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EDUCATION AND ITS EFFECTS ON SURVIVAL, INCOME AND HEALTH OF THOSE AGED SIXTY-FIVE AND OVER IN THE UNITED KINGDOM

Education and its Effects on Health, Income and Mortality of those aged Sixty-five and over in the United Kingdom

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Abstract

We explore the effects of income and, additionally education on the income, self-reported health and survival of people aged sixty-five and over in order to identify benefits resulting from education which are omitted in the conventional analysis with its focus on labour income excluding employer contributions. We find, for men, that income after the age of sixty-five is significantly influenced by educational attainment and has a significant effect on survival. Even after controlling for circumstances at age sixty-five or when first observed, we identify benefits discounted to age sixty-five of £170,000 for men with higher education qualifications as compared to those with minimal qualifications. However, similar effects are not observed for women.

JEL Codes: C33, C35, J17, J24

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8374 Words

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1 Introduction

The purpose of this paper is to explore a hitherto neglected component of the return to education- its impact post-retirement. There are two aspects to this. One is that there is a well-established link between health, mortality, income and education- although a meta-analysis (Baker et al. 2011) suggests that the effects are appreciably less clear for old people than for younger people. If life and good health are valued, then any estimate of the return to education ought to take account of both the direct effect of education and any indirect influence through income on life expectancy and health.

A second influence which is little discussed is that the focus of most studies of the effect of education is on wage income as reported in surveys such as the Labour Force Survey (see for example McIntosh (2006)). To the extent that retirement income is the combination of private pensions or other income generated by savings out of wage income and state benefits, such an approach is perfectly adequate. But historically most private pension schemes have included employer contributions as well as employee contributions and information on the former is not typically collected in the wage data provided by household surveys. Employer contributions in fact form the majority of pension saving. These are usually wage-related and have the consequence of augmenting the absolute values of the wage differentials generated by different types of education. Thus a failure to take any account of them must have the effect of depressing estimated returns to education below their true values. In this paper we estimate both these effects and indicate their discounted value.

The connections between education, income, health and mortality are well-established (Smith 1999, Marmot Review 2010) and have been explored in a number of different ways. Economou & Theodossiou (2011) find that, for people aged forty-five to sixty-five, both education and income affect health status, after using instrumental variables to correct for the possible role of health as a driver of income. Silles (2009) finds a clear causative influence of education on health for people aged sixty or under. Other studies look at the effects of lottery winnings (Lindahl 2005) and German unification (Frijters et al. 2005).

Barker et al. (2002) argue that adult disease is strongly influenced by foetal experience, although in studies of twins both Fujiwara & Kawachi (2009) and Madsen et al. (2009) find that education plays a separate role as a determinant of adult health. Gould et al. (2011) show the importance of childhood circumstances on adult outcomes. Case & Paxson (2011) establish a link between birth-weight, childhood health subsequent career success. Related work shows a connection between childhood factors and subsequent mortality. Thus Whalley & Deary (2001) find a link between IQ at age 11 and the risk of death before the age of 76 but, in the absence of other control variables, this of course does not say anything about the possible magnitude of income and education effects. Batty et al. (2006) find that the effects of income on mortality are attenuated but not removed if one takes account of respondents' IQ measured at the age of 56. But of course this, itself, may be a consequence of past education and income. Lager et al. (2009) find, on taking account of childhood IQ, education and income that the latter two that the impact of the latter to explain health and mortality is not much affected by the inclusion of childhood IQ as an explanatory variable. Eide & Showalter (2011) survey the field, suggesting that results typically depend on the way in which possible individual effects are treated.

In this paper we use the British Household Panel Survey to explore the relationship between health, income and educational status in the United Kingdom for people aged sixty-five and over. For this age group income is unlikely to be strongly influenced by current health status, although it may of course be influenced by past health status. Similarly, income is likely to be strongly influenced by past education; as noted above people are likely to receive pensions which reflect their past earnings. In most of Europe it is unlikely that income has a significant influence on access to medical care but it is easy to imagine other ways in which it can influence health, for example by affecting expenditure on heating in the winter. Education may, however, have a separate influence on both health and mortality, perhaps because ability to make good use of the National Health Service depends on education.

After estimating equations explaining self-reported health and mortality and examining influences on the incomes of people aged sixty-five and over, we then simulate them to establish the effects of education on morbidity, mortality and income. The results of this exercise depend on the conditioning assumptions. Two sets of findings are presented. The first is for a population with the characteristics of the British Household Panel Survey. Given the model developed, this means that the correlations present in the data between educational status and smoking and health status at age sixty-five are reflected in the simulated consequences of education on morbidity and mortality. Secondly, it is assumed that health status at age sixty-five and smoking behaviour are uncorrelated with education. This makes it possible to examine the marginal effect of education after conditioning on these variables.

With either set of assumptions, standard estimates of the value of a quality-adjusted life year then make it possible to estimate the present discounted value of the effect of education on morbidity and mortality to a twenty-one year old. Adding this to the component of pension income attributed to employer rather than employee contributions, and thus not shown in conventional measures of returns to education, then makes it possible to estimate the full value of the post employment benefits of education.

2 The Data

The British Household Panel Survey (BHPS) started in 1991[1]. It is an annual survey that provides a panel of socio-economic data set over time. It interviewed each member of a household aged 16 and over, from an initial sample of over five thousand households. The same household members are then re-interviewed in the following waves. If a member leaves the original sample household, that person, as well as the other members of the new household (aged 16 and over) are recruited for the panel. New households are also included in the survey each year in order to compensate for attrition. Deaths and non-responses are recorded. Our interest centered on the following information the BHPS provides.

1. The response to the question on self-assessed health, "Please think back over the last 12 months about how your health has been. Compared to people of your own age, would you say that your health has on the whole been...?" Respondents are requested to report "Excellent", "Good", "Fair", "Poor", or "Very Poor". Although this is a question about relative health, the results presented by Khoman et al. (2008) suggested it could be interpreted as a proxy for a question on absolute health. In order to avoid the numerical problems which would arise if we attempted to estimate an ordered probit model to explain health status as part of our system, we aggregate the health categories, treating someone who reports their health as fair, good or excellent as having good health, with everyone else regarded as having poor health.

2. Whether an individual did not respond or was reported dead.

3. Information on household income; this is described in more detail below.

[1] University of Essex. Institute for Social and Economic Research, British Household Panel Survey: Waves 1-17, 1991-2008 [computer file]. 6th Edition. Colchester, Essex: UK Data Archive [distributor], May 2009. SN: 5151.

4. The response of an individual to the question "Do you smoke cigarettes?" Respondents are required to report "Yes" or "No".

5. Information on qualifications; this is also set out in more detail below.

We were interested in the penultimate question because smoking is generally believed to be an important determinant of mortality; it was nevertheless not included in the variables considered by Contoyannis et al. (2004) in their study.

These data were collected in all waves except wave 9 in 1999; on that occasion there were marked differences in the way people were asked to describe their health state; secondly and perhaps more importantly, people were not asked to compare their health with that of others of the same age. Since our analysis uses both the current and lagged responses to the question on health we omit waves 9 and 10, from 1999 and 2000 from our analysis.

Non-response and death are recorded in BHPS, in the variable that states "Individual interview outcome"[2] that is recorded in two data sets of the BHPS, first the data set that contains individual-level data for respondents (i.e. record type wINDRESP) and secondly the data set that contains individual-level data for issued households (i.e. record type wINDSAMP). The former, although containing individuals' responses to the questions of our interest, covers only individuals who were actually interviewed (either in full, by proxy or by telephone). In order to obtain full information on respondents, non-respondents, and those reported dead, we merged the two data sets.

It is household income rather than individual income which should be expected to influence health and mortality. In any case for retired people the concept of individual income is not defined in the precise way that it is for employment income. State benefits, whoever they are paid to, reflect domestic circumstances and private pensions may include survivor benefits and thus are, in some sense, joint income rather than individual income. The BHPS provides a gross measure of the household income. However, the net measure of household income is more appropriate for our purposes (see Jenkins (2010)).

We therefore use the unofficial supplement to the income variables in the official BHPS release, the "British Household Panel Survey Derived Current and Annual Net Household Income Variables, BHPS waves 1-16, 1991-2007" constructed by the Institute of Social and Economic Research, University of Essex (see Levy & Jenkins (2008)) in our analysis. This supplementary data set contains information for those BHPS households

[2]This is given by variable wIVFIO.

in which all eligible household members have participated in a full interview. Those households in which one or more members refused to participate in the BHPS or whose information were given by a proxy respondents are excluded. The data set provides estimated currently weekly household net income and annual household net income for each wave. It also provides variables that classify individuals according to their family type and economic status of their family. For more detail, see Levy & Jenkins (2008). Current weekly household net income and the annual household net income are recorded in the variable "whhnetde2" and "whhnyrde2" in the ISER supplement, respectively. Both variables measure total household net income which is equivalised using the Modified OECD scale (with a single adult counting as one person and a couple as 1.5 people) to adjust for differences in household composition and size. The variables are also adjusted to January 2008 prices using a "before housing cost" price index.

The data on educational attainment in the survey are very detailed. These were classified to match, with one exception[3], the national scale which ranges from 0 (for those with no or only minimal qualifications) to 5 for those with post-graduate degrees. The system was originally designed to represent national vocational qualifications (NVQs) but academic qualifications have also been calibrated against it, allowing most qualifications to be represented on an equal basis. In common with other work (e.g. Blanden et al. (2010)) we merge categories 4 and 5. Our classification of qualifications is shown in table **??**.

To construct our sample, we merge, wave by wave, the combined wINDRESP and wINDSAMP data set of the BHPS from above to the ISER supplement using the household identifier. Since the last available wave we consider in the ISER supplement is wave 16 (year 2006), our study thus uses the data of original sample members (OSM) between 1991 to 2006, aged 65 and over.

3 Education, Income, Health and Survival in the British Household Panel Survey

In this section we present a summary of the data from the British Household Panel Survey showing, in broad terms, the relationships we subsequently explore in greater detail. Table 2 shows the mean income classified by educational level for our pooled data set. We can see clearly that the incomes of people aged sixty-five and older are

[3] Our classification differs slightly from the National Qualifications Framework which classes GSCEs at grades D to G as level 1 and grades A* to C as level 2.

Table 1: The Classification of Qualifications

Level 1
Youth training certificate
Trade appenticeship
Clerical and commercial qualifications
City and Guilds Certification Part I
SCOTVEC National Certiciate Modules
NVQ/SVQ level 1
GCSEs
SCEs grade D-E or 4-5
O grades A-C or 1-3
Standard grades 4-7
CSEs
O-levels (pre-1975), OLs (post-1975)
SLCs
Level 2
City and Guilds Certification Part II
SCOTVEC Higher National Units
NVQ/SVQ level 2
CPVE
1 A level
Standard grades 1-3
GNVQ
AS level
School Certificate or Matriculation
1 Higher School Certificate
Level 3
City and Guilds Certification Part III
SCOTVEC National Certificate or Diploma
ONC, OND, BEC/TEC/BTEC General Certificate
NVQ/SVQ level 3
2 or more A levels
2 or more Higher School Certificates
Higher grades
Certificate of 6th year studies
Level 4
HNC, HND, BEC/TEC/BTEC/SCOTVEC Higher Certificate or Higher Diploma
NVQ/SVQ level 4
Nursing qualifications (e.g. SEN, SRN, SCM, RGN)
Teaching qualification
University diploma or Foundation degree
University or CNAA First Degree (e.g. BA, B.Ed, BSc)
University or CNAA Higher Degree (e.g. MSc, PhD)

Table 2: Mean Annual Income (£2008 prices) and Qualifications

	Mean annual equivalised household income (£2008)		Number	
Qual. Level	Men	Women	Men	Women
0	10436	9644	3646	6570
1	12361	11332	1571	1470
2	15877	13302	736	855
3	14440	13296	444	171
4	18801	15443	1012	1314

Table 3: Qualfication, Self-reported Health and Smoking Behaviour

	Proportion in poor health		Proportion smoking	
Qual. Level	Men	Women	Men	Women
0	17.2%	17.9%	19.4%	16.7%
1	11.3%	14.6%	15.3%	11.0%
2	10.1%	7.3%	9.5%	11.0%
3	9.7%	18.7%	13.1%	9.4%
4	4.8%	10.3%	5.9%	7.9%

increasing in their qualification level, with the exception that men qualified to level 3 receive lower incomes than those qualified only to level 2.

Just as qualification level is related to income, so too qualification level is related to health. In table 3 we show the proportion of respondents reporting poor or very poor health classified by their qualification levels. We also show the proportion of people classified by qualification level who report that they smoke. Among men it is clear that health status improves with qualifications. The effect is less obvious with women but after one allows for the fact that there are rather few women qualified to level 3, as table 2 shows, it does appear that health status is generally improving with qualification level. Smoking is widely believed to be a cause of poor health, so we also show the relationship between smoking behaviour and qualification level. For both men and women one can observe the general pattern that smoking prevalence declines with qualification level.

Given the relationship between health and mortality one might expect to see higher mortality rates for people with low-level qualifications. So as to summarise the data compactly, we show in table 4 the mortality rates identified in the British Household Panel Survey for men and women distinguish those educated to levels 0 or 1 from those education to level 2 or higher. We can see that, for both men and women and for all age categories except women aged 70-74, mortality rates are lower for those with at least

Table 4: Mortality Rates and Education

	Men		Women	
Age	Qual. Level 0-1	Qual. Level 2-4	Qual. Level 0-1	Qual. Level 2-4
65-69	2.1%	1.0%	1.6%	0.8%
70-74	3.6%	2.9%	2.0%	2.4%
75-79	5.4%	3.2%	3.4%	2.4%
80-84	8.4%	3.7%	4.4%	4.3%
85+	12.2%	9.1%	10.9%	6.8%

level 2 education than for the rest of the survey population.

Finally, we are concerned about the relationship between income, health and mortality. An indication of the connection between health status and income is provided in table 5. Here we show the proportion of the male and female population reporting poor health (poor or very poor in the original classification) distinguishing respondents by whether their income was above or below the median. Table 6 shows mortality rates calculated on the same basis, but with the income classification based on the year before death was reported.

As the introductory discussion makes clear, we also need to address the issue of non-response. Table 7 summarises the probability of non-response as a function of age and education. Non-response rates are generally below mortality rates. Nevertheless, to the extent that unreported mortality is a substantial source of non-response, a failure to address non-response appropriately could be a substantial source of error in the component of our model which represents the risk of death.

These data show clear relationships between education, health and mortality in old age. However, since the proportion of smokers is generally higher among poorly-educated people, this effect may be a consequence of smoking behaviour. The relationship between income and health is more clearly marked for men than for women and this is also true of the apparent connection between income and mortality. The nature of these relationship is investigated further in the econometric analysis which now follows.

Table 5: Proportion Reporting Poor Health classified by Income

	Men		Women	
	Poor health	Good health	Poor health	Good health
Below median	7.8%	42.2%	8.4%	41.6%
Above median	5.3%	44.7%	7.2%	42.8%

Table 6: Mortality Rates by Income Category

	Men		Women	
Age	Below median	Above median	Below median	Above median
65-69	2.8%	1.2%	2.1%	1.0%
70-74	4.0%	2.7%	2.3%	1.9%
75-79	5.7%	3.6%	3.3%	3.1%
80-84	9.0%	4.2%	4.0%	4.9%
85+	13.4%	8.0%	11.3%	8.4%

Table 7: The Probability of Non-response given a Reply in the Previous Wave

Age	Men		Women	
	Qual. Level 0-1	Qual. Level 2-4	Qual. Level 0-1	Qual. Level 2-4
65-69	5.5%	3.7%	4.3%	2.9%
70-74	3.9%	1.3%	3.5%	1.2%
75-79	3.3%	2.3%	4.1%	1.8%
80-84	2.9%	3.0%	5.7%	2.4%
85+	6.2%	4.3%	8.1%	6.8%

4 The Econometric model

4.1 Education

The first question addressed was that of separating the effects of education and income from individual characteristics which might influence education and income but also affect health state and survival. An ordered probit model was used to explain educational status as a function of year of birth. As suggested by Silles (2009), a dummy was introduced indicating whether the respondent was born in 1933 or later, reflecting the fact that the school leaving age was raised from fourteen to fifteen in 1947. The generalised residuals from this equation (*Edres)* were introduced as explanatory variables in the subsequent equations of the model.

4.2 Health State, Mortality and Response

A set of individual variables was used to explain income, health state, mortality and response. It is helpful to set these out at this stage although not all variables are used in all equations. . First define the vector

$$\mathbf{X}_{it} = (Edres, H_i^1, H_i^2, H_i^3, H_i^4, J_i^1, J_i^2, J_i^3, J_i^4, S_{it-1}, E_i^1, E_i^2, E_i^3, E_i^4, Age, Age^2, YearDummies).$$

Here H_i^k $(k = 1..4)$ are dummies that correspond to the four health categories ("Very poor", "Poor", "Fair"and "Good") reported at age sixty-five or when first observed if later, with the dummy for the top category, excellent, omitted for identification reasons. This deals with the initial conditions problem as suggested by Wooldridge (2005), and also allows us to explore the effects of education taking health at age sixty-five as given. J_i^k represents the analogous variable for health state as reported in the first wave of the survey; the need to distinguish these from the H_i^k dummies is explained subsequently. S_{it-1} takes a value 1 if the respondent reports smoking in the previous period and 0 otherwise. E_{it-1}^k $(k = 1..4)$ is educational status, with E_i^k taking a value of 1 if the respondent is educated to level k and 0 otherwise.

The second stage of the study involved exploring the joint influences of these variables on health, mortality and response. Initially this was done using multivariate methods. So as to be able to use these the health responses were consolidated. The variable GH_{it} was set to 1 if the individual report good or excellent health and to 0 otherwise.

The latent variables that underlie the health state, mortality and participation in the survey were defined as gh_{it}, d_{it} and r_{it}. Thus, $GH_t = 1$ if $gh_{it} > 0$, $D_{it} = 1$ if $d_{it} > 0$, and $R_{it} = 1$ indicating response if $r_{it} > 0$.

The equations initially considered were then

$$gh_{it} = \alpha_1 GH_{it-1} + \vartheta_1 LY_{it-1} + \mathbf{X}_{it}\boldsymbol{\beta}_1 + \varepsilon_{1,it} \tag{1}$$

$$d_{it} == \alpha_2 GH_{it-1} + \vartheta_2 LY_{it-1} + \mathbf{X}_{it}\boldsymbol{\beta}_2 + \varepsilon_{2,it} \tag{2}$$

$$r_{it} = \alpha_3 GH_{it-1} + \vartheta_3 LY_{it-1} + \mathbf{X}_{it}\boldsymbol{\beta}_3 + \textit{Regional Dummies} + \varepsilon_{3,it} \tag{3}$$

with the coefficients on the H_i^k set to zero in equation (3) and those on the J_i^k set to zero in the other two equations.

We initially explored using a trivariate model to understand the influences on health state transition, death and non-response. With such a framework there are two forms of censoring. First, there is no information on whether non-respondents die or survive. Secondly, no health state is reported for those who die. There are obvious merits to treating death as a process separate from health state transition and non-response rather than following (Contoyannis et al. 2004), treating it as a form of non-response along with genuine non-response, or, following (Khoman et al. 2008), treating it as the lowest of a number of health states in an ordered probit model. In any case treating mortality along with other forms of non-response does not make it possible to estimate the effect of variables such as education on healthy life expectancy. Such a trivariate system might in principle be estimated from the pooled data using maximum simulated likelihood via the STATA routine *MVNP* (Cappellari & Jenkins 2003). The *MVNP* routine uses the GHK (Geweke-Hajivassiliou-Keane) smooth recursive simulator (see Geweke (1989), Hajivassiliou & Ruud (1994) and Keane (1994)) to approximate the trivariate normal density. However, this approach did not prove practical because the estimation did not converge. This was true even though regional dummies were introduced into equation (3) and restrictions on equation (1) were explored to enhance identification.

Instead, therefore we investigated the evidence for correlation between the unexplained components of the latent variables driving health, mortality and non-response. We did this by estimating three censored bivariate probit models examining jointly health state transitions and mortality, non-response and mortality, and health state transitions and the absence of a response treated in the manner of (Contoyannis et al. 2004), i.e. whether due to genuine non-response or reported mortality. The probit equations were structured using the variables we describe subsequently for the models used to explore the relationship between education, income, health and survival with the same explanatory variables used for non-response and absence of a response. The χ_1^2 likelihood ratio tests for the significance of the relevant correlations for both men and women are shown in table 8. It should be noted that, while we include health state at age sixty-five, or when first observed, as explanatory variables for mortality and health state, bivariate estimation delivers corner solutions when these are also included as explanatory variables for response. This was despite the fact that the regional dummies proved statistically significant in the response equation. The problem was avoided by including instead health state as reported in the first wave of the survey, as was also done in the trivariate specification described above.

Table 8: Pairwise LR tests for Residual Correlation

	Men	Women
Health state and mortality	1.2	0.6
Non-response and mortality	0.4	0.0
Health state and absence of response	0.1	1.8

These statistics suggest that the hypothesis of independence between the residuals can be accepted, allowing estimation of the probit models driving the relevant transitions independently of each other[4]. This does not, however, remove the need to deal with the problem of non-response; it suggests only that the coefficients of models of mortality hand health state transitions will not be significantly affected by non-response due to unobserved influences. Contoyannis et al. (2004) used weighting as a means of addressing the problem, with the weights computed from the inverses of the probabilities of response, as suggested by Wooldridge (2002). The same method is applied here, although Jones et al. (2006) suggest that, working with the first eleven waves of the same survey, weighting in this way to correct for non-response has little effect, despite the fact that health influences the probability of response.

The probability of non-response conditional on response in previous periods is given as πr_{it} =1-$\Phi\left(\alpha_3 GH_{it-1} + \vartheta_3 LY_{it-1} + \mathbf{X}_{it}\beta_3\right)$ where the coefficients take their estimated values. The weight applied to the observation for individual i in year t is then computed, with t_0 the age at which the respondent was first observed, or sixty-five if later, $\pi r_{it_0} = 1$ as

$$\prod_{\tau=t_0}^{t-1} 1/\pi r_{i\tau}.$$

These weights can be applied in estimating equations (1) and (2) and also used in estimating the income equation. Before estimating the health and mortality equations it is necessary to explore the determinants of income so as to take account of the possible individual effects which may influence both income and survival.

4.3 Income

The first step in the modelling of income is the calculation of the expected level of (log) income as a function of a respondent's characteristics at age sixty-five or when first

[4] Lillard & Panis (1998) in a study of the effects of attrition on the Panel Survey of Income Dynamics, found that there was evidence of interdependence between non-response and some other transitions of interest. However correction for the effects of interdependence was not of material importance.

observed and their actual age. Given this the framework suggested by Guvenen (2007) is used to represent income dynamics after the age of sixty-five. The specification, described by equation (4), explains income of individual i in year t, LY_{it} in terms of the vector $\mathbf{X}_{it}$ of exogenous variables also used to explain health[5] and mortality and an innovation process that is commonly considered to provide a good balance between parsimony and the complexity that characterises reality.

$$\begin{aligned} LY_{it} &= \mathbf{X}_{it}\boldsymbol{\beta}_1 + \omega_i + \varepsilon^y_{it} + z_{it} & \text{(4a)} \\ z_{it} &= \rho_b z_{it-1} + \eta_{it} & \text{(4b)} \\ \omega_i &\sim iidN\left(0, \sigma^2_\omega\right) & \text{(4c)} \\ \varepsilon^y_{it} &\sim iidN\left(0, \sigma^2_\varepsilon\right) & \text{(4d)} \\ \eta_{it} &\sim iidN\left(0, \sigma^2_\eta\right) & \text{(4e)} \end{aligned}$$

The error structure includes a fixed effect, ω_i, a serially uncorrelated effect, ε^y_{it} and a serially correlated term, z_{it}. If ρ takes the value 1, then the model has a unit root in individual income. Unlike Guvenen, however, we cannot include cohort or year dummies as influences on the error process and nor can we include individual-specific trends in earnings because our sample size is limited.

We denote the earnings residual after controlling for population average effects of individual i in year t by $u_{it} = y_{it} - \mathbf{X}_{it}\boldsymbol{\beta}_4$, with $\boldsymbol{\beta}_4$ now taking its estimated value. We set the indicator variable $I_{i,t}$ to 1 if earnings (and thus residuals) are observed for individual i in year t, and to 0 otherwise. The $\frac{T(T+1)}{2}$ elements of the covariance matrix in time of the population earnings residuals:

$$v_{t,t+k} = \frac{\sum_i u_{i,t}u_{i,t+k}I_{i,t}I_{i,t+k}}{\sum_i I_{i,t}I_{i,t+k}}, \qquad 1 \leqslant t \leqslant T, 0 \leqslant k \leqslant T-t$$

can then be evaluated. Elements of the theoretical covariance matrix implied by the model described by equations (4a) and (4e) can also be computed:

$$E\left[u_{i,t}u_{i,t+k}\right] = \sigma^2_\omega + J_k\sigma^2_\varepsilon + \rho^k\sigma^2_\eta\frac{1-\rho^{2\tau+2}}{1-\rho^2}$$

where J_k takes a value 1 if $k = 0$ and 0 otherwise, and τ is the number of years elapsed since individual i reached the age of sixty-five. Thus the theoretical counterpart of $v_{t,t+k}$ is given as:

$$\tilde{v}_{t,t+k} = \frac{\sum_i E\left[u_{i,t}u_{i,t+k}\right]I_{i,t}I_{i,t+k}}{\sum_i I_{i,t}I_{i,t+k}}, \qquad 1 \leqslant t \leqslant T, 0 \leqslant k \leqslant T-t$$

[5] Although, in keeping with most work on returns to education, we do not include smoking behaviour.

A Gauss-Newton algorithm can then be used to adjust the four model parameters $\left(\sigma_\omega^2, \sigma_\varepsilon^2, \sigma_\eta^2, \rho_\alpha\right)$ to minimise the sum of the squared difference between the fitted and theoretical values of the covariance terms:

$$\sum_{t,k} \left(v_{t,t+k} - \tilde{v}_{t,t+k}\right)^2$$

ρ_α is restricted to the interval [-1,1] by estimating a model specified in terms of $\tanh \rho_\alpha$.

The fixed effect ω_i can be estimated from $u_{i,65}$, the estimated residual for people aged sixty-five or when first observed as $Incres_i{=}\sigma_\omega^2 u_{i,65}/(\sigma_\omega^2 + \sigma_\varepsilon^2 + \sigma_\eta^2)$. This is used in the subsequent estimation of equations to explain health state and mortality.

4.4 Modelling Health and Mortality

As explained above, following on from the estimation of the income equation, the final equations explaining the latent variables which drive health and mortality are

$$\begin{aligned} gh_{it} &= \alpha_1 GH_{it-1} + \vartheta_1 LY_{it-1} + \gamma_1 Incres_i + \mathbf{X}_{it}\boldsymbol{\beta}_1 + \varepsilon_{1,it}; \\ \varepsilon_{1,it} &\sim N(0,1), E(\varepsilon_{1,it}\varepsilon_{1,it+k} = 0), k \neq 0 \end{aligned} \tag{5}$$

$$\begin{aligned} d_{it} &= \alpha_2 GH_{it-1} + \vartheta_2 LY_{it-1} + \gamma_2 Incres_i + \mathbf{X}_{it}\boldsymbol{\beta}_2 + \varepsilon_{2,it}; \\ \varepsilon_{2,it} &\sim N(0,1), E(\varepsilon_{1,it}\varepsilon_{1,it+k} = 0), k \neq 0 \end{aligned} \tag{6}$$

These are estimated after weighting to correct for the effects of subsequent non-response by initial respondents to the survey.

5 Results

Table 9 presents the parameters of an ordered probit model which explains the educational attainment of each respondent as a linear function of his/her year of birth with an extra term to represent the effects of the raising of the school leaving age from fourteen to fifteen in 1947. Each person in the pooled data set was included only once when these parameters were estimated. The significantly positive coefficient on year of birth captures the effects of the general rise in educational attainment during the twentieth century. The dummy for people born in 1933 or afterwards and thus affected by the raised school leaving age is significantly positive for men but insignificant for women.

Table 9: Parameter Estimates of an Ordered Probit Model of Educational Attainment for the BHPS Sample

Education	Men		Women	
	Coeff	s.d	Coeff	s.d
Year of birth	0.019	0.005	0.028	0.005
1933 or later	0.212	0.108	0.054	0.103
Cut 1	0.762	0.170	1.399	0.147
Cut 2	1.334	0.171	1.846	0.149
Cut 3	1.640	0.173	2.164	0.151
Cut 4	1.921	0.175	2.238	0.151
Observations	1252		1629	
Pseudo R^2	0.019		0.026	

The generalised residuals from these equations (*Edres*) are introduced as explanatory variables in the subsequent models so as to address the possibility that effects which might otherwise be attributed to education are in fact explained by other influences which also affect educational attainment.

We show in tables 10 and 11 the parameter estimates for the response, income, health and mortality and response equations for both men and women. The income equation is estimated first and the residuals (*Incres)* from this for respondents at the age of sixty-five or when first observed if older are introduced in the other equations again so as to capture the role of any individual effects established when initially observed which may be correlated with income. The only other continuous variable in the three equations are log of income, age and age^2; otherwise all variables are dummies. Thus *Smoke* takes the value 1 if an individual smokes and 0 otherwise, the variables *Qual Level 1 to Qual Level 4* take a value 1 if that particular level of qualification is the individuals highest level and 0 otherwise. *Good Health*$_{t-1}$ takes a value 1 if the individual reports good or excellent health in the previous period and the *Health* terms at age 65 or in wave 1 indicate into which of the health categories people gave in their responses at age sixty-five or initially. A positive coefficient in the second equation indicates that the respondent with the attribute represented by the related variable is more likely to be in good health; a positive coefficient in the third equation indicates that the respondent is more likely to die and a positive coefficient in the fourth equation indicates that the respondent is more likely to respond.

The general pattern is that income and health effects are better determined for men than for women. Looking at men the parameters suggest that response is significantly more likely for men in good health than in poor health, while the Wave 1 effects are not statistically significant. Conditional on health state, the significant linear and quadratic terms imply that the peak response rate occurs at age seventy-six with response rates by very old people declining. There are also significant regional effects. Turning to the average income equation, the residual for the education term is not significant, and, despite its inclusion, there are significant effects of education on income for men educated to levels 2, 3 and 4. No explanation is offered why the effect of education to level 3 is smaller than that to level 2, although this was foreshadowed in table 2. The difference between them is not of statistical significance. There are significantly effects of health at age sixty-five on subsequent income; the most obvious route for this being that health at age sixty-five is a consequence of health while younger and that this has influenced past earning capacity and therefore pension income after retirement. Previous good health is a strong indicator of subsequent good health while fair, poor or very poor health at age sixty-five are also strong influences. The education terms are not significant. While the age terms are quadratic, the parameters indicate that the probability of reporting good health declines with age over the relevant range.

The education terms were suppressed from the mortality equation because, in contrast to the health equation, they were highly insignificant even in the absence *Edres*. The parameters suggest that income is a significant negative influence on mortality risk even although *Incres* is included as an explanatory variable. Smoking is a strong influence on mortality; a failure to control for this would be likely to result in overstating the influence of other factors correlated with this. Health state in the previous period is, as often found, a highly significant predictor of mortality but, subject to this, only those with very poor health or fair at age sixty-five show significantly augmented mortality risk. When the equation was initially estimated with linear and quadratic age effects, neither was statistically significant and the quadratic term was therefore suppressed. A final point is that, for both men and women the dynamics of the income pattern, shown by the parameters of table 12, point to a combination of clear individual fixed effects, short-term noise and serially correlated shocks. Nevertheless, there is an element of reversion and the parameters are not consistent with income being a random walk.

The parameters offer a route by which it might be anticipated that educational status would have a significant influence on both expected income and expected healthy life from age sixty-five onwards, even after conditioning on health status at the age of sixty-five. Education has a significant effect on income and income has a significant effect on survival. So well-educated men might be expected both to enjoy an income higher than that received by poorly-educated men and to enjoy it for longer. Income has a positive influence on the probability of being in good health. While this is not statistically significant it is likely to augment the effects described earlier.

Turning to women, the first general point to be borne in mind is that the school-leaving dummy is not statistically significant and that therefore it is necessary to rely on non-linearity for identification. Looking at the response equation, health is once again an influence on the probability of response. The age effects are quadratic, but point to response rates declining with age from sixty-five onwards. There are regional effects, although Wales is the only region for which response rates by both men and women are low. The income equation suggests a picture rather different from that of men; the education terms are not statistically significant. If, however, *Edres*, which is not statistically significant, is suppressed, then a rather different picture emerges, with coefficients on the education terms which are significant, but smaller than those found for men. In the absence of other possible variables explaining educational status, it is, however, not possible to say whether the insignificance of the education terms is a consequence of the particular specification used or a more robust finding.

The health equation shows a significant coefficient on *Incres* and a highly insignificant coefficient on lagged income, suggesting that the influence of income on health (which is apparent if *Incres* is suppressed) arises through the individual factors which influence income at the age of sixty-five, rather than through income itself. Smoking is a significant adverse influence on health, an effect not found with men. The dynamics of health itself are similar to those of men, with previous good health a strong driver of current good health and with health state at age sixty-five also significant. The age effect is restricted to be linear, because when a quadratic term is included neither it nor the linear term are significant.

The education terms, including *Edres* are suppressed from the mortality equation for the same reason as with men; they are highly insignificant whether *Edres* is included in the equation or not. In contrast to men, the effect of income is not significant, after controlling for the income-related individual effects represented by *Incres.* The coefficient of the effect of smoking is similar to that for men and the pattern of the influence of previously reported health state and health at age sixty-five is similar although weaker than for men. Both linear and quadratic age effects are present. Not surprisingly, they imply that mortality rates increase with age over the relevant range.

In broad terms, while the general pattern of parameters estimated for men suggested routes by which education might influence income and healthy life expectancy after the age of sixty-five, such patterns cannot be seen from the parameters estimated for women.

6 Model Simulation

While it has been possible to speculate about the routes by which education might influence healthy life expectancy after the age of sixty-five for men, it is necessary to resort to simulation to quantify these influences and produce indicators of their reliability. Simulation makes it possible to examine the relationship between education and an overall indicator of welfare from age sixty-five onwards, with the latter reflecting the sum of discounted income and a valuation of discounted healthy life.

Our overall model reduces to the form shown in equations (7 - 9). Here $\mathbf{X}_{it}$ is the vector of exogenous variables (age, year, smoking status and health state when first observed), y_{it} is the log of income and GH_{t-1} is the dummy taking the value 1 if the respondent reports good health at time $t-1$. However, *Edres* set to zero in the simulations.

$$gh_{it} = \alpha_1 GH_{it-1} + \vartheta_1 LY_{it-1} + \gamma_1 Incres_i + \mathbf{X}_{it}\boldsymbol{\beta}_1 + \varepsilon_{1,it};\ Var(\varepsilon_{2,it}) = 1 \qquad (7)$$

$$d_{it} = \alpha_2 GH_{it-1} + \vartheta_2 LY_{it-1} + \gamma_2 Incres_i + \mathbf{X}_{it}\boldsymbol{\beta}_2 + \varepsilon_{2,it};\ Var(\varepsilon_{1,it}) = 1 \qquad (8)$$

$$LY_{it} = \mathbf{X}_{it}\boldsymbol{\beta}_4 + u_{i,t} \qquad u_{i,t} \text{ defined in (7)} \qquad (9)$$

To simulate the model we require appropriate values for $\mathbf{X}_{it}$ and appropriate values for the relevant error terms. It should be noted that the probability of death depends on the fitted value given by equation (8) which we denote $\hat{d}_{it}$ rather than the perturbed value. This probability is given by $\pi d_{it} = \Phi\left(\hat{d}_{it}\right)$ where $\Phi()$ is the cumulative normal density function. The mean probability of death at age $\tau, \pi d_\tau$, is then given as the average of the πd_{it} over the appropriate population. The probability of good health is similarly defined. In the simulation the year dummies are set to their average values for the sample.

6.1 Exogenous Variables

In order to simulate the effects of education, it is necessary to begin with appropriate values of $\mathbf{X}_{it}$ for population to be simulated. A sample of the required size is drawn from the population represented in the data set, sampling with replacement. Using the

Table 10: Estimation Results: Men

	Response		Income		Good Health		Mortality	
	Coeff	s.d.	Coeff	s.d.	Coeff	s.d.	Coeff	s.d.
Incres					0.082	0.077	-0.045	0.074
Edres	-0.396	0.284	-0.065	0.065	-0.001	0.182		
Log Inc_{-1}	0.031	0.061			0.087	0.062	-0.151	0.061
Smoke	-0.050	0.083			-0.081	0.075	0.299	0.075
Good Health $_{-1}$	0.212	0.094			1.244	0.084	-0.676	0.081
V. Poor Health at 65			-0.037	0.068	-1.900	0.247	0.486	0.187
Poor Health at 65			-0.195	0.061	-1.236	0.119	0.133	0.128
Fair Health at 65			-0.130	0.042	-0.595	0.097	0.206	0.090
Good Health at 65			-0.110	0.038	-0.117	0.091	0.079	0.081
V. Poor Health Wave 1	0.192	0.255						
Poor Health Wave 1	-0.026	0.134						
Fair Health Wave 1	-0.058	0.092						
Good Health Wave 1	0.012	0.079						
Education Level 1	0.532	0.323	0.128	0.076	0.147	0.206		
Education Level 2	0.829	0.466	0.440	0.118	0.243	0.308		
Education Level 3	0.788	0.534	0.339	0.125	0.238	0.372		
Education Level 4	1.082	0.710	0.654	0.157	0.297	0.443		
Age	0.183	0.090	-0.011	0.002	-0.143	0.086	0.048	0.004
$\text{Age}^2/100$	-0.120	0.057			0.079	0.056		
1993	0.021	0.106	0.074	0.016	-0.177	0.143	0.046	0.125
1994	0.435	0.128	0.046	0.017	-0.389	0.111	-0.144	0.138
1995	0.489	0.132	0.064	0.019	-0.188	0.123	-0.081	0.133
1996	0.689	0.150	0.084	0.021	-0.187	0.116	-0.141	0.132
1997	0.761	0.161	0.107	0.023	-0.365	0.123	-0.165	0.140
1998	0.808	0.166	0.103	0.022	-0.393	0.115	-0.011	0.131
2001	0.665	0.161	0.154	0.035	-0.268	0.118	-0.439	0.159
2002	0.441	0.148	0.179	0.035	-0.447	0.118	-0.230	0.144
2003	0.455	0.153	0.213	0.032	-0.304	0.126	-0.151	0.139
2004	0.533	0.166	0.237	0.031	-0.323	0.128	-0.223	0.145
2005	0.282	0.151	0.255	0.036	-0.286	0.135	-0.139	0.144
2006	0.632	0.181	0.305	0.032	-0.457	0.128	-0.175	0.146
London	0.005	0.146						
South-East	0.065	0.129						
South-West	-0.001	0.135						
East Anglia	0.171	0.163						
East Midlands	0.253	0.156						
West Midlands	0.051	0.144						
North-West	-0.038	0.134						
Yorkshire	0.355	0.157						
North	-0.159	0.146						
Wales	0.349	0.192						
Constant	-6.318	3.611	9.909	0.184	6.220	3.416	-3.455	0.704
Observations	6900		6347		6347		6665	
R^2/Pseudo R^2	0.072		0.193		0.300		0.127	
Standard error			0.480					

Table 11: Estimation Results: Women

	Response		Income		Good Health		Mortality	
	Coeff	s.d.	Coeff	s.d.	Coeff	s.d.	Coeff	s.d.
Incres					0.173	0.061	-0.105	0.072
Edres	-0.029	0.162	0.101	0.050	0.152	0.127		
Log Inc_{-1}	0.083	0.050			-0.007	0.055	-0.032	0.061
Smoke	0.055	0.076			-0.166	0.059	0.283	0.070
Good Health $_{-1}$	0.233	0.072			1.107	0.055	-0.338	0.075
V. Poor Health at 65			0.023	0.058	-1.691	0.146	0.315	0.164
Poor Health at 65			-0.119	0.047	-1.556	0.111	0.415	0.123
Fair Health at 65			-0.105	0.039	-0.862	0.091	0.270	0.102
Good Health at 65			-0.066	0.038	-0.441	0.088	0.148	0.097
V. Poor Health Wave 1	0.120	0.161						
Poor Health Wave 1	-0.060	0.111						
Fair Health Wave 1	-0.024	0.078						
Good Health Wave 1	-0.014	0.070						
Education Level 1	0.163	0.208	-0.044	0.063	-0.157	0.158		
Education Level 2	0.233	0.284	0.061	0.093	0.004	0.231		
Education Level 3	0.330	0.373	0.052	0.126	-0.295	0.283		
Education Level 4	0.374	0.376	0.167	0.113	-0.260	0.288		
Age	0.101	0.067	-0.013	0.002	-0.021	0.004	-0.172	0.070
$\text{Age}^2/100$	-0.083	0.042					0.140	0.044
1993	0.137	0.085	0.009	0.016	-0.098	0.101	0.332	0.127
1994	0.539	0.102	0.038	0.016	-0.193	0.093	0.247	0.131
1995	0.652	0.110	0.048	0.017	-0.235	0.086	0.327	0.128
1996	0.694	0.114	0.110	0.017	-0.298	0.092	0.136	0.136
1997	0.719	0.116	0.114	0.019	-0.402	0.089	0.275	0.131
1998	0.894	0.130	0.131	0.019	-0.389	0.092	0.247	0.130
2001	0.592	0.114	0.199	0.031	-0.340	0.092	0.243	0.138
2002	0.621	0.120	0.307	0.023	-0.312	0.098	0.008	0.148
2003	0.772	0.133	0.325	0.025	-0.276	0.100	0.109	0.152
2004	0.697	0.131	0.335	0.028	-0.274	0.102	0.269	0.138
2005	0.574	0.125	0.378	0.027	-0.125	0.103	0.066	0.155
2006	0.679	0.134	0.439	0.026	-0.370	0.102	0.185	0.147
London	0.033	0.111						
South-East	0.079	0.096						
South-West	0.022	0.105						
East Anglia	0.320	0.142						
East Midlands	0.252	0.122						
West Midlands	0.081	0.114						
North-West	0.353	0.110						
Yorkshire	0.129	0.107						
North	0.231	0.125						
Wales	0.240	0.133						
Constant	-2.717	2.704	10.034	0.151	2.861	0.642	3.174	2.892
Observations	9848		9105		9105		9460	
R^2/Pseudo R^2	0.091		0.172		0.273		0.117	
Standard error			0.475					

Table 12: Coefficients of the Income Process

	Men		Women	
	Coeff	s.d.	Coeff	s.d.
σ^2_ω	0.0609	0.0192	0.0712	0.014
σ^2_ε	0.0603	0.0115	0.0634	0.009
σ^2_η	0.0331	0.0073	0.0273	0.0059
tanh ρ	1.3069	0.2245	1.2855	0.2038
ρ	0.8635	0.0571	0.858	0.0538

sample population observations for initial health state, education and smoking behaviour ensures that these variables have the same correlations in the simulated population as in the sample. It might be thought desirable, of course, to use only those aged sixty-five as a basis for constructing the simulated population. However the small sample size suggested that, on balance, it would be better to use a larger group from which to sample repeatedly and we draw from the population of those aged between sixty-five and sixty-nine. The initial value of GH_{it-1} is of course consistent with the first-observed value of health status present in $\mathbf{X}_{it}$.

As noted in the introduction, these population characteristics can be varied. By allocating educational status randomly, it becomes possible to observe the effects of education conditional on health status when first observed. This has the consequence of showing the incremental effects of education on health and survival beyond the age of sixty-five while removing the influence of education on health status up to that age.

6.2 Simulation of Mortality Rates, Life Expectancy, Expected Income and Healthy Life Expectancy

It is now possible to simulate jointly income and the two latent variables which determine health state and the probability of mortality. For each individual i with specified $\mathbf{X}_{i65}$ at age 65 we draw a vector of the four required error terms $[\varepsilon^1_{it}, \varepsilon^2_{it}, \omega_i, \varepsilon^y_{it}, z_{it}]$ from the distributions specified above. This allows us to compute values of gh_{it}, providing us with the value of GH_{it} to be used subsequently, and $\hat{d}_{it}$. The latter allows us to calculate the probability of death as discussed above.

The probability of surviving from age sixty-five to the τth birthday $(\tau \geq 65)$ is

$$s_{i\tau} = \prod_{\kappa=65}^{\tau-1} (1 - \Phi\left(\hat{d}_{i\kappa}\right))$$

Life expectancy at age 65 for individual i is

$$e_{i65} = 1 + \sum_{\kappa=66}^{\infty} s_{i\kappa}.$$

There are a number of possible ways of calculating simulated expected time in good health. One is to consider the expected time spent alive with $GH = 1$, much as proposed by Sullivan (1971) and European Health Expectancy Monitoring Unit (2007). However, this does not reflect the full gamut of possible health and Cutler & Richardson (1998) make a transformation of the unbounded variable gh_{it} into the interval [0,1] as a measure of health state. The approach they adopt, working with a six-point health scale is to assume that all individuals reporting the top health state have health measured as 1 while all those in the lowest state have health measured as 0. Thus, in effect they truncate the distribution at the cut points for the top and bottom categories. Those with intermediate health are allocated values computed as the difference of their latent health variable from the lowest cut point scaled by the interval between the lowest and highest cut points. It seems preferable to use a probit transformation of gh_{it}, computed of course after including the random term ε_{it}^{h}. Then the probability that someone is alive to enjoy the level of health indicated by $\Phi(gh_{it})$ is s_{it} so that discounted health-adjusted life expectancy at age sixty-five is

$$h_{i65} = \Phi(gh_{i65}) + \sum_{\kappa=66}^{\infty} \delta^{\kappa-65} s_{i\kappa} \Phi(gh_{i\kappa}).$$

Thus the discounted value of income from sixty-five onwards[6] is given as

$$Y_{i65} = e^{LY_{i65}} + \sum_{\kappa=66}^{\infty} \delta^{k-65} s_{i\kappa} e^{LY_{ik}}.$$

The values of h_{i65} and Y_{i65} can be discounted back to age twenty-one by multiplying by δ^{44}.

The values of these variables for any subgroup, such as those with a specified level of education, are calculated as the mean value of each variable for that subgroup. Formally, if I_i is an indicator which takes a value 1 when individual i is a member of subgroup S and 0 otherwise then

$$e_{S65} = \sum_i I_i e_{i65} / \sum_i I_i; \quad i \in S$$

with similar calculations for h_{i65} and Y_{i65}.

[6] There is a question whether in assessing the benefits of education, one should take into account the risk of mortality before the age of sixty-five. We have followed general practice in not doing so.

6.3 Parameter Uncertainty

The calculations above are performed for a fixed set of model parameters estimated as described above. But the standard errors associated with these parameters do not provide any direct indication of the uncertainty surrounding our estimates of the group averages of the variables of particular interest to us. These also have to be computed by simulation.

The procedure we use is to simulate the experiences of a population of fifty thousand people five hundred times, with random values for the model parameters redrawn for each of these five hundred simulations from the distribution implied by their variance-covariance matrices and the assumption that they are jointly normally distributed. The relevant variance-covariance matrices are those associated with the parameters of tables 10, 11 and 12. For any given set of model parameters,

$$\boldsymbol{\zeta} = [\alpha_1, \vartheta_1, \boldsymbol{\beta}_1, \gamma_1, \alpha_2, \vartheta_2, \boldsymbol{\beta}_2, \gamma_2, \boldsymbol{\beta}_4, \sigma_\omega^2, \sigma_\varepsilon^2, \sigma_\eta^2, \rho_a],$$

we compute the aggregates of interest, $e_{S65}(\boldsymbol{\zeta})$, $h_{S65}(\boldsymbol{\zeta})$ and $Y_{S65}(\boldsymbol{\zeta})$. The mean values of these across the simulations provide estimates of the variables concerned. The standard errors of the simulations provide an indication of the reliability of the estimates. In these calculations we have treated the stochastic model of income disturbances and the probit model of household size as having deterministic coefficients.

In order to asses whether differences between aggregates for subpopulations, R and S are significant, it is necessary to take account of possible covariances between the disturbances to the two variables. This is most easily done by computing, for each simulation, the difference between the two aggregates, for example $e_{R65}(\boldsymbol{\zeta}) - e_{S65}(\boldsymbol{\zeta})$. The standard deviation of this can then be compared with either its simulated mean or its value computed using the originally estimated parameters so as to indicate whether $e_{R65}(\boldsymbol{\zeta}) - e_{S65}(\boldsymbol{\zeta})$ is likely to be of statistical significance. This allows us to estimate both the differences between income, healthy life expectancy and life expectancy for people of different educational attainment and also provides standard errors of these estimates.

6.4 Indicators of welfare

An overall indicator of welfare can be constructed by placing a monetary value on healthy life and adding this to remaining lifetime income. In order to do this it is necessary to value a healthy life year. Mason et al. (2009) draw attention to a range of valuations between £30,000 and £70,000 at 2005 prices. The National Institute of Clinical Excellence used £30,000 at current prices in 2008 (National Institute of Clinical Excellence 2008, Chapter 8, p.54) to value healthy life, while Muller et al. (2011) use the much larger figure of £160,000 (US$265,000) in their study of the costs of pollution damage in the United States. Nevertheless, in the light of this range we adopt a value of £40,000 per health-adjusted year of life. This builds an element of caution into the results [7].

Secondly, some account needs to be taken of the fact that, to the extent that post-retirement income is a consequence of saving out of recorded labour income, the direct benefits of it have already been accounted for traditional estimates of the returns to education. As explained in the introduction, differences in income after age sixty-five are largely a consequence of differences in occupational pensions. These are financed both by employee contributions, which are included in conventional analysis of the returns to education, and employer contributions which are omitted. Thus the income differential needs to be multiplied by the ratio of employer contributions to total contributions in order to correct for this. The national accounts show that, on average employers contributed about 70% of the total cost of pensions[8] and we therefore used this ratio to identify the impact of education on post-retirement income over and above that accounted for by saving out of reported income accruing during working life. This second indicator is referred to as an adjusted welfare indicator.

7 Post-retirement Benefits of Education

Using the methods described in section 6, we calculate the values of discounted life expectancy, discounted health-adjusted life expectancy and discounted income for people with each of the five levels of education which we identify. These calculations are performed for a non-smokers and smokers separately, who are in good health at age sixty-five. Were we to attribute differential smoking habits and health status at age sixty-five to education, then the computed benefits of education would be larger than those shown here. We also present estimates of the differences in these aggregates for

[7] An alternative approach to valuing life is provided by Murphy & Topel (2006). They base theirs on the utility enjoyed by people who are alive. But the practical problem with this approach is that it requires a cardinal utility function. The widely used CES function is negative unless some constant is added back on. The appropriate constant can be estimated only by forming a view about the level of consumption at which life becomes not worth living. Given the judgements involved it is not clear that the approach is superior to the methods surveyed by Mason et al. (2009)

[8] The average share of employer contributions in the total over the period 1974-1996 was 73%. Since 1997 the national accounts do not distinguish employee contributions from individual purchases of life insurance policies. Pensioners also typically received lump sums on retirement and we have implicitly assumed that these account for the large part of investment income received by those over sixty-five.

someone educated to levels 1 to 4 relative to someone educated to level 0.

Attention in tables 13 and 14 is focused on five variables. First life expectancy is shown. Secondly, expected remaining lifetime income is indicated, discounted back to the age of sixty-five. Thirdly, healthy life expectancy is shown, discounted on the same basis. The indicators of welfare and adjusted welfare are calculated as described above, with a healthy life year valued at £40,000. The adjusted measure is shown only in terms of its increment to welfare obtained with level 0 education, because the proportion of 70%, applied to marginal and not to overall income. Standard deviations are presented for the mean effects; these are computed from the individual simulations and thus take account of the interdependence between healthy life expectancy and income when computing the standard deviation for the estimate of overall welfare.

Two types of simulation are presented. The first is constructed using randomly-selected individuals as described in section 6.1. This process means that the correlations between education, smoking behaviour and health status at age 65 are replicated in the simulated population. The income fixed effects are also those of the population. However, these are orthogonal to educational status since they are computed from the residuals of the equation shown in table 12.

The second set of simulations is constructed with educational status allocated randomly across the sample, so that it is uncorrelated with health status and smoking behaviour at age sixty-five. It remains, of course, a driver of income from the age of sixty-five onwards, by virtue of the income equation. Nevertheless, the first set of estimates shows the effects of education if one assumes that differences in health and smoking status at age sixty-five associated with variations in education are a consequence of it. The second indicates the outcome after controlling for effects of education on health at age sixty-five and separately on smoking behaviour. While the results in Blundell et al. (2005) suggest that the former might indicate the full effects of education on income, with Silles (2009) suggesting if anything an understatement for the effects of education on health, the second approach shows only the incremental effects of education on health and income after taking account of any follow-on benefits arising from health state at age sixty-five.

For both men and women the simulations based on the representative population indicate substantial effects associated with education. For men there are statistically significant influences on life expectancy, discounted income and discounted healthy life expectancy, cumulated to substantial differences in welfare. Those with level 3 education

Table 13: The Impact of Education on Life Expectancy at Age 65 (LE), Discounted Retirement Income (Income), Discounted Healthy Life Expcetancy at age 65 (Disc HLE), Welfare and Welfare after adjusting for Employee Pension Contributions (Adj. Welf.) : Men

	Education Level					Difference from Level 0			
	0	1	2	3	4	1	2	3	4
					Representative Sample				
LE (years)	17.1	19.4	20.4	19.8	21.3	2.3	3.3	2.7	4.2
s.d	1.1	2.6	1.7	1.1	1.2	2.9	2.3	1.7	1.9
Income (£)	132,451	179,634	237,243	211,828	293,065	47,183	104,792	79,377	160,614
s.d.	9,097	17,032	23,622	20,316	35,155	21,133	28,925	26,028	41,729
HLE (years)	9.7	11.6	12.4	12.1	12.9	1.9	2.7	2.4	3.2
s.d.	0.7	1.1	1.0	0.9	1.0	1.5	1.5	1.4	1.7
Welfare (£)	520,307	642,513	731,537	695,755	810,823	122,205	211,230	175,447	290,516
s.d.	35,910	61,327	55,573	46,702	63,350	76,789	78,458	72,266	89,754
Adj. Welf.(£)						108,050	179,792	151,634	242,332
s.d.						71,238	71,851	67,162	81,119
					Education uncorrelated with Characteristics at Age 65				
LE (years)	17.9	18.7	19.6	19.4	20.3	0.8	1.7	1.5	2.4
s.d	1.0	2.4	1.6	1.1	1.2	2.7	2.1	1.7	1.8
Income (£)	143,058	164,699	229,652	208,270	286,425	21,641	86,594	65,212	143,367
s.d.	9,099	14,830	23,403	20,093	35,926	19,131	28,573	26,400	42,775
HLE (years)	10.4	11.1	11.8	11.7	12.2	0.7	1.4	1.3	1.8
s.d.	0.7	1.0	0.9	0.9	1.0	1.3	1.4	1.4	1.6
Welfare (£)	558,761	608,864	701,572	675,491	774,300	50,103	142,810	116,730	215,539
s.d.	33,137	54,361	53,408	47,319	64,372	67,910	73,540	71,573	88,603
Adj. Welf.(£)						43,610	116,832	97,167	172,529
s.d.						63,083	67,103	66,218	79,527

Table 14: The Impact of Education on Life Expectancy at Age 65 (LE), Discounted Retirement Income (Income), Discounted Healthy Life Expcetancy at age 65 (Disc HLE), Welfare and Welfare after adjusting for Employee Pension Contributions (Adj. Welf.) : Women

	Education Level					Difference from Level 0			
	0	1	2	3	4	1	2	3	4
Representative Sample									
LE (years)	20.3	21.0	22.5	20.5	21.7	0.7	2.2	0.2	1.4
s.d	0.5	0.5	0.6	0.7	0.7	0.3	0.4	0.7	0.5
Income (£)	152,349	154,695	184,876	164,256	198,435	2,346	32,527	11,907	46,086
s.d.	5,339	6,398	12,645	17,482	16,925	9,394	15,830	19,731	20,754
HLE (years)	11.3	11.3	13.0	10.3	11.6	0.1	1.8	-1.0	0.4
s.d.	0.3	0.4	0.7	1.0	0.9	0.6	0.8	1.2	1.1
Welfare (£)	602,524	607,259	705,645	575,000	663,504	4,735	103,120	-27,525	60,979
s.d.	15,381	19,487	31,373	48,322	42,475	26,199	38,181	56,181	51,496
Adj. Welf.(£)						4,031	93,362	-31,097	47,153
s.d.						25,035	35,872	53,462	48,575
Education uncorrelated with Characteristics at Age 65									
LE (years)	21.0	20.7	21.0	20.6	20.7	-0.3	0.0	-0.5	-0.4
s.d	0.5	0.5	0.5	0.6	0.6	0.3	0.4	0.5	0.5
Income (£)	159,871	152,669	169,682	166,788	185,349	-7,202	9,812	6,918	25,478
s.d.	5,667	5,986	11,3400	17,252	15,378	9,206	14,637	19,636	19,428
HLE (years)	11.8	11.2	11.8	10.6	10.8	-0.6	0.0	-1.2	-1.0
s.d.	0.3	0.5	0.7	1.0	1.0	0.6	0.9	1.2	1.2
Welfare (£)	631,970	600,713	641,349	591,560	616,009	-31,257	9,379	-40,410	-15,961
s.d.	16,003	20,357	30,780	45,929	44,371	28,116	38,112	54,223	54,305
Adj. Welf.(£)						-29,097	6,436	-42,486	-23,605
s.d.						27,033	36,369	51,808	51,946

experience, however, lower benefits than those with only level 2 education. This is a consequence of the weaker effect on income; the latter has an influence on both health state while alive and survival prospects. The second set of simulations, with health state at age sixty-five and smoking behaviour orthogonal to education shows much weaker effects on life expectancy and discounted healthy life expectancy; this reflects the importance of health state at age sixty-five as an influence on these. The reduced impact on discounted income is a consequence of the weaker impact on survival prospects, cumulating to a substantially lower impact on welfare. Nevertheless, for a man educated to level 2 there is an effect on adjusted welfare significant at a 10% level while for someone educated to level 4 the effect is significant at 5%. The difference in adjusted welfare between men educated to level 2 and to level 4 amounts, discounted to the age of twenty-one, to just under £12,500, somewhat more than the maximum annual university tuition fee of £9000 charged from 2012 onwards.

For women the effects are much weaker and less well determined than those for men, a point to be expected in the light of the weaker effects shown when comparing tables 10 and 11. In the representative sample there is a significantly positive relationship between educational attainment and life expectancy and also between education and discounted income. But the effect on healthy life expectancy and on welfare is significant only for those educated to level 2. More pertinently, looking at the effects of education on experience from the age of sixty-five onwards, the effects on both life expectancy and discounted healthy life expectancy are close to zero, suggesting that the relationship observed in the representative population is fully accounted for by the more favourable circumstances educated women enjoy at the age of sixty-five. Putting these together, it is not surprising that the impacts on welfare and adjusted welfare are, for women, insignificant and of indeterminate sign.

8 Conclusions

In this paper we have explored the relationship between income, health, mortality and education in the population aged sixty-five and over. A much clearer picture is established for men than for women. It is found that health and mortality can be modelled independently, while an analysis of non-response makes it possible to weight the sample to correct for the particular characteristics of those remaining in the sample.

For men income post retirement is found to be related to education and is a statistically significant influence on mortality; the effect on self-reported health is not found to be significant. Education does not exert separate direct effects on either health status after the age of sixty-five or on mortality. Simulation makes it possible to investigate the relationship between educational attainment, post-retirement income, life expectancy and healthy life expectancy. Conditioning on circumstances at the age of sixty-five, post-retirement income depends significantly on educational attainment. However, despite the link observed in the mortality equation, the effect on life expectancy and healthy life expectancy is not significant. Nevertheless, the analysis suggests that for men, there are substantial benefits to education accruing after the age of sixty-five, which are not included in a conventional analysis of returns to education. with the total omitted benefit for someone with higher education relative to someone with minimal qualifications amounting to £170,000 discounted to the age of sixty-five or £37,000 discounted to the age of 21. An upper limit to the benefits can be identified by looking at a simulated population with the relationship between characteristics at age sixty-five and education representative of the sampled population; this suggests a full benefit of just under £250,000 associated with higher education.

An important driver of the results is the fact that pensions received by the population studied were financed by employer contributions omitted from traditional surveys of wage income. These results are, of course, based on the population which was at least sixty-five in 1991 or reached that age between

The effects observed for women are very much weaker, with little sign of any effect after conditioning on health and other circumstances at the age of sixty-five. However, for the representative population there is some evidence of a relationship between education and life expectancy and also between education and income. However once these are combined to give indicators of welfare significant effects are found only for women educated to Level 2. It is possible only to speculate why the results for women are weaker than those for men. In a population born later than that studied here, in which women are more likely to have pursued careers of their own, it is possible both that the relationship between education and income will become better determined but it will be some time before that question can be explored.

A major driver of the finding that there are, for men, education related benefits not observed in conventional studies arises from the fact that some part of employee compensation is paid as employer-funded pension contributions. Recently many employers have reduced their pension commitments. Nevertheless Forth & Stokes (2010) show that private sector employers continue to make contributions. The mean contribution depends on the nature of the scheme but, for those with defined contribution arrangements, it found that the mean employer contribution to defined contribution occupational schemes was 14% of pay while to personal pension schemes it was 9% of pay. Thus, despite the general perception of widespread reductions in employer contributions, they remain substantial. Unless they fall further, they will continue to comprise an important component of the return to education omitted from conventional analysis.

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