimation based on reduced-form estimates from a simultaneous equations model. Health equation (for all models, except Model 2): The dependent variable is SRH (1 = poor, 5 = excellent) and additional explanatory variables are log household size, number of grandchildren, tenure and dummy variables for educational levels, survey year, 3-year age-groups, non-labour income quintiles, homeownership, marital status, and country. Wage equation: The dependent variable is the PPP-adjusted hourly net wage rate (in logs) and additional explanatory variables are dummy variables for survey year, 3-year age-groups, and country. Employment and hours equations: The dependent variables are, correspondingly, employment (1 = employed, 0 = not employed) and annual hours worked, and additional explanatory variables are log household size, number of grandchildren, tenure and its square, and dummy variables for survey year, age years, non-labour income quintiles, homeownership, marital status, and country. For Models 5–7, the last rows of the panels show chi-square test statistics with the number of restrictions (degrees of freedom, df) and *P*-values from joint significance tests on the time-varying exogenous variables for the two time periods (the correlated random effects; see section III). Standard errors, in parentheses, are clustered at the individual level. Significance levels: ***$P < 0.01$, **$P < 0.05$, *$P < 0.10$.

For Model 1, all health limitations significantly affect SRH (panel A, Table 2) and the estimates show that men with a severe chronic disease and a lower or missing grip strength (GS) are more likely to be in poor health. Respondents who are not able to do the GS test due to a health problem will have missing GS and this may explain the large negative effect of missing GS on SRH.

The estimation results of the wage equation for Model 1 show a significant and positive effect of health on wages for men (panel B, Table 2). This finding is in line with the findings in Cai (2009) for Australian men, Haveman *et al.* (1994) for U.S. men, and Jäckle and Himmler (2010) for Germany. For instance, men with health at the 75th percentile have, compared to median health individuals, about an 8% higher hourly wage rate. In addition, in line with human capital theory and previous empirical studies, education contributes positively to an individual's hourly wage rate: compared to men with the lowest level of education, those with the highest level have on average a 25 $[(\exp(0.22)-1)\times 100]$ percent higher hourly wage rate. Job tenure has a significant and positive effect on hourly wages that is concave. The effects of tenure and tenure square are jointly significant at the 1% level of significance (bottom of panel B).

The estimation results of the employment equation and hours equation are given in panels C and D, respectively. These show that employment and hours are positively and significantly affected by health. Instead, the effect of wages is insignificant in both equations, similar to Haveman *et al.*'s (1994) study. Furthermore, educational attainment is positively related to employment and hours worked, a result that remains robust across all models.

The direct and indirect effects of health on employment and hours worked are given in Table 3, correspondingly in panels A and B. As suggested by the coefficient estimates of Model 1 in Table 2, the results in panels A and B in Table 3 do not provide evidence of indirect effects of health on employment or hours worked through wages. Instead, they show that employment and hours worked are affected directly by health. The total health effects are entirely attributable to the direct effects of health on employment and hours worked and show that men with health at the 75th percentile have about a 13% point higher employment probability and work 186 hours more per year than those with median health.

The endogeneity of SRH

Unlike a Hausman–Wu test for linear models, there is no test to assess whether health is an endogenous variable in a nonlinear model such as ours. Nevertheless, previous studies suggest that dealing with various sources of endogeneity of self-reported health is important, which our results confirm. To throw light on the quantitative importance of controlling for the endogeneity stemming from measurement error or reverse causality, we first estimate the employment, hours and wage equations (equations (1)–(3)) with SRH assumed to be an exogenous regressor and refer to this model as Model 2 in Tables 2 and 3. A comparison between the results of Model 1 and Model 2 in Table 2 shows that treating SRH as an exogenous regressor leads, as in Cai (2009) and Jäckle and Himmler (2010), to an attenuation bias in the effect of health on wages (it even turns statistically insignificant). Similar results emerge for the employment equation: treating SRH as an exogenous regressor

TABLE 3

Direct and indirect effects on employment (0–1) and hours worked[a]

	Men							*Women*
	Health Index (HI)	*SRH exogenous*	*Restricted HI*	*Extended HI*	*HI & CRE*	*Restricted HI & CRE*	*Extended HI & CRE*	*HI & CRE*
	(Model 1)	*(Model 2)*	*(Model 3)*	*(Model 4)*	*(Model 5)*	*(Model 6)*	*(Model 7)*	*(Model 5)*
Panel A: Direct and indirect effects with employment								
Wage effect (+10%)	−0.0185	−0.0475***	−0.0176	−0.0159	−0.1992***	−0.2074***	−0.2031***	−0.2056***
	(0.0114)	(0.0088)	(0.0112)	(0.0111)	(0.0372)	(0.0383)	(0.0363)	(0.0707)
Direct health effect (+1 SD)	0.1453***	0.0726***	0.1292***	0.1262***	0.1998***	0.2106***	0.1657***	0.1415***
	(0.0120)	(0.0077)	(0.0089)	(0.0081)	(0.0159)	(0.0167)	(0.0140)	(0.0141)
Indirect health effect (+1 SD)	−0.0151	0.0041	−0.0071	−0.0053	−0.0754***	−0.0792***	−0.0666***	−0.0334
	(0.0095)	(0.0065)	(0.0048)	(0.0040)	(0.0240)	(0.0256)	(0.0225)	(0.0214)
Total health effect (+1 SD)	0.1302***	0.0767***	0.1221***	0.1208***	0.1244***	0.1314***	0.0991***	0.1081***
	(0.0081)	(0.0117)	(0.0082)	(0.0075)	(0.0227)	(0.0242)	(0.0219)	(0.0202)
Panel B: Direct and indirect effects with annual hours worked								
Wage effect (+10%)	−10	−108***	−4	−3	−200***	−198***	−198***	−318***
	(24)	(20)	(23)	(23)	(62)	(62)	(62)	(104)
Direct health effect (+1 SD)	194***	163***	181***	181***	171***	205***	150***	128***
	(24)	(17)	(18)	(16)	(28)	(29)	(25)	(21)
Indirect health effect (+1 SD)	−8	9	−2	−1	−76**	−75**	−65**	−52
	(19)	(15)	(9)	(8)	(31)	(31)	(28)	(33)
Total health effect (+1 SD)	186***	173***	180***	180***	95***	130***	85***	76**
	(16)	(27)	(16)	(14)	(28)	(29)	(26)	(31)

Notes: HI = health index; CRE = correlated random effects; SD = standard deviation.[a]Estimated marginal effects on employment probability and annual hours worked. Standard errors, in parentheses, are clustered at the individual level. Significance levels: ***$P < 0.01$, **$P < 0.05$, *$P < 0.10$.

attenuates the (direct) effect of health by nearly 50% (panel A, Table 3). Results for hours worked are less extreme, but also point to an attenuation bias when treating SRH as exogenous (panel B): a reduction of about 15% in the (direct) effect of health on annual hours worked.

The exogeneity of health limitations

The most likely health limitation that may be questioned as an instrument for SRH is Grip strength (GS). We thus re-estimate our model without the GS variables (i.e. the health limitations are restricted to only severe chronic conditions), which we refer to as Model 3 in Tables 2 and 3. As shown, excluding the GS variables does not change the main findings from Model 1, except for a lower health effect on wages.

Next, we include additional limitations in our HI that are commonly used in the literature such as the presence of mild chronic conditions and limitations in (instrumental) activities of daily living (Disney *et al.*, 2006; García-Gómez *et al.*, 2010; Coe and Zamarro, 2011). The estimation results using this extended HI are shown in columns (4) under the heading of Model 4 in Tables 2 and 3. We find that adding these health limitations to our Health Index (equation (4)) leaves the estimation results in the employment and hours worked equations virtually unchanged but causes an attenuation bias in the effect of health on wages of more than 50%. While these results are similar to the ones from the restricted HI, the next section shows a substantial attenuation bias in the health effects on employment and hours worked compared to those in the HI and restricted HI when unobserved time-invariant heterogeneity is taken into account. A finding, that we argue, could cast doubt on the validity of using these additional health limitations as instruments for SRH.

Unobserved time-invariant heterogeneity

It is possible that the positive health effects in Models 1, 3 and 4 are driven by unobserved time-invariant heterogeneity. To gain insights into its importance, we re-estimate these models with the inclusion of correlated unobserved effects as explained in section III and present the corresponding results under the headings of Models 5, 6 and 7. Model 5 corresponds to our main (or preferred) specification and we estimate this model as well for women (last columns of Tables 2 and 3). The last rows in each panel of Table 2 test for the importance of correlated random effects and their statistical significance suggests it is important to take this source of endogeneity into account.

Table 2 shows a positive effect of health on wages in Models 5–7, which is lower and only marginally significant for women (last column). For instance, in Models 5, men and women with health at the 75th percentile have, respectively, about a 4% and 2% higher hourly wage rate than their median health peers. Thus, in line with Jäckle and Himmler (2010), we find a significant effect of health on men's wages, one that is small and only marginally significant for women. Men's tenure-wage profile is more concave when correlated unobserved effects are considered, but importantly the effects of tenure and tenure square remain jointly significant at the 5% level of significance. For women, instead, they are insignificant at any standard level of statistical significance (bottom of Panel B). Thus, identification of the effect of wages on employment and hours worked for women is based on functional form only and their results should be treated with some caution.

Table 3, shows that once controlled for correlated random effects (Models 5–7) the direct effect of health on employment increases (panel A), while it leaves the direct effect of health on hours by and large unchanged (panel B). Driven by a negative effect of wage on labour supply, the indirect health effects are negative and significant in Models 5–7 that control for correlated random effects. A comparison of the total health effects for men in Models 1 and 5 corresponding to a one-SD increase in health finds similar effects on employment, of about 13% point, but smaller ones on hours worked, 95 vs. 186 hours more per year. The last column in Table 3 shows that the effects of health on labour supply are somewhat smaller for women (11% point for employment and 76 hours more per year for hours worked).

Regarding the exogeneity of health limitations, excluding the GS variables in Model 6 does not change the health effect on wages in Table 2 but the point estimates of the direct and total health effect in Table 3 are somewhat larger compared to those in Model 5, especially for hours worked, showing a total health effect of 130 vs. 95 hours more per year. Nevertheless, these are minor differences given the standard errors. Instead, including additional limitations in our HI as in Model 7, while leaving the estimation results in the wage equation mostly unchanged, causes an attenuation bias in the total effect of health on employment and hours worked of about 20% and 12%, respectively, which is due to an attenuated direct effect of health on employment and hours worked.[20] Thus, overall the health effects are more similar in Models 1, 2 and 3 than in, respectively, Models 5, 6 and 7, which may cast some doubts on the validity of using these additional health limitations as instruments for SRH.

Robustness of results to an alternative hours equation specification

Finally, in a simultaneous equations model like ours, misspecification of one of the equations can affect the other equations. We, therefore, estimated an alternative model where we set zero hours to missing and use the logarithm of hours as dependent variable in equation (3). The hours equation is estimated as a linear model and is identified by excluding non-labour income.[21] For this alternative model, most health effects in the hours equation are smaller and not statistically significant. The point estimates for the health effects in the wage equation are similar to the earlier ones, but the standard errors are larger resulting in statistically insignificant effects, mostly. Overall, however, and in the employment equation in particular, the main conclusions of the paper remain: the large total effect of health on employment is attributable to the direct health effect and not to its indirect effect through wages (results are available upon request).

[20] A comparison of the total health effects on employment and hours worked in Models 7 and 6 would results in a larger attenuation bias of 25% and 35%, correspondingly.

[21] As this exclusion restriction can seem arbitrary, this additional analysis can be considered a robustness check only.

V. Conclusions

Theoretical economic models predict, based on productivity and reservation wage arguments, that an individual's health affects his or her wage rate and that health and wages affect the employment decision. In fact, the major role of health in determining employment among older workers is well documented in the literature on the health-employment nexus (see e.g. Currie and Madrian, 1999, and references therein). However, with the possible exceptions of Chirikos and Nestel (1985) and Haveman *et al.* (1994), the empirical literature has not disentangled health's direct effect on employment from its indirect effect through wages (Cai, 2009, 2010). This may have led to an incorrect assessment of the hypothesized direct effect of health on employment and, consequently, of the importance of policies aimed at helping employers to accommodate workers with health limitations to keep them employed at older ages.

We have therefore estimated a system of equations for health, wages, employment and hours of work that enables a quantification of both the direct and indirect effects (through wages) of health on employment and hours worked. The model takes into account the endogeneity of the self-reported health measure and our results show that ignoring this attenuates the effects of health on wages, employment and hours worked.

Our findings show that health has positive effects on wages, employment and hours worked. In terms of a health deterioration, defined as a change in health from the 75th to the 50th percentile in the health distribution (or about a 1 SD change), the results from our preferred specification (Model 5) show that it leads for men to about a 12% point lower employment probability and 95 fewer hours worked per year, on average. These effects on the employment probability are the sum of a 20% point direct negative effect and an indirect positive effect of about 8% points. Likewise, the effects on hours worked are the sum of a 171 hours negative direct effect and a 76 hours positive indirect effect. These indirect effects have signs opposite to the signs of the direct effects because of negative wage effects on hours worked and employment. This also suggests that ignoring wages in employment or hours equations leads to an underestimation of the direct health effects. Concerning the effects on hours, it needs to be noted, however, that they appear not robust to using a different specification for the hours equation (section 'Robustness of results to an alternative hours equation specification'). The results for women are similar to those of men with the exception that their hours worked is more elastic with respect to wages which are themselves less (or no) responsive to health, resulting in relatively smaller indirect effects of health on hours worked and employment than that for men.

From a policy perspective, in particular the large direct effects of health on employment imply an instrumental role for policy aimed at helping employers accommodate workers with health limitations so as to keep them on the job at older ages. Such an inference is very much in line with recent calls by Autor and Duggan (2010) and Burkhauser and Daly (2011) for supported work over cash benefits for people with disabilities and, in particular, increased employer incentives to accommodate work-limited employees (Burkhauser and Daly, 2012; OECD, 2017).

Final Manuscript Received: June 2018

References

Autor, D. H. and Duggan, M. (2010). *Supporting Work: A Proposal for Modernizing the U.S. Disability Insurance System* [WWW Document], The Brookings Institution. https://www.brookings.edu/research/supporting-work-a-proposal-for-modernizing-the-u-s-disability-insurance-system/ (accessed 1 February 2013).

Becker G. S. (1964). *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*, University of Chicago Press for the National Bureau of Economic Research, Chicago, IL.

Blundell, R. and MaCurdy, T. (1999). 'Labor supply: a review of alternative approaches', in Ashenfelter O. and Card D. (eds), *Handbook of Labor Economics*, Vol. 3, Amsterdam: Elsevier Science B.V., pp. 1559–1695.

Blundell, R., French, E. and Tetlow, G. (2016). 'Retirement incentives and labor supply', in Piggott J. and Woodland A. (eds), *Handbook of the Economics of Population Aging*, Vol. 1, Amsterdam: Elsevier Science B.V., pp. 457–566.

Bonsang, E., Adam, S. and Perelman, S. (2012). 'Does retirement affect cognitive functioning?', *Journal of Health Economics*, Vol. 31, pp. 490–501.

Börsch-Supan, A. and Jürges, H. (Eds.). (2005). *The Survey of Health, Ageing and Retirement in Europe – Methodology*, MEA, Mannheim.

Bound, J. (1991). 'Self-reported versus objective measures of health in retirement models', *Journal of Human Resources*, Vol. 26, pp. 106–138.

Bound, J., Schoenbaum, M., Stinebrickner, T. and Waidmann, T. (1999). 'The dynamic effects of health on the labor force transitions of older workers', *Labour Economics*, Vol. 6, pp. 179–202.

Bound, J., Brown, C. and Mathiowetz, N. (2001). 'Measurement error in survey data', in Heckman J. J. and Leamer E. (eds), *Handbook of Econometrics*, Vol. 5, New York: Elsevier Science, pp. 3705–3843.

Brown, S., Roberts, J. and Taylor, K. (2010). 'Reservation wages, labour market participation and health', *Journal of the Royal Statistical Society: Series A*, Vol. 173, pp. 501–529.

Burkhauser, R. V. and Daly, M. C. (2011). *The Declining Work and Welfare of People with Disabilities: What Went Wrong and a Strategy for Change*, AEI Press, Washington, DC.

Burkhauser, R. V. and Daly, M. C. (2012). 'Social security disability insurance: time for fundamental change', *Journal of Policy Analysis and Management*, Vol. 31, pp. 454–461.

Burkhauser, R., Glenn, A. and Wittenburg, D. C. (1997). 'The disabled worker tax credit', in Reno V., Mashaw J. and Gradison W. (eds), *Challenges for Social Insurance, Health Care Financing, and Labor Market Policy*, Washington, DC: National Academy of Social Insurance, pp. 47–65.

Cai, L. (2009). 'Effects of health on [the] wages of Australian men', *Economic Record*, Vol. 85, pp. 290–306.

Cai, L. (2010). 'The relationship between health and labour force participation: evidence from a panel data simultaneous equation model', *Labour Economics*, Vol. 17, pp. 77–90.

Chamberlain, G. (1984). 'Panel data', in Griliches Z. and Intriligator M. D. (eds), *Handbook of Econometrics*, Vol. 2, Amsterdam: Elsevier Science B.V., pp. 1247–1318.

Chirikos, T. N. and Nestel, G. (1985). 'Further evidence on the economic effects of poor health', *Review of Economics and Statistics*, Vol. 56, pp. 61–69.

Chung, S., Domino, M. E. and Stearns, S. C. (2009). 'The effect of retirement on weight', *Journal of Gerontology: Social Sciences*, Vol. 64B, pp. 656–665.

Coe, N. B. and Zamarro, G. (2011). 'Retirement effects on health in Europe', *Journal of Health Economics*, Vol. 30, pp. 77–86.

Contoyannis, P. and Rice, N. (2001). 'The impact of health on wages: evidence from the British Household Panel Survey', *Empirical Economics*, Vol. 26, pp. 599–622.

Crossley, T. F. and Kennedy, S. (2002). 'The reliability of self-assessed health status', *Journal of Health Economics*, Vol. 21, pp. 643–658.

Currie, J. and Madrian, B. C. (1999). 'Health, health insurance and the labor market', in Ashenfelter O. and Card D. (eds), *Handbook of Labor Economics*, Vol. 3, Amsterdam: Elsevier Science B.V., pp. 3309–3415.

Daly, M. C. and Bound, J. (1996). 'Worker adaptation and employer accommodation following the onset of a health impairment', *Journal of Gerontology*, Vol. 51, pp. S53–S60.

Datta Gupta, N., Larsen, M. and Stage Thomsen, L. (2015). 'Do wage subsidies for disabled workers reduce their non-employment? Evidence from the Danish Flexjob scheme', *IZA Journal of Labor Policy*, Vol. 4, pp. 1–26.

Disney, R., Emmerson, C. and Wakefield, M. (2006). 'Ill health and retirement in Britain: a panel data based analysis', *Journal of Health Economics*, Vol. 25, pp. 621–649.
Flores, M. and Kalwij, A. (2014). 'The associations between early life circumstances and later life health and employment in Europe', *Empirical Economics*, Vol. 47, pp. 1252–1282.
García-Gómez, P. (2011). 'Institutions, health shocks and labour market outcomes across Europe', *Journal of Health Economics*, Vol. 30, pp. 200–213.
García-Gómez, P., Jones, A. M. and Rice, N. (2010). 'Health effects on labour market exits and entries', *Labour Economics*, Vol. 17, pp. 62–76.
Geweke, J. (1989). 'Bayesian inference in econometric models using Monte Carlo integration', *Econometrica*, Vol. 57, pp. 1317–1339.
Gordon, R. and Blinder, A. (1980). 'Market wages, reservation wages, and retirement decisions', *Journal of Public Economics*, Vol. 14, pp. 277–308.
Gronau, R. (1974). 'Wage comparisons – a selectivity bias', *Journal of Political Economy*, Vol. 82, pp. 1119–1143.
Grossman, M. (1972). 'On the concept of health capital and the demand for health', *Journal of Political Economy*, Vol. 80, pp. 223–255.
Grossman, M. (2001). 'The human capital model', in Culyer A. J. and Newhouse J. P. (eds), *Handbook of Health Economics*, Vol. 1A, Amsterdam: Elsevier Science B.V., pp. 347–408.
Hajivassiliou, V. and McFadden, D. (1998). 'The method of simulated scores for the estimation of LDV models', *Econometrica*, Vol. 66, pp. 863–896.
Haley, W. J. (1976). 'Estimation of the earnings profile from optimal human capital accumulation', *Econometrica*, Vol. 44, pp. 1223–1238.
Haveman, R., Wolfe, B., Kreider, B. and Stone, M. (1994). 'Market work, wages, and men's health', *Journal of Health Economics*, Vol. 13, pp. 163–182.
Heckman, J. J. (1976). 'A life-cycle model of earnings, learning, and consumption', *Journal of Political Economy*, Vol. 84, pp. S11–S44.
Heckman, J. J. (1979). 'Sample selection bias as a specification error', *Econometrica*, Vol. 47, pp. 153–161.
Jäckle, R. and Himmler, O. (2010). 'Health and wages: panel data estimates considering selection and endogeneity', *Journal of Human Resources*, Vol. 45, pp. 364–406.
Kalwij, A. and Vermeulen, F. (2008). 'Health and labour force participation of older people in Europe: What do objective health indicators add to the analysis?', *Health Economics*, Vol. 17, pp. 619–638.
Kapteyn, A., Smith, J. P. and Van Soest, A. (2007). 'Vignettes and self-reports of work disability in the United States and the Netherlands', *American Economic Review*, Vol. 97, pp. 461–473.
Keane, M. P. (1994). 'A computationally practical simulation estimator for panel data', *Econometrica*, Vol. 62, pp. 95–116.
Kodde, D. A., Palm, F. C. and Pfann, G. A. (1990). 'Asymptotic least-squares estimation efficiency considerations and applications', *Journal of Applied Econometrics*, Vol. 5, pp. 229–243.
Layard, R., Nickell, S. and Jackman, R. (1994). *Unemployment: Macroeconomic Performance and the Labour Market*, Oxford University Press, Oxford.
Lazear, E. (1986). 'Retirement from the labor force', in Ashenfelter O. and Layard R. (eds), *Handbook of Labor Economics*, Vol. 1, Amsterdam: Elsevier Science B.V., pp. 305–355.
Lee, L.-F. (1982). 'Health and wage: a simultaneous equation model with multiple discrete indicators', *International Economic Review*, Vol. 23, pp. 199–221.
Lindeboom, M. and Kerkhofs, M. (2009). 'Health and work of the elderly: subjective health measures, reporting errors and endogeneity in the relationship between health and work', *Journal of Applied Econometrics*, Vol. 24, pp. 1024–1046.
Llena-Nozal, A., Lindeboom, M. and Portrait, F. (2004). 'The effect of work on mental health: does occupation matter?', *Health Economics*, Vol. 13, pp. 1045–1062.
Meijer, E., Kapteyn, A. and Andreyeva, T. (2011). 'Internationally comparable health indices', *Health Economics*, Vol. 20, pp. 600–619.
Mincer, J. (1974). *Schooling, Experience, and Earnings*, Columbia University Press for the National Bureau of Economic Research, New York.

Mroz, T. A. (1987). 'The sensitivity of an empirical model of married women's hours of work to economic and statistical assumptions', *Econometrica*, Vol. 55, pp. 765–799.

OECD. (2017). *Preventing Ageing Unequally*. OECD Publishing, Paris. https://doi.org/10.1787/9789264279087-en

Rohwedder, S. and Willis, R. J. (2010). 'Mental retirement', *Journal of Economic Perspectives*, Vol. 24, pp. 119–138.

Roodman, D. (2011). 'Fitting fully observed recursive mixed-process models with CMP', *The Stata Journal*, Vol. 11, pp. 159–206.

Schultz, T. P. and Tansel, A. (1997). 'Wage and labor supply effects of illness in Côte d'Ivoire and Ghana: instrumental variable estimates for days disabled', *Journal of Development Economics*, Vol. 53, pp. 251–286.

Semykina, A., Wooldridge, J. W. (2010). 'Estimating panel data models in the presence of endogeneity and selection', *Journal of Econometrics*, Vol. 157, pp. 375–380.

Snyder, S. E. and Evans, W. N. (2006). 'The effect of income on mortality: evidence from the social security notch', *Review of Economics and Statistics*, Vol. 88, pp. 482–495.

Stern, S. (1989). 'Measuring the effect of disability on labor force participation', *Journal of Human Resources*, Vol. 24, pp. 361–395.

Trevisan, E., Zantomio, F. (2016). 'The impact of acute health shocks on the labour supply of older workers: evidence from sixteen European countries', *Labour Economics*, Vol. 43, pp. 171–185.

Verbeek, M., Nijman, T. (1992). 'Testing for selectivity bias in panel data models', *International Economic Review*, Vol. 33, pp. 681–703.

Westerlund, H., Vahtera, J., Ferrie, J. E., Singh-Manoux, A., Pentti, J., Melchior, M., Leineweber, C., Jokela, M., Siegrist, J., Goldberg, M., Zins, M. and Kivimäki, M. (2010). 'Effect of retirement on major chronic conditions and fatigue: French GAZEL occupational cohort study', *British Medical Journal*, Vol. 341, pp. c6149.

Wooldridge, J. M. (1995). 'Selection corrections for panel data models under conditional mean independence assumptions', *Journal of Econometrics*, Vol. 68, pp. 115–132.

Wu, S. (2003). 'The effects of health events on the economic status of married couples', *Journal of Human Resources*, Vol. 38, pp. 219–230.

Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix S1. Additional table.