Wages and the Demand for Health – A Life Cycle Analysis*

Christian Dustmann† Frank Windmeijer‡

IFS Working Paper No. W99/20

Abstract

This paper presents a life cycle model for the demand for health, and derives empirical specifications that distinguish between permanent and transitory wage responses. Using panel data, we estimate dynamic health and health input demand equations. We find evidence of negative transitory wage effects, and positive permanent effects. Our results emphasise the importance to analyse health related behaviour in a dynamic life cycle context.

Key Words: Demand for Health, Life Cycle Models, Panel Data
JEL- Classification: C23, D91, I12

1 Introduction

Individual health and longevity are of rising public and political concern as both have important effects on public spending. Low health standards impose a heavy burden on welfare institutions, and many government interventions in Western countries are aimed at improving health levels. Across populations, we observe considerable variations in life expectancy and health status, which are largely explained by factors like wealth, technology, and the availability of medical services. On an individual level, genetic conditions may trigger illnesses, and impact on health and longevity. However, much of the variation in health status as well as longevity between individuals is due to the way resources are allocated to health enhancing measures. Conditional on genetic factors and other exogenous determinants, health as well as longevity are largely objects of individual choice.

To understand the links between individuals' socio-economic characteristics and their health status is an important prerequisite for successful health related policies. To define target groups for government health programs requires an understanding of which groups are most at risk. It is not surprising that much research effort has been devoted to establishing a link between individual specific characteristics, and health status as well as longevity. In this context, an interesting question for economists is how individual health is related to the individual's income situation. Although it is well understood

* We are grateful for comments on earlier drafts of the paper by Jerome Adda, Orazio Attanasio, Laura Blow, Richard Blundell, Axel Borsch-Supan, Hide Ichimura, Costas Meghir, Ian Preston, Walter Ried, Jayne Taylor, Adam Wagstaff, and seminar participants at the 5^{th} European workshop on Econometrics and Health Economics, the Universities of Bielefeld, Cambridge, Kent and Sussex, and the Institute for Fiscal Studies. This study is part of the programme of research of the ESRC Center for the Microeconomic Analysis of Fiscal Policy at IFS. The financial support of the ESRC is gratefully acknowledged.

†University College London, Department of Economics, Gower Street, London WC1E 6BT, and Institute for Fiscal Studies.

‡The Institute for Fiscal Studies, 7 Ridgmount Street, London WC1E 7AE.

that there is an association between income and health on an individual level, the precise nature of this relationship is not clear.

To date, the empirical evidence which exists on the link between income, or wages, and individual health status is not conclusive. In other areas of economics, like consumer behaviour or labour supply, it is by now well understood that the effect of wages on decisions concerning these choices have to be analysed within a life cycle decision model. The empirical health literature however tends to neglect the implications of the intertemporal nature of the demand for health when estimating health demand functions.

The theoretical foundations for understanding the demand for health in an intertemporal context have long been laid. An important first contribution to analysing the demand for health within a choice theoretical framework was made by Grossman (1972a, 1972b). In his model, health can be augmented by health investments, which are generated by combining medical care services and time. Health serves two purposes. Firstly, it affects longevity. Secondly, it generates instantaneous benefits by enhancing productive time in every period, and by providing direct utility. Grossman's model has in subsequent years been extended in various directions. Recent contributions have, for instance, explored the implications of uncertainty for the optimal demand for health (e.g. Dardanoni and Wagstaff (1990), Seldon (1993), Picone, Uribe and Wilson (1998), and Liljas (1998)), or they have enhanced the understanding of the comparative dynamics of the model (e.g. Ried (1998, 1999), and Eisenring (1999)).

In a recent paper, Ehrlich and Chuma (1990) develop a version of the Grossman model in continuous time. Unlike in Grossman's original work, in their model health investments are produced by combining goods and time using a technology which exhibits decreasing (as opposed to constant) returns to scale. They argue that a constant returns to scale technology introduces an indeterminacy with respect to the optimal health investment and health maintenance choices, and that no interior solution for the demand for health investments generally exists.[1] While in Grossman's original work the demand for health is generated by its instantaneous benefit only, in Ehrlich and Chuma's version of Grossman's model, the demand for health is derived in conjunction with longevity and consumption choices. It depends on current period variables, as well as initial endowments, and is defined also if health creates no instantaneous benefit.

The empirical implications of Ehrlich and Chuma's work have long gone unnoticed. Based on their version of the Grossman model, we derive *Frisch* demand functions (see Browning, Deaton and Irish (1985)) for health and health inputs. These demand functions relate current period demands to current period variables, and to the relative marginal utility of health to wealth. This parameter links current period decisions with the entire future and history of the individual's optimisation problem. It is a sufficient statistic for all out of period information which affects current period demand. Frisch demand functions provide a natural way to distinguish between transitory and permanent demand responses. Changes in current period wages affect demand for health and health services by moving an individual along her wage profile. Across individuals, differences in current period wages lead to variations in the entire wage profile.

In contrast, Grossman's (1972a) empirical formulation of his model produces demand functions which are determined by current period variables only if the instantaneous benefit of health is to enhance time (the *investment model*); they depend, in addition, on the marginal utility of wealth if the instantaneous benefit is to increase utility (the *consumption model*). These demand functions can not be derived without assuming an instantaneous benefit of health. Most empirical papers take

[1]See Ried (1998, 1999) on this point, who argues that under certain conditions, the *derived* demand for health inputs can be determined.

Grossman's equations for the demand for health and health services as a starting point for econometric specifications (for instance, Cropper (1981), Muurinen (1982), Wagstaff (1985, 1993), Pohlmeier and Ulrich (1995), and Geil et al. (1997)). Nearly all these models relate current period health measures to current period variables only.[2]

In our empirical specification, the demand for health and health services depends on contemporaneous variables, and on an individual specific parameter which represents all outside period information influencing current period decisions. This parameter is not observable, and it is a function of all present, future, and historic values of the model variables. In our empirical analysis, we concentrate on wage elasticities of the demand for health and health inputs. So far, the empirical literature has led to ambiguous results concerning this elasticity. We show that straightforward regression analysis, as, for instance, suggested by Grossman's investment model, produces parameter estimates which may not be meaningful. These estimates are a mixture of transitory and permanent wage responses.

We estimate demand for health capital equations, where we use as an approximation for health capital the (self-reported) state of health of individuals. We also estimate demand for health investment equations, where health investment is a combination of time and health services, which are bought in the market. We use as a measure for health investment whether the individual is involved in sporting activities. On both variables, we have repeated information on the same individual. The additional variation in demands within the same individual over time allows us to identify short term wage responses. Under the assumption that health capital provides no instantaneous benefits, differencing techniques can be used to identify transitory wage responses. In a second stage we impose structure on the shadow price of health capital, which allows us to identify permanent effects as well.

We propose a simple test for whether health capital has instantaneous benefits. If health provides instantaneous benefits, estimators based on within-individual differencing do not identify the parameters of interest. To identify transitory wage responses in this case, we rely on a matching type estimation procedure which compares individuals with the same predicted unobserved heterogeneity components.

Our results lend support to a dynamic model structure which distinguishes between permanent and temporary wage responses. We obtain negative transitory wage effects, and positive permanent effects. The implications for health related policies to be drawn from our specification are different, and may even lead to opposite conclusions, than those drawn from a model which neglects the inherent dynamic structure of the problem.

The structure of the paper is as follows. In section 2, the equations for the demand for health services, health inputs and the stock of health are derived. Section 3 describes the data. Section 4 discusses the empirical estimation of these equations and presents the results of our empirical analysis. Section 5 concludes.

2 The Model

We follow Ehrlich and Chuma (1990) and develop a version of the Grossman model in continuous time. We then derive the demand functions for health and health services. Individuals maximize utility which is defined over consumption $c(t)$ and healthy time $h(t)$. They invest in health for two reasons: to delay death, which is endogenously determined, and to obtain an instantaneous benefit. This benefit is created by enhancing healthy time $h(t)$. Healthy time has three purposes: It is allocated

[2] A notable exception is Wagstaff (1986), who estimates the consumption model where health demand depends on the marginal utility of wealth.

to labour market activities, it increases utility, and it is invested into health production. Death occurs when the stock of health hits a critical minimum level. Healthy time at t depends on the stock of health capital $H(t)$, which depreciates over the life cycle with an increasing rate $\sigma(t)$. Health capital is produced using time $m(t)$ and health services $M(t)$ as inputs.

The equation of change for health capital is given by

$$\dot{H}\left(t\right)=I\left(t\right)-\sigma\left(t\right)H\left(t\right); \quad H\left(0\right)=H_{0}, \tag{1}$$

where $I(t)$ is investment in health capital, $\sigma\left(t\right)$ is the depreciation rate on health capital, with $\dot{\sigma}\left(t\right)>0$, and H_0 is the stock of health at $t=0$.

Investments in health capital, $I(t)$, are produced with a decreasing returns to scale technology, using goods (or health services) $M(t)$ and time $m(t)$. We assume the technology to be of a constant elasticity type:

$$I\left(t\right)=\phi\left(t\right)M\left(t\right)^{a}m\left(t\right)^{b}, \tag{2}$$

where the parameters a and b denote the shares of $M(t)$ and $m(t)$ respectively, with $a+b<1$. The good $M\left(t\right)$ summarises all inputs into the production of health capital which can be bought in the market place. The parameter $\phi\left(t\right)$ is a technology parameter.

The individual's time constraint is given by

$$h\left(t\right)=m\left(t\right)+l\left(t\right), \tag{3}$$

where $h\left(t\right)$ is healthy time, which is a concave function of the stock of health at time t. It is divided between time used to produce health capital, $m\left(t\right)$, and time devoted to the labor market, $l\left(t\right)$. Accordingly, health capital enhances the total time available for these two activities.

The cost minimizing demand function for services $M\left(t\right)$ is given by

$$M\left(t\right)=\left[\frac{a}{b}\right]^{\frac{b}{a+b}}p_{M}^{-\frac{b}{a+b}}w\left(t\right)^{\frac{b}{a+b}}\phi\left(t\right)^{-\frac{1}{a+b}}I\left(t\right)^{\frac{1}{a+b}}. \tag{4}$$

The resulting cost function is given by

$$C\left(t\right)=\pi\left(w\left(t\right),p_{M},\phi\left(t\right)\right)I\left(t\right)^{\frac{1}{a+b}}, \tag{5}$$

with unit cost π:

$$\pi\left(w\left(t\right),p_{M},\phi\right)=B\phi(t)^{-\frac{1}{a+b}}p_{M}^{\frac{a}{a+b}}w\left(t\right)^{\frac{b}{a+b}} \quad ; \quad B=\left[\frac{a}{b}\right]^{\frac{b}{a+b}}+\left[\frac{a}{b}\right]^{\frac{-a}{a+b}}, \tag{6}$$

where $w\left(t\right)$ is the wage rate per unit of time, and p_M is the price for inputs into health production. For simplicity, p_M is assumed constant over time.

Using (3), (5), and (6), wealth develops according to the following equation of change:

$$\dot{A}=rA\left(t\right)-\pi(t)I\left(t\right)^{\frac{1}{(a+b)}}-p_{c}c\left(t\right)+w\left(t\right)h\left(t\right); \quad A\left(0\right)=A_{0}, \tag{7}$$

where r is a (time-constant) interest rate, and A_0 is the initial stock of wealth. Consumption in period t is given by $c\left(t\right)$, with unit price p_c.[3]

[3]In contrast to Grossman's model, where $c\left(t\right)$ is also produced inside the household, we assume for simplicity that consumption goods are purchased directly in the market place.

The individuals' utility function is given by

$$\int_0^T [u(c(t)) + v(h(t))]\, e^{-\rho t} dt, \tag{8}$$

where $u\,(.)$ and $v\,(.)$ are strictly concave, and ρ is the rate of impatience.

Death occurs at time T, which is endogenously determined. The individual dies when the state of health hits a critical level H^C. At the end of life, the individual is assumed to leave no debts. The optimization problem is now to maximize (8) with respect to (1) and (7) and the following two end point restrictions:

$$H\,(T) = H^C, \;\; A\,(T) \geq \overline{A}, \tag{9}$$

where $\overline{A} \geq 0$ is the stock of wealth at $t = T$.

Denote the marginal utility of wealth and the marginal utility of health by $\lambda_1\,(t)$ and $\lambda_2\,(t)$ respectively. Then the Hamiltonian is given by

$$\begin{aligned} K &= [u(c(t)) + v(h(t))]e^{-\rho t} \\ &\quad + \lambda_1\,(t) \left[rA\,(t) - \pi I\,(t)^{\frac{1}{(a+b)}} - p_c c\,(t) + w\,(t)\, h(t) \right] \\ &\quad + \lambda_2\,(t)\, [I\,(t) - \sigma\,(t)\, H\,(t)]\,. \end{aligned} \tag{10}$$

This is a free endpoint optimal control problem, which can be solved using Pontryagin's maximum principle. Individuals choose consumption and investment into health production, where investment is a combination of time and health services. These optimal choices determine the path of capital and health capital.

2.1 The Demand for Health, Health Services and Health Investment

We derive the demand for health services $M(t)$ and health investment $I(t)$ in appendix A. Taking logs of equation (38) in the appendix gives the (log) demand equation for health services $M(t)$:

$$\ln\, M\,(t) = \beta_0 \,+\, \beta_1 \ln\, \phi(t) \,-\, \beta_2 \ln\, p_M \,-\, \beta_3 \ln\, w\,(t) \,+\, \beta_4 \ln\, \eta(t), \tag{11}$$

where the β's are functions of a and b, and $\eta(t) = \lambda_2(t)/\lambda_1(t)$ is the relative shadow value of health capital.

The demand for health investment equation is given by (37) in the appendix. Taking logs leads to

$$\ln I\,(t) = \delta_0 + \delta_1 \ln \phi(t) - \delta_2 \ln p_M - \delta_3 \ln w\,(t) + \delta_4 \ln \eta\,(t)\,, \tag{12}$$

where the δ's are functions of a and b.

Demand equations like (11) and (12) are Frisch demand functions; they depend on the parameter $\eta(t)$, the relative shadow value (or relative marginal utility) of health. For our model, $\eta(t)$ is given by[4]

$$\eta\,(t) = \eta\,(0)\, e^{\int_0^t [\sigma(\tau)+r]d\tau} - E(t) - F(t)\,, \tag{13}$$

where

$$E(t) = \int_0^t \, w(\tau)\, h'(\tau)\, e^{\int_\tau^t \, [\sigma(s)+r]\, ds} \, d\tau\,,$$

[4]Equation (13) is obtained by solving equation (33) in the appendix.

$$F(t) = \int_0^t h'(\tau)\, v_h\, e^{(r-\rho)\tau}\, \frac{1}{\lambda_1(0)}\, e^{\int_\tau^t [\sigma(s)+r]\, ds}\, d\tau\,,$$

and h' is the derivative of healthy time $h(t)$ with respect to the stock of health capital, $H(t)$. The parameter $\lambda_1(0)$ is the shadow value (or marginal utility) of wealth at $t = 0$; the parameter $\eta(0)$ is the shadow value of health, relative to the shadow value of wealth, at time 0.

The term $E(t)$ reflects the instantaneous benefit of health by enhancing time which may be allocated to the marketplace. The term $F(t)$ captures the instantaneous benefit of healthy time by increasing contemporaneous utility levels. If health is beneficial only to delaying death, total time available does not depend on the period stock of health capital. In this case, $h(H(t)) = h$, where h is constant, and the shadow value of health reduces to

$$\eta(t) = \eta(0)\, e^{\int_0^t [\sigma(\tau)+r] d\tau}. \tag{14}$$

Notice that the assumption of instantaneous health benefits affects the demand equations (11) and (12) only via $\eta(t)$.

Consider now the effect of wage changes on the demands for $I(t)$ and $M(t)$, and let $\eta(t)$ be given by (14). The parameter $\eta(0)$ summarises all relevant information from other periods; it links the demand for $M(t)$ or $I(t)$ in the current period to all historic and future values of the model variables. It is therefore a sufficient statistic for all outside period information which affects the current period demand. In a world of perfect certainty, any changes in wages do not affect $\eta(0)$, since they are fully anticipated by the individual. The effect of a change in current wages is a response along an individual's wage profile, and is sometimes referred to as response to *evolutionary* wage changes (see MaCurdy (1981), Blundell and MaCurdy (1999)). The elasticity of health service or health investment demand with respect to evolutionary wage changes is an intertemporal substitution elasticity. This substitution elasticity (i.e. the wage response conditional on $\eta(t)$) reflects that time allocated to the labour market competes with time invested into health production. It is negative for both demands, implying that demands for services and inputs are lower when wages are high.

The effect on demands via $\eta(0)$ is determined by the three equilibrium conditions for $\eta(0)$, the marginal utility of wealth $\lambda_1(0)$, and the optimal longevity T (see equations (34) -(36) in the appendix). This effect is a *permanent* wage effect, in the sense that it shifts the entire life cycle profile of demand. It measures permanent differences in demands *across* individuals.

If there is an instantaneous benefit of health, equation (13) applies, and changes in current wages affect the value of health $\eta(t)$, conditional on $\eta(0)$. The first effect works through $E(t)$. This reflects the assumption that health enhances time allocated to the labour market. A higher wage allows the individual to accumulate the same earnings with a lower stock of health capital; hence, the instantaneous value of health capital decreases. The second effect works through $F(t)$; changes in wages change $\lambda_1(0)$, the marginal utility of wealth. This is again a permanent effect, reflecting differences in wage profiles across individuals.

If equations (11) and/or (12) represent the correct underlying structure, then results from a model which relies on straightforward regression analysis, using across-individual variation only to identify wage responses, are a mixture of transitory and permanent effects. In fact, they may suggest opposite conclusions than results from a model which distinguishes between permanent and transitory responses. Assume, for instance, that $h' = 0$ (there is no instantaneous health benefit), and equation (12) is estimated, unconditional on $\eta(t)$. Suppose that the effect of an increase in wages on health investments via $\eta(0)$ is positive. Since $\eta(0)$ is a function of the entire future and history of wages, the estimated coefficient is a mixture of the association of contemporaneous wages with the entire wage path of the individual (via $\eta(0)$), and of the negative transitory effect. If the first effect overcompensates the negative transitory response, the estimated wage coefficient may erroneously be interpreted as suggesting that higher current period wages induce a higher demand for health investment. Possible policy implications would be to target individuals with low current wages, since they seem to neglect their health investments. This would include students (who may have a high expected life income and who are on a high demand schedule), but exclude professionals at the peak of their individual wage profile.

When distinguishing between permanent and transitory wage responses, implications may be very different. Individuals with a high permanent income (students, for example) are on a high demand profile, and, additionally, on a low section of their life cycle wage profile, inducing them to substitute health input demand now for later. On the other side, high income individuals who are at the peak of their professional career may, although being on a high profile of health input demand, neglect current health care since they substitute time away from health enhancing activities to the market place. Implications to be drawn from the results of this model are obviously very different than those drawn from a purely static analysis.

In section 4, we estimate demand for health investment equations and demand for health equations. We distinguish between evolutionary wage responses, and permanent wage responses. To identify these two effects, we use data from a long panel, which we describe in the next section.

3 The Data

The data we use are from the German Socio Economic Panel (GSOEP), and cover the period between 1984 and 1995. We select a sample of working males, between 25 and 60 years of age. The sample is unbalanced, allowing for attrition from the survey, as well as for new entrants to the sample.

As a measure for the stock of health, we use a self-reported measure of contentment with health, which is reported in all 12 years on an eleven point scale. Self assessed health status has been found in many studies to be a useful measure in assessing the overall health of an individual, see for example Wannamethee and Shaper (1991) and references therein.[5] We rescale this measure to be bounded between 0 and 1. As a measure for investment into health we use information on whether the individual performs some kind of sporting activity on a weekly basis. Sporting activities are clearly a combination of health input goods $M(t)$ and time $m(t)$, and contribute to increasing the stock of health capital. The medical literature has established a clear link between physical fitness, and longevity.[6] Information on this investment measure is available in 5 out of the 12 years of data. We recode this measure into a binary variable, where 1 indicates that the individual pursues sports activities at least once a week. The wording of the questions in the questionnaire is given in appendix B, and Table 1 reports the frequencies of occurrence and summary statistics.

As a measure for wages w_{it}, we use hourly wages measured in 1984 DM. In all 12 years of the survey we observe monthly gross earnings, as well as hours worked, hours worked overtime, and whether overtime is paid for. The wage variable is constructed by dividing monthly earnings by the number of paid hours worked per month.

[5] Wannamethee and Shaper (1991) assess the health status of middle-aged British men, using a number of objective medical measures. They also ask individuals for their subjectively perceived health status. Comparing these measures, they conclude that (p. 245) "The results of this study strongly suggest that a simple question on perceived health status is a useful indicator of health status in middle-aged men and appears to reflect their current health status".

[6] For instance, Lee, Blair and Jackson (1999) investigate 22000 males aged between 30 and 83 over an 8 year period. They found that physical fitness, conditional on body weight, is significantly and positively associated with longevity.

Table 1: Summary Statistics

	Health	*Sport*
Definition	Contentment with health	Doing sports at least once a week
Range	0,0.1,...,1 1 = very content	0,1
Years available	84-95	85,86,88,92,94
# individuals	3324	2791
# observations	19100	7818
mean	0.7056	0.3058
std dev	0.2083	0.4608
within std dev	0.1369	0.2542
between std dev	0.1762	0.4041

Figures 1 to 4 present graphical information of some the variables we use in our analysis. In figure 1, the age distribution in the sample is displayed. The highest frequency is at age 29, the lowest at age 60. Figure 2 presents the average log real wage by age. Wages rise substantially between the ages of 25 and 44, level out, and slightly decline after age 48.

The mean for our measure for the stock of health at different ages is depicted in figure 3. It declines steadily with age, from an average value of 0.77 at age 25, to a low of 0.61 at age 59.

The respective pattern for sport activities is depicted in figure 4. It also declines, with 44% of the sample participating at age 28, whereas only 12% do sports on a weekly basis at age 58. This is not compatible with what we should expect on the grounds of our theoretical model, where investments into health should counteract an increasing depreciation of the stock of health capital. It suggests that this measure is only proxying one component of investment, and may be substituted by other components later in life. It may also suggest cohort effects: Doing sports may be a way of improving health which is related to the individual's cohort.

To distinguish between age and cohort effects, we have plotted the mean of the health and sport variables over the 12 years period for different cohorts, where we define the cohort by the age of the individual in 1984 (figures 5 and 6). Figure 5 shows that within cohorts, the measure for the stock of health clearly declines with age; there are some slight level differences between the various cohorts. Figure 6 illustrates the same for the sport activity variable. It shows that within cohorts, the demand for sports is quite volatile, and no clear pattern is visible. Demand for sports is lower the older the cohort, which has contributed to generating the downward trend in figure 4.

The figures indicate that the sport variable is capturing only some components of health investments, and it is related to cohort, and age; it may also be related to occupational characteristics. In our estimations, we difference out all time constant characteristics; furthermore, we condition on age and time, which should account for the cohort effects visible in the figures. The remaining signal in this variable should be a good proxy for health investments.

In figure 7, we have plotted the lifetime health paths for quartiles of the household income distribution, computed as the average household income over the entire observation period. This should be a rough approximation of permanent income. The profiles decline with age, and are clearly higher for the higher income quartiles. This indicates a higher health path for individuals with higher permanent income. Figure 8 illustrates this pattern for the sports variable; again, a wealth effect is clearly visible.

4 Empirical Analysis

We estimate a demand equation for health investment, $I(t)$, and for the health stock, $H(t)$. Our empirical specifications are based on models (12) and (1). The demand for health investment equation is already in a log-linear form. The health stock equation is a dynamic equation, and we consider its discrete counterpart:

$$\begin{aligned} H(t) &= (1-\sigma)\,H(t-1) \\ &\quad + \exp\left(\delta_0 + \delta_1 \ln \phi(t-1) - \delta_2 \ln p_M - \delta_3 \ln w\,(t-1) + \delta_4 \ln \eta\,(t-1)\right)\ , \end{aligned} \tag{15}$$

where we have substituted the expression for $I(t-1)$ in (12). Alternatively, it follows from (1) that the log of the stock of health capital at t can be written as $\ln H(t) = \ln I(t) - \ln \sigma(t) - \ln(1 + \widetilde{H}/\sigma(t))$, where $\widetilde{H} = \dot{H}\ /H$ is the relative change in health capital. If one is willing to assume that $\widetilde{H}/\sigma(t) = 0$, then one obtains (using (12)):

$$\ln H\,(t) = \xi_0 + \xi_1 \ln \phi\,(t) - \xi_2 \ln p_M - \xi_3 \ln w\,(t) + \xi_4 \ln \eta\,(t) - \ln \sigma\,(t)\ . \tag{16}$$

The assumption that $\widetilde{H}/\sigma(t) = 0$ implies that investment into health capital exactly offsets depreciation. Over large parts of the life cycle, this assumption may not be unreasonable. Furthermore, when estimating a differenced version of (16), we only require $\widetilde{H}/\sigma(t)$ to be constant between two periods. Accordingly, equation (16) may be a good starting point for an empirical model. We estimate both the dynamic model in (15), and its simpler version in (16).

The wage elasticities δ_3 and ξ_3 are measure the response of current health to changes in wages, due to changes in investments. Parameter estimates for wage responses of equations (12), (15), and (16) should therefore all be similar.

Our first estimation strategy is to estimate the restricted model where health has no instantaneous benefit, which results in an expression for $\eta(t)$ as in (14). Notice that the two important mechanisms by which wages affect $H(t)$ and $I(t)$ are present in this model: a direct (negative) effect by substituting time away from production of health to the marketplace, and an indirect and permanent effect by shifting the entire health profile of the individual. We estimate the transitory wage effect by (quasi-) differencing out the term $\eta(0)$. We then estimate permanent wage effects, where we approximate $\eta(0)$ as a function of initial health, initial wealth, and individual lifetime wage profiles.

We test this version of the model against models where health has an instantaneous benefit. The idea of our testing procedure is that in the latter case, differencing of $\ln \eta(t)$ leads to an equation with an error term which still contains a function of $\eta(0)$ (and, if healthy time enters the utility function, of $\lambda_1(0)$, see (13)), and the lifetime path of wages up to time t. This term should then be correlated with past wages and other variables which affect $\eta(0)$, which is testable. Our test results indicate that the restricted version of the model can not be rejected against a model with instantaneous health benefits.

If instantaneous health benefits were present, the parameter $\eta(t)$ would be given by equation (13). An estimation strategy which can identify transitory wage responses in this case is a matching type estimator, which differences across individuals with the same $\eta(t)$, where $\eta(t)$ is specified as a function of life-cycle wages, life-cycle wealth, initial wealth and health, age, and education. To ensure the robustness of our estimates, we report results of this estimator as well.

4.1 No instantaneous health benefits

If there are no instantaneous health benefits, $\eta(t)$ is given by (14). Define the variable Y_{it}, which corresponds to I_{it} or H_{it} in equations (12) and (16), where $i = 1, ..., N$ is the index for individuals and $t = 1, ..., T$ is the time index. Furthermore, summarise variables which determine the demand in the vector X, and the corresponding parameters in δ. Then the generic empirical model for equations (12) and (16) is given by[7]

$$\ln Y_{it} = X_{it}'\delta + \zeta_1 \ln w_{it} + \ln \eta_i^0 + u_{it}, \tag{17}$$

where u_{it} is an error term, which we will discuss below.

If repeated information on the same individual is available, estimation of equation (17) after taking first differences is straightforward. Denote the difference operator between period t and $t-1$ by Δ, then

$$\Delta \ln Y_{it} = \Delta X_{it}'\delta + \zeta_1 \Delta \ln w_{it} + \Delta u_{it}. \tag{18}$$

Estimation of equation (18) allows us to identify the response of Y_{it} to evolutionary wage changes. The vector X_{it} includes (log) prices, the rates of interest and depreciation, the rate of decay of health capital, the technology parameter, and other time constant variables which affect the demand for health and health investment. We assume the log of the rate of depreciation $\sigma(t)$ to be quadratic in age. Furthermore, any changes in prices or the technology parameter should be picked up by time dummies, and by age effects. Accordingly, in our empirical specification, $\Delta X_{it} = [\delta_{0t}, \Delta age_{it}^2]$, where the δ_{0t} are time effects.

At the level of empirical implementation, we allow for possible feedback mechanisms of health on wages. Notice that, as in all surveys, the wage at the time of the interview is likely to be set at an earlier date. Therefore, current observed wages are not *contemporaneously* correlated with health shocks. However, wages at interview time may be correlated with past health status, and, accordingly, with u_{it-s}, $s > 0$. Hence, estimating the parameters in model (18) by OLS will result in biased coefficient estimates.[8] We use an instrumental variable Generalised Methods of Moments (GMM) estimator, instrumenting the current wage difference by lagged levels of wages.[9] The full instrument set used in the estimation is

$$z_{it} = \left[1, \ln w_{it-1}, \ln w_{it-2}, \ln w_{it-3}, age_{it}, age_{it}^2, educ_i, educ_i^2, educ_i \times age_{it}\right], \tag{19}$$

where $educ_i$ is the years of schooling of individual i.[10] The *age* variable is rescaled to be 0 at age 25.

The estimation results are presented in Table 2. The parameter $\bar{\delta}_{0t}$ is the mean of the time dummies. This parameter is interpretable as the combined effect of the linear age term, and cohort effects. It is negative for the health equation, reflecting a constant deterioration in the stock of health

[7]Throughout the empirical analysis, we use as measures for $\ln H$ and $\ln I$ the scaled health index and the binary sports variable respectively.

[8]For the same reason, a within groups estimator can not be used here.

[9]Let Z_i be a matrix of instruments, and u_i be a vector of prediction errors. The GMM estimator minimises $\left(\frac{1}{N}\sum_i Z_i'u_i\right)' W_N \left(\frac{1}{N}\sum_i Z_i'u_i\right)$, where W_N is a weight matrix. Given consistent estimates using an initial weight matrix, with residuals $\widetilde{u}_i$, the efficient two-step GMM estimator uses $\left(W_N = \frac{1}{N}\sum_i Z_i'\widetilde{u}_i\widetilde{u}_i' Z_i\right)^{-1}$. See Hansen (1982), Arellano and Bond (1991).

[10]The instrument set for an individual over time is given by

$$Z_i = \begin{bmatrix} z_{i1} & 0 & 0 & 0 \\ 0 & z_{i2} & 0 & 0 \\ & & \ddots & \\ 0 & 0 & & 0 \\ 0 & 0 & 0 & z_{iT-1} \end{bmatrix}.$$

The parameters are estimated by GMM using the program DPD98 for Gauss, Arellano and Bond (1998).

over the life cycle, as indicated in figure 3. It is also negative for the sports equation, which could be due to the cohort effect we have pointed out above.

For both the health and health investment equations the response to evolutionary wage changes is negative. This is compatible with a negative intertemporal substitution elasticity, as predicted by our model. As both variables are scaled between 0 and 1, the numbers suggest that a 1 percent wage increase decreases the health stock by 1.6 percentage points as a result of a neglect into health investments. Based on the health investment equation, the effect is about 3 percentage points. Both effects are not estimated with great precision.

Table 2. Estimation results for first-differenced models

	$\ln H$		$\ln I$	
	coeff	std err	coeff	std err
$\overline{\delta_{0t}}$	-0.0090	0.0015	-0.0119	0.0040
$age^2/100$	-0.0041	0.0044	0.0084	0.0108
$\ln w$	-0.0163	0.0187	-0.0308	0.0680
Sargan (p-value)	74.32	(0.741)	12.44	(0.992)
# of individuals	2662		2002	
# of observations	13906		4718	

Efficient two-step GMM results.
Standard errors are robust to heteroscedasticity and correlation over time.
$\overline{\delta_{0t}}$ is the mean of the time effects, weighted for unequal period lengths in the health investment equation.
The Sargan test is a test for instrument validity.

Results obtained from a standard levels model on pooled data, where we condition on age, age squared, education, and time dummies, are very different. The estimated wage coefficient for the health equation is 0.044, with standard error 0.011; in the health investments equation, the coefficient on wages is 0.125, with a standard error of 0.029. Inspection of the estimated serial correlation matrices of these levels models indicates the presence of a fixed unobserved component, suggesting that the obtained coefficients in a level equation are a combination of a transitory and (positive) permanent wage effect.

We now turn to the dynamic health stock equation in (15), which can be written as:

$$\begin{aligned} H_{it} &= \alpha H_{it-1} + I_{it-1} \\ &= \alpha H_{it-1} + \exp\left(X'_{it-1}\delta + \zeta_1 \ln w_{it-1}\right) \eta_i^0 \, v_{it} \, , \end{aligned}$$

where $\alpha = (1-\sigma)$, and v_{it} is an idiosyncratic (multiplicative) error term. Notice that the dynamic model is multiplicative in η_i^0, so that straightforward differencing is not feasible. We can however quasi-difference the model to eliminate the fixed effect. The quasi-differenced equation is given by:[11]

$$\begin{aligned} & \left(H_{it} - \alpha H_{it-1}\right) \exp\left(-\left(\Delta X'_{it-1}\delta + \zeta_1 \Delta \ln w_{it-1}\right)\right) - \left(H_{it-1} - \alpha H_{it-2}\right) \\ = \; & v_{it} \exp\left(-\left(\Delta X'_{it-1}\delta + \zeta_1 \Delta \ln w_{it-1}\right)\right) - v_{it-1} \, , \end{aligned} \tag{20}$$

[11] See Chamberlain (1992), Wooldridge (1997) and Blundell, Griffith and Windmeijer (1999).

where the error term on the right hand side has zero mean, conditional on appropriate instruments. The parameters of the model can be estimated by GMM, where we use as instruments the variables[12]

$$z_{it} = \left[1, H_{it-3}, H_{it-4}, H_{it-5}, \ln w_{it-1}, \ln w_{it-2}, \ln w_{it-3}, age_{it-1}, age^2_{it-1}, educ_i, educ^2_i, educ_i \times age_{it-1}\right].$$

Table 3: Results for quasi-differenced multiplicative model for Health

	coeff	std err	coeff	std err
H_{-1}	0.2068	0.0743	0.3084	0.0675
$(age * H)_{-1}$			-0.0058	0.0011
$\ln w_{-1}$	-0.0465	0.0265	-0.0420	0.0269
age_{-1}	-0.0061	0.0025		
$age^2_{-1}/100$	-0.0036	0.0060		
Sargan test (p-value)	113.0	(0.1423)	113.3	(0.1551)
# individuals	1870		1870	
# observations	9054		9054	

Efficient, iterated GMM results for quasi-differenced model
Standard errors are robust to heteroscedasticity and correlation over time
The Sargan test is a test for instrument validity

The estimation results are displayed in Table 3. In the first column, we present results where we assume that the rate of depreciation $\sigma(t)$ is time constant. In the second column, we add a lagged interaction term of age and the health stock variable, thus allowing for an increase in the depreciation rate of health capital over the life cycle.

The wage effects are very similar in both specifications, and they reflect our previous findings. The estimated coefficient is negative, and significant at the 10 percent level. The interpretation of this coefficient is the same as in the above models: It is the transitory wage effect on health investment. The estimate is slightly larger than the estimate obtained from the previous model.

We have also estimated a level model, where we do not control for η_i^0. In this model, the parameter estimate of the wage coefficient is positive, with a coefficient estimate of 0.0433 (standard error 0.0124). Again, this is likely to be due to the permanent term η_i^0 being positively correlated with the wage variable in period t. Taken at face value, these results suggest a positive association between current wages and health (investments).

The parameter on the lagged health stock variable corresponds to $(1-\sigma)$ in our theoretical model, where σ is the rate of depreciation. Estimation of the simple level model (where we instrument H_{it-1} by H_{it-2} due to an MA(1) error process) gives an estimate for σ of a magnitude of 0.078 (standard error 0.014). When we control for fixed effects (column 1 in Table 3), the estimate becomes unreasonably large, and the standard error increases. After controlling for the permanent effect, it seems difficult to identify σ separately.[13] In the second column, we allow for an increasing rate of

[12] As the error process in the quasi-differenced equation displays an MA(2) structure, possibly due to measurement error in H_{it-1}, we use H_{it-3} and further lags as instruments.

[13] A possible reason is the persistence in the health variable over time. It is therefore likely that our instruments are poor predictors of the quasi-differenced health variable, which could lead to a downward weak instrument bias, see Blundell and Bond (1998).

health depreciation. Our formulation corresponds to an additively linear depreciation rate of the form $\sigma(t) = \sigma_0 + \sigma_1 * Age\,(t)$. The parameter estimate for σ_1 is negative, which is in accordance with our model.

4.1.1 Permanent Wage Effects

To recover the permanent wage effect, we need to impose structure on the individual specific effects. We use a parameterisation similar to MaCurdy (1981) and Blundell and MaCurdy (1999).

Suppose that $\ln \eta_i^0$ is a function of initial wealth A^0, initial health H^0, and the entire lifetime wage path:

$$\ln \eta_i^0 = \alpha_0 A_i^0 + \gamma_0 H_i^0 + \sum_{s=0}^{T_W} \theta_s \ln w_{is} + v_i, \tag{21}$$

where the working life of the individual has length T_W, and v_i is an idiosyncratic error term.[14]

Specify individual i's wage in period t as

$$\ln w_{it} = \pi_{0i} + age_{it}\pi_{1i} + age_{it}^2\pi_{2i} + u_{it}\,, \tag{22}$$

where the π_{ji}, $j = 0, 1, 2$, are individual-specific lifetime wage parameters. Similarly, i's nonwage income in period t (A_{it}) and health are specified as

$$\begin{aligned} A_{it} &= \tau_{0i} + age_{it}\tau_{1i} + age_{it}^2\tau_{2i} + v_{it}\,, \\ H_{it} &= \omega_{0i} + age_{it}\omega_{1i} + age_{it}^2\omega_{2i} + s_{it}, \end{aligned} \tag{23}$$

where τ_{0i} and ω_{0i} correspond to the initial stocks of resources and health respectively, and the τ_{ji} and ω_{ji}, $j = 1, 2$, are individual-specific lifetime wealth and health parameters.

Combining (21), (22) and (23), $\ln \eta_i^0$ can be written as

$$\ln \eta_i^0 = \alpha_1 + \pi_{0i}\overline{\theta}_0 + \pi_{1i}\overline{\theta}_1 + \pi_{2i}\overline{\theta}_2 + \tau_{0i}\overline{\alpha}_0 + \omega_{0i}\overline{\gamma}_0 + \varepsilon_i, \tag{24}$$

where

$$\overline{\theta}_j = \sum_{t=0}^{T_W} t^j \theta_t, \quad j = 0, 1, 2, \quad \overline{\alpha}_0 = \frac{\alpha_0}{r}, \quad \overline{\gamma}_0 = \frac{\gamma_0}{r + \sigma}.$$

We obtain unbiased estimates of π_{0i}, π_{1i}, π_{2i}, τ_{0i} and ω_{0i}, following the procedure outlined by MaCurdy (1981).[15] For the construction of the individual specific initial wealth parameter τ_{0i}, we use as a measure for non-wage income, A_{it}, observed real total household income, excluding the earnings of the individual male.[16] To recover the parameter ω_{i0}, we use the self reported health measure. Estimates of π_{0i}, π_{1i}, π_{2i}, τ_{0i}, and ω_{i0} are based on the longest available series on log wages, household income, and health respectively.

---

[14] In the theoretical model, the length of life is endogenously determined; we assume here that the length of life exceeds the working life of the individual, and is the same across individuals.

[15] The unbiased estimators of the π's are given by $\widehat{\pi}_{2i} = \frac{1}{T_i - 2}\sum_{j=1}^{T_i - 2}\frac{1}{j}\left[\frac{\ln w_{ij+2} - \ln w_{i1}}{j+1} - (\ln w_{i2} - \ln w_{i1})\right]$, $\widehat{\pi}_{1i} = \frac{1}{T_i - 1}\sum_{j=1}^{T_i - 1}\left[\frac{\ln w_{ij+1} - \ln w_{i1}}{j} - \widehat{\pi}_{2i}\,(2age_{ij+1} - j)\right]$ and $\widehat{\pi}_{0i} = \frac{1}{T_i}\sum_{j=1}^{T_i}\left[\ln w_{ij} - \widehat{\pi}_{1i}age_{ij} - \widehat{\pi}_{2i}age_{ij}^2\right]$, where j denote observed sample periods, and $\ln w_{ij}$ are log wages of individual i in period j. The τ's and ω's are computed in a similar manner, with residual total household income and health status substituted for log wages.

[16] We have also estimated the models using different measures of non wage income. The results were very similar to those presented below.

From the estimation results of the differenced models the individual specific effects can be estimated by

$$\widehat{\ln \eta_i^0} = \frac{1}{T_i} \sum_{t=1}^{T_i} \left[\ln Y_{it} - \widehat{\zeta}_1 \ln w_{it} - age_{it} \overline{\widehat{\delta}}_0 - age_{it}^2 \widehat{\delta} \right],$$

with $\overline{\widehat{\delta}}_0$ equal to the average of the $\widehat{\delta}_{0t}$. For the dynamic equation, we obtain an estimate of $\ln \eta_i^0$ as

$$\widehat{\ln \eta_i^0} = \ln \left(\frac{1}{T_i - 1} \sum_{t=2}^{T_i} \frac{H_{it} - \widehat{\alpha} H_{it-1}}{\exp\left(\widehat{\zeta}_1 \ln w_{it-1} + age_{it} \widehat{\delta}_0 + age_{it}^2 \widehat{\delta}\right)} \right).$$

Using $\widehat{\ln \eta_i^0}$, $\hat{\pi}_{0i}$, $\hat{\pi}_{1i}$, $\hat{\pi}_{2i}$, $\hat{\tau}_{0i}$ and $\hat{\omega}_{0i}$ we estimate equation (24) to obtain estimates of α_1, $\overline{\theta}_0$, $\overline{\theta}_1$, $\overline{\theta}_2$ and $\overline{\alpha}_0$, using IV (since the explanatory variables are by construction correlated with the error term). Our vector of instruments is given by

$$z_i = \left[1, educ_i, educ_i^2, feduc_i, meduc_i, agefb_i, agemb_i, fbluec_i, fwhitec_i, fcivserv_i \right],$$

where $f\,(m)\,educ$ is the number of years of schooling of the father (mother), $agef\,(m)\,b$ is the age of the father (mother) at birth, and $fbluec$, $fwhitec$ and $fcivserv$ indicate whether the father was/is occupying a blue-collar job, a white-collar job, or a civil servant job respectively.

The estimation results are presented in Table 4. The coefficient on initial wealth ($\overline{\alpha}_0$) is negative in the health equation and positive in the health investment equation. For both equations, the estimates of the coefficient on initial health ($\overline{\gamma}_0$) is positive. Also, for both equations, $\overline{\theta}_1$, $\overline{\theta}_2$, and $\overline{\theta}_3$ are positive, indicating positive permanent wage effects. All these effects are however not precisely estimated. The joint test of significance for the permanent wage parameters is significant for the health investment equation only.

Table 4: Estimation results for permanent effects model

	Health		*Health (Dynamic Model)*		*Health Investment*	
	est	std err	est	std err	est	std err
const	0.7819	0.1689	0.5785	0.2538	0.1959	0.3297
$\overline{\theta}_0$	0.0590	0.0615	0.0634	0.0970	0.1483	0.1225
$\overline{\theta}_1$	1.0435	1.0180	1.2074	1.6226	2.9034	2.0005
$\overline{\theta}_2$	13.8553	13.0137	16.7098	20.0566	36.1682	23.7592
$\overline{\alpha}_0$	-0.0007	0.0007	-0.0008	0.0010	0.0002	0.0015
$\overline{\gamma}_0$	0.0022	0.0034	0.0024	0.0043	0.0021	0.0068
Sargan test (p-value)	0.415	0.981	0.352	0.986	1.926	0.749
Wald test (p-value)	1.291	0.721	1.618	0.655	8.446	0.038
# of individuals	1420		1415		1370	

Efficient two-step GMM results.
Standard errors are robust to heteroscedasticity.
The Sargan test is a test for instrument validity.
The Wald test is a test for joint significance of $\overline{\theta}_0$, $\overline{\theta_1}$ and $\overline{\theta_2}$.

The overall response to a change in wages can be obtained by combining the estimation results for ζ_1, $\overline{\theta}_0$, $\overline{\theta}_1$, and $\overline{\theta}_2$. For example, the responses to a change in π_{0i}, i.e. a parallel shift in the log wage profile, are given by $\partial H/\partial \pi_0 = 0.0590 - 0.0163 = 0.0427$ for the (non-dynamic) health equation. Accordingly, a one percent permanent increase in wages results in a four percentage points upward shift of the health stock profile.

4.2 Instantaneous Benefits of Health

So far we have assumed that there are no instantaneous health benefits: $h' = 0$. A simple test of this assumption is based on the following idea. Recall equation (13), and define $D(t) = e^{\int_0^t [\sigma(\tau)+r]d\tau}$. Then the first difference of the log of $\eta(t)$ can be written as

$$\begin{aligned} \ln \eta(t) - \ln \eta(t-1) &= \ln D(t) - \ln D(t-1) \\ &\quad + \ln\left(1 - \frac{E(t)+F(t)}{\ln D(t)\eta(0)}\right) - \ln\left(1 - \frac{E(t-1)+F(t-1)}{D(t-1)\eta(0)}\right) \\ &= \ln D(t) - D(t-1) + \Gamma(t). \end{aligned} \tag{25}$$

If health has an instantaneous benefit ($h' \neq 0$), then straightforward differencing, or quasi-differencing, does not eliminate the permanent effect. The residual in the first differenced model will contain the term $\Gamma(t)$, which is a function of $\eta(0)$, $\lambda_1(0)$, and past wages. Hence, a test whether $h' = 0$ is a test for the validity of lagged wages as instruments in our model above.

An appropriate test is the Sargan test for overidentifying restrictions. We present the test statistics and the p-values of this test in Tables 2 and 3. The p-values strongly indicate that the errors are not correlated with the instruments, for both the health and the health investment equations. We conclude from these results that the simple model where health has no instantaneous benefit can not be rejected against a model where the stock of health has a time enhancing effect.

To check the robustness of our results, we use an alternative estimation strategy which allows us to identify the evolutionary wage effects if there are instantaneous benefits ($h' \neq 0$). The parameter η is a function of variables that are correlated with the regressors. Individuals who have similar values of those variables will also be similar in the correlated component of η. Hence, differencing across individuals with the same values of these variables should eliminate the variation in η which is correlated with wages.

This estimator is a matching estimator. It is consistent as long as the remaining error term in the differenced equation is no longer correlated with wages. Note that, for obtaining a consistent estimate of the transitory wage response, it is not necessary that the matching procedure completely determines η.

We illustrate this estimator for the log-linear specifications (12) and (16). The parameter η_{it} is a function of life cycle wages, life cycle wealth, and initial wealth and health conditions. To implement the estimator, we match observations exactly on age and education, and on kernel weighted distances between predicted life cycle wages and life-cycle wealth, the individual specific sample means of these variables, and on initial wealth and health. All these variables are constructed in the same way as for the estimation of the permanent effects in the previous section. We then estimate pair-wise differenced equations between individuals.

Our matching estimator is similar to the estimation strategy explained in Kyriazidou (1997) for sample selection panel data models and is given by

$$\widehat{\zeta}^M = \left[\sum_{j=1}^{J}\sum_{k=1}^{K_j}\sum_{l>k}\psi_{jN}\left(x_{jk}-x_{jl}\right)\left(x_{jk}-x_{jl}\right)'\right]^{-1}\sum_{j=1}^{J}\sum_{k=1}^{K_j}\sum_{l>k}\psi_{jN}\left(x_{jk}-x_{jl}\right)\left(y_{jk}-y_{jl}\right)',$$

where J is the number of groups of individuals with the same age and years of education, with each group containing K_j observations. The x_{jk} and x_{jl} are the observations on the explanatory variables, in our case wages and time effects, for individuals k and l in age-education group j respectively. The kernel weights ψ_{jN} decline to zero as the magnitude of the difference between the matching variables increases. These weights are specified as

$$\psi_{jN} = \prod_{q=1}^{Q}\frac{1}{h_{Nq}}\phi\left(\frac{z_{jk}^q - z_{jl}^q}{h_{Nq}}\right),$$

where Q is the number of (standardised) matching variables z^q, h_{Nq} is a sequence of bandwidths that tend to zero as the number of individuals goes to infinity ($N \to \infty$), and ϕ is the standard normal density function. For the choice of the bandwidth parameter, we follow Kyriazidou (1997), and set the bandwidth $h_{Nq} = h_q \times N^{-1/5}$, where $h_q = 1$ for the predicted life cycle wages and life-cycle wealth and their individual specific means, and $h_q = 2$ for initial wealth and health, because of the slightly fatter tails of the distributions of these two variables, and hence ensuring sufficient data coverage.

The estimates of the coefficient on $\ln w$ are -0.0185 (standard error 0.0111) in the equation for $\ln H$ and -0.0353 (standard error 0.0495) in the equation for $\ln I$. These estimates are remarkably similar to the ones found for the differenced models, as reported in Table 2. This supports our previous findings, suggesting that there are negative responses of health investments to transitory wage changes. Furthermore, together with the test results, the similarity between the sets of estimates indicate that instantaneous health benefits do not affect transitory wage elasticities.

5 Conclusion

We present a life cycle model for health demand, and derive and estimate *Frisch* demand functions for health and health investment. We focus our analysis on the effect of wages on health and health investment. We distinguish between permanent and transitory wage responses. Identification of transitory wage effects relies on (quasi-) differencing procedures. In a second step, we estimate the permanent effect of wage changes on the demand path for health and health inputs. If health provides instantaneous benefits, simple differencing does not eliminate the variation in the latent individual effect which is correlated with the model regressors. We propose a simple test for the restricted model against a model where health does provide instantaneous benefits. We also propose an estimation strategy, relying on a matching type estimator, which allows us to identify transitory wage effects if simple differencing does not eliminate the latent individual effect.

We use data on contentment with health and the demand for sport activities from a long panel. In accordance with the theoretical model, we find negative transitory wage effects, indicating that individuals substitute time for health production for time in the labour market during high wage periods over their life cycle. Furthermore, we find positive permanent effects, indicating that individuals with higher permanent wages are on a higher health profile. These results are in contrast to what is obtained when estimating a simple static model. In such a model, wages are strongly and positively associated with health.

The implications of our model for health policies are very different than those which may be drawn from a cross sectional analysis. Estimation results of a simple static model suggest that individuals with low wages suffer from poorer health conditions, and choose lower inputs into health maintenance. An implication for health policies is to target individuals in the lower quantiles of the wage distribution. Our estimation results suggest that individuals with higher *permanent* wages are on a higher health (and health investment) profile. However, individuals tend to neglect their health status at peak points of their wage profile. It is compatible with the observation that individuals with a high permanent income nevertheless suffer from serious illness as a result of a temporary neglect of their health.[17] Our analysis emphasises the need to consider health related behaviour in a truly intertemporal context. This seems particularly important when exploring how the economic position of individuals relates to their health related well-being.

References

[1] Arellano, M. and S. Bond (1991) Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *Review of Economic Studies*, 58, 277-298.

[2] Arellano, M. and S. Bond (1998) Dynamic Panel Data Estimation using DPD98 for Gauss, manual, The Institute for fiscal Studies.

[3] Blundell, R. and S. Bond (1998) Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, *Journal of Econometrics*, 87, 115-143.

[4] Blundell, R., R. Griffith and F. Windmeijer (1999) Individual Effects and Dynamics in Count Data Models, Working Paper No. W99/3, The Institute for Fiscal Studies.

[5] Blundell, R. and T. MaCurdy (1999) Labor Supply: A Review of Alternative Approaches, in: O. Ashenfelter and D. Card (eds.), *Handbook of Labor Economics*, Volume III, North-Holland, Amsterdam.

[6] Browning, M., Deaton, A. and M. Irish (1985) A Profitable Approach to Labour Supply and Commodity Demand over the Life Cycle, *Econometrica*, 53, 503 - 543.

[7] Chamberlain, G. (1992) 'Comment: Sequential Moment Restrictions in Panel Data', *Journal of Business & Economic Statistics*, 10, 20-26.

[8] Cropper, M.L. (1981) Measuring the Benefits from Reduced Morbidity, *American Economic Review*, 71, 235–240.

[9] Dardanoni, V. and A. Wagstaff (1990) Uncertainty and the Demand for Medical Care, *Journal of Health Economics*, 9, 23 – 38.

[10] Eisenring, C. (1999) Comparative Dynamics in a Health Investment Model, forthcoming *Journal of Health Economics*.

[11] Ehrlich, I. and H. Chuma (1990) A Model of the Demand for Longevity and the Value of Life Extension, *Journal of Political Economy*, 98, 761-782.

[17] For example, Marmot et al. (1997) show that, after controlling for working conditions, it is those in the highest social/occupational grade that have the highest incidence of stress related illness.

[12] Geil, P., A. Million, R. Rotte and K.F. Zimmermann (1997) Economic Incentives and Hospitalization in Germany, *Journal of Applied Econometrics*, 12, 295-312.

[13] Grossman, M. (1972a) *The Demand for Health: A Theoretical and Empirical Investigation*, NBER, New York.

[14] Grossman, M. (1972b) On the Concept of Health Capital and the Demand for Health, *Journal of Political Economy*, 80, 223–255.

[15] Hansen, L.P. (1982) 'Large Sample Properties of Generalized Method of Moments Estimators', *Econometrica*, 50, 1029-1054.

[16] Kyriazidou, E. (1997) Estimation of a Panel Data Sample Selection Model, *Econometrica*, 65, 1335-1364.

[17] Lee C. D., S. N. Blair and A. S. Jackson (1999) Cardiorespiratory Fitness, Body Composition, and All-Cause and Cardiovascular Disease Mortality in Men, *The American Journal of Clinical Nutrition*, 69, 373-380.

[18] Liljas, B. (1998) The Demand for Health with Uncertainty and Insurance, *Journal of Health Economics*, 17, 153–171.

[19] MaCurdy, T.E. (1981) An Empirical Model of Labor Supply in a Life–Cycle Setting, *Journal of Political Economy*, 89, 1059–1086.

[20] Marmot, M., C. D. Ryff, L. L. Bumpass, M. Shipley and N. F . Marks (1997) Social Inequalities in Health: Next Questions and Converging Evidence, *Social Science & Medicine,* 44, 901-910.

[21] Muurinen, J.M. (1982) Demand for Health: A Generalized Grossman Model, *Journal of Health Economics*, 1, 5–28.

[22] Picone, G., Uribe, M. and R. M. Wilson (1998) The Effect of Uncertainty on the Demand for Medical Care, Health Capital, and Wealth, *Journal of Health Economics*, 17, 153–171.

[23] Pohlmeier, W. and V. Ulrich (1995) An Econometric Model of the Two-Part Decision-making Process in the Demand for Health Care, *Journal of Human Resources*, 30, 339–361.

[24] Ried, W. (1998) Comparative Dynamic Analysis of the Full Grossman Model, *Journal of Health Economics*, 17, 383-425.

[25] Ried, W. (1999) Optimal Length of Life: Another Perspective, *Journal of Health Economics*, forthcoming.

[26] Wagstaff, A. (1986) The Demand for Health: Some New Empirical Evidence, *Journal of Health Economics*, 5, 195–233.

[27] Wagstaff, A. (1993) The Demand for Health: An Empirical Reformulation of the Grossman Model, *Health Economics*, 2, 189–198.

[28] Wannamethee, G. and A.G. Shaper (1991) Self-assessment of Health Status and Mortality in Middle-Aged British Men, *International Journal of Epidemiology*, 20, 239-245.

[29] Wooldridge, J.M. (1997) 'Multiplicative Panel Data Models without the Strict Exogeneity Assumption', *Econometric Theory*, 13, 667-678.

Appendix A: Solving the Model

The Hamiltonian is given by equation (10) above. Using Pontryagin's maximum principle, the optimal paths of the variables $I(t)$, $C(t)$, $\lambda_1(t)$, $\lambda_2(t)$, $H(t)$ and $A(t)$ as well as T are determined by equations (1) and (7) and the following system of equations:

$$\frac{dK}{dc} \quad : \quad e^{-\rho t}u_c - \lambda_1(t)\,p_c = 0 \tag{26}$$

$$\frac{dK}{dI} \quad : \quad \lambda_2 - \lambda_1 \pi \left(\frac{1}{a+b}\right) I(t)^{\frac{1}{a+b}-1} = 0 \tag{27}$$

$$-\frac{dK}{dH} = \dot{\lambda}_2 \quad : \quad \dot{\lambda}_2(t) = \lambda_2(t)\,\sigma(t) - \lambda_1(t) w(t)\,h' - e^{-\rho\, t}\, v_h\, h' \tag{28}$$

$$-\frac{dK}{dA} = \dot{\lambda}_1 \quad : \quad \dot{\lambda}_1 = -\lambda_1 r. \tag{29}$$

The transversality conditions are given by:

$$\lambda_1(T)\left(A(T) - \overline{A}\right) = 0, \tag{30}$$

$$\lambda_2(T)\left(H(T) - H_c\right) = 0. \tag{31}$$

The termination condition becomes:

$$u\left(c(T) + v(h(T))\right) e^{-\rho T} + \lambda_1(T)\,\dot{A}(T) + \lambda_2(T)\,\dot{H}(T) = 0. \tag{32}$$

Ehrlich and Chuma (1990) show that the length of life is finite if three conditions are fulfilled: health depreciation increases with age, the critical minimum health level is positive, and the maximum debt is limited to the finite magnitude of human wealth. We assume that these conditions are fulfilled.

Define the shadow price of health capital as $\eta(t) = \frac{\lambda_2(t)}{\lambda_1(t)}$. Then it follows from the first order conditions that:

$$\eta(t)\left[\sigma(t) + r - \frac{\dot{\eta}(t)}{\eta(t)}\right] = w(t)\,h' - e^{(r-\rho)t}\, v_h \frac{1}{\lambda_1(0)} h', \tag{33}$$

where h' denotes the derivative of h with respect to $H(t)$. Equation (33) is the equilibrium condition for investment in health capital. The left hand side corresponds to the marginal cost of changing the stock of health capital, while the right hand side is the instantaneous marginal benefit.

Solving equation (33) results in equation (13) above. The parameter $\eta(0)$ is the shadow value of health at time 0. It is a function of the lifetime profile of earnings, prices, tastes, and the rates of interest, impatience, and depreciation. It is determined simultaneously with the optimal longevity T, and the marginal utility of wealth $\lambda_1(0)$ by the following system of equations:

$$H(T) = e^{-\int_0^T \sigma(\tau)d\tau}\left[H(0) + \int_0^T I(s)\, e^{\int_0^s \sigma(\tau)d\tau} ds\right] = H^C \tag{34}$$

$$A(T) = \int_0^T \left[w(\tau)\,h(\tau) - \pi(\tau)\,I(\tau)^{\frac{1}{a+b}} - p_c c(\tau)\right] e^{r(T-\tau)} d\tau + e^{rT} A(0) = \overline{A}, \tag{35}$$

and

$$\begin{aligned} &\frac{1}{\lambda_1(0)}\left[u(c(T)) + v(h(T))\right] e^{(r-\rho)T} \\ &+ \left[rA(T) - \pi I(T) - p_c c(T) + w(T)\,h(T)\right] \\ &+ \eta(T)\ \left[I(T) - \sigma(T)\,H(T)\right] = 0\,. \end{aligned} \tag{36}$$

With decreasing returns to scale, the demand for health investments is given by:

$$I(t) = \left[\frac{\eta(t)(a+b)}{\pi(p_M, w(t), \phi(t))} \right]^{\frac{a+b}{1-a-b}} . \tag{37}$$

Equation (37) follows directly from the derivative of the Hamilton function with respect to investment. Investment $I(t)$ increases in $\eta(t)$, and decreases in $\pi(t)$.

Combining (37) and (4) yields the demand for health services $M(t)$:

$$M(t) = B\phi^{\frac{1}{1-a-b}} p_M^{-\frac{1-b}{1-a-b}} w(t)^{-\frac{b}{1-a-b}} \eta(t)^{\frac{1}{1-a-b}} . \tag{38}$$

Appendix B: The Questionnaire

The question on contentment with health is stated as
How content are you with your heath status? Answers are possible on an 11 point scale, ranging from *entirely uncontent* to *entirely content.*

The question on sportive activities is available for the years 85, 86, 88, 92, and 94. There were also respective questions in 84 and 95, but the coding was different, and not compatible with the questions in the remaining years. We therefore exclude these years.

The Wording of the questions is
Which of the following activities do you pursue in your leisure time? Please state how often you engage in this activity.
Possible answers for the category *Active Sport* are: *each week*, *each month*, *rarely ever*, *never*. The variable we constructed from this information assumes the value 1 if the individual classifies into the category *each week*.

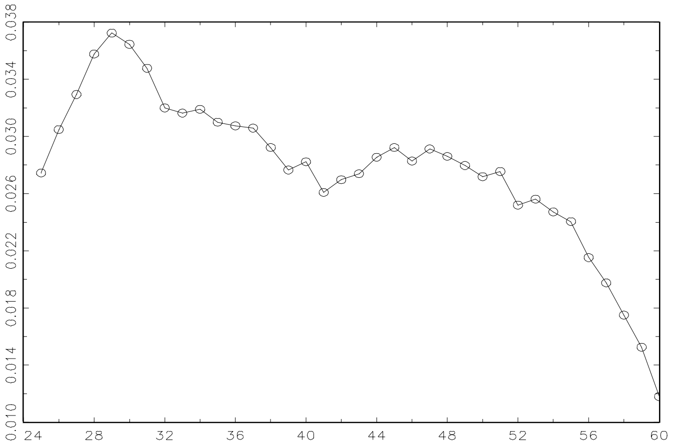

Figure 1: Sample frequency by age

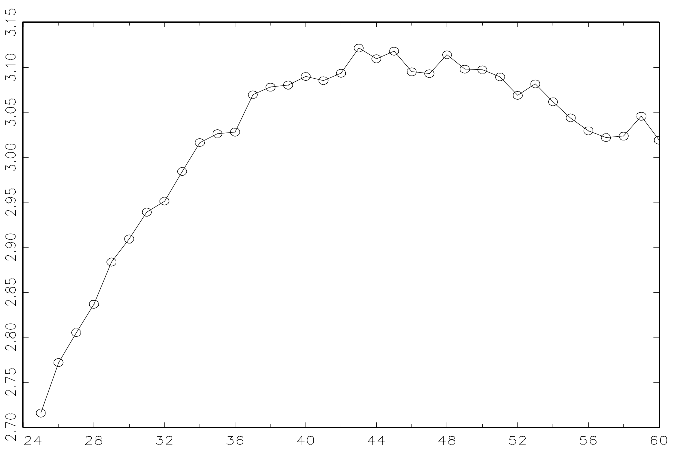

Figure 2: Average of log real wage by age

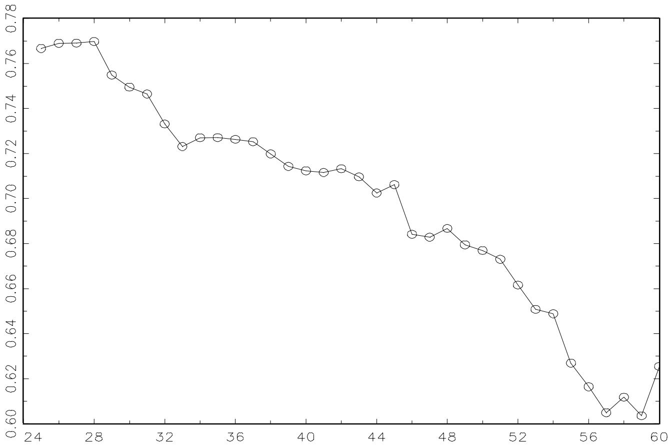

Figure 3: Average of health by age

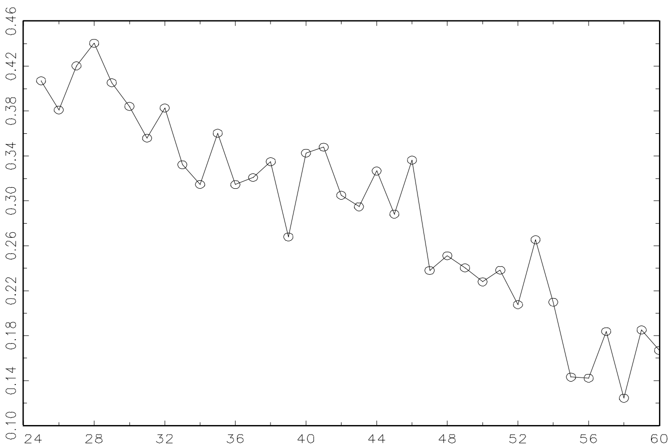

Figure 4: Average of sport by age

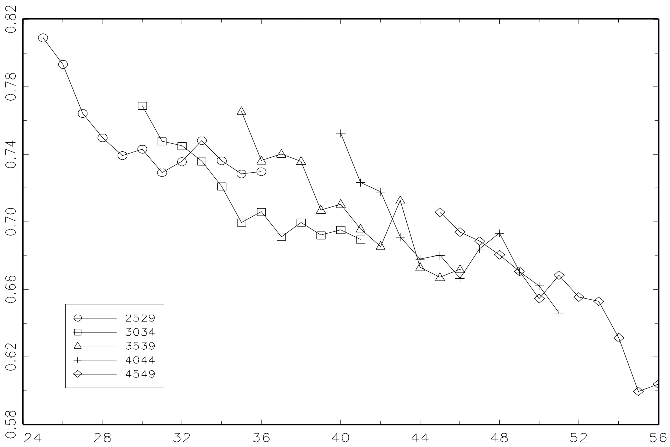

Figure 5: Average of health by age for 1984 age cohorts

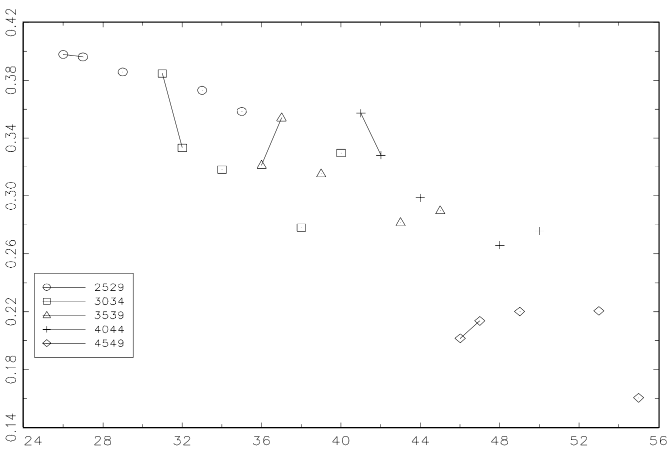

Figure 6: Average of sport by age for 1984 age cohorts

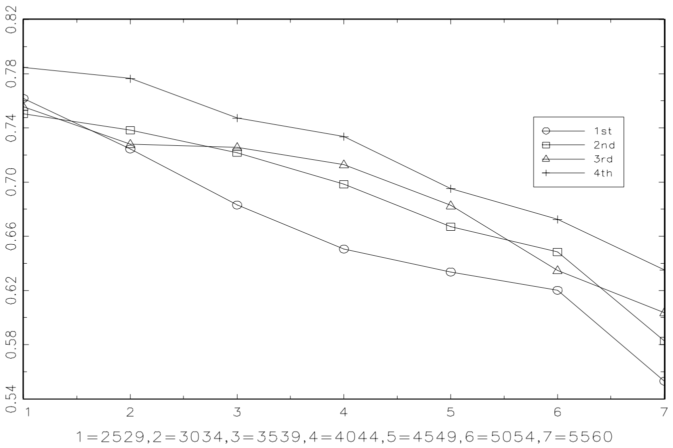

Figure 7: Average health by average household income quartile for 7 age groups

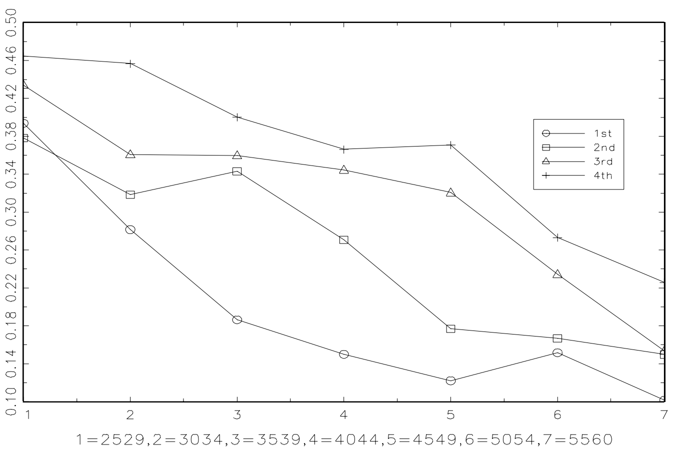

Figure 8: Average of sport by average houshold income quartile for 7 age groups