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MODELLING OPPORTUNITY IN HEALTH UNDER PARTIAL OBSERVABILITY OF CIRCUMSTANCES

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SUMMARY

This paper proposes a behavioural model of inequality of opportunity in health that integrates John Roemer's framework of inequality of opportunity with the Grossman model of health capital and demand for health. The model generates a recursive system of equations for health and lifestyles, which is then jointly estimated by full information maximum likelihood with freely correlated error terms. The analysis innovates by accounting for the presence of unobserved heterogeneity, therefore addressing the partial-circumstance problem, and by extending the examination of inequality of opportunity to health outcomes other than self-assessed health, such as long-standing illness, disability and mental health. The results provide evidence for the existence of third factors that simultaneously influence health outcomes and lifestyle choices, supporting the empirical relevance of the partial-circumstance problem. Accounting for these factors, the paper corroborates that the effect of parental and early circumstances on adult health disparities is paramount. However, the particular set of circumstances that affect each of the analysed health outcomes differs substantially. The results also show that differences in educational opportunities, and in social development in childhood, are crucial determinants of lifestyles in adulthood, which, in turn, shape the observed health inequalities. Copyright © 2010 John Wiley & Sons, Ltd.

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1. INTRODUCTION

Recent empirical papers, such as Trannoy *et al.* (2009) and Rosa Dias (2009), provide evidence of substantial and persistent inequality of opportunity in health in European countries. They also suggest that unjust circumstances affect health through a network of indirect effects whose causal nexus is often ambiguous. This has led authors such as Fleurbaey and Schokkaert (2009) to propose that such complex interactions be clarified through the specification of a structural model of inequality of opportunity; this paper follows this line of research.

This paper is grounded on the framework of Roemer (1998, 2002), which draws a distinction between *circumstance* and *effort* variables: the outcome of interest is health as an adult; *circumstances* (beyond individual control) are proxied by parental socioeconomic status and childhood health, while *effort* is proxied by factors that are at least partly within individual control, such as health-related lifestyles and educational attainment. This framework is then embedded in a structural model, along the lines of Fleurbaey and Schokkaert (2009). Since the outcome of interest in this paper is health, the model is a normative interpretation of Grossman's (1972) model of health capital and demand for health; this

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closes the gap between the literature on the production of health and the normative literature on health inequalities.[1]

This structural model generates the demand for health and for each of the effort factors. These define a recursive system of equations that is estimated jointly by full information maximum likelihood (FILM), allowing the system error terms to be freely correlated so as to account for unobserved common factors, such as unobserved or unmeasured circumstances, that impact simultaneously on health and effort factors. The purpose of this approach is twofold. First, it sheds light on the relationship between circumstances, effort and health. Second, it addresses the problem posed by the partial observability of the relevant set of circumstances, referred to in the literature as the *partial-circumstance problem*. The model is estimated using data from the National Child Development Study (NCDS), which follows the cohort of individuals born in the week of 3rd March 1958 up to age 46.

2. EQUALITY OF OPPORTUNITY: THE ROEMER MODEL IN THE CONTEXT OF HEALTH

The Roemer (1998, 2002) model partitions all factors influencing individual attainment into a category of *effort factors*, for which individuals should be held partly responsible and a category of *circumstance factors*, which, being beyond individual control, are the only source of illegitimate differences in outcomes. In this paper the outcome of interest is health as an adult (H), which results from a health production function, $H(C,E(C))$, where C denotes individual circumstances, E denotes effort, and in which it is explicitly recognised that effort can be shaped by circumstances.

The specification of the causal factors that constitute circumstances in a health context follows the vast published literature on the impact of childhood circumstances on health outcomes in adulthood: for example, Kuh and Wadsworth (1993), Barker (1995), Marmot *et al.* (2001), Case *et al.* (2005) and Lindeboom *et al.* (2006) are key references. Following this strand of research, this paper treats as circumstances parental socioeconomic characteristics, spells of financial hardship during the cohort members' childhood and adolescence, proxies of congenital endowment such as the prevalence of chronic conditions in the family, and the incidence of acute and chronic illnesses and obesity in childhood and early adolescence. All these factors affect people before the age of 16, reflecting conditions and behaviours that are largely beyond individual control. Since cognitive ability, social development in childhood and educational attainment are likely to be decisively influenced by parental and environmental factors, they are also considered a circumstance in terms of its influence on health in adulthood.

The choice of the effort factors is also guided by the literature, namely by work done on the relationship between health and lifestyles, such as Mullahy and Portney (1990), Kenkel (1995), Contoyannis and Jones (2004) and Balia and Jones (2008). This paper treats as effort a set of lifestyles, such as cigarette smoking, alcohol consumption and dietary choices that are, at least partly, within individual control.

The Roemer model defines social types consisting of individuals who share exposure to the same circumstances. The set of observed individual circumstances allows the specification of these social types in the data. A fundamental aspect in this setting is the fact that the distribution of effort within each type (F^t) is itself a characteristic of that type; since this is beyond individual control, it constitutes a circumstance.

In order for the degree of effort expended by individuals of different types to be comparable, Roemer proposes the definition of quantiles of the effort distribution (in this case, for example the number of cigarettes per day or number of units of alcohol consumed per week) within each type: two individuals are deemed to have exerted the same degree of effort if they sit at the same πth quantile of their type's distribution of effort. When effort is observed, this definition is directly applicable. However, if effort is unobservable, an additional assumption is required: by assuming that the average outcome, health in

[1]Other applications of the Grossman model to the analysis of health inequalities can be found in Dardanoni and Wagstaff (1987) and Contoyannis and Forster (1999).

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this case, is monotonically increasing in effort, i.e. that healthy lifestyles are a positive contribution to the health stock, effort becomes the residual determinant of health once types are fixed; therefore, those who sit at the πth quantile of the outcome distribution also sit, on average, at the πth quantile of the distribution of effort within their type.

The definition of equality of opportunity used in this paper also follows from the Roemer model: equality of opportunity in health attains when average health outcomes are identical across types, at fixed levels of effort. This means that, on average, all those who adopt identical lifestyles should be entitled to experience a similar health status, irrespective of their circumstances. Such a situation corresponds to a full nullification of the effect of circumstances, keeping untouched the differences in health outcomes that are caused solely by effort.

3. OUTLINE OF THE STRUCTURAL MODEL

Economists typically assume that levels of effort are the consequence of utility maximisation subject to constraints, yet the determination of effort levels is omitted by the Roemer model. Fleurbaey and Schokkaert (2009) propose the formulation of a behavioural model to explain the interaction between legitimate and illegitimate sources of inequality and hence the channels by which circumstances affect health outcomes. The nature of the data used here also permits such a model to link the literature on childhood circumstances to the research on health and lifestyles; these have evolved in relative isolation. The structural model put forward in this paper is a normative interpretation of Grossman's (1972) seminal model, which also draws on more recent variants of this specification, such as Lechene and Adda (2004), Contoyannis and Jones (2004) and Balia and Jones (2008).

Following Grossman (1972), it is assumed that health is a fundamental commodity[2] produced by inputs that are labelled as either circumstances or effort by the researcher. The production of health at date t is given by production function, $f(E_t, C_t, \mu_H)$, where E_t denotes observed effort expended at date t, C_t denotes observed circumstances at date t and μ_H reflects unobserved factors affecting the production of health. As in the original Grossman model, the health production function is assumed to be increasing and concave in effort.

The health stock at any date $t+1$ is given by the production of health at date $t+1$ and the depreciated health stock from the previous time period (t), where the depreciation rate (δ) is positive and smaller than unity. The law of motion of the health stock can thus be expressed by:

$$H_{t+1} = f(E_t, C_t, \mu_H) + (1 - \delta_t)H_t \tag{1}$$

Effort factors are choice variables, by definition, and their marginal product is assumed to be known to the individuals. Each individual chooses demand for a vector of effort commodities and health to maximise lifetime utility, subject to income and time constraints, as well as uncertainty regarding the time of death. This uncertainty takes the form of a known hazard rate, $\sigma_t(H_t)$, which denotes the probability of surviving from date t to date $t+1$ and depends on the value of the health stock at date t.

In each time period, instantaneous utility $U(\cdot)$ depends on observed effort, observed circumstances, the health state variable and, given only partially observable circumstances, on factors that are unobserved by the researcher (although arguably known to the individual), μ_U. For example, genetic propensities are circumstances that may condition effort responses aimed at offsetting the risk of illness, but which are hidden to the researcher. Instantaneous utility is discounted by a subjective discount

[2]Two aspects deserve clarification. First, health constitutes a *fundamental commodity* in the sense that it is an argument of the (direct) utility function; no ethical judgment is attached to this assumption. Second, the literature encompasses more refined versions of the Grossman model than the one presented here: Dardanoni and Wagstaff (1987) and Forster (2001) explore modelling health as an investment good; Carbone *et al.* (2005) allow for individual adaptation to an anchoring health state. These features are not essential in this analysis, hence excluded for parsimony.

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factor, β, which lies between 0 and 1, and the probability of survival until the next period, $\sigma_t(H_t)$. Each individual's maximization problem can thus be described by:

$$\max_{E,H} \sum_{t=0}^{\infty} \beta^t \sigma_t(H_t) U\left(E_t, H_t; C_t, \mu_U\right) \tag{2}$$

Total expenditure at time t on commodities belonging to the effort vector, $p_{jt}E_{jt}$, needs to be met by exogenous income (y_t) and labour income (w_tL_t), where p_{jt} denotes the price of commodity j, w_t denotes the hourly wage and L_t denotes labour supply. The amount of time required to consume a unit of commodity E_{jt} is denoted τ_{jt}; the total time available (T) net of working hours (L_t) therefore needs to equal the time required for consumption. Hence, individuals maximise (2) subject to the following within-period income and time constraints:

$$\sum_{j=1}^{J} p_{jt}E_{jt} \leq y_t + w_tL_t$$

$$\sum_{j=1}^{J} \tau_{jt}E_{jt} = T - L_t, \quad j = 1, \ldots, J \tag{3}$$

Since $L_t = T - \sum_{j=1}^{J} \tau_{jt}E_{jt}$ the two constraints may be combined and expressed in terms of full prices and income:

$$\sum_{j=1}^{J} (p_{jt} + w_t\tau_{jt})E_{jt} \leq y_t + w_tT \tag{4}$$

The transition equation (1) ensures the recursive nature for this maximisation problem whose Bellman equation is[3]:

$$V(H_t) = \max_{E_t} \{U_t(E_t, H_t) + \beta \mathrm{E}_t[V(H_{t+1})]\} \tag{5}$$

The solution of the individuals' optimisation problem, given by (6), consists of the demand for health ($1 \times t$ vector H) and demands for effort factors ($j \times t$ matrix E), where demands are expressed as functions of observed circumstances and the vector of unobservable factors, μ, where $\mu = \left[\mu_U, \mu_H\right]$:

$$\begin{aligned} H &= g_H(C, \mu) \\ E &= g_E(C, \mu) \end{aligned} \tag{6}$$

Roemer's assumption that health outcomes are monotonically increasing in effort remains sensible in this behavioural framework: healthy lifestyles and education in general are believed to improve health; however, individual preferences and probabilities of survival may dictate a utility maximising behaviour that diverges from the simple intertemporal maximisation of the health stock.

This paper estimates an empirical version of the system of equations (6) to illuminate the triangular relationship between circumstances, effort and health, accounting for the effect of unobserved factors, such as unmeasured circumstances, present in the μ terms.

[3]It is assumed that individuals are alive at period t, hence the mathematical expectation E_t is taken over the uncertain future survival reflected by σ_t.

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4. DATA

The National Child Development Study (NCDS) follows a cohort of 17 000 individuals born in Great Britain during the week of 3rd March 1958, from birth up to age 46. The cohort members' parents were interviewed for the first time in 1958 and extensive medical data on the children were collected; comprehensive information about the cohort-members' parental background, childhood health and educational achievement was compiled during the first three waves of the study. From wave four onwards, the NCDS questionnaires were addressed to the cohort members and cover a broad range of subjects encompassing employment, health and health-related behaviour, education, citizenship and values, parenting and housing.[4]

Three separate health outcomes are used in the paper . The first is self-assessed health (SAH) at age 46, measured on a five-point scale: excellent, good, fair, poor and very poor health. SAH is widely used in health economics and has been shown to predict mortality and deterioration of health even after controlling for the medical assessment of health conditions; Idler and Kasl (1995) provide an extensive literature review on this issue. In the specific case of the NCDS, the use of SAH is also corroborated by its high correlation with reported disability and number of hospitalisations.[5] The second health outcome is an indicator variable for whether the individuals report to suffer from a long-standing illness or disability at age 46. The third health outcome used in the paper is an index of mental illness: respondents answer a series of questions from the Cornell Medical Index Questionnaire, each targeting a particular mental ailment; the number of positive answers given at age 42 is then used as a malaise score, along the lines of Carneiro *et al*. (2007).

Three main categories of circumstance variables are used in the paper: parental socioeconomic background; congenital and childhood health of the cohort members; cognitive ability, social development in childhood and educational achievement. In terms of parental background, the NCDS contains rich information that allows tracing the social class and years of schooling of the parents and of both grandfathers of cohort members. Along the lines of Case *et al*. (2005) and Lindeboom *et al*. (2006), this information is complemented by data on the incidence of financial difficulties during cohort members' childhood.

Cohort members' childhood health is characterised by a set of morbidity measures, aggregating 12 categories of acute and chronic health conditions, constructed according to Power and Peckham (1987). Indicator variables for the occurrence of diabetes, epilepsy and chronic heart conditions in parents and siblings are also included in order to account for the incidence of hereditary conditions. Finally, obesity at age 16 and parental smoking during the cohort members' childhood and adolescence are also treated as circumstances.

Recent research has provided evidence of a long-term direct effect of cognitive ability and social development in childhood on a wide range of behaviours in adulthood with potential impacts on health.[6] These factors are largely beyond individual control, hence can be regarded as circumstances. Scores of ability tests taken at age 11 are used as proxies of cognitive ability, covering three fundamental dimensions: mathematics, reading and general ability. These test scores are highly correlated at the individual level, leading to multicollinearity in the econometric models. To avoid this problem, the

[4]The issue of attrition has been considered both in research papers and in reports produced by the NCDS advisory panel. Attrition does not appear to be associated with socioeconomic status, as shown in Case *et al*. (2005), and has modest positive correlation with cohort members' unemployment as reported by Lindeboom *et al*. (2006). In this paper, a variable addition test was carried-out to investigate whether health-related attrition is a problem: ordered probit regressions were used to ascribe whether being in subsequent waves of the panel is a determinant of health status. The results show that, after controlling for a rich set of regressors, the fact that an individual is observed in subsequent waves of the NCDS is not significantly associated with their self-assessed health.

[5]See Case *et al*. (2005, p. 370).

[6]See Heckman *et al*. (2006), Carneiro *et al*. (2007) and references therein.

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paper follows the approach of Galindo-Rueda *et al*. (2005), using principal components analysis of the test scores to construct a single measure of cognitive ability based on the first principal component.

To measure social development in childhood, the paper uses scores of the Bristol Social Adjustment Guide (BSAG), following Carneiro *et al*. (2007). These are used as measures of social maladjustment at age 11: teachers are asked whether the child has problems in 12 behavioural domains such as hostility towards children and adults, anxiety, withdrawal, 'writing off' adults, unforgivingness, depression, restlessness, acceptance by adults, inconsequential behaviour and miscellaneous psychological and nervous symptoms. One point is attributed to each positive answer; the points are then summed to obtain the BASG social maladjustment score.

The paper also treats as circumstances the highest educational qualifications attained by the cohort members, since these are likely to be decisively influenced by parental and environmental factors. Cumulative indicator variables are used to categorise the highest educational qualifications obtained: no formal qualifications; Certificates of Secondary Education (CSE), O-levels or higher qualification; A-levels or higher qualification; university degree or equivalent.[7]

The effort factors considered in the paper are health-related lifestyles. These may be constrained by circumstances, but also reflect individual choices. The paper uses self-reported individual data on cigarette smoking and on the consumption of alcohol and fried food. Cigarette smoking is proxied by an indicator variable for whether the individual is a smoker at age 33. Alcohol consumption is measured by the number of units of alcohol consumed on average per week at age 33. NCDS respondents are asked about their weekly consumption of a wide range of alcoholic drinks (glasses of wine, pints of beer and so forth). These are then converted into units of alcohol using the UK National Health Service (NHS) official guidelines.[8] The consumption of fried food is measured by a categorical variable reflecting its frequency in the individuals' weekly diet at age 33. It should be noted that health outcomes are measured either at age 46 or at age 42, but effort factors are measured at age 33, so as to rule-out reverse causality due to a direct effect of the current health status on behavioural choices.

5. METHODS

The empirical formulation of the model consists of a one-period version of the system of reduced form equations (6) in which health outcomes and each of the effort factors depend solely on circumstances and unobserved factors. Health is represented by a vector with three components (SAH; long-term illness and disability; mental illness) and effort by a vector composed of three lifestyles (cigarette smoking; weekly consumption of fried food; weekly consumption of alcohol).

This system is estimated by full information maximum likelihood, allowing the system error terms to be freely correlated so as to account for unobserved common factors that impact simultaneously on health and effort factors. This method of dealing with selection on unobservables has been implemented in recent papers such Pudney and Shields (2000), Vera-Hernandez (2003), Deb and Trivedi (2006), and Balia and Jones (2008), but not yet in the literature on inequality of opportunity. However, as made clear by Roemer (2004), Lefranc *et al*. (2009) and Fleurbaey (2008, p. 240), accounting for this type of heterogeneity should be important in this context since, in practice, it is often impossible to observe the entire set of relevant circumstances likely to influence the outcome of interest. Although the theoretical bounds for the error incurred through partial observation of circumstances have not been derived, the several types of bias arising from this in the estimation and measurement of inequality of opportunity

[7]CSEs and O-level (Ordinary levels) were secondary education qualifications corresponding, typically, to 11 years of education. A-levels (Advanced levels) are a qualification which corresponds to 13 years of education. Completion of A-levels is ordinarily a prerequisite for university admission.

[8]These are publicly available at: http://www.nhsdirect.nhs.uk/magazine/interactive/drinking/index.aspx.

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are known as the *partial-circumstance problem* and extensively discussed in Fleurbaey (2008, p. 240–241).

The equations for SAH and for the consumption of fried food are estimated using ordered probit models. The models for the incidence of long-standing illness and cigarette smoking are probits, and the equations for mental illness and alcohol consumption are linear regressions. Multivariate normality of the error terms is assumed and, given that the estimation of this system requires computation of multidimensional integrals, a maximum simulated likelihood procedure is implemented using the Geweke–Hajivassiliou–Keane (GHK) simulator.[9] The system is intrinsically non-linear and hence identified by the set of functional assumptions on the error term.

6. RESULTS

The importance of unobserved factors, which simultaneously affect both health outcomes and lifestyle choices, can be evaluated by examining the estimates of the correlation coefficients between the error terms of the system equations that are shown in Table I. The correlation coefficients between the errors of the SAH equation and those of the equations for the incidence of long-standing illness and disability and for mental illness are negative and statistically significant; this indicates the existence of unobserved factors that exert a positive effect on SAH and which, simultaneously, reduce the incidence of long-standing illness and mental health conditions. The correlation between the error terms of the equation for long-standing illness and disability and of the equation for mental illness are positive and statistically significant, due to third factors that favour the occurrence of both types of health problems.

The correlation coefficients between the equation for cigarette smoking and the equations for the consumption of fried food and alcohol are positive and statistically significant. This is in line with evidence that suggests the existence of an individual (genetic or otherwise) propensity for addictive behaviours, affecting simultaneously the three detrimental lifestyles considered in the system. Furthermore, the correlation between the error terms of the equations for SAH and for each of these lifestyles is negative and statistically significant, confirming the presence of unobservables that increase the probability of reporting good health and that, at the same time, reduce the likelihood of individuals smoking, dinking alcohol and consuming fried food. Finally, there are also unobserved factors that jointly increase the incidence of mental illness and the consumption of alcoholic drinks and cigarettes. These estimated correlations corroborate fully the relevance of the partial-circumstance problem put forward in Fleurbaey (2008), highlighting the vital importance of dealing with unobserved heterogeneity in the context of inequality of opportunity. Previous work, such as Trannoy *et al.* (2009) and Rosa Dias (2009), do not take this into account.

The estimated marginal effects[10] for the one-period version of the system of equations (6) are shown in Table II. The estimates for the SAH equation are in line with the previous literature that examines inequality of opportunity using self-assessed health as the only proxy for health status in adulthood. After controlling for social class in adulthood, the cohort members whose father was in the top occupational category in 1958 are 6.2 percentage points more likely to report excellent health at age 46 than those whose father was in the bottom social class. This partial effect is 4.3 percentage points for those whose father was in the middle social class. The incidence of childhood morbidities and the prevalence of chronic illnesses such as epilepsy in the family have a large negative effect on SAH in

[9]Practical implementation was carried out using the Stata module *cmp*. Full details on this Stata module can be found in Roodman (2009).

[10]The marginal effects for the health equation are computed for the probability of reporting excellent health. The marginal effects for the equation for the consumption of fried food correspond to the probability of reporting to 'eat fried food every day, more than once per day'.

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Table I. System errors correlation matrix

System equations	Rho	Std. dev.
SAH/Long-standing illness	−0.534***	0.032
SAH/Mental illnesss	−0.267***	0.023
SAH/Smoker	−0.181***	0.034
SAH/Consumption of fried food	−0.07***	0.024
SAH/Alcohol consumption	−0.051**	0.023
Long-standing illness/Mental illness	0.205***	0.026
Long-standing illness/Smoker	−0.034	0.040
Long-standing illness/Consumption of fried food	−0.025	0.029
Long-standing illness/Alcohol consumption	−0.034	0.028
Mental illness/Smoker	0.068**	0.029
Mental illness/Consumption of fried food	0.021	0.021
Mental illness/Alcohol consumption	0.058***	0.022
Smoker/Consumption of fried food	0.177***	0.032
Smoker/Alcohol consumption	0.146***	0.031
Consumption of fried food/alcohol consumption	0.032	0.023

Statistical significance levels: $^{***}p<0.01$; $^{**}p<0.05$.

adulthood, in line with evidence provided by Case *et al*. (2005). Also in line with the previous literature, obesity in adolescence is responsible for a 6 percentage point reduction in the probability of reporting excellent health at age 46.

Educational qualifications are also positively associated to the probability of reporting excellent health in adulthood. Conversely, there is a negative and statistically significant effect of social maladjustment at age 11 on SAH at age 46, after controlling for cognitive ability and for the highest academic qualifications attained. Although this circumstance factor has received little attention in the literature on inequality of opportunity, this result is in line with evidence provided by Heckman *et al*. (2006) on the large impact of non-cognitive skills and social development in childhood on a wide range of outcomes and behaviours in adulthood.

The general pattern of how circumstances influence health outcomes changes considerably once alternative components of the health vector are considered. Contrary to the results obtained for SAH, parental social class, education and household finances do not have a statistically significant effect on the incidence of long-standing illness and disability at age 46. This is mainly determined by gender, with males being 5 percentage points more likely to be affected by these conditions, childhood health and by a strong hereditary component: individuals in whose close relatives suffer from epilepsy are 7 percentage points more likely to have developed a chronic illness at age 46; this difference is of roughly 12 percentage points for cohort members whose close relatives suffer from chronic heart disease. Social maladjustment at age 11 is also positive and statistically significantly associated with the development of chronic illness in adulthood. Finally, the NCDS cohort members who are in the top social class in adulthood are approximately 5 percentage points less likely to suffer from a long-standing illness at age 46 than those in the bottom social class.

The estimates for the occurrence of mental illness at age 46 also follow a different pattern of influence to SAH, with parental social class found not to be statistically significant. At age 46, the male cohort members are less likely to report mental health problems than females. The incidence of these has a positive and statistically significant association with poor childhood health and with the prevalence of chronic conditions in close relatives. Social maladjustment in childhood has a statistically significant positive impact on mental illness in adulthood. Educational attainment has a protective effect: the completion of O-levels or of a higher qualification has a strong and statistically significant negative association with the occurrence of mental health conditions at age 46.

These results show that while the three elements of the health vector are strongly affected by unfair circumstances, each of them responds to a different subset of circumstance factors. In particular,

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Table II. System estimates (one-period version of the system of equations denoted (3) in Section 3)

	Dep. variable		Dep. variable		Dep. variable		Dep. variable		Dep. variable		Dep. variable	
	SAH (Ordered probit estimates)		Long-standing illness/disability (Probit estimates)		Mental illness (OLS estimates)		Indicator: Smoker (Probit estimates)		Fried food (Ordered probit estimates)		Alcohol (OLS estimates)	
	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.
Male	0.035	0.013	0.153***	0.052	−0.678***	−0.678	−0.149	−0.03	0.646***	0.0330	16.627***	16.627
	(0.0461)		(0.055)		(0.126)		(0.062)		(0.046)		(1.544)	
Parental at birth: High	0.167**	0.061	−0.107	−0.036	−0.017	−0.017	−0.15	−0.038	−0.098	−0.0040	2.545	2.545
	(0.0745)		(0.089)		(0.206)		(0.101)		(0.072)		(2.045)	
Parental at birth: Middle	0.119*	0.043	−0.078	−0.027	0.069	0.069	−0.075	−0.019	−0.051	−0.0020	2.393	2.393
	(0.065)		(0.076)		(0.173)		(0.082)		(0.06)		(1.782)	
Years of education: Father	−0.015	−0.005	−0.012	−0.004	0.049	0.049	−0.0002	−0.005	0.006	0.0003	0.167	0.167
	(0.0171)		(0.02)		(0.05)		(0.024)		(0.018)		(0.517)	
Years of education: Mother	0.018	0.006	−0.031	−0.010	0.008	0.008	0.08**	0.021	0.052**	0.0026	−0.321	−0.321
	(0.0192)		(0.023)		(0.055)		(0.025)		(0.019)		(0.583)	
Financial hardship (age 11)	−0.121	−0.043	0.005	0.001	0.41	0.41	0.06	0.017	−0.0002	0.0000	1.466	1.466
	(0.104)		(0.131)		(0.263)		(0.138)		(0.099)		(2.707)	
Physical/mental	−0.059***	−0.021	0.060***	0.020	0.149***	0.149	−0.009	−0.002	−0.014	−0.0007	0.233	0.233
impairments (age 16)	(0.0180)		(0.021)		(0.046)		(0.024)		(0.017)		(0.5)	
Number of hospitalisations	−0.054	−0.019	0.029	0.010	0.032	0.032	0.016	0.004	−0.001	−0.0001	−0.475	−0.475
(age 11)	(0.0383)		(0.045)		(0.1)		(0.05)		(0.036)		(1.07)	
Diabetes in parents or	−0.134	−0.047	−0.053	−0.018	−0.152	−0.152	−0.08	−0.022	0.018	0.0009	0.898	0.898
siblings	(0.137)		(0.191)		(0.452)		(0.211)		(0.147)		(4.52)	
Epilepsy in parents or	−0.170**	−0.060	0.196*	0.070	−0.022	−0.022	0.15	0.041	0.016	0.0008	−0.442	−0.442
siblings	(0.086)		(0.107)		(0.243)		(0.117)		(0.085)		(2.723)	
Chronic heart disease	−0.080	−0.028	0.322*	0.119	1.009**	1.009	−0.279	−0.064	−0.01	−0.0005	−0.887	−0.887
	(0.142)		(0.174)		(0.411)		(0.262)		(0.164)		(4.5)	
Mother smoker (age 16)	−0.007**	−0.002	−0.002	−0.001	0.014	0.014	0.016***	0.004	0.00008	4.42e-06	0.023	0.023
	(0.003)		(0.003)		(0.008)		(0.004)		(0.003)		(0.092)	
Obesity (age 16)	−0.176	−0.061	0.105	0.037	−0.035	−0.035	0.228	0.065	−0.307***	−0.0120	−2.749	−2.749
	(0.111)		(0.134)		(0.299)		(0.142)		(0.106)		(3.254)	
Cognitive ability (age 11)	0.006	0.002	−0.009	0.000	0.03	0.03	0.018	0.004	0.01	0.0005	1.612***	1.612
	(0.020)		(0.024)		(0.054)		(0.026)		(0.019)		(0.595)	
Social development (age 11)	−0.007***	−0.002	0.008**	0.003	0.03***	0.03	0.0187***	0.004	0.001	0.0001	0.131*	0.131
	(0.002)		(0.003)		(0.007)		(0.003)		(0.002)		(0.0792)	
University degree or	−0.038	−0.014	−0.037	−0.01	−0.149	−0.149	−0.171	−0.042	−0.054	−0.0020	−2.5	−2.5
equivalent	(0.077)		(0.095)		(0.234)		(0.121)		(0.081)		(2.285)	
A-levels or higher	0.108*	0.039	0.06	0.02	−0.29	−0.29	−0.251**	−0.06	−0.14**	−0.0060	−1.527	−1.52
qualification	(0.112)		(0.085)		(0.204)		(0.1009)		(0.071)		(1.959)	

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Table II. *Continued*

	Dep. variable		Dep. variable		Dep. variable		Dep. variable		Dep. variable		Dep. variable	
	SAH (Ordered probit estimates)		Long-standing illness/disability (Probit estimates)		Mental illness (OLS estimates)		Indicator: Smoker (Probit estimates)		Fried food (Ordered probit estimates)		Alcohol (OLS estimates)	
	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.	Coefficient	Marg. eff.
O-levels or higher qualification	0.084 (0.079)	0.030	0.004 (0.095)	0.00	−0.356** (9.193)	−0.356	−0.32*** (0.099)	−0.093	−0.252*** (0.071)	−0.0154	−2.443 (2.048)	−2.443
Own socioeconomic status: High[a]	0.243*** (0.078)	0.088	−0.155* (0.091)	−0.05	−0.133 (0.206)	−0.133	−0.235** (0.102)	−0.061	−0.143** (0.074)	−0.0070	0.087 (2.178)	0.087
Own socioeconomic status: Middle[a]	0.258*** (0.074)	0.094	−0.112 (0.086)	−0.04	−0.093 (0.186)	−0.093	−0.039 (0.093)	−0.01	0.008 (0.068)	0.0004	0.031 (2.089)	0.031
Constant			−0.255 (0.282)		2.88 (0.599)	2.88	−1.09*** (0.312)				22.729*** (6.987)	22.729

[a]At age 33. Coefficients and marginal effects for regional variables are suppressed here (due to statistical insignifiance) but available upon request.
Standard error in parentheses; ***$p<0.01$; **$p<0.05$; *$p<0.1$.

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parental socioeconomic status and parental education have a decisive effect on SAH at age 46 but no statistically significant association with the remaining health outcomes.

The remaining three equations of the system concern effort factors. The first of these is a probit model for the probability of an individual being a smoker at age 33. This has a statistically significant association with parental smoking, but not with parental socioeconomic status. Social maladjustment in childhood and differences in educational achievement play a key role in explaining differences in the probability of smoking in adulthood: cohort members who obtained O-levels or a higher qualification are 9.3 percentage points less likely to smoke at age 46 than those without formal qualifications, after controlling for a wide set of childhood circumstances, ability and social class in adulthood. This corroborates results from the previous literature suggesting that complementary policies in the education sector may be crucial for reducing inequality of opportunity in health. There is also a clear socioeconomic gradient in the probability of smoking: those in the top social class in adulthood are roughly 6 percentage points less likely to be smokers than the cohort members in the bottom social class.

The fifth equation in the system is an ordered probit for the weekly frequency of the consumption of fried food. The estimated marginal effects show gender differences: male cohort members are around 4 percentage points more likely to consume fried food every day than females. Similar to the case of cigarette smoking, there is no statistically significant association between parental social class and the consumption of fried food. Obesity at age 16 has a negative and statistically significant effect on the consumption of fried food: on average, individuals who were obese in adolescence are 1.2 percentage points less likely to consume fried food every day than those who were not. This is in line with the rationale of individual offsetting of health risks in the face of perceived frailty. It also confirms that the harmful impact of childhood obesity on adult health is mainly a direct one, which does not operate solely through dietary choices in adulthood; this favours tackling childhood obesity as a policy objective in its own right.

Educational achievement is also found to have a negative impact on the consumption of fried food: individuals who attained O-levels or a higher qualification are approximately 1.5 percentage points less likely to eat fried food on a daily basis than the cohort members without formal qualifications. In addition, the results provide evidence of a negative association between this lifestyle and high socioeconomic status in adulthood: the cohort members in the top social class at age 42 are nearly 1 percentage point less likely than those in the bottom social class to consume fried food daily.

Finally, the estimates for the weekly consumption of alcohol at age 33 show that gender differences are decisive with respect to this lifestyle: males are associated with a much higher consumption of alcohol than females. The estimates do not show an association between parental social class at birth and the consumption of alcohol in adulthood, or a clear gradient defined in terms of the individuals' educational qualifications and social class in adulthood. The results also do not provide evidence of an ability gradient: both cognitive ability and social maladjustment in childhood show a positive and statistically significant association with the consumption of alcohol at age 33.

7. DISCUSSION AND CONCLUSIONS

This paper develops a behavioural model of inequality of opportunity in health in which lifestyle choices are the consequence of a utility maximising behaviour subject to constraints. This integrates John Roemer's framework of inequality of opportunity with the Grossman model of health capital and demand for health. The model generates a recursive system of equations for health and lifestyles which is jointly estimated by full information maximum likelihood with freely correlated error terms. The purpose of this approach is twofold. First, it sheds light on the triangular relationship between

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circumstances, effort and health. Second, it addresses the problem posed by partial observability of the relevant set of circumstances, known as the *partial-circumstance problem*.

The results indicate the presence of unobserved factors that impact simultaneously on the various health outcomes and effort factors considered in the system; this confirms the crucial importance of taking into account unobserved heterogeneity in a context of partially observed circumstances. This aspect, widely discussed in the theoretical literature, has been ignored in earlier empirical work on inequality of opportunity; it is therefore a promising avenue for further research.

Taking into account the effect of these unobserved factors, the system estimates for SAH at age 46 corroborate the key results of the existing literature on inequality of opportunity in health, which is almost exclusively focused on this health outcome. SAH in adulthood is strongly impacted by circumstances such as parental socioeconomic status and childhood health conditions, establishing the existence of inequality of opportunity. However, once alternative health outcomes are considered, such as the incidence of long-standing illness, disability and mental health problems, the pattern of inequality of opportunity changes substantially, with no role for parental social class and education in the determination of these health outcomes in adulthood. While the three elements of the health vector are strongly affected by unfair circumstances, each of them responds to a different subset of circumstance factors.

Finally, the results also show that circumstances affect health outcomes both directly and indirectly, through their effect on effort. An important example relates to social development in childhood and educational qualifications, which have important implications for the lifestyle choices considered in this paper. This corroborates evidence from earlier literature, suggesting that complementary policies in the educational sector may be key to reducing health inequalities.

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REFERENCES

Balia S, Jones AM. 2008. Mortality, lifestyle and socio-economic status. *Journal of Health Economics* **27**(1): 1–26.
Barker DJP. 1995. Foetal origins of coronary disease. *British Medical Journal* **311**: 171–174.
Carbone JC, Kverndokk S, Rogeberg OJ. 2005. Smoking, health, risk and perception. *Journal of Health Economics* **24**(4): 631–653.
Carneiro P, Crawford C, Goodman A. 2007. The impact of cognitive and non-cognitive skills on later outcomes. *CEE Discussion Papers*.
Case A, Ferting A, Paxon C. 2005. The lasting impact of childhood health and circumstance. *Journal of Health Economics* **24**: 365–389.
Contoyannis P, Forster M. 1999. The distribution of health and income: a theoretical framework. *Journal of Health Economics* **18**: 605–622.
Contoyannis P, Jones AM. 2004. Socio-economic status, health and lifestyle. *Journal of Health Economics* **23**(5): 965–995.
Dardanoni V, Wagstaff A. 1987. Uncertainty, inequalities in health and the demand for health. *Journal of Health Economics* **6**(4): 283–290.
Dardanoni V, Wagstaff A. 1990. Uncertainty and the demand for medical care. *Journal of Health Economics* **9**(1): 23–38.
Deb P, Trivedi P. 2006. Specification and simulated likelihood estimation of a non-normal outcome model with selection: application to health care utilization. *Econometrics Journal* **9**(2): 307–331.

DOI: 10.1002/hec

Fleurbaey M. 2008. *Fairness, Responsibility and Welfare*. Oxford University Press: Oxford.
Fleurbaey M, Schokkaert E. 2009. Unfair inequalities in health and health care. *Journal of Health Economics* **28**(1): 73–90.
Forster M. 2001. The meaning of death: some simulations of a model of healthy and unhealthy consumption. *Journal of Health Economics* **20**: 613–638.
Galindo-Rueda F, Vignoles A. 2005. The declining relative importance of ability in prodicting educational attainment. *Journal of Human Resources* **40**(2): 335–353.
Grossman M. 1972. On the concept of health capital and the demand for health. *Journal of Political Economy* **80**(2): 223–255.
Heckman J, Stixurd J, Urzua S. 2006. The effects of cognitive and noncognitive abilities on labour market outcomes and social behavior. *Journal of Labor Economics* **24**(3): 411–482.
Idler EL, Kasl SV. 1995. Self-ratings of health: do they also predict change in functional ability? *Journal of Gerontology* **50**(6): 344–353.
Kenkel DS. 1995. Should you eat breakfast? Estimates from health production functions. *Health Economics* **5**: 15–25.
Kuh DJ, Wadsworth ME. 1993. Physical health status at 36 years in a British national cohort. *Social Science and Medicine* **37**(7): 905–916.
Lechene V, Adda J. 2004. On the identification of the effect of smoking on mortality. *CeMMAP Working Paper Series No. CWP13/04*.
Lefranc A, Pistolesi N, Trannoy A. 2009. Equality of opportunity: definitions and testable conditions with an application to income in France. *Journal of Public Economics* **93**(11–12): 1189–1207.
Lindeboom M, Llena-Nozal A, van der Klaauw B. 2006. Disability and work: the role of childhood circumstances. *Tinbergen Institute Discussion Paper 06-039/3*, Tinbergen Institute.
Marmot MG, Brunner S, Hemingway S. 2001. Relative contributions of early life and adult socioeconomic factors to adult morbidity in the Whitehall II study. *Journal of Epidemiology and Community Health* **55**: 301–307.
Mullahy J, Portney P. 1990. Air pollution, cigarette smoking and the production of respiratory health. *Journal of Health Economics* **9**: 193–205.
Power C, Peckham C. 1987. Childhood morbidity and adult ill-health. *National Child Development Study User Support Working Paper No. 37*.
Pudney S, Shields MA. 2000. Gender and racial discrimination in pay and promotion for NHS nurses. *Oxford Bulletin of Economics and Statistics* **62**: 801–835.
Roemer JE. 1998. *Equality of Opportunity*. Harvard University Press: Harvard.
Roemer JE. 2002. Equality of opportunity: a progress report. *Social Choice and Welfare* **19**: 455–471.
Roemer JE. 2004. Equal opportunity and intergenerational mobility: going beyond intergenerational income transition matrices. In *Generational Income Mobility in North America and Europe*, Corak M (ed.). Cambridge University Press: Cambridge.
Roodman D. 2009. Estimating fully observed recursive mixed-processes models with cmp. *Center for Global Development Working Paper No. 168*.
Rosa Dias P. 2009. Inequality of opportunity in health: evidence from a UK cohort study. *Health Economics* **18**(9): 1057–1074.
Trannoy A, Tubeuf S, Jusot F, Devaux M. 2009. Inequality of opportunities in health in France: a first pass. *Health Economics*, DOI: 10.1002/hec.1528.
Vera-Hernandez M. 2003. Structural estimation of a principal agent model: moral hazard in medical insurance. *The RAND Journal of Economics* **34**: 670–693.