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Health, Health Care, and the Environment.
Econometric Evidence from German Micro Data

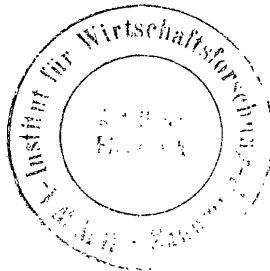Manfred Erbsland, Walter Ried and Volker Ulrich

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by

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Abstract:

The paper develops and applies a Grossman-style health production model set up in discrete time to explain the impact of environmental pollution on the demand for both health and health care. In order to introduce the environment, our analysis takes changes in environmental conditions to influence the rate at which an individual's stock of health depreciates. While the theoretical part of our paper also contains a discussion of the full model, we restrict our analysis to a submodel which is known as the pure investment model. This is because the other submodel, the pure consumption model, implies a rather implausible case of satiation with respect to the individual's preferences.

Our empirical findings are based on data taken from the German Socio-economic Panel (SOEP). The stock of health capital and environmental pollution are treated as latent variables and estimated using a LINCS model. The quality of the environment turns out to be an important determinant of health capital. From the point of view of health economics, improvements in environmental conditions can be interpreted as preventive measures. In terms of prevention, public policies designed to protect the environment also yield significant health effects. As regards health care demand the influence is not clearcut, i.e. one cannot necessarily expect a reduction in resource use.

1. Introduction

In the developed countries, a substantial amount of the resources available is devoted to health care. Indeed, the provision of a broad range of high quality health care services can safely be taken to play a major role in maintaining and promoting the health of a given population. While there is evidence for the significance of a sophisticated system of health care, the potential importance of other determinants of individual health must not be overlooked. Among the first to observe this was Sir William Petty in his investigations on "Political Arithmeticks". As early as the seventeenth century, he was able to demonstrate the considerable influence of sanitary conditions on human mortality. From the point of view of allocation theory, those determinants other than health care gain significance mainly with respect to the following two issues. First, what is their specific contribution to the attainment of health targets? And, second, to what extent is it possible, by relying more on those other determinants, to reduce consumption of health care?

Our paper investigates the influence of several variables on both individual health and consumption of medical care in the Federal Republic of Germany. In the course of our empirical analysis, we focus on the impact of the quality of the environment since this is often hypothesized to be an important factor affecting health in industrialized countries. This observation notwithstanding, the interactions between environmental conditions, health and health care have failed, in our view, to receive much attention in the literature.[1] Given that the quality of the environment cannot be observed directly, we proceed by modelling it as a latent variable which may be described by means of suitable indicators. A major aim of our paper is to provide answers to the questions raised above as they are suggested by the specific data set considered below. Inasmuch as environmental quality affects individual health and/or consumption of medical care, this has implications for environmental policy as well. More precisely, any policy geared at improving the quality of the environment needs to be evaluated with respect to its side effects as regards health care, too.

The conceptual framework of our paper is given by the notion, dating back to Mushkin (1962), that an individual's health may usefully be considered as a capital stock which, in the course of time, provides services to its owner.[2] At the same time, it is possible to augment this stock of capital by means of gross investment which encompasses, among other inputs, consumption of medical care. Thus, while his stock of health represents the ultimate objective of a rational individual, his demand for medical care can be derived from it. One of the advantages of this approach is to provide a clear distinction between health on the one hand and use of medical care on the other. This enables us to analyse the effects of the quality of the environment on both variables separately.

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[1] A notable exception is Cropper (1981).

[2] Essentially, Mushkin applied a similar notion, which figures prominently in the economics of education to the field of health economics.

Our paper is organized as follows. In section two we present the basic Grossman model which formalizes Mushkin's ideas within the context of an intertemporal utility maximization problem. From this we derive a submodel of much simpler structure which also provides the background for our empirical specification. Section three contains a brief description of the database underlying our empirical analysis. Furthermore, we combine the structural model of section two with a measurement model in order to account for the latent variables considered. In addition, we refer to the estimation and testing procedures employed. Section four gives estimation results where we also provide an interpretation for the more important parameter estimates. In particular, we discuss our results with respect to the impact of the quality of the environment. Finally, section five contains our conclusions while also offering several suggestions for future research.

2. The Grossman approach
2.1. Preliminary remarks

In the following two sections, we present the model introduced by Grossman as well as a submodel constituting a special case of it from a theoretical point of view. On the one hand, this will help to bring out clearly those additional restrictions imposed in section 2.4. which underlie our empirical analysis. On the other hand, this provides a convenient opportunity to characterize fully the main equations of the model and the dynamics of the stock of health capital. In our view, the literature up to now has failed to take those latter two aspects adequately into consideration.[3]

While, more recently, the Grossman model or generalizations thereof have been presented mainly in continuous time (cf. Cropper 1981, Muurinen 1982, Wagstaff 1986), we have chosen, following Grossman, to work in discrete time. This implies a period analysis which, among others, offers the advantage of being better suited to empirical data referring to intervals of time. The latter holds, for example, for the data collected by the German Socio-economic Panel (SOEP), which supplies the data base for our empirical analysis.

2.2. The model

In his model Grossman combines both life cycle and household production theory with the concept of health as a capital stock which is subject to depreciation but can be augmented by means of gross investment.[4] In every period, this health capital stock provides services accruing as "healthy time" which the individual is free to use either as working time or as an input to his household production.

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[3]This is true even for the pioneering work of Grossman (1972).

[4]As Muurinen (1982) has shown, the major results obtained by Grossman do not depend on his employing a household production approach.

More specifically, we consider an individual whose decision problem is to choose, for the remainder of his lifetime, time paths for his health capital as well as for consumption of commodities in an optimal way. The terminal time of this optimization problem is determined endogenously, it is reached as soon as the stock of health capital is equal to or falls below a given lower bound. Some constraints of this problem are technological, this concerns, in particular, the output from household production activities. Further restrictions on the set of feasible solutions are given by an intertemporal budget constraint, a flow equation for the stock of health capital and an upper bound on the uses of time given by the length of the period under consideration.

The starting point for the individual's decision problem is given by an intertemporal utility function U as follows:

(1) $$U = \sum_{t=0}^{n} m_t u_t$$

(1a) $$u_t = u(h_t, Z_t)$$

u_t refers to utility in period t as generated by the pair (h_t, Z_t), with h_t representing the services of the health capital stock and Z_t the commodities produced by the individual. As relation (1) illustrates, total intertemporal utility is given by a weighted sum of the utilities u_t. Essentially, the weights m_t are determined by the individual's rate of time preference. Moreover, equation (1) implies intertemporal separability of the utility function U, which, in effect, leads to rather simple solutions in the optimization problem considered below.[5]

For the services of the health capital stock as measured in units of healthy time, assume

(2) $$h_t = h(H_t); \qquad \frac{\partial h}{\partial H_t} > 0,$$

with the derivative expressing the positive influence of health on healthy time.

The production of commodities takes place by transforming consumption goods purchased in the marketplace with the help of an additional time input. For the sake of simplicity, we focus on a single aggregate commodity whose production depends on an aggregate consumption good G_t and a time input T_t. In addition, the output of production activity is taken to be affected by an exogenous parameter X_t:

(3) $$Z_t = Z(G_t, T_t; X_t)$$

X_t denotes the level of education of the individual, i.e. his stock of human capital (excluding his health capital stock). We assume the production function Z_t to be linear homogenous with respect to (G_t, T_t) which implies constant marginal costs of the production of commodities in every period.

The change in the stock of health capital over time is given by netting out gross investment I_t with depreciation of the existing stock:

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[5]On the implications of this restriction see Killingsworth (1983, p. 220f.) Grossman implicitly employed this assumption in his comparative static analysis.

(4) $\qquad \Delta H_{t+1} = H_{t+1} - H_t = I_t - \delta_t H_t$,

where δ_t denotes the rate of depreciation taken to be constant within a period. The individual is capable of producing gross investment by combining medical care M_t and a time input TH_t in the following way:

(5) $\qquad I_t = I(M_t, TH_t; X_t)$.

Just like the production of commodities, this household production function exhibits parametric dependence on X_t. Furthermore, we assume I_t to be linear homogeneous in (M_t, TH_t). Therefore, in any period, production of gross investment takes place at a constant marginal cost.

In addition, it is necessary to observe another restriction relating work income, expenditures on both the aggregate consumption good and medical care with the change in the individual's wealth position. With respect to period t, the budget constraint is given by

(6) $\qquad V_{t+1} = (1+r)(V_t + W_t TW_t - P_t^M M_t - P_t^G G_t)$,

with V_t denoting financial wealth, r the rate of interest (taken to be constant over time), W_t the wage rate, TW_t working time and P_t^M (P_t^G) the price of medical care (of the aggregate consumption good), all of period t.[6] For the present value change in financial wealth, one obtaines the following flow equation:

(6a) $\qquad \dfrac{V_{t+1}}{(1+r)^{t+1}} - \dfrac{V_t}{(1+r)^t} = \dfrac{W_t TW_t - P_t^M M_t - P_t^G G_t}{(1+r)^t}.$

Finally, in every period, by definition the total time budget will be exhausted by healthy time h_t on the one hand and sick time TL_t on the other:[7]

(7) $\qquad \Omega = h_t + TL_t$.

In the following, we assume h_t to be spent exclusively on the three uses of time already mentioned above. In other words, h_t covers either working time or the individual's time input to household production.[8] Thus, we have:

(7a) $\qquad \Omega = TW_t + TH_t + T_t + TL_t$.

Now the individual's intertemporal optimization problem can be stated as a problem of discrete optimal control (cf. Léonard/ van Long 1992, p. 129ff.). The objective is to maximize

$$\sum_{t=0}^{n} m_t u[h(H_t), Z_t]$$

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[6]The values of TW_t, M_t and G_t correspond to the supply and demand decisions as planned by the individual, i.e. we consider no rationing.

[7]As it stands, (7) implies that the length of a period is measured in other units (e.g. years) than time within a period (e.g. days).

[8]Within the framework of the Grossman model, an individual will not wish to exhaust h_t by the uses discussed so far only if each yields a marginal utility of zero. Such a case, however, would appear rather implausible (see Ried 1994).

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subject to the restrictions given by (3), (4), (5), (6a) and (7a). The stock of health capital and the present value of financial wealth represent state variables whose values at time $t = 0$ constitute additional restrictions. Moreover, a terminal condition - e.g., non-negativity - will have to be met for financial wealth, while the terminal time of the optimization problem is determined endogenously by the time path of health capital according to:

(8) $\qquad n = \min\{i \in N \,|\, H_i \leq H_{min}\}$

with N denoting the set of natural numbers and H_{min} representing a lower bound on the stock of health capital.

As for the set of control variables, its composition will, in general, depend on which specific problem one intends to study. In what follows, we shall focus on M_t and Z_t. Therefore, suppose an "interior solution" holds for these two variables and for TW_t as well. Then, after performing some algebraic manipulation, one obtains four necessary conditions representing the core of the model:[9]

(9) $\qquad \left(\dfrac{m_t (1+r)^t}{\lambda_0^v} \dfrac{\partial u}{\partial h_t} + W_t \right) \dfrac{\partial h}{\partial H_t} = \pi_{t-1}' (1+r) - \pi_t' (1-\delta_t)$

(10) $\qquad \dfrac{m_t (1+r)^t}{\lambda_0^v} \dfrac{\partial u}{\partial Z_t} = \pi_t^z$

(11) $\qquad V_0 + \displaystyle\sum_{t=0}^{n} \dfrac{W_t h_t - \pi_t' \left(\dfrac{\partial \pi_t'}{\partial P_t^M} \right)^{-1} M_t - \pi_t^z Z_t}{(1+r)^t} = 0$

(12) $\qquad \Delta H_{t+1} = H_{t+1} - H_t = \left(\dfrac{\partial \pi_t'}{\partial P_t^M} \right)^{-1} M_t - \delta_t H_t$

λ_0^v is a time invariant costate variable which gives the marginal utility of the present value of financial wealth, while π_t' (π_t^z) represents marginal costs of gross investment (the commodity) in period t. In equations (11) and (12), we have replaced I_t because, due to the assumption of an interior solution with respect to M_t - which implies an interior solution with respect to I_t as well - one has, according to Shepard's lemma:

(13) $\qquad M_t = \dfrac{\partial \pi_t'}{\partial P_t^M} I_t \quad,$

building on the homogeneity property of the production function I.

Now suppose conditions sufficient for a maximum are fullfilled. Then, the system of equations (9) to (12) not only determines an optimal value for λ_0^v but also optimal time paths for the stock of health capital H_t, the commodity Z_t, and the demand for medical care M_t. In this general case, equations (9) and (10) contain H_t, Z_t and λ_0^v as endogenous variables, while the intertemporal budget constraint (11) gives an equation in H_t, Z_t and M_t. Finally equation (12) implicitly is an equation in all endogenous variables. This can be made explicit by approximating ΔH_{t+1} by an

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[9]To be sure, a complete presentation of the set of necessary conditions would have to include, in particular, a transversality condition for the stock of health capital.

appropriate expression which has been obtained by taking first differences of (9) and (10).[10]

It is important to see that equation (9) describes the optimality condition for health capital in period t. If the individual wishes to increase H_t by a marginal unit without modifying the remainder of the corresponding time path, gross investment in period (t-1) will need to be increased by a marginal unit as well. At the same time, I_t can be reduced by $(1 - \delta_t)$ because a higher stock of health capital in period t allows for lower gross investment given that H_{t+1} does not change. The costs associated with this move are given by the right hand side of equation (9). The left hand side depicts the benefits associated with a marginally higher H_t resulting from an increase in healthy time. The first term represents the benefit due to a higher consumption of h_t, while the second term captures the benefit relating to the productive use of the additional time, either as working time or as an input to household production.[11] Although this choice of terminology is not entirely satisfactory, it is customary to describe these effects as consumption and investment benefits, respectively, of a marginal increase in the stock of health capital. To sum up, equation (9) characterizes the optimal time path of health capital by equilibrating marginal benefits and marginal cost for every element H_t.

For an empirical analysis, it is useful to simplify the rather complicated structure of the model given by equations (9) to (12). Following Grossman, the literature has focussed mainly on the analysis of two submodels, each taking into account but part of the marginal benefits of health capital. As their names suggest, the pure consumption model deals exclusively with the consumption benefit, while the pure investment model emphasizes the investment benefit. It can be shown, however, that the pure consumption model, by neglecting any investment benefit, implies a rather implausible case of satiation with respect to the individual's preferences.[12] This surely limits its usefulness in any applied work. Therefore, in what follows we shall rely on the pure investment model which also provides the theoretical background for our empirical analysis.

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[10]By relying on a Taylor approximation, taking first differences of equation (9) and (10) yields ΔH_{t+1} and ΔZ_{t+1} as functions of H_t, Z_t, λ_0^V, the exogenous variables contained in these equations and the corresponding first differences, if one observes the time invariance of λ_0^V. For a particularly simple application of this procedure, see section 2.3.

[11]Neglecting corner solutions, at an optimal position any possible use of additional time must yield the same marginal benefit. In general, therefore, a marginal change in H_t will tend to affect all uses of time considered.

[12]See footnote 5 and, for a more complete statement, Ried (1994).

2.3. The pure investment model

In the investment submodel, the consumption benefit of health - at the optimum position - is taken to be zero, or somewhat more cautiously, to be negligible. In other words, suppose:

$$(14) \qquad \frac{\partial u}{\partial h_t} \approx 0 \qquad t = 0, 1, ..., n.$$

This assumption is not quite as restrictive as it may appear at first sight. No matter how additional healthy time due to a better health (in the sense of a higher stock of health capital) will be spent - it may even represent "pure leisure" -, the resulting benefit is already accounted for. This is true because, for example, "pure leisure" in the sense of time spent without either working or transforming consumption goods may be interpreted as part of the aggregate commodity which we consider in this model. Thus, given our household production approach, it is rather difficult to detect a consumption benefit proper of the service "healthy time" which does not just represent a double counting of the investment benefit.[13]

Utilizing condition (14) helps to simplify the Grossman model considerably in that it leads to a partly recursive structure. Consider first the optimality condition for health capital which now reads:

$$(9a) \qquad W_t \frac{\partial h}{\partial H} = \pi'_{t-1}(1+r) - \pi'_t(1-\delta_t) \ .$$

Since it contains no other endogenous variables, this equation alone determines the optimal stock of health capital in period t. Taking the first difference of (9a) and using a first order Taylor approximation for $\frac{\partial h}{\partial H_{t+1}}$, one obtains for the change in health capital, ΔH_{t+1}:

$$(15) \qquad \Delta H_{t+1} = \frac{\Delta \pi'_{t-1} r - \Delta^2 \pi'_{t+1} + \Delta \delta_{t+1} \pi'_{t+1} + \delta_t \Delta \pi'_{t+1} - \Delta W_{t+1} \dfrac{\partial h}{\partial H_t}}{W_{t+1} \dfrac{\partial^2 h}{\partial H_t^2}}$$

As might be expected in the context of an intertemporal optimization problem, the development of health capital is governed essentially by the development of those parameters which determine H_t. It may come as a surprise that the second difference of the marginal cost of gross investment π'_{t+1} affects ΔH_{t+1} as well. As the right hand side of equation (9) or equation (9a), respectively, reveals, however, the first difference $\Delta \pi'_t$ already affects the capital stock itself. This is because $\Delta \pi'_t$, as a negative cost, represents the capital gains associated with gross investment in (t-1). This explains why ΔH_{t+1} is determined, among others, by the second difference of

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[13]In line with this argument, note that, in the household production approach, there is no point in including working time (i.e. labor supplied) directly in the individual's utility function. Rather, the disutility of work is given as an opportunity cost due to household production foregone. Thus, considering a marginal increase in labor supply, what represents a negative consumption benefit in traditional utility theory, now has become a negative investment benefit.

the marginal cost of gross investment which constitutes but the change in these capital gains.

If the marginal cost of gross investment and the rate of depreciation stay constant over time, the partial influence of changes in the wage rate on the stock of health capital can be read off from (15). Changes in health capital and changes in the wage rate occur in the same direction (in opposite directions), if h is a concave (convex) function. In this sense, the relation between the stock of health capital and the services provided by it govern the influence of, e.g., a rising wage rate on health.

Using (15) in (12) yields:

$$\frac{\Delta\pi_t^I r - \Delta^2\pi_{t+1}^I + \Delta\delta_{t+1}\pi_{t+1}^I + \delta_t\Delta\pi_{t+1}^I - \Delta W_{t+1}\dfrac{\partial h}{\partial H_t}}{W_{t+1}\dfrac{\partial^2 h}{\partial H_t^2}} = \left(\frac{\partial\pi_t^I}{\partial P_t^M}\right)^{-1} M_t - \delta_t H_t$$

and, solving for M_t:

$$(12a) \qquad M_t = \frac{\partial\pi_t^I}{\partial P_t^M}\left(\delta_t H_t + \frac{\Delta\pi_t^I - \Delta^2\pi_{t+1}^I + \Delta\delta_{t+1}\pi_{t+1}^I + \delta_t\Delta\pi_{t+1}^I - \Delta W_{t+1}\dfrac{\partial h}{\partial H_t}}{W_{t+1}\dfrac{\partial^2 h}{\partial H_t^2}}\right).$$

Since condition (14) does not modify the other two equations, the pure investment model is given by equations (9a), (10), (11), and (12a). With values for the optimal stock of health capital determined according to (9a), the optimal time path for consumption of medical care is given by (12a). Furthermore, equation (10) yields optimal values for Z_t given λ_0^*. After inserting these into the intertemporal budget constraint (11), one can solve for λ_0^*. This, in turn, gives the optimal time path for Z_t.

If one is interested only in the development of health capital H_t and medical care M_t, the structure of the pure investment model makes it possible to restrict the analysis to equations (9a) and (12a). This holds because, as has been outlined above, the optimal time paths for H_t and M_t are determined independently of both λ_0^* and the optimal time path for Z_t. For this reason, in what follows we will neglect equations (10) and (11).

As regards comparative static analysis, it is useful to distinguish between two categories of effects. In order to see this, look at equation (12a) and let us investigate the effects of a change in a parameter which determines the stock of health capital according to (9a). Since any parameter affecting health capital is contained in equation (12a) as well, the change under consideration gives rise to two effects. In the first place, there is a direct influence on the demand for medical care, which captures the effect on M_t for a given stock of health capital. It is customary to describe this effect as the <u>direct effect</u> of the parameter variation. Apart from this, another effect operates through the influence on the individual's health. The corresponding change in M_t represents the <u>indirect effect</u> of the parameter variation which is brought about

solely through its effect on H_t. The <u>total effect</u> on the demand for medical care is given by the sum of both effects, direct and indirect.

The distinction between direct and indirect effects of parametric changes is of considerable importance since both effects may operate in opposite directions. This may be illustrated briefly by looking at the example of a marginal change in the rate of depreciation δ_t. The comparative static effect on H_t is given by:

$$(16) \qquad \frac{\partial H_t}{\partial \delta_t} = \frac{\pi_t'}{W_t \dfrac{\partial^2 h}{\partial H_t^2}} \cdot$$

Is h is concave (convex) which implies decreasing (increasing) marginal productivity of health capital, a marginal increase in δ_t will lower (raise) H_t. Taking into account equation (12), one obtains for the corresponding influence on the demand for medical care:[14]

$$(17) \qquad \frac{\partial M_t}{\partial \delta_t} = \frac{\partial \pi_t'}{\partial P_t^M} \left[H_t - (1 - \delta_t) \frac{\partial H_t}{\partial \delta_t} \right] \cdot$$

The first term on the right hand side represents the direct effect of a marginal increase in the rate of depreciation. It is unambiguously positive since, in order to maintain a given stock of health capital, a higher rate of depreciation necessarily involves higher gross investment and, thus, a higher demand for medical care so as to compensate for the faster deterioration of health capital. The second term captures the indirect effect on M_t. If one assumes $0 < \delta_t < 1$, with h convex the marginal increase in the rate of depreciation generates a negative indirect effect on the demand for medical care. In this case, it pays to react to the higher rate of depreciation by increasing gross investment in period (t-1) in order to build up a higher stock of health capital H_t. This offers the opportunity to reduce gross investment as well as the demand for medical care in period t which explains the negative sign of the indirect effect.[15]

2.4. Empirical specification

On the way to a version of the model given by equations (9a) and (12a) which can be estimated empirically, we still need to address two issues. First, both equations exhibit a structure which is partly additive, and partly multiplicative. Since we intend to estimate the model by means of a linear approach, we shall introduce additional assumptions such that the multiplicative structure "prevails". Second, for some variables such as, e.g., the rate of depreciation we need to give functional specifications describing the influence of exogenous variables. In both instances, we

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[14]We use equation (12) because it is better suited to distinguishing between direct and indirect effects on the demand for medical care. If instead one uses equation (12a) to determine the effects on M_t, the results will, in general, be slightly different since (12a) holds only approximately.

[15]In line with this interpretation, there is a positive indirect effect on M_{t-1}, while the corresponding direct effect is equal to zero.

will follow previous work by Grossman, Cropper and Wagstaff to a considerable degree, although our approach is slightly different.[16]

Taking natural logarithms of equation (9a) yields:

(9b) $\qquad \ln W_{\hat{n}} + \ln \dfrac{\partial h}{\partial H_{\hat{n}}} = \ln\left[\pi^I_{t-1,i}(1+r) - \pi^I_{\hat{n}}(1-\delta_{\hat{n}})\right]$,

where we have added an index "i" as second subscript in order to emphasize the dependence of both endogenous and exogenous variables on the individual under consideration. Following Grossman, we choose as functional form for the function h measuring the services provided by the stock of health capital in units of healthy time:

(18) $\qquad h = \Omega - \alpha_1 H_{\hat{n}}^{-\alpha_2}; \ \ \alpha_1 > 0, \ \alpha_2 > 0.$

This implies a concave h, i.e. decreasing marginal productivity of health capital.

Transforming the right hand side of (9b) by factoring out the product of the rate of depreciation and the marginal cost of gross investment yields:

(19) $\qquad \ln\left[\pi^I_{t-1,i}(1+r) - \pi^I_{\hat{n}}(1-\delta_{\hat{n}})\right] = \ln \pi^I_{\hat{n}}\delta_{\hat{n}} + \ln\left[1 + \dfrac{\pi^I_{t-1,i}\left(r - \dfrac{\Delta\pi^I_{\hat{n}}}{\pi^I_{t-1,i}}\right)}{\pi^I_{\hat{n}}\delta_{\hat{n}}}\right].$

The difference $\left(r - \dfrac{\Delta\pi^I_{\hat{n}}}{\pi^I_{t-1,i}}\right)$ compares the rate of return on an asset with the capital gains component of gross investment I_{t-1}. We assume that this term or, more precisely, the whole expression $\pi^I_{t-1,i}\left(r - \dfrac{\Delta\pi^I_{\hat{n}}}{\pi^I_{t-1,i}}\right)\left(\pi^I_{\hat{n}}\delta_{\hat{n}}\right)^{-1}$ is close to zero. In addition, we take the corresponding derivation to be distributed randomly over individuals. Hence, the second term on the right hand side of (19) may be interpreted as a stochastic error term.

Furthermore, let us suppose the production function for gross investment is of the Cobb-Douglas type. Thus, the logarithm of marginal cost can be expressed as a weighted sum of the logarithms of factor prices, if one takes into account the parametric influence of X_{ti}:

(20) $\qquad \ln \pi^I_{\hat{n}} = \alpha_3 \ln W_{\hat{n}} + (1-\alpha_3)\ln P^M_{\hat{n}} + \alpha_4 X_{\hat{n}} \ ; 0 < \alpha_3 < 1.$

If the individual's level of education as measured by X_{ti} exerts a positive influence on his investment productivity, we should expect a positive sign for α_4.

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[16]Cf. Grossman (1972, p. 39ff.), Cropper (1981) and Wagstaff (1986). The main difference arises because these authors, in their empirical specification, have opted to work in continuous time. Interestingly, this is true even for Grossman who otherwise adopted a discrete time approach. On the one hand, this leads to a different optimality condition for the stock of health capital. On the other, several variables have to be interpreted differently (e.g. instead of flow variables such as gross investment, one considers, working in continuous time, the corresponding rates, i.e. their time derivatives).

Finally, following Cropper, suppose the logarithm of the rate of depreciation to be given by:

(21) $\qquad \ln \delta_{ti} = \ln \delta_0 + \alpha_5 t_i + \alpha_6 Y_{ti}$,

with Y_{ti} representing a vector of parameters other than the age factor that affect depreciation of health capital. In particular, this vector contains an element describing environmental conditions. Given that, at least in theory, an improvement in the quality of the environment should reduce depreciation of the stock of health capital ceteris paribus, we expect a negative sign for the corresponding element of the parameter vector α_6.

With these assumptions, one obtains for equation (9b), solving for $\ln H_{ti}$:

(9c) $\qquad \ln H_{ti} = \dfrac{1}{\alpha_2 + 1}\left[k_1 + (1 - \alpha_3)\ln W_{ti} - (1 - \alpha_3)\ln P_{ti}^M - \alpha_4 X_{ti} - \alpha_5 t_i - \alpha_6 Y_{ti} + u_{ti}\right]$,

where $k_1 = \ln \alpha_1 \alpha_2 - \ln \delta_0$ and $u_{ti} = -\ln\left[1 + \dfrac{\pi_{t-1,i}^I \left(r - \dfrac{\Delta \pi_{ti}^I}{\pi_{t-1,i}^I}\right)}{\pi_{ti}^I \delta_{ti}}\right]$ hold.

In order to get an estimable equation for the consumption of medical care, take natural logarithms of equation (12):

(12b) $\qquad \ln M_{ti} = \ln \dfrac{\partial \pi_{ti}^I}{\partial P_{ti}^M} + \ln\left(\delta_{ti} H_{ti} + \Delta H_{t+1,i}\right)$.

Utilizing the specification for the marginal cost of gross investment, one obtains:

$$\ln \dfrac{\partial \pi_{ti}^I}{\partial P_{ti}^M} = \ln(1 - \alpha_3) + \ln \pi_{ti}^I - \ln P_{ti}^M$$

and, after replacing $\ln \pi_{ti}^I$:

(22) $\qquad \ln \dfrac{\partial \pi_{ti}^I}{\partial P_{ti}^M} = \ln(1 - \alpha_3) + \alpha_3 \ln W_{ti} - \alpha_3 \ln P_{ti}^M + \alpha_4 X_{ti}$.

Furthermore, the second term on the right hand side of equation (12b) can be transformed as follows:

(23) $\qquad \ln\left(\delta_{ti} H_{ti} + \Delta H_{t+1,i}\right) = \ln \delta_{ti} H_{ti} + \ln\left(1 + \dfrac{\Delta H_{t+1,i}}{\delta_{ti} H_{ti}}\right)$.

The fraction $\dfrac{\Delta H_{t+1,i}}{\delta_{ti} H_{ti}}$ measures the change in health capital $\Delta H_{t+1,i}$ relative to depreciation occurring in period t. If, firstly, the exogenous variables determining the stock of health capital change only slightly over time and, secondly, the rate of depreciation is sufficiently bounded away from zero, then this fraction will be close to zero. In what follows, we assume that the deviations of this fraction from zero are distributed in a random manner over individuals (cf. Wagstaff 1986, p. 201). Hence, the second term on the right hand side of equation (23) may be interpreted as an error term. Consequently, one arrives at the following specification for the logarithm of the demand for medical care:

(12c) $\qquad \ln M_{ti} = k_2 + \alpha_3 \ln W_{ti} - \alpha_3 \ln P_{ti}^M + \alpha_4 X_{ti} + \alpha_5 t_i + \alpha_6 Y_{ti} + \ln H_{ti} + v_{ti}$,

where $k_2 = \ln(1-\alpha_3) + \ln\delta_0$ and $v_{ti} = \ln\left(1 + \dfrac{\Delta H_{t+1,i}}{\delta_{ti} H_{ti}}\right)$ hold.

Apart from a minor aspect, the task of providing an empirical specification appropriate for linear analysis has been accomplished. As can be seen from equation (12c), our specification implies the logarithm of health capital to influence the logarithm of medical care with a coefficient equal to one. In contrast to physical capital, for example, it is characteristic of the stock of health capital, however, that it cannot be observed directly but needs to be captured by using appropriate health indicators. In general, approaches to the measurement of health supply values which are determined only up to some kind of (e.g., monotonic) transformation. In this sense, any empirical measurement of health is subject to a certain degree of arbitrariness. Therefore, it seems sensible not to determine the coefficient on $\ln H_{ti}$ on a priori grounds.

Thus, our final equation for the logarithm of consumption of medical care reads as follows:

(12d) $\ln M_{ti} = k_2 + \alpha_3 \ln W_{ti} - \alpha_3 \ln P_{ti}^M + \alpha_4 X_{ti} + \alpha_5 t_i + \alpha_6 Y_{ti} + \alpha_7 \ln H_{ti} + v_{ti}$,

where we expect a positive sign for α_7.

3. Empirical analysis
3.1. Structural and measurement equations

Health capital as given by equation (9c) represents a multidimensional variable which is neither directly observable nor measurable. One can only observe causes for and indicators of good or bad health. A potential cause for bad health is environmental pollution. Information on this variable is often limited, too, i.e. if only a few environmental indicators are available to the researcher. The basic idea of the empirical specification is to treat both the stock of health capital (H*) and environmental pollution (E*) as latent variables that can be sufficiently described in terms of indicators. While health capital is determined endogenously, environmental pollution is treated as a latent exogenous variable which reflects its role as a potential determinant of health.

A particular specification of the latent variable model is given by the LINCS (Linear Covariance Structures) model, which in general consists of a structural and a measurement submodel (see e.g. Schoenberg/Arminger 1989/90, Leu et al. 1992).[17] As applied to our problem, the structural submodel consists of equation (9c) for the stock of health capital and of equation (12d) for the demand for medical care. In order to measure the latent variables H* and E* a measurement submodel is added, which contains a set of indicators for each variable.

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[17]Compared to the well-known LISREL (Linear Structural Relationships) model of Jöreskog and Sörbom (1989), the main difference of LINCS is the corresponding software package. Unlike LISREL, LINCS is a program written in GAUSS, developed by Schoenberg and Arminger (1989/90), which allows for flexible programming and provides, for instance, heteroskedasticity-consistent estimates of the standard errors.

Beginning with the structural model, the formal structure of the LINCS model is as follows

(24) $\eta = B\eta + \zeta = (I - B)\zeta^{-1}$.

Here B denotes the matrix of regression parameters, and ζ is a disturbance term. Denoting the covariance matrix of the latent variables $E(\eta\eta')$ by Φ, we have

$$\Phi = (I - B)^{-1}\Psi(I - B)^{-1'},$$

where $\Psi = E(\zeta\zeta')$ characterizes the covariance matrix of the disturbances variables.

The measurement submodel is given by:

(25) $Y = \Lambda\eta + \varepsilon$.

In the measurement part of the model, the vector of the latent variables η is explained by a set Y of observable indicators. The coefficient matrix Λ contains the parameters to be estimated, while ε is a vector of measurement errors. Assuming that all indicators are corrected by their mean value, the resulting covariance matrix of Y is as follows:

$$\Sigma = E(YY') = \Lambda\Phi\Lambda' + \Theta,$$

with $E(\varepsilon\varepsilon') = \Theta$, $E(\eta\eta') = \Phi$ and $E(\varepsilon\eta') = 0$.

Combining the two submodels in (24) and (25) yields the LINCS model:

(26) $\Sigma = \Lambda(I - B)^{-1}\Psi(I - B)^{-1'}\Lambda' + \Theta$.

If we assume that there is no measurement model, the indicators and the latent variables are identical, i.e. $Y \equiv \eta$, and equation (26) collapses to a standard simultaneous equation model:

$$Y = BY + \zeta \quad \text{with} \quad \Sigma = (I - B)^{-1}\Psi(I - B)^{-1'}.$$

Another submodel is given by the model of factor analysis. Here we have no structural equations, e.g. $B = 0$ and hence $\Psi = 0$, which leads to:

$$Y = \Lambda\eta + \varepsilon \quad \text{with} \quad \Sigma = \Lambda\Psi\Lambda' + \Theta.$$

Apart from these special cases, the LINCS model combines factor with regression analysis. In this case, the model contains both variables that are intrinsically unobservable and that are represented by "proxy variables" or "indicators", and variables that are measured without errors.[18]

Using standard notation for simultaneous equation modelling, our concrete LINCS specification is as follows:

(27) $\ln HI_i = \lambda_{hi} \ln E^* + \epsilon_i,$ $i = 1, 2, 3, 4,$

(28) $EI_j = \lambda_{ej} E^* + \delta_j$ $j = 1, 2,$

(29) $\ln H^* = \gamma_{11}E^* + \gamma_{12}X + \zeta_1$ and

(30) $\ln HD_k = \beta_k \ln H^* + \gamma_{k1}E^* + \gamma_{k2}X + \zeta_k,$ $k = 2, 3, 4$

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[18]It is obvious, that for exactly measured variables ($Y_i = \eta_i$, $\epsilon_i = 0$), the corresponding element in θ is equal to zero.

where the model's variables are given by:

$\ln HI_i$ ... logarithm of health indicator i,

EI_j ... environmental indicator j,

$\ln H^*$ ... logarithm of latent variable health,

E^* ... latent exogenous variable environmental pollution,

$\ln HD_k$... logarithm of demand for medical service k,   and

X ... vector of additional exogenous variables.

The unknown coefficients and vectors to be estimated are: λ_{hi}, λ_{ej}, γ_{11}, γ_{12}, β_k, γ_{k1}, and γ_{k2}. The unobservable scalar disturbances are denoted by ϵ_i, δ_j, ζ_1, and ζ_k. Figure 1 below depicts the system given by equations (27) - (30) in terms of a path diagram.

Figure 1: Path diagram of the model

$k = 2, 3, 4.$
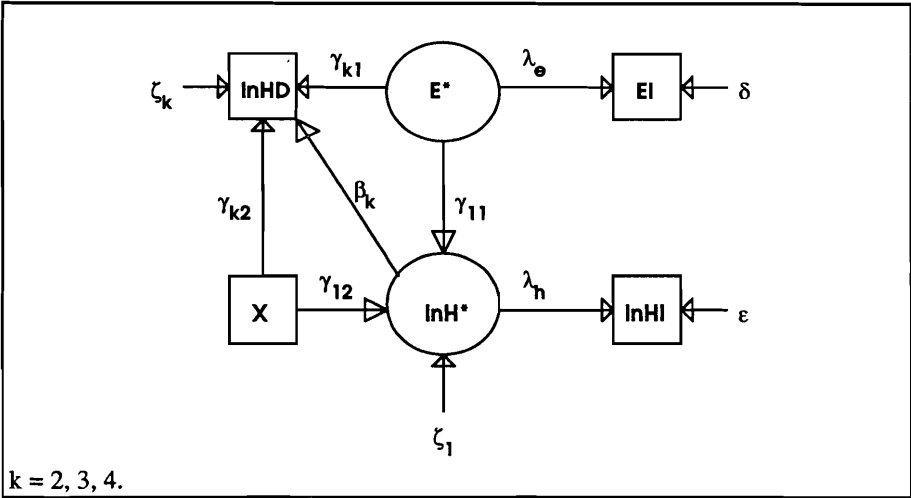
The structural submodel contains the equations (29) and (30) and is shown on the left half of the figure. Here, E^* exerts a direct effect on the stock of health capital H^* and on the demand for medical care HD. The vector X contains additional variables, which potentially influence the rate of depreciation (e.g. age, sex, doing sports etc.), and, therefore, exert an effect on both health and health care demand. Furthermore, we have included in X variables concerning the individual's level of education and variables capturing the access to the medical care system.[19] The measurement submodel is given by the equations (27) and (28) and corresponds to the right part of

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[19]For the German health care system the opportunity costs of visiting a physician are of particular importance, since the actual pecuniary prices of medical services are negligible.

the diagram. HI, the indicators of the latent variable health H*, represent individually observed dimensions of health status (handicapped individual, self-rated health, duration of sick leave, chronical complaints). As proxies (EI) for the latent exogenous variable environmental pollution (E*), we have chosen the indicators air and noise pollution.

3.2. Data and estimation technique

Our data source is the third wave of the West German Socio-economic Panel (SOEP), collected in 1986.[20] Apart from standard questions which are repeated on a yearly basis, this particular wave additionally contains self-rated information on housing conditions. According to our model, housing conditions may be interpreted as indicators of the latent variable environmental pollution and, thus, enter the vector of EI-variables. In order to comply fully with the theoretical analysis presented in section 2, our sample is restricted to those individuals who exhibit a positive demand for health services. Since our empirical analysis includes three demand variables, a positive demand for health services is equivalent to at least one positive entry in any of these components. In addition, we confine the analysis to the working population, since the use of the duration of sick leave as health indicator makes only sense for working individuals. This leaves us with an actual sample of 3317 observations for our estimation. Table 1 summarizes the basic descriptive statistics of the variables used in our study.

In order to scale the dimension of the latent variables H* and E* all observable variables enter the estimation as deviations from their means. Furthermore, we choose λ_{h3} and λ_{e1} as reference indicators for the two latent variables and restrict them to unity. This implies that a 10 percent increase in health status results in a 10 percent increase in self-related health. Similarly, pollution of the environment is measured in units of noise pollution. Identification is obtained by imposing a number of additional zero-restrictions on the parameters of our model.[21] The disturbances are assumed to be independently normally distributed with zero expectation. These assumptions enable us to estimate equations (27) - (30) by Full Information Maximum Likelihood using the GAUSS-module LINCS.

Since in most applications the assumption of multivariate normality of the data cannot be maintained, the precondition for MLE no longer holds. Hence, ML-estimates based on the false distributional assumption should more accurately be referred to as "Pseudo Maximum Likelihood Estimates" (see Gouriéroux/Monfort/Trognon (1984) for this concept). Nevertheless, the ML-estimates computed under the erroneous

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[20]See Deutsches Institut für Wirtschaftsforschung (1993) and Projektgruppe Sozio-ökonomisches Panel (1993). Burkhauser (1990) gives an introduction to english speaking researchers.

[21]The zero-restrictions can be read off from tables 2 and 4.

Variable	Definition	Mean	Standard deviation
Environmental indicators			
	noise pollution 1 - 5	2.0678	1.1010
CH07			
CH08	air pollution 1 - 5	2.0932	1.0906
Health indicators			
lnCP69	handicapped individual 1 - 3	0.2828	0.3872
lnCP70	chronical complaints	0.2140	0.3203
lnCP0101	self-rated health 1 - 11	1.9903	0.4033
lnCP7302	duration of sick leave (days)	1.5382	1.5278
Demand for health services			
lnCP7102	number of visits to a general practitioner	0.7595	0.7176
lnFARZT	number of visits to a specialist	0.9155	0.8523
lnCP7203	hospital days 1985	0.3695	0.9658
X - variables			
lnCP5202	net monthly income	7.4279	0.5442
CP8801	sex	0.4169	0.4931
CP8802	age in years	39.0865	11.6048
CPNAT	nationality	0.2819	0.4500
CPSBIL	education 1 - 3	2.0422	0.4692
CP0903	doing sports 1 - 4	2. 0389	1.2742
CP6204	private insurance	0.0868	0.2816
CGGK	community size1 - 7	4.4540	1.7997
CH0603	accessibility of resident physician 1 - 4	1.8478	1.0185

1) Employees only; third wave of the Socio-economic Panel (SOEP); the variable names CH07, CH08, CP69, CP70, CP0101, CP7302, CP7102, CP7203, CP8801, CP8802, CPNAT, CPSBIL, CP0903, CP6204, CGGK, and CH0603 correspond to the original description of the reference manual (cf. Deutsches Institut für Wirtschaftsforschung 1993; ln in front of a variable the natural logarithm. If a zero value is possible for a variable, we have added one before performing the log transformation.

assumption of multivariate normality are not meaningless, since they minimize the Kullback information criterion and can be interpreted as "Minimum-Ignorance-Estimators" (Gouriéroux/Monfort 1989a, p. 17f.). While the consistency of the parameter estimates may hold, estimates of the corresponding standard errors using

the false distributional assumption are no longer valid.[22] Thus, it is necessary to use heteroskedasticity-consistent standard errors which can be computed according to White's proposal (1980), given the consistency of parameter estimates.[23]

In order to test for the consistency of our parameter estimates, we apply a Hausman-type specification test. In this modified Hausman-test proposed by Schoenberg and Arminger (1989/90, p. 18 f.), the FIML-estimator which is consistent and efficient under the null hypothesis but inconsistent and inefficient under the alternative, is compared to a weighted estimator which is consistent but inefficent under both alternatives. The weights are introduced to increase the power of the test. They are chosen such that observations in which the endogenous variables are poorly predicted get a higher weight than observations that predict the endogenous variables well (see Arminger/Schoenberg 1989/90, p. 18 f.; Krämer/Sonnberger 1986, p. 85 f.). A sufficiently well specified model should result only in small differences between the two estimates. The test statistic of the Hausman-type specification test has a χ^2-distribution and allows to test for misspecification.[24]

4. Results

The following three tables present the estimation results based on the standardized solution.[25] Table 2 (4) contains the estimation results for the direct effects of the structural (measurement) submodel, whereas table 3 illustrates the estimated indirect and total effects of the exogenous variables on the demand for medical services. The signs of most of the coefficients are in accordance with the predictions based on our theoretical model.

With respect to the influence of the stock of health on the demand for health care variables (general practitioner visits, specialist visits, hospital days, see table 2), however, we obtain a negative coefficient for H* which is statistically significant in all three cases. While this finding is in line with the results of other studies, it clearly disagrees with our empirical specification as proposed in section 2.4. It is tempting to conclude that, given this discrepancy, the corresponding structural parameters are of

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[22]In principle, the asymptotic variance-covariance matrix of the parameter estimates under MLE corresponds to the inverse of the Fisher information matrix (see Davidson/MacKinnon 1993, p. 262 f.).

[23]For an exact calculation see Schoenberg/Arminger (1989/90, p. 16 f.) and Arminger/Mueller (1990, p. 19 f.).

[24]Nevertheless, in case of misspecification the underlying reason remains open. Misspecification may be due to the omission of variables, errors in variables, or a false functional specification (see Hübler 1989, p. 322).

[25]This implies, that all variances of the variables are equal to one (see Jöreskog/Sörbom 1989, p. 38 f.; Schoenberg/Arminger 1989/90, p. 24).

Table 2: Estimation results: structural equations

Explanatory variables	Health capital (lnH*)	Number of visits to a general practitioner (lnCP7102)	Number of visits to a specialist (lnFARZT)	Hospital days (lnCP7203)
		Dependent variables		
Health (lnH*)		-0.2557 (-10.3470)	-0.2977 (-11.6480)	-0.2640 (-8.3756)
Environmental pollution (E*)	-0.0909 (-3.5654)	-0.0001 (-0.0052)	-0.0018 (-0.0766)	-0.0567 (-2.8219)
Income (lnCP5202)	0.0591 (2.2741)	-0.0708 (-3.5549)	0.0485 (2.4051)	-0.0145 (-0.7330)
Sex (CP8801)	-0.0188 (-0.8103)	-0.0823 (-4.2424)	0.1377 (6.9292))	-0.0352 (-1.7756)
Age (CP8802)	-0.2961 (-13.2913)	0.0513 (2.6955)	-0.0876 (-4.8428)	-0.0465 (-2.2985)
Nationality (CPNAT)	0.0206 (0.9317)	0.0578 (2.9759)	-0.0661 (-3.3930)	0.0385 (1.8505)
Education (CPSBIL)	0.0727 (3.2325)	-0.0323 (-1.7002)	0.0338 (1.8240)	0.0027 (0.1451)
Doing sports (CP0903)	0.1075 (5.3503)	-0.0281 (-1.6082)	0.0739 (4.2965)	0.0026 (0.1436)
Private insurance (CP6204)	0.0163 (0.8596)	-0.0343 (-2.0653)	0.0273 (1.6408)	
Community size (CGGK)	-0.0412 (-2.1259)	-0.1519 (-8.7691)	0.1431 (8.4429)	-0.0227 (-1.3164)
Accessibility of resident physician (CH0603)	-0.0666 (-3.3909)	-0.0132 (-0.7890)		
R²	0.1383	0.1243	0.1284	0.0676

Total number of observations: 3317; t-values in brackets, based on robust standard errors. The coefficient of determination R^2 is one minus the ratio of error and variable variance. The latter is equal to one in the standardized model.

Table 3: Indirect and total effects on the demand for health services

| Explanatory variables | Demand for health services | | | | | |
| | Number of visits to a general practitioner (lnCP7102) | | Number of visits to a specialist (lnFARZT) | | Hospital days (lnCP7203) | |
	indirect effect	total effect	indirect effect	total effect	indirect effect	total effect
Environmental pollution (E*)	0.0232 (3.4068)	0.0231 (1.0989)	0.0271 (3.4750)	0.0253 (1.1410)	0.0240 (3.3614)	-0.0327 (-1.3718)
Income (lnCP5202)	-0.0151 (-2.2360)	-0.0859 (-4.1845)	-0.0176 (-2.2913)	0.0309 (1.5316)	-0.0156 (-2.2339)	-0.0301 (-1.5257)
Sex (CP8801)	0.0048 (0.8046)	-0.0775 (-3.9031)	0.0056 (0.8083)	0.1433 (7.0917)	0.0050 (0.8083)	-0.0302 (-1.5179)
Age (CP8802)	0.0757 (7.8333)	0.1270 (7.1818)	0.0881 (9.2857)	0.0005 (0.0769)	0.0782 (7.2222)	0.0317 (1.6250)
Nationality (CPNAT)	-0.0053 (-0.9333)	0.0525 (2.6551)	-0.0061 (-0.9280)	-0.0722 (-3.6069)	-0.0054 (-0.9286)	0.0331 (1.5480)
Education (CPSBIL)	-0.0186 (-3.0870)	-0.0509 (-2.6141)	-0.0216 (-3.1440)	0.0122 (0.6377))	-0.0192 (-3.0153)	-0.0165 (-0.8715)
Doing sports (CP0903)	-0.0275 (-4.8438)	-0.0556 (-3.1616)	-0.0320 (-4.9767)	0.0419 (2.3932)	-0.0284 (-4.5745)	-0.0258 (-1.4130)
Private insurance (CP6204)	-0.0042 (-0.8548)	-0.0385 (-2.2581)	-0.0049 (-0.8547)	0.0224 (1.3114)	-0.0043 (-0.8506)	-0.0043 (-0.8506)
Community size (CGGK)	0.0105 (2.1000)	-0.1414 (-7.9437)	0.0123 (2.0714)	0.1554 (8.9634)	0.0109 (2.0714)	-0.0168 (-0.6702)
Accessibility of resident physician (CH0603)	0.0170 (3.2432)	0.0038 (0.2250)	0.0198 (3.2549)	0.0066 (3.2549)	0.0176 (3.2115)	0.0176 (3.2115)

Number of observations: 3317; t-values in brackets, based on robust standard errors.

the "wrong" sign (cf. Wagstaff 1986, p. 216 f., Leu/Gerfin 1992, p. 72). This, however, would be premature[26]. Looking at equation (12), it is straightforward to show that the impact of a marginal increase in health capital on the demand for health care is given by

$$(31) \qquad \frac{\partial M_t}{\partial H_t} = -\frac{\partial \pi_t'}{\partial P_t^M} (1 - \delta_t).$$

If one takes reasonable values for δ_t to be restricted by $0 < \delta_t < 1$, then the Grossman model obviously implies a negative influence of health on consumption of medical care. Thus, while our empirical results certainly disagree with our empirical specification, they do not provide evidence against the Grossman model[27].

As expected, the latent variable environmental pollution E* exerts a negative impact on the stock of health capital H*. Increasing environmental pollution goes along with a higher rate of depreciation and, hence, induces a decrease in the stock of health capital. Contrary to the prediction of our theoretical model, we find a negative relationship between environmental pollution and health care demand. However, the direct effects on the number of G.P. visits and on specialist visits are not significant. The corresponding indirect effects of environmental pollution on the three health care demand variables are both positive and significant, i.e. the increased rate of depreciation implies a higher consumption of medical services (see table 3). In this case, medical consumption may be interpreted as a gross investment which tends to compensate for the higher rate of depreciation. From the class of X-variables, the parameters corresponding to the variables income, age, and education display the theoretically expected impact on the latent variable health capital H*.

High income earners visit a general practitioner less frequently, but have more contacts to a specialist. If the general practitioner treats only minor health problems, opportunity costs might play an important part. There are controversial opinions on the sign of the income variable. Van de Ven and van der Gaag (1982) find a negative effect of income on the demand for medical services. On the one hand, a high income results in a high demand (direct effect), but, on the other hand, this leads to a higher level of health capital which reduces consumption (indirect effect). A priori the total effect is undetermined. Our estimation results indicate that with regard to G.P. visits the direct and the indirect effect are both significant and point in the same direction, resulting in a negative total effect (see table 3). The direct and the indirect effect of income on the number of specialist visits are of opposite signs, while the resulting total effect is not significant.

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[26]Besides, a model predicting a higher level of health always to go along with a higher demand for medical care would appear somewhat strange.

[27]Unfortunately, up to now we have not been able to find a different specification for the demand equation which both preserves the negative coefficient of health capital and yields a plausible interpretation for the corresponding error term.

The binary variable for the type of medical insurance is only significant for visits to a general practitioner. Individuals that are privately insured pay fewer visits to a general practitioner. This result reflects mainly the institutional setting of Germany, where the G.P. has no gate-keeper function for privately insured patients. Unlike a patient insured in the statutory health insurance, a privately insured patient can choose his physician(s) without any restriction.

As regards sex (female = 1), our estimation results indicate no significant difference of health capital between male and female but more visits to a specialist and less visits to a G.P. for women. Foreigners consume more medical services compared to natives, with the exception of fewer consultations to specialists.[28]

As expected, the age variable exerts a negative impact on the stock of health capital. Puzzling are the direct effects of age on the demand for health services, which turn out to be both negative and significant as far as the number of specialist visits and hospital days are concerned. One explanation for this finding might be due to our modelling of the age effect, because we consider only a linear age term. However, it is well known that age possesses a convex relationship with respect to health care demand. This implies that the number of physician visits and hospital days first decreases and then increases with age. Nevertheless, the total effect of age on health care demand (G.P. visits, specialist visits, hospital days) has the expected positive sign and is statistically significant for G.P. and specialist visits. Another reason could be that the number of visits to selected specialists included in our sample, e.g. gynaecologists or specialists for accident injuries, decreases with age.

Doing sports has a positive effect on the stock of health capital. More ambiguous is the relationship between sports and the consumption of medical services. The direct effect in table 2 is only significant for visits to specialists and the positive sign indicates the consequences of sporting accidents. This result contrasts with the indirect effects, which operate through the stock of health capital and reduce the demand for health services (see table 3). Only for the number of specialist visits, the resulting total effect is significant at the 5 percent level. This increased demand for specialist services can be interpreted as gross investment which is to compensate for the hazards potentially associated with doing sports.

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[28]An alternative estimation, however, where the sample has been enlarged to include individuals with a zero demand for health services, indicates a lower stock of health capital for women. Furthermore, foreigners appear to be more healthy than Germans. This may be due to self selection. It is reasonable to assume, that only people in good physical condition choose to migrate to a foreign country. Given the inverse relationship between the stock of health capital and the demand for health care, the smaller sample discussed in the text contains a negative selection of all subgroups as regards health. As our results illustrate, these selection effects tend to affect both men and women as well as natives and foreigners in a way such that there are no more differences in the stock of health capital which are statistically significant.

Table 4: Estimation results: measurement equations

Indicators	Latent variables		R^2
	Environmental pollution (E^*)	Health capital ($\ln H^*$)	
Noise pollution (CH07)	0.7539		0.5623
Air pollution (CH08)	0.8318 (4.1045)		0.6920
Duration of sick leave (lnCP7302)		-0.3308 (-13.4703)	0.1094
Handicapped individual (lnCP69)		-0.8140 (-23.8913)	0.6627
Self-rated health (lnCP0101)		0.6273	0.3936
Chronical complaints (lnCP70)		-0.6493 (-22.2958)	0.4217

Total number of observations: 3317; t-values in brackets, based on robust standard errors. The coefficient of determination R^2 is one minus the ratio of error and variable variance. The latter is equal to one in the standardized model.

Between community size and the number of specialist visits we find a positive direct effect which reflects the overproportional supply of specialists in larger communities. In addition, the corresponding coefficient in the G.P. equation is negative, indicating that G.P. services are substituted by specialist services in larger communities and cities.

The effect of the accessibility of the resident physician in the demand equation for G.P. visits, a potential proxy for the corresponding time costs, is not significant. However, in the health capital equation, we find a significant negative sign, indicating that a small distance to the resident physician increases self-rated health.

In discussing the estimation results for our measurement model, we concentrate on the coefficient of determination (R^2). As can be seen from table 4, 56.2 (69.2) percent of the covariance of the proxy variable noise pollution (air pollution) can be explained by the latent variable environmental pollution. The corresponding figures for the health indicators turn out to be lower, with the exception of the indicator "handicapped individual" (66.2 percent of its variance is explained). This indicator proxies the latent variable health capital best, whereas the indicator "duration of sick leave" seems to be not well suited to proxy health capital. One reason might be that this variable is more likely to reflect the individual's satisfaction with the work place instead of pointing to a specific illness.

Table 5: Results of the specification tests

Model part to be analyzed	Test statistics[1]
Value of the Hausman-type specification test when analyzing structural parameters only	HTST = 0.11 DG = 44 Pr = 1.0
Value of Hausman-type specification test for all parameters	HTST = 1238.61 DG = 55 Pr = 0.00

1) HTST = Test statistic of the Hausman-type specification test; DG: degrees of freedom; Pr: Probability-level.

Finally, table 5 summarizes the results of the specification tests. Note that there is no evidence for misspecification of the structural model, while the overall specification of our model has to be rejected. An explanation for the strong discrepancies in the test results might be the extremely parsimonious specification of the covariance structure of the disturbances.

5. Conclusions

On the basis of a Grossman-type health production model, the determinants of the stock of health capital and the demand for medical services have been analyzed and estimated. In this model, health is viewed as capital stock which is subject to depreciation but can be augmented by means of gross investment. A special concern of the paper is to investigate the relationship between the quality of the environment, the stock of health capital and the demand for medical services. Therefore, we have added the latent variable environment pollution as explanatory variable to our model. This variable exerts a direct impact on health capital via a change in the rate of depreciation. As regards health care demand, environmental pollution is modelled to have a direct effect on the consumption of medical services as well as an indirect effect. The indirect effect operates through the stock of health capital. As mentioned, environmental pollution cannot be observed directly. The same is true for the stock of health capital. In order to account for this, in our empirical specification we have added a measurement submodel to the structural equations. In this measurement part of the model, the latent variables are explained by a set of observable indicators.

In particular, we would like to emphasize the following results concerning the relationship between health, health care, and environmental pollution:

(1) Health exerts a negative impact on the consumption of medical services. In other words, good health, which is expressed in a high stock of health capital, reduces the number of visits to a physician and the number of days spent in hospital.

While this conflicts with our empirical specification, this is exactly what the theoretical model predicts. Hence, future research efforts should be directed at improving the empirical specification as far as the relation between health and health care demand is concerned.

(2) The quality of the environment as measured negatively by environmental pollution turns out to be an important determinant of health capital. The relationship between the environment and health care demand, however, is not clear-cut.The direct effect of environmental pollution on health care demand is negative, but it is only significant for the number of hospital days. In contrast, the corresponding indirect effect on all three demand variables is both positive and significant, i.e. the increased rate of depreciation of the stock of health capital caused by environmental pollution implies a higher consumption of medical services.

These results suggest that any policy directed at improving the quality of the environment is likely to generate benefits with respect to health care, too. More precisely, because of its positive effect on health, a higher quality of the environment ceteris paribus enables the individual to enter any time period with a higher stock of health capital. In this sense, then, any such environmental policy can be interpreted in terms of preventive medicine, too.[29]

(3) In order to test for the model fit, we have performed a Hausman-type specification test. We find no evidence for misspecification of the structural model while the overall specification of our model has to be rejected. One reason might be the limitations of our measurement model. Unfortunately, household surveys, like the SOEP, do not contain much information on environmental factors and allow only a satisfactory description of individual health, but not of the quality of the environment.

Our results indicate two further aspects for future research on the relationship between health and the environment. First, an attempt should be made to map latent variables and indicators more accurately. Furthermore, in our view the application of panel data is of special interest to cope with the impact lag which characterizes the influence of environmental pollution on both health and health care demand.

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[29]This reflects the fact that the Grossman model seems best suited to explain the use and influence of preventive medicine.

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