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Wages and the Demand for Health - A Life Cycle Analysis

Christian Dustmann
Frank Windmeijer

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Christian Dustmann

University College London, IFS, CEPR, London and IZA, Bonn

Frank Windmeijer

The Institute for Fiscal Studies, London and IZA, Bonn

ABSTRACT

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

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. Estimation results based on our life cycle framework lead to very different conclusions than those based on static cross section analyses that are common in the literature. The analysis emphasises the importance to analyse health related behaviour in a dynamic life cycle context.

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Christian Dustmann
Department of Economics
University College London
Gower Street
London WC1E 6BT
UK
Tel.: +44 20 7679 5212
Fax: +44 20 7916 2775
Email: c.dustmann@ucl.ac.uk

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1 Introduction

Individual health and longevity are of rising public and political concern as both have important e®ects on public spending. Low health standards impose a heavy burden on welfare institutions. 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. Much of the variation in health status as well as longevity between individuals is however 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 pre-requisite for successful health related policies. To de¯ne target groups for government health programmes requires to understand which groups are most at risk. It is not surprising that much research e®ort has been devoted to establishing a link between individual speci¯c characteristics, and health status as well as longevity. In this context, an interesting and important question is how individual health is related to the individuals' income. Although it is well understood that there is an association between income and health on an individual level, the precise nature of this relationship is not clear.

The theoretical foundations for understanding the demand for health in an intertemporal context have long been laid. An important ¯rst contribution to analysing the demand for health within a choice theoretical framework has been 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 a®ects longevity. Secondly, it generates instantaneous bene¯ts 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 our understanding of the comparative dynamics of the model (e.g. Ried (1998, 1999), and Eisenring (1999)).

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). Also, these demand functions can not be derived without assuming an instantaneous benefit of health.

Most empirical papers take 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.[1] The empirical health literature thus tends to neglect the implications of the intertemporal nature of the demand for health when estimating health demand functions. The empirical evidence these papers produce on the link between wages and individual health is not conclusive.

In a recent paper, Ehrlich and Chuma (1990) develop a version of the Grossman model in continuous time. Other than 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.[2] While in Grossman's

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[1] A notable exception is Wagstaff (1985), who estimates the consumption model, where health demand depends on the marginal utility of wealth.

[2] See Ried (1998, 1999) on this point, who argues that under certain conditions, the derived demand

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original work the demand for health is generated by its instantaneous bene⁻t 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 de⁻ned also if health creates no instantaneous bene⁻t.

In this paper we assess the empirical implications of Ehrlich and Chuma's work. 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 a parameter which links current period decisions with the entire future and history of the individual's optimisation problem (the relative marginal utility of health to wealth). This parameter is a su±cient statistic for all out of period information which a®ects current period demand. Frisch demand functions provide a natural way to distinguish between transitory and permanent demand responses.

In our empirical analysis, we estimate wage responses of the demand for health and health inputs. We distinguish between three parameters of interest. First, the response of an individual to wage changes along the individual's wage pro⁻le. Second, the di®erence in health (or health investments) between individuals due to a permanent wage di®erence. And third, the total di®erence in health (or health investments) between individuals with permanent wage di®erences. Within the model we develop, these parameters have a clear structural interpretation. They distinguish between wage responses over an individual's life cycle due to intertemporal substitution, and di®erences in health and health investments across individuals due to di®erences in permanent wages.

In contrast, straightforward regression analysis, as, for instance, suggested by Grossman's investment model, produces parameter estimates which have no clear interpretation within our life cycle framework. They are a mixture of evolutionary wage responses

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for health inputs can be determined.

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along an individual's life cycle wage pro¯le, and responses to wage di®erences across individuals. We demonstrate that these parameters may result in misleading conclusions.

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 estimate short term wage responses.

In our model, individuals invest into health capital to delay death, which is endogenously determined. Furthermore, health capital may provide an instantaneous bene¯t by enhancing healthy time. We ¯rst assume that health capital provides no instantaneous bene¯ts. In this case, di®erencing techniques can be used to identify evolutionary wage responses. In a second stage we impose structure on the shadow price of health capital, which allows us to identify permanent e®ects as well.

If health provides instantaneous bene¯ts, estimators based on within-individual di®erencing do not identify the parameters of interest. We propose a simple test for instantaneous health bene¯ts, and suggest an estimator which identi¯es evolutionary wage responses in this case. This is a matching type estimator, 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 evolutionary wage e®ects, and positive permanent e®ects. The implications for health related policies to be drawn from our speci¯cation are di®erent, and may even lead to opposite conclusions, than those drawn from a model which neglects the inherent dynamic structure of the problem.

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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, where the technology of health production exhibits diminishing returns (rather than constant returns, as in Grossman's model). 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 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 $\frac{3}{4}(t)$. 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

$$\dot{H}(t) = I(t) - \tfrac{3}{4}(t) H(t); \quad H(0) = H_0, \tag{1}$$

where $I(t)$ is investment in health capital, $\frac{3}{4}(t)$ is the depreciation rate on health capital, with $\dot{\tfrac{3}{4}}(t) > 0$, 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

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technology to be of a constant elasticity type:

$$I(t) = \acute{A}(t) M(t)^a m(t)^b ; \qquad (2)$$

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

The individual's time constraint is given by

$$h(t) = m(t) + I(t) ; \qquad (3)$$

where h(t) 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(t), and time devoted to the labor market, I(t). Accordingly, health capital enhances the total time available for these two activities.

The cost minimizing demand function for services M(t) is given by

$$M(t) = \frac{\dot{a}}{b}^{\circ \frac{b}{a+b}} p_M^{i\frac{b}{a+b}} w(t)^{\frac{b}{a+b}} \acute{A}(t)^{i\frac{1}{a+b}} I(t)^{\frac{1}{a+b}} : \qquad (4)$$

The resulting cost function is given by

$$C(t) = \tfrac{1}{4}(w(t); p_M; \acute{A}(t)) I(t)^{\frac{1}{a+b}} ; \qquad (5)$$

with unit cost ¼:

$$\tfrac{1}{4}(w(t); p_M; \acute{A}) = B\acute{A}(t)^{i\frac{1}{a+b}} p_M^{\frac{a}{a+b}} w(t)^{\frac{b}{a+b}} \quad ; \quad B = \frac{\dot{a}}{b}^{\circ \frac{b}{a+b}} + \frac{\dot{a}}{b}^{\circ i \frac{a}{a+b}} ; \qquad (6)$$

where w(t) 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:

$$\dot{A} = rA(t) \; ¡ \; \tfrac{1}{4}(t) I(t)^{\frac{1}{(a+b)}} \; ¡ \; p_c c(t) + w(t) h(t) ; \quad A(0) = A_0; \qquad (7)$$

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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 (t), with unit price p_c.[3]

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:

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

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

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

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.

[3]Other than in Grossman's model, where c (t) is also produced inside the household, we assume for simplicity that consumption goods are purchased directly in the market place.

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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 (39) in the appendix gives the (log) demand equation for health services $M(t)$:

$$\ln M(t) = \bar{}_0 + \bar{}_1 \ln \acute{A}(t) - \bar{}_2 \ln p_M - \bar{}_3 \ln w(t) + \bar{}_4 \ln \acute{}(t); \qquad (11)$$

where the $\bar{}$'s are functions of a and b, and $\acute{}(t) = \,_2(t)=\,_1(t)$ is the relative shadow value of health capital.

The demand for health investment equation is given by (38) in the appendix. Taking logs leads to

$$\ln I(t) = \pm_0 + \pm_1 \ln \acute{A}(t) - \pm_2 \ln p_M - \pm_3 \ln w(t) + \pm_4 \ln \acute{}(t); \qquad (12)$$

where the $\pm$'s are functions of a and b.

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

$$\acute{}(t) = \acute{}(0)\, e^{\int_0^t [\frac{3}{4}(\iota)+r]d\iota} - E(t) - F(t); \qquad (13)$$

where

$$E(t) = \int_0^t w(\iota)\, h^0(\iota)\, e^{\int_\iota^t [\frac{3}{4}(s)+r]\,ds}\, d\iota;$$

$$F(t) = \int_0^t h^0(\iota)\, v_h\, e^{(r-\frac{1}{2})\iota}\, \frac{1}{\,_1(0)}\, e^{\int_\iota^t [\frac{3}{4}(s)+r]\,ds}\, d\iota;$$

and h^0 is the derivative of healthy time $h(t)$ with respect to the stock of health capital, $H(t)$. The parameter $\,_1(0)$ is the shadow value (or marginal utility) of wealth at $t = 0$; the parameter $\acute{}(0)$ is the shadow value of health, relative to the shadow value of wealth, at time 0.

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[4] Equation (13) is obtained by solving equation (34) in the appendix.

The term $E(t)$ re°ects the instantaneous bene¯t of health by enhancing time which may be allocated to the marketplace. The term $F(t)$ captures the instantaneous bene¯t of healthy time by increasing contemporaneous utility levels. If health is bene¯cial 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

$$´(t) = ´(0) e^{\int_0^t [¾(¿)+r]d¿} :$$

(14)

Notice that the assumption of instantaneous health bene¯ts a®ects the demand equations (11) and (12) only via $´(t)$.

2.2   Permanent and Evolutionary Wage Responses

Consider now the e®ect of wage changes on the demands for $I(t)$ and $M(t)$, and let $´(t)$ be given by (14). The parameter $´(0)$ 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 su±cient statistic for all outside period information which a®ects the current period demand. In a world of perfect certainty, any changes in wages do not a®ect $´(0)$, since they are fully anticipated by the individual. The e®ect of a change in current wages is a response along an individual's wage pro¯le, and is sometimes referred to as response to evolutionary wage changes (see MaCurdy (1981), Blundell and MaCurdy (1999)). The elasticity of health service demand or health investment with respect to evolutionary wage changes is an intertemporal substitution elasticity. The wage response conditional on $´(t)$ re°ects 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 e®ect on demands via $´(0)$ is determined by the three equilibrium conditions for $´(0)$, the marginal utility of wealth $_1(0)$, and the optimal longevity T (see equations (35) -(37) in the appendix). This e®ect is a permanent wage e®ect, in the sense that

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it shifts the entire life cycle pro⁻le of demand. It measures permanent di®erences in demands across individuals.

Consider the health investment equation (12). With respect to wage responses, there are three parameters of interest. The ⁻rst is the evolutionary response of health investments to changes in wages. This parameter answers the question to which extent individuals change their health investments when wages change along their wage pro⁻le, as a consequence of substituting time away from health enhancing activities to the workplace. This is the e®ect of changes in wages, conditional on ´(0).

The second is the di®erence in health investments between individuals due to a permanent di®erence in their wages, induced solely by di®erences in ´(0) (remember that ´(0) is a function of the entire future and history of wages). This parameter answers the question to what extent a permanent di®erence in wages between individuals contributes to a shift in the investment pro⁻le.

The third is a combination of the ⁻rst and the second. It answers the question to which extent a permanent di®erence in wages between two individuals is associated with di®erences in health investments, being due to both permanent di®erences in the investment pro⁻le, and evolutionary responses along an individual's pro⁻le.

All three parameters are important for health related policies. None can be iden-ti⁻ed by simple cross section regression analysis, as done in most of the empirical literature. Empirical results from a model which relies on straightforward regression analysis, using across-individual variation only to identify wage responses, yields a mixture of evolutionary and permanent wage responses.

We have illustrated this in ⁻gure 1, where the vertical axis carries time, and the horizontal axis to the left of the time axis carries health investments I (t), and to the right of the time axis wages w(t). We consider two individuals, A and B, with the same initial wages. Individual A has a steeper wage pro⁻le than individual B, and therefore a higher life cycle wage income. To simplify the exposition, consider a stylised version of (12), which describes the relationship between health investments of individual J,
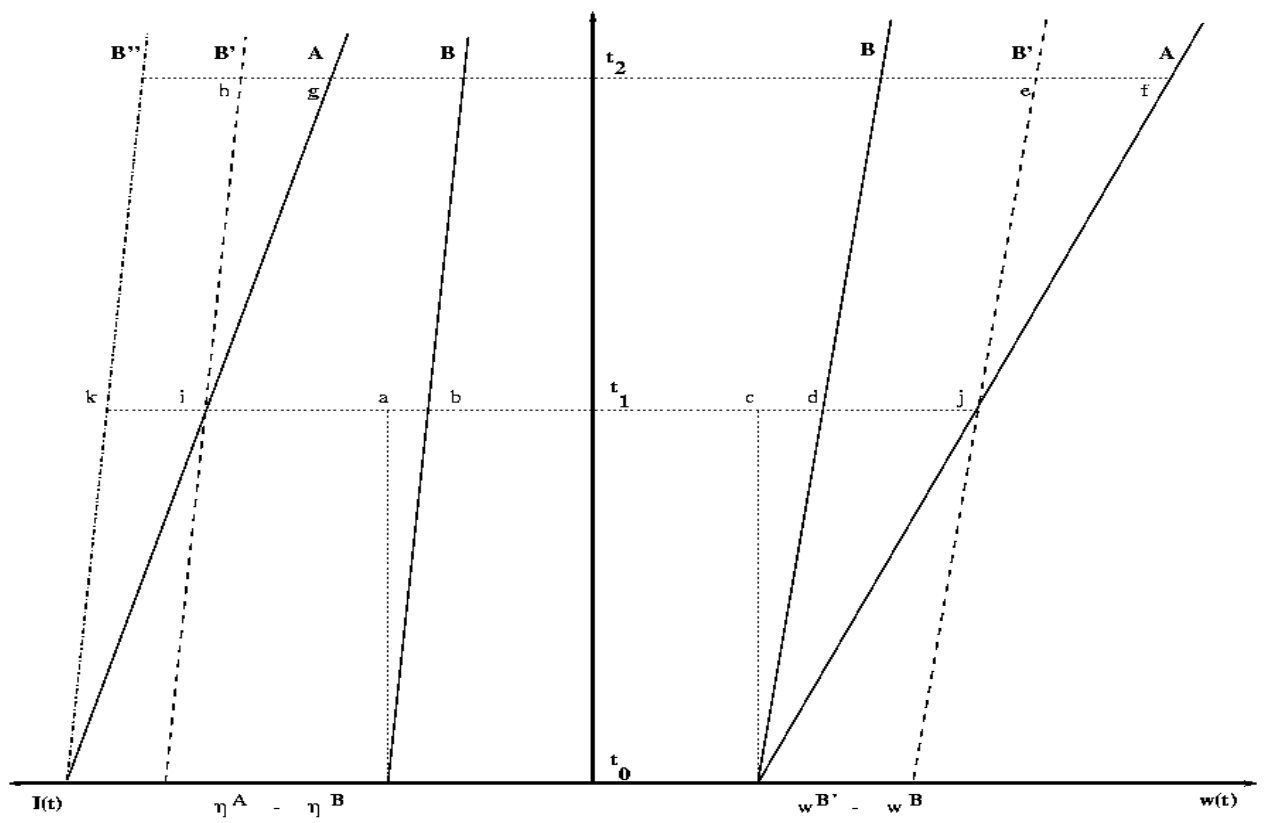
Figure 1: Evolutionary and Permanent Wage Responses

wages and the parameter γ:

$$I^J(t) = a_0 + a_1 w^J(t) + \gamma^J; \quad J = A, B; \quad \text{where} \quad a_1 < 0.$$

The parameter γ is an increasing function of the entire wage profile of the individual. Accordingly, $\gamma^A > \gamma^B$, and health investments are on a higher profile for individual A. At t_0, wages for the two indviduals are the same, and the difference in health investments is due to differences in γ only: $I^A(t_0) - I^B(t_0) = \gamma^A - \gamma^B$.

In our simple graphical representation, the evolutionary wage effect is given by the ratio of health investments to wages at two points along an individual's wage and health investment profiles. There are at least two possibilities to identify this parameter. First, by using variations within individuals only. For example, choosing periods t_0 and t_1, the evolutionary wage effect is given by $a_1 = (I^B(t_1) - I^B(t_0))=(w^B(t_1) - w^B(t_0))$ (corresponding to $(b-a)=(d-c)$ in the figure), which is negative. Second, by matching individuals with different life cycle wage paths, but with the same γ. To illustrate this, we have drawn the individual B', which has the same wage path as B, but at a level such that $\gamma^{B'} = \gamma^A$. If we now choose any time t (say t_2), then a_1 is equal to $(I^A(t_2) - I^{B'}(t_2))=(w^A(t_2) - w^{B'}(t_2))$ (corresponding to $(g-h)=(f-e)$).

The permanent difference in health investments between A and B due to permanent differences in their wages is equal to $I^A(t_0) - I^B(t_0)$. This is equal to $\gamma^A - \gamma^B$, and it corresponds to the difference in health investments at a point where wages for the two individuals are equal. The second parameter of interest is this difference, relative to the difference in permanent wages. We have drawn the wage path of individual B', which we obtain by shifting B to the right, so that the life cycle wage for A and B' are equal. Accordingly, $\gamma^{B'} = \gamma^A$. Then the permanent wage difference is equal to $w^{B'} - w^B$, and the parameter of interest is $(\gamma^A - \gamma^B)=(w^{B'} - w^B)$.

Finally, the third parameter of interest is the total effect of a permanent change in wages on health investments between two individuals. Consider again shifting B's profile to B'. We have also drawn the corresponding investment profile, which is also

labeled by B^0. The total e®ect on health investments of this shift is the combined permanent and evolutionary response, which is given by

$$\frac{I^{B^0} - I^{B}}{w^{B^0} - w^{B}} = \frac{´^{B^0} - ´^{B}}{w^{B^0} - w^{B}} + a_1:$$

In the ¯gure, this corresponds to $(k - b)=(j - d) + (i - k)=(j - d)$.

Now suppose we estimated the above relationship by straightforward regression, using a cross section of individuals. Suppose further we observe both A and B in t_2. Then the parameter we obtain is equal to

$$\frac{I^{A}(t_2) - I^{B}(t_2)}{w^{A}(t_2) - w^{B}(t_2)} = \frac{´^{A} - ´^{B}}{w^{A}(t_2) - w^{B}(t_2)} + a_1:$$

This parameter is a compound e®ect of the (negative) evolutionary wage response, and a term which involves di®erences in the permanent response, normalised by di®erences in wages in the observation period. For the way we have drawn the diagram, this compound e®ect is positive.[5] This estimated parameter does not correspond to any of the parameters of interest. It is di®erent for any t we choose; in applications, it depends on the distribution of the sample.

It may give misleading answers to questions like "Should individuals with low wages be targeted by government programmes to enhance health standards". Suppose that the estimated parameter from a simple cross section estimation is positive. Then this may wrongly be interpreted as individuals with higher wages invest more into health. But temporarily poor people may well invest more into health than temporarily rich people, if their total life cycle income is higher. In our ¯gure, individuals A and B have the same wages in t_0; nevertheless, investments of A are higher than investments of B, because A⁰s life cycle income is higher. Cross section results would identify both individuals as equally eligible for any support programme.

Over an individual's life cycle wage path, however, a large transitory increase in wages may lead to a strong reduction in health investments, because individuals may

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[5]This is also the case for our applications below.

substitute away time from health enhancing activities. Individuals with high wages may therefore suffer from serious illness as a result of a temporary neglect of their health. That health hazards induced by temporary neglect of health of high wage individuals can be severe is well documented in the medical literature.[6] Again, cross section results would fail to identify these individuals as individuals who are at risk.

In our figure, for instance, the distance in health investments between A and B narrows, while the contemporaneous wage differential increases. This is due to A experiencing a higher wage growth than B, and thus substituting time away from health investment to the market place. A simple cross section analysis would identify A and B as investing equally in health at t_0, whereas at t_0 we observe the largest difference in health investment between the two; it would also suggest that the difference between A and B is largest in t_2, whereas it is smallest (and it could even be negative if the response of health investments to evolutionary changes in wages is sufficiently large).

The discussion shows the importance of distinguishing between evolutionary and permanent wage responses. In section 4, we estimate demand for health investment equations and demand for health equations, distinguishing 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

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[6]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.

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.[7] We rescale this measure to be bound 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 ¯tness, and longevity.[8] 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 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. Summary statistics are reported in Table 1.

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[7]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 re°ect their current health status".

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

Table 1: Summary Statistics

Variable	Health	Health Investment	Log Wages
Acronym	H D	I D	ln w
De¯nition	Contentment with health	Doing sports at least once a week	Log Real Hourly Wage
Range	0,0.1,...,1 1 = very content	0,1	
Years available	84-95	85,86,88,92,94	84-95
# individuals	3324	2791	3324
# observations	19100	7818	19100
mean	0.7056	0.3058	3.0123
std dev	0.2083	0.4608	0.3606
within std dev	0.1369	0.2542	0.1681
between std dev	0.1762	0.4041	0.3529

Figures 2 to 5 present graphical information of some of the variables we use in our analysis. In ¯gure 2, the age distribution in the sample is displayed. The highest frequency is at age 29, the lowest at age 60. Figure 3 presents the average log real wage by age. Wages rise substantially between age 25 and 44, level out, and slightly decline after age 48.

The mean for our measure for the stock of health at di®erent ages is depicted in ¯gure 4. It declines steadily with age, from an average value of 0.77 at age 25, to a low of 0.61 at age 59.
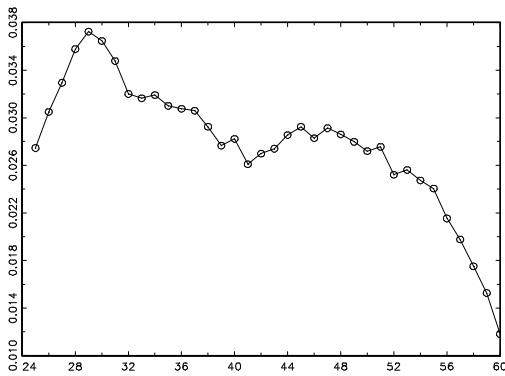
Figure 2: Sample frequency by age
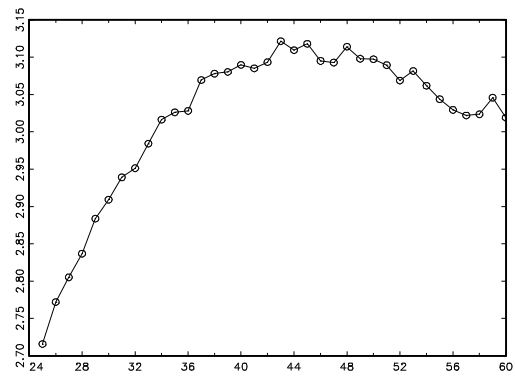
Figure 3: Average of log real wage by age
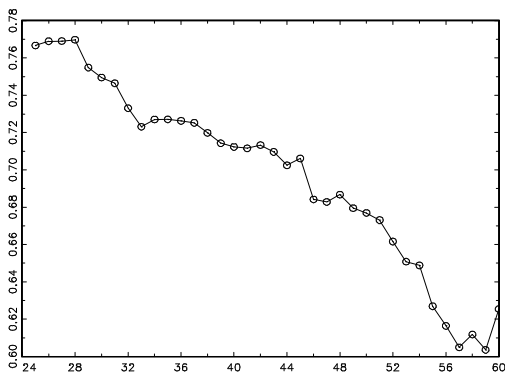
Figure 4: Average of HD by age
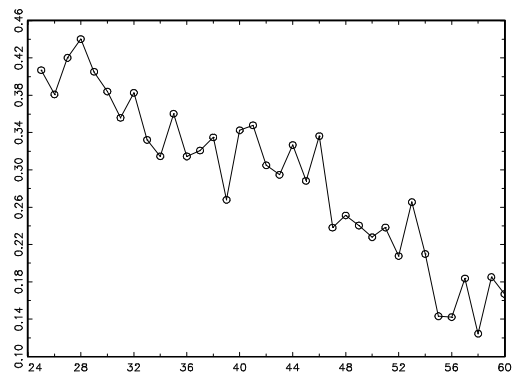
Figure 5: Average of ID by age

The respective pattern for sport activities is depicted in figure 5. 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 6 and 7). Figure 6 shows

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that within cohorts, the measure for the stock of health clearly declines with age; there are some slight level di®erences between the various cohorts. Figure 7 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 ¯gure 5.
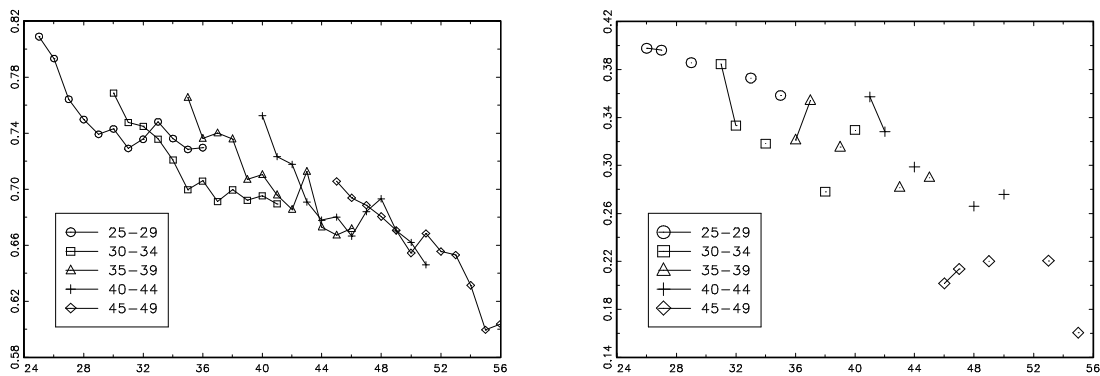
Figure 6: Average of HD by 1984 age cohort   Figure 7: Average of ID by 1984 age cohort

The ¯gures 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 di®erence out all time constant characteristics; furthermore, we condition on age and time, which should account for the cohort e®ects visible in the ¯gures. The remaining signal in this variable should be a good proxy for health investments.

In ¯gure 8, 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 pro¯les 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 9 illustrates this pattern for the sports variable; again, a wealth e®ect is clearly visible.

0.82 0.78 0.74 0.70 0.66 0.62 0.58 0.54

0.50 0.46 0.42 0.38 0.34 0.30 0.26 0.22 0.18 0.14 0.10

1st qrt
2nd qrt
3rd qrt
4th qrt

1=25−29,2=30−34,3=35−39,4=40−44,5=45−49,6=50−54,7=55−60

1=25−29,2=30−34,3=35−39,4=40−44,5=45−49,6=50−54,7=55−60
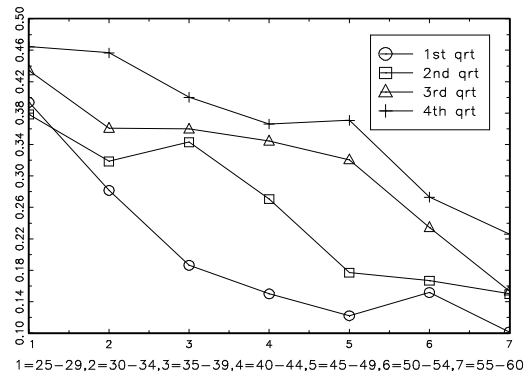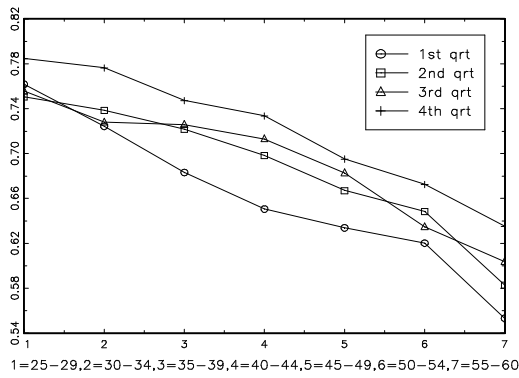
Figures 8 and 9: Average of H D and I D by mean HH income quartile for 7 age groups

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:

$$H(t) = (1 - \delta)H(t-1) \tag{15}$$
$$+ \exp(\pm_0 + \pm_1 \ln A(t-1) - \pm_2 \ln p_M - \pm_3 \ln w(t-1) + \pm_4 \ln \gamma(t-1));$$

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 $\ln H(t) = \ln I(t) - \ln \delta(t) - \ln(1 + \dot{H}=\delta(t))$, where $\dot{H} = \dot{H}=H$ is the relative change in health capital. If one is willing to assume that $\dot{H}=\delta(t) = 0$, then one obtains (using (12)):

$$\ln H(t) = \chi_0 + \chi_1 \ln A(t) - \chi_2 \ln p_M - \chi_3 \ln w(t) + \chi_4 \ln \gamma(t) - \ln \delta(t): \tag{16}$$

The assumption that $\dot{H}=\delta(t) = 0$ 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 $\dot{H}=\delta(t)$ to be constant between two periods. Accordingly, equation (16) may

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be a good starting point for an empirical model. We estimate both the dynamic model in (15), and its simpler version in (16).

Our first estimation strategy is to estimate a model where health has no instantaneous benefit, which results in an expression for $\acute{}(t)$ 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 evolutionary wage effect by differencing out the term $\acute{}(0)$. We then estimate permanent wage effects, where we approximate $\acute{}(0)$ 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 $\acute{}(t)$ leads to an equation with an error term which still contains a function of $\acute{}(0)$ (and, if healthy time enters the utility function, of $_{,1}(0)$, 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 $\acute{}(0)$, 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 $\acute{}(t)$ would be given by equation (13). An estimation strategy which can identify evolutionary wage responses in this case is a matching type estimator, which differences across individuals with the same $\acute{}(t)$. Matching is done on 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, $\acute{}(t)$ 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 $t = 1, \ldots, T$ is the time index. Furthermore, summarise variables which determine the demand in the vector X, and the corresponding parameters in $\pm$. Then the generic empirical model for equations (12) and (16) is given by

$$\ln Y_{it} = X_{it}'\pm + \beta \ln w_{it} + \ln \gamma_i^0 + v_{it}. \tag{17}$$

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

$$\Delta \ln Y_{it} = \Delta X_{it}'\pm + \beta \Delta \ln w_{it} + \Delta v_{it}. \tag{18}$$

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 $\frac{3}{4}(t)$ 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.[9] Accordingly, in our empirical specification, $\Delta X_{it} = [\pm_{0t}, \Delta age_{it}^2]$, where the $\pm_{0t}$ are time effects.

The dependent variables in equations (17) and (18) are $\ln H$ and $\ln I$. These variables are unobservable and we use as proxy variables the self-reported health index, HD, and the binary indicator for doing sports at least once a week, ID, respectively. It is natural to assume that there exists the following mapping from $\ln H$ to HD

$$HD = j \quad \text{if} \quad c_{j-1} < \ln H < c_j$$

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[9] In Germany, medical services are financed by contributions to a compulsory insurance scheme. Contributions are in the form of a payroll tax, income dependent, and financed to equal parts by the employed and the employee. This scheme finances services also for the non-employed family members of the contributing individual. The scheme covers about 90 percent of the German population (see Pohlmeier and Ulrich, 1995, for details). Accordingly, there is little heterogeneity in the price of medical care due to differences in insurance schemes, as, for instance, in the US.

for $j = 0; 0:1; ::::; 1$, and where the c_j are threshold parameters. As ID is a simple binary indicator the postulated relationship between ln I and ID is

$$ID = 1 \quad \text{if} \quad \ln I > c:$$

It is common practice to estimate the parameters in these models by (ordered) probit estimation techniques. Estimating (ordered) probit models with ¯xed e®ects and weakly exogenous variables (see the discussion below) is di±cult. We therefore estimate linear models with the indices HD and ID as the dependent variables. Under some general assumptions on the data generating process, these linear models will estimate the parameters up to scale.[10]

Because of the scaling of the parameters, as in all models with discrete dependent variables, interpretation of the size of the coe±cients is problematic. In a linear model, not only does the standard deviation of the error term scale the parameters. The varying width of the intervals between the thresholds further scales the coe±cients, as it is unlikely that the distance for an individual between a reported 2 and 3 is the same as the distance between 7 and 8. We therefore refrain from any direct interpretation of the size of the coe±cients. However, we can assess the relative magnitude of permanent and evolutionary wage responses.

De¯ne the variable YD_{it} which corresponds to ID_{it} or HD_{it}, then the empirical model in ¯rst di®erences is speci¯ed as[11]

$$\mathcal{C} YD_{it} = \mathcal{C} X_{it}^{0} \pm^{\alpha} + {}^{3\alpha} \mathcal{C} \ln w_{it} + \mathcal{C} u_{it}: \qquad (19)$$

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

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[10] See Chung and Goldberger (1984), Ruud (1986) and Newey (1986).

[11] In the remainder, we drop the α superscripts when we present estimation results.

correlated with past health status, and, accordingly, with $u_{it_i - s}$; $s > 0$. Hence, estimating the parameters in model (19) by OLS will result in biased coefficient estimates.[12] We use an instrumental variable Generalised Methods of Moments (GMM) estimator, instrumenting the current wage difference by lagged levels of wages.[13] The full instrument set used in the estimation is

$$z_{it} = \left[1; \ln w_{it_i - 1}; \ln w_{it_i - 2}; \ln w_{it_i - 3}; age_{it}; age_{it}^2; educ_i; educ_i^2; educ_i \pounds age_{it} \right]; \quad (20)$$

where $educ_i$ is the years of schooling of individual i.[14] The age variable is rescaled to be 0 at age 25.

The estimation results are presented in Table 2. The parameter $\bar{\pm}_{0t}$ 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 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. Both effects, however, are not estimated very precisely.

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

[13] 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 $\hat{u}_i$, the efficient two-step GMM estimator uses $W_N = \left(\frac{1}{N} \sum_i Z_i' \hat{u}_i \hat{u}_i' Z_i \right)^{-1}$. See Hansen (1982).

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

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

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

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Table 2. Estimation results for first-di®erenced models

Dependent variable	Health		Health Investment	
	HD		I D	
	coe®	std err	coe®	std err
$\overline{\pm_{0t}}$	-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		2791	
# of observations	13906		7818	

E±cient two-step GMM results.

Standard errors are robust to heteroscedasticity and correlation over time.

$\overline{\pm_{0t}}$ is the mean of the time e®ects, weighted for unequal period lengths

in the health investment equation.

The Sargan test is a test for instrument validity.

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

$$H_{it} = {}^{®}H_{it_i 1} + I_{it_i 1}$$
$$= {}^{®}H_{it_i 1} + \exp\left(X^{0}_{it_i 1}\pm + {}_{3}\ln w_{it_i 1}\right)\,{}^{0}_{i}v_{it};$$

where $® = (1_i \tfrac{3}{4})$, and v_{it} is an idiosyncratic (multiplicative) error term. Notice that the dynamic model is multiplicative in ${}^{0}_{i}$, so that straightforward di®erencing is not feasible. We can however quasi-di®erence the model to eliminate the fixed e®ect. The quasi-di®erenced equation is given by:[15]

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[15]See Chamberlain (1992), Wooldridge (1997) and Blundell, Gri±th and Windmeijer (1999).

$$(H_{it} - {}^{\circledR}H_{it-1}) \exp\left(-{}^3\mathbb{C} X^0_{it-1}\pm + {}^3\mathbb{C}\ln w_{it-1}\right) - (H_{it-1} - {}^{\circledR}H_{it-2}) \quad (21)$$

$$= v_{it} \exp\left(-\mathbb{C} X^0_{it-1}\pm + {}^3\mathbb{C}\ln w_{it-1}\right) - v_{it-1};$$

where the error term on the right hand side has zero mean, conditional on appropriate instruments. As H is unobserved, we estimate the model using e^{HD} to approximate H. Again, this implies that the parameters $\pm$ and ^{3} are estimated up to scale. The parameters of the model can be estimated by GMM, where we use as instruments the variables[16]

$$z_{it} = [1; e^{HD_{it-3}}; e^{HD_{it-4}}; e^{HD_{it-5}}; \ln w_{it-1}; \ln w_{it-2}; \ln w_{it-3}; age_{it-1}; age^2_{it-1};$$

$$educ_i; educ^2_i; educ_i \pounds age_{it-1}]:$$

The estimation results are displayed in Table 3. In the ¯rst column, we present results where we assume that the rate of depreciation ¾(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 e®ects are very similar in both speci¯cations, and they re°ect our previous ¯ndings. The estimated coe±cient is negative, and signi¯cant at the 10 percent level. The interpretation of this coe±cient is the same as in the above models: It is a scaled evolutionary wage e®ect on health investment. The estimate is slightly larger than the estimate obtained from the previous model.

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[16]As the error process in the quasi-di®erenced equation displays an MA(2) structure we use $e^{HD_{it-3}}$ and further lags as instruments.

Table 3: Results for quasi-di®erenced multiplicative model for Health

Dependent variable	exp (HD)		exp (HD)	
	coe®	std err	coe®	std err
$\exp(HD_{i\,1})$	0.2068	0.0743	0.3084	0.0675
$(age \,\text{¤}\, \exp(HD))_{i\,1}$			-0.0058	0.0011
$\ln w_{i\,1}$	-0.0465	0.0265	-0.0420	0.0269
$age_{i\,1}$	-0.0061	0.0025		
$age^2_{i\,1}=100$	-0.0036	0.0060		
Sargan test (p-value)	113.0	(0.1423)	113.3	(0.1551)
# individuals	1870		1870	
# observations	9054		9054	

E±cient, iterated GMM results for quasi-di®erenced model.

Standard errors are robust to heteroscedasticity and correlation over time.

The Sargan test is a test for instrument validity.

The parameter on the lagged health stock variable corresponds to $(1 \text{ ¡ } \text{¾})$ in our theoretical model, where ¾ is the rate of depreciation. Estimation of the simple level model (where we instrument $\exp(H_{it\,1})$ by $\exp(H_{it\,2})$ due to an MA(1) error process) gives an estimate for ¾ of a magnitude of 0.078 (standard error 0.014). When we control for ¯xed e®ects (column 1 in Table 3), the estimate becomes unreasonably large, and the standard error increases. After controlling for the permanent e®ect, it seems di±cult to identify ¾ separately.[17] In the second column, we allow for an increasing rate of health depreciation. Our formulation corresponds to an additively linear depreciation rate of the form $\text{¾}(t) = \text{¾}_0 + \text{¾}_1 \text{ ¤ } Age(t)$. The parameter estimate

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[17]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-di®erenced health variable, which could lead to a downward weak instrument bias (see Blundell and Bond (1998)).

for γ_1 is negative, which is in accordance with our model.

4.2   Permanent Wage Effects

To recover the response in health or health investment to permanent shifts in wages, 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 $\ln \lambda_i^0$ is a function of initial wealth A^0, initial health H^0, and the entire lifetime wage path:

$$\ln \lambda_i^0 = \beta_0 A_i^0 + \alpha_0 H_i^0 + \sum_{s=0}^{T_W} \mu_s \ln w_{is} + v_i; \tag{22}$$

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

Specify individual i's wage in period t as

$$\ln w_{it} = \gamma_{0i} + age_{it}\gamma_{1i} + age_{it}^2\gamma_{2i} + u_{it}; \tag{23}$$

where the γ_{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

$$A_{it} = \zeta_{0i} + age_{it}\zeta_{1i} + age_{it}^2\zeta_{2i} + v_{it}; \tag{24}$$
$$H_{it} = \omega_{0i} + age_{it}\omega_{1i} + age_{it}^2\omega_{2i} + s_{it};$$

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

Combining (22), (23) and (24), $\ln \lambda_i^0$ can be written as

$$\ln \lambda_i^0 = \beta_1 + \gamma_{0i}\bar{\mu}_0 + \gamma_{1i}\bar{\mu}_1 + \gamma_{2i}\bar{\mu}_2 + \zeta_{0i}\tilde{\beta}_0 + \omega_{0i}\tilde{\alpha}_0 + \varepsilon_i; \tag{25}$$

where

$$\bar{\mu}_j = \sum_{t=0}^{T_W} t^j \mu_t; \quad j = 0; 1; 2; \quad \tilde{\beta}_0 = \frac{\beta_0}{r}; \quad \tilde{\alpha}_0 = \frac{\alpha_0}{r + \gamma}:$$

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We obtain unbiased estimates of γ_{0i}, γ_{1i}, γ_{2i}, ζ_{0i} and η_{0i}, following the procedure outlined by MaCurdy (1981).[18] For the construction of the individual speci¯c initial wealth parameter ζ_{0i}, we use as a measure for non-wage income, A_{it}, observed real total household income, excluding the earnings of the individual male.[19] To recover the parameter η_{i0}, we use the self reported health measure. Estimates of γ_{0i}, γ_{1i}, γ_{2i}, ζ_{0i}, and η_{i0} are based on the longest available series on log wages, household income, and health respectively.

From the estimation results of the di®erenced models the individual speci¯c e®ects can be estimated by

$$
\ln \hat{\eta}_i^0 = \frac{1}{T_i} \sum_{t=1}^{T_i} \left(YD_{it} - \beta \ln w_{it} - age_{it}\bar{b}_0 - age_{it}^2 \bar{b}_1 \right);
$$

with $\bar{b}_0$ equal to the average of the b_{0t}. For the dynamic equation, we obtain an estimate of $\ln \hat{\zeta}_i^0$ as

$$
\ln \hat{\zeta}_i^0 = \ln \left(\frac{1}{T_i - 1} \sum_{t=2}^{T_i} \frac{\exp(HD_{it}) - \beta \exp(HD_{it-1})}{\exp\left(\beta \ln w_{it-1} + age_{it}\bar{b}_0 + age_{it}^2 \bar{b}_1 \right)} \right);
$$

Using $\ln \hat{\eta}_i^0$, γ_{0i}, γ_{1i}, γ_{2i}, $\hat{\zeta}_{0i}$ and $\hat{\eta}_{0i}$ we estimate equation (25) to obtain estimates of β_1, $\bar{\mu}_0$, $\bar{\mu}_1$, $\bar{\mu}_2$ and β_0, using IV (since the explanatory variables are by construction

---

[18]The unbiased estimators of the γ's are given by

$$
b_{2i} = \frac{1}{T_i - 2} \sum_{j=1}^{T_i-2} \frac{1}{j} \left(\frac{\ln w_{ij+2} - \ln w_{i1}}{j+1} - (\ln w_{i2} - \ln w_{i1}) \right)
$$

$$
b_{1i} = \frac{1}{T_i - 1} \sum_{j=1}^{T_i-1} \left(\frac{\ln w_{ij+1} - \ln w_{i1}}{j} - b_{2i}(2age_{ij+1} - j) \right)
$$

$$
b_{0i} = \frac{1}{T_i} \sum_{j=1}^{T_i} \left\{ \ln w_{ij} - b_{1i}age_{ij} - b_{2i}age_{ij}^2 \right\}
$$

where j denote observed sample periods, and $\ln w_{ij}$ are log wages of individual i in period j. The ζ's and η's are computed in a similar manner, with residual total household income and health status substituted for log wages.

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

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.

Table 4: Estimation results for permanent effects model

	Health		Health (Dynamic Model)		Health Investment	
	coeff	std err	coeff	std err	coeff	std err
const	0.7819	0.1689	0.5785	0.2538	0.1959	0.3297
$\bar{\mu}_0$	0.0590	0.0615	0.0634	0.0970	0.1483	0.1225
$\bar{\mu}_1$	1.0435	1.0180	1.2074	1.6226	2.9034	2.0005
$\bar{\mu}_2$	13.8553	13.0137	16.7098	20.0566	36.1682	23.7592
β_0	-0.0007	0.0007	-0.0008	0.0010	0.0002	0.0015
γ_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 $\bar{\mu}_0$, $\bar{\mu}_1$ and $\bar{\mu}_2$.

The estimation results are presented in Table 4. The coefficient on initial wealth (β_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 (γ_0) is positive.

Also, for both equations, $\bar{\mu}_0$, $\bar{\mu}_1$, and $\bar{\mu}_2$ are positive, indicating positive permanent wage e®ects. All these e®ects are however not precisely estimated. The joint test of signi¯cance for the permanent wage parameters is signi¯cant for the health investment equation.

The overall response to a change in wages can be obtained by combining the estimation results for ^{3}, $\bar{\mu}_0$, $\bar{\mu}_1$, and $\bar{\mu}_2$. For example, a change in $\frac{1}{4}_0$ would correspond to a permanent parallel shift in the log wage pro¯le, as, for instance, a shift from B to B^0 in ¯gure 1. As we have discussed above, such a hypothetical shift creates a permanent response, and an evolutionary response. For the (non-dynamic) health equation the permanent response is given by $\frac{@ \,\acute{}_0}{@ \,\frac{1}{4}_0} = \mu_0^1 = 0{:}0590$. The evolutionary response is given by $^3 = \;¡\; 0{:}0163$.

The total response to this shift is given by combining the permanent response across two individuals, and the evolutionary response. For the (non-dynamic) health equation, this parameter is $\frac{@ \mathrm{HD}}{@ \,\frac{1}{4}_0} = 0{:}0590 \;¡\; 0{:}0163 = 0{:}0427$. For the health investment equation, the total e®ect is given by $\frac{@ \mathrm{ID}}{@ \,\frac{1}{4}_0} = 0{:}1483 \;¡\; 0{:}0308 = 0{:}1075$. These estimates seem to suggest that evolutionary responses are relatively small, as compared to permanent responses. Notice however that here we shift the entire wage pro¯le. But a one percent increase in wages at one point in time would not lead to a one percent increase in permanent wages. Accordingly, at stages in the life cycle where wages grow very rapidly, the negative evolutionary response may lead to serious drops in health and health investments.

To illustrate this, we have simulated an individual who's wage pro¯le is the average wage pro¯le of the sample, as depicted in ¯gure 3. For this individual we can estimate $\frac{1}{4}_0$, $\frac{1}{4}_1$ and $\frac{1}{4}_2$. We use the estimated parameters for the (non-dynamic) health equation and obtain an estimate of $\ln \,\acute{}_0$ (where we assume that initial health and wealth are zero).

Now consider a second individual, with exactly the same wage pro¯le, except that he has 10% higher wages for 4 years between the ages 40-43. Consequently, for this

individual the estimate for $\ln \acute{} _0$ is slightly larger (by 0.04%), and this individual is on a higher permanent health path. However, during the 4 years of higher wages, his health stock is lower, due to the dominating evolutionary component. Using our estimates, the (negative) evolutionary response to this increase between the ages 40-43 is 18 times larger than the permanent response.

As a comparisson, we have also estimated standard cross section models on pooled data, where we condition on age, age squared, education, and time dummies. The estimated wage coe±cient for the health equation is 0.044, with standard error 0.011; in the health investments equation, the coe±cient on wages is 0.125, with a standard error of 0.029. We have also estimated a cross section model of the dynamic health equation, where we do not control for $\acute{} _i^0$. The parameter estimate of the wage coe±cient is 0.0433 (standard error 0.0124). All these coe±cients suggest a positive relationship between wages and health. They are compound e®ects of evolutionary, and weighted permanent wage responses. As we have illustrated in section (2.2), they do not correspond to any of the parameters of interest, and may wrongly identify individuals to be in need of possible health support. Conclusions based on these results would suggest that there is no di®erence between the health stocks of the two individuals in our above example, except for the 4 years of higher wages of the second individual, where the health stock of the second individual is larger. This is clearly in contrast to the conclusions we draw from our life cycle analysis.

4.3   Instantaneous Bene¯ts of Health

So far we have assumed that there are no instantaneous health bene¯ts: $h^0 = 0$. A simple test of this assumption is based on the following idea. Recall equation (13), and de¯ne $D(t) = e^{\int_0^t [\frac{3}{4}(\imath)+r]d\imath}$. Then the ¯rst di®erence of the log of $\acute{} (t)$ can be written as

$$
\begin{aligned}
\ln \acute{} (t) \; \mathbf{i} \; \ln \acute{} (t \; \mathbf{i} \; 1) \; = \; & \ln D(t) \; \mathbf{i} \; \ln D(t \; \mathbf{i} \; 1) \\
& + \ln \left(1 \; \mathbf{i} \; \frac{E(t) + F(t)}{\ln D(t) \acute{} (0)} \right) \; \mathbf{i} \; \ln \left(1 \; \mathbf{i} \; \frac{E(t \; \mathbf{i} \; 1) + F(t \; \mathbf{i} \; 1)}{D(t \; \mathbf{i} \; 1) \acute{} (0)} \right)
\end{aligned}
\tag{26}
$$

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$$= \ln D(t) - D(t - 1) + \varepsilon(t):$$

If health has an instantaneous benefit ($h^0 \neq 0$), then straightforward differencing, or quasi-differencing, does not eliminate the permanent effect. The residual in the first differenced model will contain the term $\varepsilon(t)$, which is a function of $\nu(0)$, $\nu_{-1}(0)$, and past wages. Hence, a test whether $h^0 = 0$ 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 ($h^0 \neq 0$). The parameter ν 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 ν. Hence, differencing across individuals with the same values of these variables should eliminate the variation in ν 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 evolutionary wage response, up to scale, it is not necessary that the matching procedure completely determines ν.

We illustrate this estimator for the log-linear specifications (12) and (16).[20] The parameter ν_{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

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[20]See also the discussion in section (2.2) for a graphical explanation of the matching estimator.

and education, and on kernel weighted distances between predicted life cycle wages and life-cycle wealth, the individual speci¯c 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 e®ects in the previous section. We then estimate pair-wise di®erenced 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

$$
\hat{b}_M = \left[\sum_{j=1}^{J} \sum_{k=1}^{K_j} \sum_{l>k} \tilde{A}_{jN} (x_{jk} - x_{jl})(x_{jk} - x_{jl})' \right]^{-1} \sum_{j=1}^{J} \sum_{k=1}^{K_j} \sum_{l>k} \tilde{A}_{jN} (x_{jk} - x_{jl})(yd_{jk} - yd_{jl})'
$$

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 e®ects, for individuals k and l in age-education group j respectively. The kernel weights $\tilde{A}_{jN}$ decline to zero as the magnitude of the di®erence between the matching variables increases. These weights are speci¯ed as

$$
\tilde{A}_{jN} = \prod_{q=1}^{Q} \frac{1}{h_{Nq}} \acute{A} \left(\frac{z_{jk}^q - z_{jl}^q}{h_{Nq}} \right) ;
$$

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 in¯nity (N ! 1), and Á is the standard normal density function. For the choice of the bandwidth parameter, we follow Kyriazidou (1997), and set the bandwidth $h_{Nq} = h_q \pounds N^{-1=5}$, where $h_q = 1$ for the predicted life cycle wages and life-cycle wealth and their individual speci¯c 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 su±cient data coverage.

The estimates of the coe±cient on ln w are ¡ 0:0185 (standard error 0:0111) in the equation for H D and ¡ 0:0353 (standard error 0:0495) in the equation for I D. These estimates are remarkably similar to the ones found for the di®erenced models, as reported in Table 2. This supports our previous ¯ndings, suggesting that there are

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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 bene¯ts do not a®ect estimates of evolutionary wage responses.

5   Conclusion and Discussion

In this paper, we present a life cycle model for health demand, and derive and estimate Frisch demand functions for health and health investment. In our model, changes in wages induce a permanent and an evolutionary wage response of health (or health investment). We suggest two estimation strategies which allow us to distinguish between permanent and evolutionary responses. The ¯rst strategy relies on di®erencing procedures. Our second estimation strategy relies on a matching type estimator, which allows us to identify transitory wage e®ects if simple di®erencing does not eliminate the latent individual e®ect. This is the case if health provides instantaneous bene¯ts, since simple di®erencing does not eliminate the variation in the latent individual e®ect which is correlated with the model regressors. We also propose a simple test for the restricted model against a model where health does provide instantaneous bene¯ts.

We use data on contentment with health and the demand for sport activities from a long panel. In accordance with the theoretical model, we ¯nd negative evolutionary wage e®ects, indicating that individuals substitute time for health production for time in the labour market during high wage periods over their life cycle. Furthermore, we ¯nd positive permanent e®ects, indicating that individuals with higher permanent wages are on a higher health pro¯le. These results are in contrast to what we obtain when estimating a simple cross section model. In our cross section models, contemporaneous wages are strongly and positively associated with health and health investments.

Estimates obtained from a simple cross section analysis suggest therefore that individuals with low wages su®er from poorer health conditions, and have lower health investments. An implication for health policies is to target individuals in the lower

quantiles of the wage distribution. In contrast, our model suggests that the intertemporal dimension is important for assessing issues relating health and wages. In fact, the current wage situation of an individual may be a poor indicator for health investments and health status.

Individuals with higher life cycle wages may be on a higher health (and health investment) pro¯le, although they may (temporarily) have low wages. Conclusions based on a simple cross section analysis may wrongly identify temporarily poor individuals as being in need of health support.

On the other side, our model identi¯es high wage individuals as being possibly threatened by health risks. At peak periods of their individual wage pro¯les, individuals may tend to substitute time away from health enhancing activities to the work place. Our model is compatible with observations in the medical literature that individuals in the highest occupational groups su®er from serious illness (see Marmot et al., 1997). Simulations based on our model estimates suggest that responses to evolutionary wage increases may indeed be detrimental to health and health investment. Our analysis emphasises the need to consider health related behaviour in a truly intertemporal context. Any examination of the connections between wages and health will need to address the issues raised in this paper.

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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:

$$\frac{dK}{dc} \;:\; e^{-\rho t} u_c - \lambda_1(t)\, p_c = 0 \tag{27}$$

$$\frac{dK}{dI} \;:\; \lambda_2 - \lambda_1 \mu \frac{1}{a+b} I(t)^{\frac{1}{a+b}-1} \P = 0 \tag{28}$$

$$-\frac{dK}{dH} = \dot{\lambda}_2 \;:\; \dot{\lambda}_2(t) = \lambda_2(t)\,\delta(t) - \lambda_1(t) w(t) h' - e^{-\rho t} v_h h' \tag{29}$$

$$-\frac{dK}{dA} = \dot{\lambda}_1 \;:\; \dot{\lambda}_1 = -\lambda_1 r: \tag{30}$$

The transversality conditions are given by:

$$\lambda_1(T)^3 \left(A(T) - \bar{A} \right) = 0; \tag{31}$$

$$\lambda_2(T) \left(H(T) - H_c \right) = 0: \tag{32}$$

The termination condition becomes:

$$u(c(T))\, e^{-\rho T} + \lambda_1(T)\, \dot{A}(T) + \lambda_2(T)\, \dot{H}(T) = 0: \tag{33}$$

For sufficiency, we need that $\lambda_1(t) \geq 0\ \forall t$. 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 $\pi(t) = \frac{\lambda_2(t)}{\lambda_1(t)}$. Then it follows from the first order conditions that:

$$\pi(t)\left[\delta(t) + r - \frac{\dot{\pi}(t)}{\pi(t)} \right] = w(t) h' - e^{(r-\rho)t} v_h \frac{1}{\lambda_1(0)} h'; \tag{34}$$

where h' denotes the derivative of h with respect to $H(t)$. Equation (34) 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 bene¯t.

Solving equation (34) results in equation (13) above. The parameter $´(0)$ is the shadow value of health at time 0. It is a function of the lifetime pro¯le 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 $_{,}1(0)$ by the following system of equations:

$$H(T) = e^{i \int_o^T ¾(¿)d¿} \left[H(0) + \int_0^T I(s) e^{\int_o^s ¾(¿)d¿} ds \right] = H^C \quad (35)$$

$$A(T) = \int_0^T \left[w(¿)h(¿) \; i \; ¾(¿)I(¿)^{\frac{1}{a+b}} \; i \; p_c c(¿) \right] e^{r(T i ¿)}d¿ + e^{rT} A(0) = \overline{A}; \quad (36)$$

and

$$\frac{1}{_{,}1(0)}[u(c(T)) + v(h(T))] e^{(r i ½)T} \quad (37)$$
$$+ [rA(T) \; i \; ¾I(T) \; i \; p_c c(T) + w(T)h(T)]$$
$$+ ´(T)[I(T) \; i \; ¾(T)H(T)] = 0:$$

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

$$\dot{I}(t) = \left[\frac{´(t)(a+b)}{¾(p_M; w(t); \acute{A}(t))} \right]^{\frac{a+b}{1 i a i b}} : \quad (38)$$

Equation (38) follows directly from the derivative of the Hamilton function with respect to investment. Investment $I(t)$ increases in $´(t)$, and decreases in $¾(t)$.

Combining (38) and (4) yields the demand for health services $M(t)$:

$$M(t) = B\acute{A}^{\frac{1}{1 i a i b}} p_M^{i \frac{1 i b}{1 i a i b}} w(t)^{i \frac{b}{1 i a i b}} ´(t)^{\frac{1}{1 i a i b}} : \quad (39)$$

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 sport 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 di®erent, 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 classi¯es into the category each week.

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