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# Measuring equity in health: a normative decomposition

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**Abstract**

This paper proposes a new approach to the measurement of equality of opportunity in health, based on the path independent Atkinson index of equality. The proposed decomposition is applied both to the ex-ante and the ex-post methodologies recently adopted by the literature. The approach is applied to the measurement of equality of opportunity in health using ten waves of the British Household Panel Survey. Results confirm that socioeconomic background is an important factor determining individual health in adulthood while the incidence of equality of opportunity is around one third of the overall equality according to a substantial stable pattern over years. Our findings also depict that differences in education, in social conditions and in the life style are crucial determinants of the shape of the observed health equalities in adulthood, explaining how potential differences can be derived by the combination of different circumstances.

*JEL Classification Numbers:* C52, D82, G22, I10.

*Keywords*: Equality of opportunity; health inequalities; Atkinson index; responsibility.

## 1 Introduction

There is a large literature on the measurement and the evaluation of inequality in health. Most of this literature focuses on socioeconomic inequalities in health and in the delivery of health care, trying to explain observable health inequalities by differences in factors as living and working conditions, access to health care, or health-related behaviours (Wagstaff and van Doorslaer, 2000; van Doorslaer

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and Jones, 2003; van Doorslaer and Koolman, 2004; Jones and Lopez, 2004; Laudicella *et al.*, 2009; Culyer and Wagstaff, 1993; Wildman and Jones, 2008).

The focus on social determinants of health and income-related health inequality suggests that an implicit distinction is made between some "illegitimate" inequalities, that policy-makers are more concerned or should be more concerned about, and other "legitimate" inequalities. As Fleurbaey and Shokkaert (2009) put it 'the most obvious justification for making this distinction between *legitimate* and *illegitimate* differences is that the former can be attributed to causes that belong to individual responsibility'. Now, in the last two decades a large literature has flourished in the fields of social choice which puts the responsibility principle at centre stage of equity judgements: the so called equality of opportunity (EOp) literature (see Roemer 1998, Fleurbaey 2008). This literature originates from a well developed debate in the field of political philosophy which has emphasized the importance of focusing on inequalities that originate from circumstances or resources that do not depend on the individual responsibility (see Rawls (1971), Arneson (1989), Cohen (1989), Dworkin (1981a, b)). These ethical principles have been translated into formal economic models and are increasingly influential in the debate about the measurement of inequalities in different fields of social life: the main consequence is that the objects of the measurement of inequality are less and less the individual achievements and more the individual opportunities. A range of approaches to measure 'inequality of opportunity' or 'responsibility sensitive inequality' have been proposed and applied in the recent literature, mainly in the context of income inequality and education: see, among others, Bourguignon *et al.* (2007), Checchi and Peragine (2010), Ferreira and Gignoux (2008), Lefranc *et al.* (2008, 2009), Peragine (2002, 2004 a,b), Peragine and Serlenga (2008). For a recent survey, see Pignataro (2011).

More recently, a number of papers, starting with the seminal contribution by Fleurbaey and Shokkaert (2009), have tried to link the theoretical framework developed in the EOp literature with the long lasting tradition in health economics on the measurement of social and income related inequalities in health (see, in particular Rosa Dias, 2009, 2010; Trannoy *et al.,* 2010).

This paper is a contribution in this direction.

We first propose a methodology to measure the unfair inequality (inequality of opportunity) in health and to decompose overall health inequality into a legitimate and an illegitimate component. The methodology is based on a two-step procedure: first, the actual distribution of individual health status is transformed into an artificial distribution that reflects only and fully the inequality due to exogenous circumstances such as family background and ethnicity, while all the effort-based inequality has been removed. As a second step, a measure of inequality is applied: we exploit the path independent property of the Atkinson index in order to obtain a suitable decomposition of overall inequality. Following the existing literature (see, in particular, Fleurbaey, 2008 and Fleurbaey and Peragine, 2009), we explore both the ex ante and the ex post approaches to equality of opportunity.

Then we apply our methodology to measure equality of opportunity in health by using ten waves of the British Household Panel Survey. Our results show that inequality of opportunity accounts for between one third and one half of overall inequality, according to the specific measurement approach one decides to adopt. In particular, our results support the idea that social economic background is an important determinant of individual health achievement in the adulthood, although individual choices on health related habits play also an important role in determining individual health in adulthood.

The paper is organized as follows. Section 2 summarizes the EOp theory and proposes a model to measure inequality of opportunity in health; it also compares our approach with the approaches proposed by Fleurbaey and Shokkaert (2009); section 3 proposes a methodology, based on the Atkinson index of equality, to decompose overall inequality into a legitimate and an illegitimate component; Section 4 describes the data used in the empirical analysis. Section 5 illustrates the empirical strategy. Section 6 presents and discuss the empirical results. Section 7 concludes.

# 2 Measuring inequality of opportunity in health: the approach

Let us consider a society in which each individual is fully described by two sets of traits: circumstances beyond individual responsibility, $\mathbf{c}$ ,and responsibility characteristics (or effort), $e$. Circumstances belong to a finite set $\{\mathbf{c_1}, ..., \mathbf{c_n}\} = \Omega$, and effort is a scalar belonging to the set $\Theta = \{e_1, ..., e_m\}$.

The outcome of interest, health in our case, is generated by a function $g : \Omega \times \Theta \to \mathbb{R}_+$:

$$x = g(\mathbf{c}, e)$$

By $x_{i,j}$ we denote the health status of an individual with circumstances $\mathbf{c}_i$ and effort $e_j$. Hence, this model excludes the existence of random components[1].

Given a distribution of individual outcomes $X$, we can introduce two different partitions. The first partition is defined by the circumstances: each group in this partition is called a 'type' and includes all individuals sharing the same circumstances. Hence, for $i = 1, ..., n$, type $i$ is the set of individuals with circumstances $\mathbf{c}_i$; the outcome distribution of type $i$ is denoted by $\mathbf{x}_i$ and $\mu_i$ is the average outcome of type $i$. The overall outcome distribution can be written as $X = \{\mathbf{x_1}, \mathbf{x_2}, ..., \mathbf{x_n}\}$. The second partition is defined by effort: each group in this partition is called a 'tranche', and includes all individuals that exerted the same effort. For all $j = 1, ..., m$, tranche $j$ is the set of individuals who have chosen effort $e_j$; the tranche $j$ outcome distribution is denoted by $\mathbf{x}^j$ and $\mu^j$ is the average outcome of tranche $j$.Therefore the outcome distribution can also be written as $X = \{\mathbf{x^1}, \mathbf{x^2}, ..., \mathbf{x^m}\}$.

Clearly, any inequality measure applied to distribution $X$, would capture the overall health inequality in our society. The problem we address is: how

[1]See Lefranc *et al.* (2009) for a different model in which there is an additional factor, luck.

to go from overall inequality to inequality of opportunity for health? And, possibly, how to decompose the overall inequality into opportunity inequality and effort-based inequality?

Checchi and Peragine (2005, 2010) and Fleurbaey and Shokkaert (2009) have proposed a two-step procedure: first, the actual distribution $X$ is transformed into an artificial distribution ($\tilde{X}$ hereafter) that reflects only and fully the opportunity inequality in $X$, while all the effort-based inequality has been removed. As a second step, a measure of inequality is applied to $\tilde{X}$.

How to construct the artificial distribution $\tilde{X}$? The axiomatic literature on EOp has shown that the ideal of equality of opportunity can be decomposed into two distinct ethical principles: the first states that differences in individual achievements which can be unambiguously attributed to differences in *circumstances* are inequitable and to be compensated by society; this is called the principle of compensation. On the other hand, differences of achievements which can be attributed to *effort* are equitable and should not be compensated; this is called the principle of reward.

Hence, Compensation requires that people with the same effort should obtain the same outcome. For, any outcome inequality among them can only be attributed to the different circumstances. Therefore, outcome inequality among individuals with the same effort, or outcome inequality within tranches, is an expression of inequality of opportunity.

On the other hand, the Reward principle states that inequality of outcome among individuals with the same circumstances, that is inequality of outcome within types, is fair. Hence a measure of inequality of opportunity in a given distribution should be independent of the inequality of outcome within types.

By putting together these requirements, we can state that an artificial distribution consistent with the compensation and the reward principles is a distribution that:

(i) preserves fully the outcome inequality among individuals with the same effort;

(ii) does not contain any outcome inequality among individuals with the same circumstances.

Any inequality measure applied to such distribution would be a measure of opportunity inequality consistent with both the reward and the compensation principles.

However, as the social choice literature has shown[2], it is impossible to construct such a distribution as soon as the effect of circumstances on outcome is not independent of the effort. In general, the artificial distribution will violate either condition (i) or condition (ii). In turn, inequality of opportunity measures will be either fully consistent with the reward or with the compensation principle. That is, any measure of opportunity inequality is the product of a compromise between the compensation and reward principles, where priority is given either to the former or to the latter.

[2]This literature started with Bossert (1995) and Fleurbaey (1995). For a recent survey see Fleurbaey (2008).

In a recent contributions, Fleurbaey & Schokkaert (2009) have proposed two artificial distributions, called respectively *fairness gap* and *direct unfairness,* which are respectively fully consistent with the compensation and the reward principle, while violating the other principle. The first distribution, *Fairness Gap* ($\tilde{X}^{\ FC}$) is obtained by substituting to each individual outcome $x_{i,j} = g(c_i, e_j)$ the difference between such outcome and the outcome that would be generated by a reference circumstance $\tilde{c}$, given the function $g$ and the effort $e_j$ . On the other hand, the *Direct Unfairness* distribution ($\tilde{X}^{\ DU}$) is obtained by substituting, to each individual outcome $x_{i,j} = g(c_i, e_j)$ the outcome that would be generated by a reference effort $\tilde{e}$, given the function $g$ and the circumstances $c_i$.

Formally[3]:

- **Fairness gap** ($\tilde{X}^{FG}$): take $\tilde{c}$ as the reference circumstance. Then $\tilde{x}_{i,j} = g(c_i, e_j) - g(\tilde{c}, e_j), \quad \forall i \in \{1, ..., n\}$ and $\forall j \in \{1, ..., m\}$.
- **Direct unfairness** ($\tilde{X}^{DU}$): take $\tilde{e}$ as the reference effort. Then $\tilde{x}_{i,j} = g(c_i, \tilde{e}), \quad \forall i \in \{1, ..., n\}$ and $\forall j \in \{1, ..., m\}$.

It is easy to see that $\tilde{X}^{FG}$ is consistent with the principle of compensation, in fact $\tilde{X}^{FG}$ fully accounts for inequality within the tranche as they are made by the actual outcome minus a reference outcome. On the other hand $\tilde{X}^{FG}$ does not guarantee reward: except in the reference type, where the $\tilde{X}^{FG}$ is made of zeros, the other types do contain some inequality. Hence an inequality measure applied to distribution $\tilde{X}^{\ FG}$ would capture such a fair inequality. For all others $c_i \neq \tilde{c}, \quad \tilde{x}_{i,j} = g(c_i, e_j) - g(\tilde{c}, e_j) \neq g(c_i, e_h) - g(\tilde{c}, e_h) = \tilde{x}_{i,h}$ where no unfair difference should be found within types.

Dually it is immediate to notice that *direct unfairness* is consistent with the principle of reward: $\tilde{X}^{DU}$ does not contain any inequality within type as each type is made by replications of the same value of outcome. On the other hand *direct unfairness* does not guarantee compensation: $\tilde{X}^{DU}$ reflects unfair distances between individuals in the reference tranche which, because of the non additive decomposability of $g(c, e)$, necessarily differ from distances in the other tranches. For at least one $e_j \neq \tilde{e}$ and for at least two $i, h \in \{1, ..., n\}$, we can have no inequality in $\tilde{X}^{DU}$ $(IOp = 0)$ and $g(c_i, e_j) \neq g(c_h, e_j)$.

In this paper, following Checchi and Peragine (2005, 2010), we propose an alternative procedure to go from the original distribution $X$ to the artificial distribution $\tilde{X}$, i.e., from overall to unfair health inequality.

We also propose two definitions of equality of opportunity: *ex post* and *ex ante,* which are respectively fully consistent with the compensation and the reward principle, while violating the other principle. Hence, similarly to *direct*

[3]Notice that Fleurbaey and Shokkaert (2009) adopt an absolute, i.e., translation invariant approach to inequality measurement, while Checchi and Peragine (2005, 2010) adopt a relative, i.e., scale invariant approach. In this paper we also use a relative approach, which is more common in inequality analysis. A relative version or the Fairness gap distribution of Fleurbaey and Shokkaert (2009) would simply be obtained by taking $\tilde{x}_{i,j} = \frac{g(c_i, e_j)}{g(\tilde{c}, e_j)}, \quad \forall i \in \{1, ..., n\}$ and $\forall j \in \{1, ..., m\}$.

*unfairness* and *fairness gap* these solutions weaken one of the two principles focusing on the other[4]. The first distribution, *Ex post* ($\tilde{X}^{EP}$), is obtained by substituting to each individual outcome in a given tranche, the ratio between such outcome and the average outcome of that tranche. This normalization procedure is intended to remove all inequalities between tranches and to leave unchanged the inequality within tranches. On the other hand, the *Ex ante* distribution[5] ($\tilde{X}^{EA}$) is obtained by substituting, to each individual outcome, the average outcome of the type she belongs. Such smoothing transformation is intended to remove all inequality within types. Formally:

- **Ex post** ($\tilde{X}^{EP}$): *For all* $j \in \{1, ..., m\}$ *and for all* $i \in \{1, ..., n\}$, $\tilde{x}_{i,j} = \frac{g(c_i, e_j)}{\mu^j}$.
- **Ex ante** ($\tilde{X}^{EA}$): *For all* $j \in \{1, ..., m\}$ *and for all* $i \in \{1, ..., n\}$, $\tilde{x}_{i,j} = \mu_i$.

It is easy to see that *ex post* is consistent with the principle of compensation: each tranche is obtained by dividing the actual outcome by the mean outcome of the tranche, therefore $\tilde{X}^{EP}$ accounts for all variability within tranches. On the other hand it does not guarantee reward: for at least one $i$ and a couple $j, h$, $\tilde{x}_{i,j} = \frac{g(c_i, e_j)}{\mu^j} \neq \frac{g(c_i, e_h)}{\mu^h} = \tilde{x}_{i,h}$ , while no unfair difference should be found within types. Dually it is immediate to notice that *ex ante* is consistent with the principle of reward: the types of $\tilde{X}^{EA}$ are made by replications of the same outcome and therefore the artificial distribution does not reflect any inequality within type. On the other hand the $\tilde{X}^{EA}$ does not reflects inequality within tranches and hence it never guarantees consistency with compensation.

Hence, for any inequality index $I$ and any distribution $X$, we have two different measures of opportunity inequality: the ex post measure, $I(\tilde{X}^{EP})$,which is fully consistent with the compensation principle but violates reward; the ex ante measure, $I(\tilde{X}^{EA})$,which is fully consistent with the reward principle but violates compensation.

Once the artificial distribution has been constructed, the next step is: which inequality measure to use? It would be desirable to use an inequality index that allow to decompose the overall inequality into the legitimate and the illegitimate components. In the next section we propose a measurement strategy based on the multiplicative decomposition of the Atkinson index of equality (Atkinson, 1970).

[4]For a comparison between the ex ante/ex post approach and the direct unfairness/fairness gap approach see Brunori and Peragine (2011). In fact, Brunori and Peragine show that ex ante and ex post distributions can be rationalized as the distributions that, while fully consistent with the reward and compensation principle respectively, minimize the violations of the principle not fully satisfied.

[5]We call this approach simply ex ante, although we should qualify it as *utilitarian ex ante*. See Fleurbaey and Peragine (2009) for a discussion of the different versions of the *ex ante* and *ex post* approaches and the incompatibilities among them.

# 3 Decomposing health equality by the Atkinson index

The literature on inequality decomposition has investigated the way in which, for a population partitioned in different groups, it is possible to express the total inequality in the population as sum of a between-group and a within-group inequality term. In the seminal works on additively decomposable inequality measures (see Bourguignon, 1979; Shorrocks, 1980; Cowell, 1980) the between-group part is obtained as the inequality of a hypothetical distribution in which each individual outcome is replaced by the mean outcome of the subgroup, while the within-group component is a weighted sum of the subgroup inequality levels. The only (relative) inequality measures that meet this additive decomposability property - and other additional standard conditions - are the Generalized Entropy measures. A serious drawback of this decomposition is that the two components are not independent each other: as long as the weighting scheme in the within part depend on the average outcome of the groups, it is clear that changes in the between group inequality can produce modifications not only in the between-group component but also in the within-group one, notwithstanding there may have been no change in the within-group share[6]. An alternative decomposition property, path independence, has been proposed in order to obtain the independence among the between and the within group components: in the path independence decomposition the within part is obtained by rescaling each outcome by the mean outcome of the sub-group it belongs, so that in this new standardized distribution all groups have the same mean. Foster and Shneyerov (2000) have characterized the entire class of path independent measures and have shown that, the only path independent measure that uses the arithmetic mean as the representative outcome of each group and that satisfy the Pigou-Dalton Transfer Principle is the mean log deviation (MLD, hereafter). This measure has been first applied in the context of inequality of opportunity by Checchi and Peragine (2005, 2010).

In this paper we keep the concepts of smoothed and standardized distributions in order to obtain a between and a within component; however, we propose a different decomposition, based on the Atkinson index of equality, which is a normatively based index of inequality that explicitly express the degree of inequality aversion. Building on results by Lasso de la Vega and Urrutia (2003, 2005, 2008), who characterize the class of path independent multiplicative decomposable indices, we propose to use the Atkinson index for a specific value of the inequality aversion parameter, as the only one to be decomposable, path independent and based on the arithmetic mean.

Consider a distribution of $N$ individuals $X = (x_1, ..., x_N)$ partitioned in $m$ groups, with $j \in \{1, ..., m\}$ , with group $j$ distribution $X_j$, grand mean $\mu$, group $j$ mean $\mu_j$, group $j$ population size $N_j$ and population share $p_j$. The smoothed

[6] The only additively decomposable measure that has a "pure" weighting scheme, and hence does not suffer of this problem, is the mean log deviation (Theil's second measure).

distribution associated to $X$ is defined as

$$X_B = \{\mu_1 1_{N_1}, ..., \mu_m 1_{N_m}\}$$

where $1_{N_j}$ is the unit vector of length $N_j$. The standardized distribution $X_W$ is obtained by rescaling each outcome in group $j$, for all groups $j$, by the group mean, so that all groups have the same mean outcome:

$$x \to \frac{\mu}{\mu_i} x$$

The distribution $X_B$ exhibits only inequality between groups, while $X_W$ only expresses inequality within groups.

An inequality measure $I$ has a path independent multiplicative decomposition based on the arithmetic mean (Lasso de la Vega and Urrutia, 2005) if and only if:

$$(1 - I(X)) = (1 - I(X_B))(1 - I(X_W))$$

or equivalently, in terms of equality indices:

$$E(X) = E(X_B) E(X_W)$$

Notice that for a multiplicative path independent index, the within group term can also be expressed as the product of each subgroup index. That is:

$$E(X_W) = \prod_{j=1}^{m} E_j^{p_j}$$

Now, the Atkinson index of equality $E_A$ for the overall distributions is given by:

$$E_A(X) = \frac{\left[\prod_{i=1}^{N} x_i\right]^{\frac{1}{N}}}{\mu} \tag{4}$$

Let $E_A^B$ be the between-group component which can be interpreted as the equality associated with a population of $m$ types:

$$E_A(X_B) = \frac{\prod_{j=1}^{m} (\mu_j)^{p_j}}{\mu} \tag{5}$$

We define the Atkinson's equality index within type-$j$, $E_j$ as follows:

$$E_{A,J} = E_A(X_j) = \frac{\left[\prod_{i=1}^{N_j} x_{ji}\right]^{\frac{1}{N_j}}}{\mu_j} \tag{6}$$

From eq. (5) and eq. (6), the Atkinson index of equality $E_A$ can be further portrayed into:

$$E_A = \frac{\left[\prod_{i=1}^{N} x_i\right]^{\frac{1}{N}}}{\mu} = \frac{\prod_{j=1}^{m}\left[\frac{\left(\prod_{i=1}^{N_j} x_{ji}\right)^{\frac{1}{N_j}}}{\mu_j}\mu_j\right]^{p_j}}{\mu} = \frac{\prod_{j=1}^{m}\left(E_j\mu_j\right)^{p_j}}{\mu} \quad (7)$$

By construction, the within part of the Atkinson index of equality is defined as the product of the equality index for each group-$j$:

$$E_A\left(X_W\right) = \frac{E_A\left(X\right)}{E_A\left(X_B\right)} = \frac{\prod_{j=1}^{m}\left(E_j\mu_j\right)^{p_j}}{\mu}\frac{\mu}{\prod_{j=1}^{m}\left(\mu_j\right)^{p_j}} = \prod_{j=1}^{m} E_j^{p_j} \quad (8)$$

Consequently, it follows that:

$$E_A\left(X\right) = E_A\left(X_W\right)E_A\left(X_B\right) \quad (9)$$

which can be linearly transformed into the following form:

$$ln(E_A) = ln(E_A\left(X_W\right)) + ln(E_A\left(X_B\right)) \quad (10)$$

where the percentage change of each component is additively decomposable.

The Atkinson index of equality has a very intuitive interpretation, especially if used within the equality of opportunity framework. First, the multiplicative property allows us to appraise the impact of marginal changes in a given component on the overall distribution. Second, the logarithmic additive translation as in (10) permits to observe the overall percentage rate of equality change as the sum of the percentage changes in the within- and the between- schedules. This manipulation can be very convenient in opportunity egalitarianism to account for changes in the overall equality in terms of the changes inside the opportunity and responsibility components (within- and between- parts as a function of the methodologies discussed). Finally, the social preference for equality (of opportunity) is made explicit in the choice of the inequality aversion parameter.

The decomposition above can be applied both to the ex ante and the ex post approaches.

## 3.1 The ex-ante decomposition

The ex ante artificial distribution $X^{EA}$ was defined by replacing each individual status in $X$ with its type-specific mean $\mu_j$. Hence, by denoting with $1_{N_j}$ is the unit vector of size $N_j$ (the type $j$ population), we have

$X^{EA} = \{\mu_1 1_{N_1}, ..., \mu_j 1_{N_j}, ..., \mu_m 1_{N_m}\}$.

Distribution $X^{EA}$ eliminates within-types inequality and preserves only the between part inequality, which, in the ex-ante approach, reflects the inequality of opportunity.

Now we can define a *standardized* distribution $X_W^{EA}$ which is obtained for each type-$i$ by replacing each individual health $x$ in $X$ with:

$$x \rightarrow \frac{\mu}{\mu_i} x$$

where $\mu$ is the overall mean. It eliminates all between-types equality, leaving only equality within-types which can be interpreted as equality due to individual effort.

By applying the Atkinson equality index $E_A$, given the path independent property, the equality of opportunity component, that is the equality in the *standardized* distribution, can be obtained residually by the ratio between $E_A(X)$ and $E_A(X_W^{EA})$:

$$E_A(X^{EA}) = \frac{E_A(X)}{E_A(X_W^{EA})} \tag{11}$$

Eq. (11) can also be linearly defined as:

$$ln\left[E_A(X^{EA})\right] = ln\left[E_A(X)\right] - ln\left[E_A(X_W^{EA})\right]$$

## 3.2 The ex-post decomposition

A dual exercise can be depicted for the ex-post methodology. The artificial distribution $X^{EP}$ is obtained from the original distribution $X$ by replacing each individual health $x$ in tranche $j$ with:

$$x \rightarrow \frac{\mu}{\mu^j} x$$

This transformation eliminates all between-tranche inequality, leaving only inequality within-tranche, which can be interpreted as inequality of opportunity.

Now we can describe a *smoothed* distribution $X_B^{EP}$ which is obtained by replacing each individual status $x$ in $X$ with its tranche specific mean $\mu^j$. Thus, $X_B^{EP}$ eliminates within-tranche inequality summarizing directly the between component which in turn, in the ex-post approach, measures the inequality due to effort.

Again, by applying the Atkinson equality index, the equality of opportunity component can be obtained residually by the ratio between $E_A(X)$ and $E_A(X_B^{EP})$:

$$E_A(X^{EP}) = \frac{E_A(X)}{E_A(X_B^{EP})} \tag{12}$$

Eq. (12) can be linearly transformed as:

$$ln\left[E_A(X^{EP})\right] = ln\left[E_A(X)\right] - ln\left[E_A(X_B^{EP})\right]$$

## 4 Data and descriptive statistics

The BHPS is a longitudinal survey of British households in Great Britain (England, Scotland and Wales) plus Northern Ireland, from 1995 to 2005. Descriptive statistics and variable definitions for the final unbalanced panel. Since we intend to measure the effect of socioeconomic background on the late adulthood we consider a sample of individuals older than 55. The total number of observations and the descriptive statistics are reported in table 1 and 2.

It includes a measure of self-assessed health (SAH). SAH is well known in the literature on income related health inequality and has been also used as health indicator in other studies on equality of opportunity in health (see e.g. Rosa Dias 2009, 2010; and Trannoy *et al.*, 2010). This variable is based on a simple question asking the respondents to rate their own health on a five points categorical scale ranging from very poor to excellent health status. For waves 1995-1998 and 2000-2005, the SAH variable represents "health status over the last 12 months" and the answer is framed in the following five categories: excellent, good, fair, poor, very poor. However, for the wave in the 1999 an additional health questionnaire has been included and the SAH variable in this case refers to "general state of health", with the answer defined by the following categories: excellent, very good, good, fair, poor. As a result we collapse the SAH in four categories ranging from "very poor/poor" to "very good/excellent" health. In the sample about 54% of individuals reports at least good health, and about 15% very poor/poor health status.

Our first interest focus on parental background, i.e., father's socioeconomic status (SES) when individual aged 14, used as a proxy of individual circumstances. Particularly, BHPS measures father's social conditions in eighteen categories with respect to the type of job performed (see tables 1 and 2). In addition to the father's SES we also include other variables which are likely to affect individual health in the adulthood, but are likely to be independent from the individual level of effort. In particular we include 1) an ethnicity indicator, which equals one if individual is non white; 2) country of birth indicator, which takes 1 if individual born in the UK, and 3) a health accident indicator, which equals 1 if the respondent had any (unintentional) kind of accident which required a doctor or specialist visits.

For what involves the behavioural decisions of people a set of variables has been included to capture health related individual's effort. In particular we included a smoking indicator, which takes 1 if individual is not currently a smoker. About 80% of individuals in the sample reports to do not smoke over years. In addition to this variables we also include the educational level, which takes 1 if individual obtains at least an advanced degree plus an economic status indicator, which takes 1 if an individual reports to have a professional or managerial occupation.

Other demographic factors like age and gender are also included. In particular the gender indicator takes 1 if the individual reports being a female. In the sample there are about 56% of female and the mean age is represented by a 68 years old individual.

# 5 Empirical strategy

In order to apply the ex ante and the ex post methodologies and to decompose the opportunity egalitarian Atkinson index of equality, we propose for illustrative purposes an application where the outcome variable is the individual health in the adulthood. Empirically this is implemented in two steps. Since individual health is not directly observable, in the first step we need to recover an individual health measure and then in the second step the estimated measure is used in the decomposition as explained in section 3.

A standard strategy to measure individual health status is to assume that the responses of SAH status are generated by a corresponding continuous latent variable representing self-perceived health $H_i^*$, which is determined by individual circumstances and effort, see eq. (1). However the impact of social background on health is made of two effects: a direct effect, which captures how socioeconomic background affects individual health, and an indirect effect through the influence of circumstances on the characteristics (effort) of the descendant. Therefore to estimate individual health we need to consider and take into account that it is likely that the proxies for individual effort are correlated with social and family background. As in Trannoy *et al.* (2010), our strategy relies on regressing the effort measures (namely the level of education, the SES and a no-smoking indicators of the descent) within three separated equations against the vector of circumstances. For each of these regressions we compute the residuals, which are then introduced in the health outcome equation.

Let indicate with $Educ_i^*$, $SES_i^*$ and $NoSmoke_i^*$ the latent variables representing respectively the individual education, socioeconomic status and smoking behaviour. Therefore the model can be written as follows:

$$\begin{aligned} Educ_i^* = {} & \alpha_0^a + \alpha_1^a Gender_i + \alpha_2^a Age_i + \alpha_3^a Age_i^2 + \\ & + \sum_{k}^{18-1} \beta_k^a SES_i^{Father}(k) + \gamma_1^a Ethnicity_i + \gamma_2^a Country_i + u_i^a \end{aligned} \tag{13a}$$

$$SES_i^* = \alpha_0^b + \alpha_1^b Gender_i + \alpha_2^b Age_i + \alpha_3^b Age_i^2 + \\ + \sum_k^{18-1} \beta_k^b SES_i^{Father}(k) + \gamma_1^b Ethnicity_i + \gamma_2^b Country_i + \\ + \alpha_4^b \hat{u}_i^a + u_i^b \quad (13b)$$

$$NoSmoke_i^* = \alpha_0^c + \alpha_1^c Gender_i + \alpha_2^c Age_i + \alpha_3^c Age_i^2 + \\ + \sum_k^{18-1} \beta_k^c SES_i^{Father}(k) + \gamma_1^c Ethnicity_i + \gamma_2^c Country_i + \\ + \alpha_4^c \hat{u}_i^a + \alpha_5^c \hat{u}_i^b + u_i^c \quad (13c)$$

$$H_i^* = \alpha_0^d + \alpha_1^d Gender_i + \alpha_2^d Age_i + \alpha_3^d Age_i^2 + \\ + \sum_k^{18-1} \beta_k^d SES_i^{Father}(k) + \gamma_1^d Ethnicity_i + \gamma_2^d Country_i + \gamma_3^d Accident_i + \\ + \alpha_4^d \hat{u}_i^a + \alpha_5^d \hat{u}_i^b + \alpha_6^d \hat{u}_i^c + u_i^d \quad (13d)$$

In the model above equation 13a-13c are estimated with a Probit model, while equation 13d with a ordered Logit model where the dependent variable is the SAH status.[7] Let also $\hat{u}^a$ , $\hat{u}^b$ and $\hat{u}^c$ be the generalised residuals corresponding to the conditional expected value of the residuals given the outcomes $E\left(u_i^a/Educ_i^{High}\right)$, $E\left(u_i^b/SES_i^{High}\right)$ and $E\left(u_i^c/NoSmoke_i\right)$ (Gourieroux *et al.,* 1987). Clearly to obtain a measure of the individual health status there are several strategies (van Doorslaer and Jones, 2003; O'Donnell *et al.*. 2008) one can adopt. For example a common approach is to take the linear prediction of equation $(13d)$ and then use it directly as outcome in the decomposition. However such as approach would require an arbitrary rescaling since the proposed decomposition is defined in $\mathbb{R}_+$, while the linear prediction may not fully accomplish this requirements. Thus, we adopt another strategy which consists of using the distribution of the predicted probability of reporting at least a certain category of the SAH status (see e.g. Wagstaff and van Doorslaer, 1994; Trannoy *et al.*, 2010). In particular in our case the reference distribution is based on the predicted probability of having at least a good or very good SAH

[7]Since SAH can be affected by unobserved heterogeneity in the self-reported behaviour, we also test the proportional odds assumption, which is not rejected in our data.

status. This strategy does not requires any arbitrary rescaling since the probability distribution is defined in $\mathbb{R}_+$, and then provides a health measurement which can be directly employed as outcome in the decomposition.

In the second step we proceed with the Atkinson index decomposition. Types are defined by grouping in a single categorical variable: the SES of father, the individual ethnic group and country of birthplace and an accident indicator. Finally tranches are defined by grouping the individual's SES, education and a not-smoking indicator. To allow for sampling error, the standard errors of the Atkinson index decomposition are bootstrapped in each year from the 1995 to the 2005, with independent re-sampling within each of the subgroup types (tranche). The *bootstrap* estimates for standard errors are based on 3000 replications[8].

Before discussing the results on the overall level of equality of opportunity, it is worth to note that any empirical appraisal to the measurement of equality of opportunity involves the well known issue of *partial circumstances*. In fact, a true measure of equality of opportunity would imply the evaluation of all relevant circumstances. However, this is hard to be implemented with the most available datasets as they may not contain the desiderated set of proxies. Recently this issue has been investigated in the health context by Rosa Dias (2010) who exploited a matrix correlation between individual health measures and effort variables to study the existence of unobserved factors conditional on observed circumstance measures. Thus, as usual in the literature and also in our case, the right interpretation of our estimates should be only in terms of lower-bound estimates of the actual equality of opportunity that one would obtain in the case of the inclusion of all relevant circumstances.

# 6 Results

The estimated coefficients of model 13a-13d for each year are reported in tables 4-9 in the Appendix. A quick glance at the results reveals that a higher father's SES affects positively and significantly both the individual health in the adulthood as well as the probability of reaching an advanced education, having a high SES and being a non smoker. Interestingly the estimated coefficients associated with the generalized residuals for each of these equation are also significant at 1% statistical level and are positively associated with the individual health status[9].

[8]A STATA routine, available from the authors upon request, has been developed to compute the opportunity egalitarian Atkinson index of equality and other inequality of opportunity indexes (e.g. the Mean-Log Deviation and the Gini Opportunity Index). The procedure provides also the relevant bootstrapped standard error for the computed measures.

[9]For sensitivity we estimated the model using different specifications. In particular we also tried to aggregate differently the father's socioeconomic condition and the other variables capturing the individual circumstances. However the results either of the model's estimation and the decomposition of the Atkinson index do not substantially vary.

Table 3 reports the decomposition of the Atkinson Index of equality. In particular it shows the decomposition of the outcome equality into the opportunity and responsibility profiles for both ex-ante and ex-post methodologies, dissecting on one side the equality within- and between- types and on the other side the equality between- and within- tranches as commented on section 3. The level of the overall outcome equality (see eq. 7) seems to be stable along years around 0.91 and clearly it coincides between the two approaches (see the second and the sixth columns). Taking into account the multiplicative property of the Atkinson index, this result suggests that in UK more than 90% of health profile is equally distributed during the period 1995-2005. Interestingly, taking the inverse of this index $(1 - E_A(X))$ one can find the more traditional interpretation corresponding to around 10% of health inequality. This result supports many empirical studies on health and income-related health inequality developed in the last decade (see among others Van Doorslaer and Jones, 2003; and Van Doorslaer and Koolman, 2004).

Let us now consider the decomposition of the overall equality in the health distribution with respect to the ex-post and ex-ante approaches and distinguishing the within- from the between- components.

Starting by the ex-ante procedure, we measure the equality in health status among individuals conditioned to different opportunity sets (circumstances) as defined above. In this case, the percentage of equality of opportunity (i.e., the equality between types $E_A(X^{EA})$) refers to the share of the health distribution which is equal among types. Thus, looking at table 3, we observe that around 96%-97% of the health profile is equally distributed among circumstances. While, the contribution of responsibility is measured by leaving the individuals totally responsible for their own choice of smoking within each set. Thus, the equality of responsibility (i.e., the equality within types, $E_A(X_W^{EA})$) corresponds to the percentage described in the fourth column of table 3. In this case, we observe that the share of health distribution equally distributed within types is around 93%-94% conditioned by years. Naturally the incidence of equality of opportunity is given by the percentage share of the overall outcome equality originated by individual circumstances. We compute the incidence as the share-ratio between the contribution of the equality of opportunity and the overall equality linearly defined in the logarithmic form. Our results reported in the fifth column of table 3 reveals that the share of equality of opportunity accounts for between one third and one half of the entire equality from 1995 to 2005. These findings suggest that individual social background is substantially important in determining individual health in the adulthood and then they widely support the policy insight suggested by Rosa Dias (2010). A brief overview over years indicates that the lowest measure is originated in 2001 with an incidence of about 32% of equality opportunity. This percentage rises over the years, while the pick is observed in 1996 when more than half of equality is due to individual background. Considering the changes in the share for the ex-ante approach, there is not a clear trend since the incidence falls dramatically from 42% in 1995 to 34% in 2005 with some rises along the ten years. Note that this approach is extremely suitable to evaluate the effect of public policy devoted to induce equality of opportunity.

The counterpart of the incidence of equality of opportunity (not indicated in table 3) is guided by the effort component which can be interpreted as the share of equality determined by individual choices, behaviour or efforts. We may conclude that the share of equality of responsibility is always higher than that of equality of opportunity and this results is interesting particularly in terms of potential target intervention (e.g. smoking ban, providing incentives for higher educational level, etc). Thus, taking into account that a relatively limited number of proxies for circumstances is available in the BHPS, our results can be interpreted as a lower bound estimation of the 'true' equality of opportunity and they do not enclose any evaluation of inequality of opportunity (which should be measured by other indexes). However the estimated share of equality of opportunity gives an additional insight on the role played by circumstances in determining individual health in the adulthood, in particular comparing it with the field of inequality of opportunity as it emerges using the Gini coefficient by Rosa Dias (2009) and the Erreygers index by Trannoy *et al.* (2010). Summing up, in terms of absolute levels, we observe that our estimated equality measurements are all statistically significant at 5% level and that the overall equality of opportunity is constant around 96%, while a slight variation (at a lower level) is noted for the overall equality from 92% in 2001 to 89% in 2005. Moreover giving a glance at figure 1, one notes that equality of opportunity (in magenta) and health equality (in red) follow two distinctive patterns indicating that they depict different features on health distribution (something empirically confirmed in other context, i.e., earnings, income, also by Bourguignon *et al.*, 2007 and Pistolesi, 2009).

Finally the last four columns of table 3 report the overall equality decomposition obtained using the ex-post approach. This is measured among individuals with the same degree of responsibility characteristics. Thus, equality of opportunity is measured by the equality within tranches (i.e., $E_A(X^{EP})$ on eq. (12)) as indicated in the last but one column. In this case around 96%-97% of the health distribution is equal within tranches. Interestingly for this decomposition approach the share of equality of opportunity is even higher as compared with the ex-ante procedure, while the analysis of the incidence of equality of opportunity (last column) for the ex-post approach show that differences among opportunity sets accounts for between 30% and 63% of the health equality during these ten years. The lowest measure is discovered now in 1999 while the highest one is realized in 1996. Also in this case we are not able to find a clear trend since the discontinues variations of equality of opportunity over years. The share equality of responsibility (i.e. equality between tranches, $E_A(X_B^{EP})$ described in the seventh column) seems to be higher than that of the equality of opportunity (similar to the ex-ante way) although the differences in absolute terms between the opportunity and responsibility components are rather attenuated. In figure 2 we can observe that the trend between equality of opportunity (in magenta) and overall health equality (in red) remains dissimilar over years although differences are heavily reduced with respect to the ex-ante approach. Figure 3 shows the different pattern of shares obtained by the ex-ante and the ex-post methods. This difference accounts for about 5% and the value of equality of opportunity seems to be constant among the years (around 95%-96%), while the trend is similar to both procedures. Therefore, our results provide an important tools to have an insight of the shape of equality in the distribution of individual health in the adulthood. In addition these tools are suitable to evaluate the effect of public policy devoted to increase equality among individuals. Our results indicate that individual health circumstances (e.g. social background, sex, ethnicity, country of birth, etc.) affect the health distribution, though the shape is mainly driven by the set of individual responsibilities. This corroborates the idea that circumstances are crucial determinants of lifestyles in adulthood influencing substantially individual health.

# 7 Concluding remarks

In this paper we have proposed a methodology to measure inequality of opportunity in health and to decompose overall health inequality into a legitimate and an illegitimate component. The methodology is based on a two-step procedure: first, the actual distribution of individual health status is transformed into an artificial distribution that reflects only and fully the inequality due to exogenous circumstances such as family background and ethnicity, while all the effort-based inequality is removed. As a second step, a measure of inequality is applied: we exploited the path independent property of the Atkinson index in order to obtain a suitable decomposition of overall inequality. Following the existing literature (see, in particular, Fleurbaey 2008 and Fleurbaey and Peragine, 2009), we explored both the ex ante and the ex post approaches to equality of opportunity. These approaches captures different normative judgments on equity and, as we show in the empirical application, they can lead to different results.

We believe that the decomposition we propose can be extensively used in the health context where individual health outcome in adulthood is function of the initial condition and health related lifestyle, which are also likely affected by circumstances.

We applied our methodology to measure equality of opportunity in health by using ten waves of the British Household Panel Survey. The empirical results suggest that the lower bound estimation of equality of opportunity of health accounts for between one third and one half on the ex ante and ex-post methods, which seems highly robust and consistent with previous studies.

# 8 Appendix

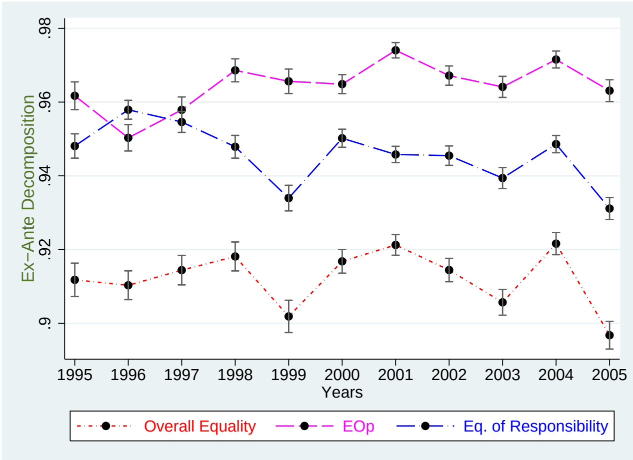


Figure 1: The ex-ante approach of Atkinson Decomposition


Figure 2: The ex-post approach of Atkinson Decomposition

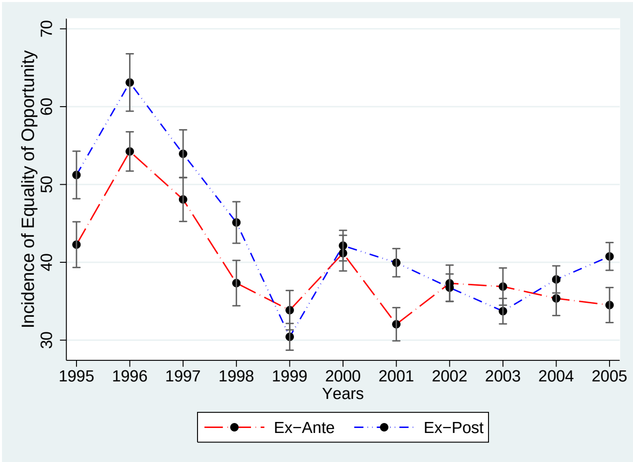


Figure 3: The incidence of Equality of Opportunity

Table 1: Descriptive statistics

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Self Assessed Health Status | 2.650 | 2.665 | 2.608 | 2.546 | 2.121 |
| Gender | 0.561 | 0.565 | 0.565 | 0.566 | 0.557 |
| Age | 68.496 | 68.590 | 68.741 | 68.818 | 68.446 |
| Advanced Education | 0.094 | 0.098 | 0.087 | 0.089 | 0.102 |
| High Socio Economic Status | 0.080 | 0.081 | 0.073 | 0.075 | 0.076 |
| Non Smoker | 0.811 | 0.813 | 0.800 | 0.799 | 0.794 |
| Father Deceased | 0.085 | 0.085 | 0.089 | 0.089 | 0.090 |
| Unemployed | 0.026 | 0.025 | 0.029 | 0.028 | 0.027 |
| Agricultural | 0.039 | 0.038 | 0.041 | 0.039 | 0.040 |
| Skilled agricultural | 0.018 | 0.017 | 0.017 | 0.017 | 0.021 |
| Farmers | 0.024 | 0.023 | 0.024 | 0.024 | 0.023 |
| Own account | 0.043 | 0.042 | 0.041 | 0.042 | 0.044 |
| Unskilled | 0.050 | 0.052 | 0.054 | 0.053 | 0.058 |
| Semi-skilled manual | 0.116 | 0.115 | 0.123 | 0.124 | 0.143 |
| Skilled manual | 0.250 | 0.246 | 0.251 | 0.249 | 0.241 |
| Foreman manual | 0.103 | 0.106 | 0.099 | 0.099 | 0.097 |
| Junior non-manual | 0.042 | 0.042 | 0.039 | 0.040 | 0.040 |
| Non-manual Foreman | 0.020 | 0.019 | 0.017 | 0.017 | 0.014 |
| Armed forces | 0.035 | 0.037 | 0.037 | 0.037 | 0.034 |
| Office clerks and service workers | 0.022 | 0.020 | 0.022 | 0.023 | 0.021 |
| Prof. self-employed | 0.006 | 0.006 | 0.006 | 0.007 | 0.005 |
| Managers, small | 0.013 | 0.012 | 0.011 | 0.011 | 0.011 |
| Employers | 0.058 | 0.058 | 0.049 | 0.051 | 0.040 |
| Senior managers and professionals | 0.051 | 0.055 | 0.051 | 0.051 | 0.050 |
| Black or other minorities | 0.012 | 0.012 | 0.011 | 0.011 | 0.010 |
| Born outside UK | 0.048 | 0.049 | 0.048 | 0.047 | 0.040 |
| Any accident | 0.093 | 0.088 | 0.085 | 0.084 | 0.089 |
| # of Observations | 2227 | 2246 | 2831 | 2885 | 4175 |

Table 2: Descriptive statistics: continued

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Self Assessed Health Status | 2.519 | 2.583 | 2.591 | 2.596 | 2.624 | 2.631 |
| Gender | 0.558 | 0.558 | 0.549 | 0.552 | 0.556 | 0.556 |
| Age | 68.266 | 68.173 | 67.785 | 67.879 | 67.864 | 67.971 |
| Advanced Education | 0.110 | 0.105 | 0.124 | 0.129 | 0.138 | 0.141 |
| High SES | 0.081 | 0.083 | 0.098 | 0.097 | 0.099 | 0.100 |
| Non Smoker | 0.810 | 0.812 | 0.815 | 0.823 | 0.824 | 0.839 |
| Father Deceased | 0.088 | 0.082 | 0.075 | 0.074 | 0.071 | 0.068 |
| Unemployed | 0.027 | 0.028 | 0.027 | 0.028 | 0.026 | 0.027 |
| Agricultural | 0.038 | 0.041 | 0.038 | 0.036 | 0.036 | 0.036 |
| Skilled agricultural | 0.021 | 0.029 | 0.027 | 0.026 | 0.024 | 0.025 |
| Farmers | 0.024 | 0.045 | 0.045 | 0.043 | 0.042 | 0.042 |
| Own account | 0.045 | 0.047 | 0.044 | 0.043 | 0.045 | 0.044 |
| Unskilled | 0.057 | 0.067 | 0.065 | 0.064 | 0.066 | 0.065 |
| Semi-skilled manual | 0.138 | 0.128 | 0.126 | 0.125 | 0.123 | 0.122 |
| Skilled manual | 0.238 | 0.226 | 0.225 | 0.227 | 0.229 | 0.231 |
| Foreman manual | 0.102 | 0.095 | 0.101 | 0.105 | 0.103 | 0.103 |
| Junior non-manual | 0.041 | 0.039 | 0.040 | 0.041 | 0.043 | 0.045 |
| Non-manual Foreman | 0.016 | 0.015 | 0.019 | 0.018 | 0.020 | 0.020 |
| Armed forces | 0.037 | 0.038 | 0.040 | 0.040 | 0.039 | 0.039 |
| Office clerks and service workers | 0.021 | 0.018 | 0.020 | 0.020 | 0.019 | 0.019 |
| Prof. self-employed | 0.006 | 0.005 | 0.006 | 0.006 | 0.007 | 0.008 |
| Managers, small | 0.010 | 0.012 | 0.014 | 0.014 | 0.014 | 0.015 |
| Employers | 0.039 | 0.040 | 0.043 | 0.043 | 0.043 | 0.043 |
| Senior managers and professionals | 0.052 | 0.044 | 0.047 | 0.046 | 0.049 | 0.049 |
| Black or other minorities | 0.011 | 0.009 | 0.011 | 0.012 | 0.012 | 0.012 |
| Born outside UK | 0.040 | 0.042 | 0.045 | 0.046 | 0.047 | 0.048 |
| Any accident | 0.078 | 0.077 | 0.081 | 0.072 | 0.076 | 0.076 |
| # of Observations | 4139 | 5091 | 4503 | 4466 | 4332 | 4254 |

Table 3: Atkinson Decomposition

| Year | Ex-Ante Approach | | | | Ex-Post Approach | | | |
|---|---|---|---|---|---|---|---|---|
| | Overall Equality $E_A(X)$ | Equality of Opportunity $E_A(X^{EA})$ | Equality of Responsibility $E_A(X_W^{EA})$ | Incidence of Equality of Opportunity % | Overall Equality $E_A(X)$ | Equality of Responsibility $E_A(X_B^{EP})$ | Equality of Opportunity $E_A(X^{EP})$ | Incidence of Equality of Opportunity % |
| 1995 | 0.9118 | 0.9617 | 0.9481 | 42.2724 | 0.9118 | 0.956 | 0.9538 | 51.2243 |
| | (0.0022) | (0.0018) | (0.0017) | (1.5036) | (0.0022) | (0.0023) | (0.9561) | (1.6023) |
| 1996 | 0.9103 | 0.9503 | 0.9579 | 54.2435 | 0.9103 | 0.9659 | 0.9424 | 63.1041 |
| | (0.0019) | (0.0018) | (0.0013) | (1.2577) | (0.0019) | (0.0023) | (0.9448) | (1.8837) |
| 1997 | 0.9144 | 0.9579 | 0.9546 | 48.0788 | 0.9144 | 0.9596 | 0.9529 | 53.9428 |
| | (0.0021) | (0.0018) | (0.0015) | (1.4443) | (0.0021) | (0.0022) | (0.9545) | (1.5551) |
| 1998 | 0.9181 | 0.9686 | 0.9479 | 37.3319 | 0.9181 | 0.9542 | 0.9622 | 45.1173 |
| | (0.002) | (0.0016) | (0.0015) | (1.4896) | (0.002) | (0.0021) | (0.9637) | (1.3384) |
| 1999 | 0.9019 | 0.9656 | 0.934 | 33.8523 | 0.9019 | 0.9307 | 0.9691 | 30.4293 |
| | (0.0022) | (0.0016) | (0.0018) | (1.295) | (0.0022) | (0.0023) | (0.9701) | (0.8836) |
| 2000 | 0.9168 | 0.9649 | 0.9502 | 41.1793 | 0.9168 | 0.951 | 0.9641 | 42.1461 |
| | (0.0016) | (0.0013) | (0.0012) | (1.1781) | (0.0016) | (0.0016) | (0.9652) | (0.9912) |
| 2001 | 0.9213 | 0.9741 | 0.9458 | 32.044 | 0.9213 | 0.952 | 0.9678 | 39.9507 |
| | (0.0015) | (0.0011) | (0.0012) | (1.0954) | (0.0015) | (0.0015) | (0.9688) | (0.893) |
| 2002 | 0.9145 | 0.9672 | 0.9455 | 37.3044 | 0.9145 | 0.945 | 0.9677 | 36.7478 |
| | (0.0016) | (0.0013) | (0.0014) | (1.2341) | (0.0016) | (0.0017) | (0.9687) | (0.8938) |
| 2003 | 0.9057 | 0.9641 | 0.9394 | 36.8836 | 0.9057 | 0.9365 | 0.9672 | 33.7239 |
| | (0.0018) | (0.0014) | (0.0015) | (1.1907) | (0.0018) | (0.0019) | (0.9683) | (0.8457) |
| 2004 | 0.9216 | 0.9716 | 0.9486 | 35.3634 | 0.9216 | 0.9505 | 0.9696 | 37.804 |
| | (0.0015) | (0.0012) | (0.0012) | (1.1704) | (0.0015) | (0.0015) | (0.9707) | (0.8912) |
| 2005 | 0.8968 | 0.9631 | 0.9311 | 34.5114 | 0.8968 | 0.9375 | 0.9566 | 40.7568 |
| | (0.0019) | (0.0015) | (0.0015) | (1.0972) | (0.0019) | (0.0019) | (0.9581) | (0.9075) |

Bootstrapped S.E. in brackets.

Table 4: Estimates for years 1995-1996

| | 1995 | | | | 1996 | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variable | Education | SES | No Smoker | SAH | Education | SES | No Smoker | SAH |
| Gender | -0.304** | -0.478** | -0.0190 | -0.197* | -0.270** | -0.519** | 0.035 | -0.268** |
| Age | 0.051 | -0.275* | -0.171** | 0.0621 | -0.027 | -0.218 | -0.139* | -0.101 |
| $Age^2$ | -0.001 | 0.002 | 0.001** | -0.002 | -0.005 | 0.001 | 0.001 ** | 0.002 |
| Father Deceased | 0.205 | 0.185 | 0.0499 | 0.400 | 0.017 | 0.380 | 0.0638 | 0.078 |
| Agricultural | -0.725 | 0.426 | 0.168 | 0.438 | -0.882 | 0.405 | 0.140 | 0.363 |
| Skilled agricultural | -0.175 | 0.415 | 0.034 | 0.538 | -0.338 | 0.474 | -0.055 | 0.351 |
| Farmers | 0.059 | 0.347 | 0.486 | 0.304 | 0.057 | 0.459 | 0.580 | 0.104 |
| Own account | 0.345 | 0.550 | 0.175 | 0.332 | 0.192 | 0.727 | 0.143 | 0.268 |
| Unskilled | -0.527 | -0.357 | -0.237 | 0.011 | -0.540 | 0.0411 | -0.163 | -0.141 |
| Semi-skilled manual | -0.063 | 0.086 | -0.144 | 0.150 | -0.226 | 0.159 | -0.114 | -0.107 |
| Skilled manual | 0.137 | -0.244 | 0.004 | 0.239 | -0.021 | -0.027 | -0.049 | -0.010 |
| Foreman manual | 0.0169 | -0.105 | 0.0961 | 0.201 | -0.067 | 0.108 | 0.057 | -0.096 |
| Junior non-manual | 0.472 | 0.510 | 0.499* | 0.805* | 0.410 | 0.553 | 0.547* | 0.458 |
| Non-manual Foreman | 0.660 | 0.316 | 0.293 | 0.463 | 0.507 | 0.664 | 0.349 | -0.102 |
| Armed forces | 0.701* | 0.878* | -0.0116 | 1.051** | 0.417 | 0.986* | -0.063 | 1.165** |
| Office clerks and service workers | 0.947** | 0.868* | 0.180 | 1.054** | 0.935** | 1.000* | 0.742* | 0.470 |
| Prof. self-employed | 1.896** | 1.441** | 0.195 | 1.393** | 1.733** | 1.377* | 0.554 | 2.195** |
| Managers, small | 0.799* | 0.722 | -0.095 | 0.951* | 0.665 | 1.149* | -0.262 | 0.365 |
| Employers | 0.515 | 0.624 | 0.0327 | 0.617* | 0.369 | 0.816 | -0.113 | 0.616* |
| Senior managers and professionals | 0.812** | 0.780* | 0.322 | 0.770** | 0.669* | 0.877* | 0.320 | 0.530 |
| Black or other minorities | -0.018 | -0.720* | -0.165 | -1.921** | 0.0483 | -0.482 | -0.075 | -1.376** |
| Born outside UK | 0.254 | 0.239 | -0.105 | 0.088 | 0.249 | 0.182 | -0.195 | -0.417 |
| Any accident | | | | -0.274* | | | | -0.506** |
| Residuals: Education equation | | 0.497** | 0.345** | 0.366** | | 0.458** | 0.399** | 0.342** |
| Residuals: High SES equation | | | 0.138 | 0.249** | | | 0.104 | 0.121 |
| Residuals: No-smoker equation | | | | 0.274** | | | | 0.224** |

Significance level: ** $p<0.01$, * $p<0.05$

Table 5: Estimates for years 1997-1998

| | 1997 | | | | 1998 | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variable | Education | SES | No Smoker | SAH | Education | SES | No Smoker | SAH |
| Gender | -0.248** | -0.431** | -0.0446 | -0.202** | -0.269** | -0.421** | -0.0215 | -0.149* |
| Age | -0.0186 | -0.240* | -0.126* | -0.109* | -0.027 | 0.0442 | -0.0830 | -0.0918 |
| Age$^2$ | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | -0.001 | 0.001* | 0.004 |
| Father Deceased | 0.108 | -0.065 | -0.171 | 0.141 | 0.136 | 0.049 | -0.0395 | 0.333 |
| Agricultural | -0.768 | 0.288 | 0.051 | 0.293 | -0.478 | 0.427 | 0.0324 | 0.341 |
| Skilled agricultural | -0.142 | 0.554 | -0.0134 | 0.459 | -0.141 | 0.593 | 0.0228 | 0.642* |
| Farmers | 0.419 | 0.124 | 0.193 | 0.075 | 0.543 | 0.296 | 0.259 | 0.452 |
| Own account | 0.282 | 0.269 | -0.143 | 0.307 | 0.261 | 0.346 | -0.0330 | 0.407 |
| Unskilled | -0.337 | -0.332 | -0.338 | -0.032 | -0.352 | -0.074 | -0.287 | 0.001 |
| Semi-skilled manual | -0.058 | -0.175 | -0.306 | 0.169 | -0.0196 | 0.145 | -0.139 | 0.158 |
| Skilled manual | 0.092 | -0.423 | -0.084 | 0.169 | 0.110 | -0.119 | 0.0521 | 0.266 |
| Foreman manual | 0.114 | -0.190 | -0.086 | 0.252 | 0.190 | 0.033 | 0.0336 | 0.463 |
| Junior non-manual | 0.624* | 0.297 | 0.361 | 0.439 | 0.643* | 0.401 | 0.386 | 0.835** |
| Non-manual Foreman | 0.623 | 0.227 | 0.149 | 1.087** | 0.608 | 0.473 | 0.191 | 0.614 |
| Armed forces | 0.629* | 0.626 | -0.168 | 0.994** | 0.578* | 0.815* | -0.146 | 0.771** |
| Office clerks and service workers | 0.984** | 0.600 | 0.391 | 0.679 | 0.906** | 0.854* | 0.542* | 0.631 |
| Prof. self-employed | 1.571** | 0.888 | 0.263 | 1.453** | 1.555** | 1.186* | 0.453 | 1.104** |
| Managers, small | 0.856* | 0.447 | -0.609* | 1.019* | 0.744* | 0.379 | -0.516 | 0.612 |
| Employers | 0.471 | 0.663 | -0.132 | 0.691* | 0.471 | 0.662 | 0.0534 | 0.863** |
| Senior managers and professionals | 0.750** | 0.550 | 0.363 | 0.554* | 0.728** | 0.748* | 0.437* | 0.891** |
| Black or other minorities | -0.127 | -0.971* | 0.071 | -1.074** | -0.231 | -1.004* | -0.0567 | -0.573 |
| Born outside UK | 0.203 | 0.0432 | -0.236 | -0.0944 | 0.219 | 0.240 | -0.257 | -0.377* |
| Any accident | | | | -0.734** | | | | -0.341* |
| Residuals: Education equation | | 0.416*** | 0.312** | 0.274** | | 0.408** | 0.269** | 0.310** |
| Residuals: High SES equation | | | 0.205** | 0.380** | | | 0.177** | 0.334** |
| Residuals: No-smoker equation | | | | 0.267** | | | | 0.274** |

Significance level: ** $p<0.01$, * $p<0.05$

Table 6: Estimates for years 1999-2000

| | 1999 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variable | Education | SES | No Smoker | SAH | Education | SES | No Smoker | SAH |
| Gender | -0.247** | -0.318** | -0.0503 | -0.107 | -0.244** | -0.445** | -0.0768 | -0.146* |
| Age | -0.040 | -0.194 | -0.077 | -0.019 | -0.0390 | -0.075 | -0.077 | 0.016 |
| $Age^2$ | 0.003 | 0.001 | 0.002** | 0.001 | 0.002 | -0.001 | 0.002** | -0.002 |
| Father Deceased | 0.324 | 0.323 | -0.081 | 0.603** | 0.375 | 0.103 | 0.119 | 0.355 |
| Agricultural | -0.220 | 0.457 | 0.111 | 0.751** | -0.305 | -0.056 | 0.233 | 0.592* |
| Skilled agricultural | 0.504 | 0.945** | -0.110 | 0.765** | 0.580** | 0.890** | 0.149 | 1.031** |
| Farmers | 0.634* | 0.283 | 0.089 | 0.653** | 0.527* | 0.593* | 0.240 | 0.357 |
| Own account | 0.496 | 0.500 | 0.091 | 0.841** | 0.577** | 0.283 | 0.231 | 0.837** |
| Unskilled | 0.116 | 0.076 | -0.224 | 0.192 | 0.0891 | -0.233 | -0.073 | 0.046 |
| Semi-skilled manual | 0.127 | 0.135 | -0.169 | 0.424* | 0.184 | -0.098 | 0.072 | 0.204 |
| Skilled manual | 0.277 | 0.019 | -0.089 | 0.500* | 0.330 | -0.096 | 0.116 | 0.224 |
| Foreman manual | 0.432 | 0.316 | 0.074 | 0.464* | 0.477** | 0.0746 | 0.221 | 0.290 |
| Junior non-manual | 0.714** | 0.341 | 0.309 | 1.015** | 0.756*** | 0.158 | 0.535** | 0.809** |
| Non-manual Foreman | 0.964** | 0.564 | 0.077 | 0.906** | 1.214*** | 0.451 | 0.134 | 0.847** |
| Armed forces | 0.953** | 0.982** | 0.127 | 0.853** | 0.958*** | 0.550 | 0.314 | 0.547* |
| Office clerks and service workers | 1.312** | 0.806* | 0.521* | 1.147** | 1.229*** | 0.438 | 0.455* | 0.710* |
| Prof. self-employed | 1.457** | 1.364** | 0.266 | 1.431** | 1.463*** | 1.350** | 0.254 | 1.238** |
| Managers, small | 0.840** | 0.488 | -0.377 | 1.025** | 0.831** | 0.396 | 0.010 | 0.714* |
| Employers | 0.609* | 0.576 | -0.083 | 0.967** | 0.677*** | 0.537 | 0.090 | 0.552* |
| Senior managers and professionals | 1.063** | 0.909** | 0.292 | 1.024** | 1.124*** | 0.621* | 0.449* | 0.817** |
| Black or other minorities | -0.039 | 0.002 | -0.001 | -0.226 | -0.448 | 0.072 | 0.125 | -0.120 |
| Born outside UK | 0.020 | 0.084 | -0.216 | -0.260 | 0.165 | 0.291 | -0.125 | -0.429* |
| Any accident | | | | -0.334** | | | | -0.507** |
| Residuals: Education equation | | 0.402** | 0.243** | 0.441** | | 0.412** | 0.267** | 0.330* |
| Residuals: High SES equation | | | 0.189** | 0.319** | | | 0.172** | 0.321** |
| Residuals: No-smoker equation | | | | 0.288** | | | | 0.297** |

Significance level: ** p<0.01, * p<0.05

Table 7: Estimates for years 2001-2002

| | 2001 | | | | 2002 | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variable | Education | SES | No Smoker | SAH | Education | SES | No Smoker | SAH |
| Gender | -0.230** | -0.506** | -0.027 | -0.194** | -0.253** | -0.449** | -0.0959* | -0.170** |
| Age | -0.033 | -0.335** | -0.038 | -0.0289 | -0.0382 | -0.229** | -0.0189 | -0.0060 |
| $Age^2$ | 0.005 | 0.002** | 0.004 | 0.003 | 0.002 | 0.001 | 0.001 | -0.001 |
| Father Deceased | 0.253 | 0.114 | 0.056 | 0.260 | 0.387* | -0.004 | 0.222 | 0.421* |
| Agricultural | -0.644* | -0.297 | 0.260 | 0.431* | -0.481 | -0.197 | 0.318 | 0.629** |
| Skilled agricultural | 0.301 | 0.719** | 0.345 | 0.740** | 0.357 | 0.316 | 0.416* | 0.922** |
| Farmers | -0.014 | 0.520* | 0.316 | 0.139 | 0.223 | 0.468* | 0.320 | 0.388* |
| Own account | 0.446* | 0.254 | 0.223 | 0.674** | 0.574* | 0.0396 | 0.358* | 0.698** |
| Unskilled | -0.324 | -0.248 | -0.175 | -0.063 | -0.189 | -0.387 | -0.131 | -0.039 |
| Semi-skilled manual | 0.0429 | -0.131 | -0.0134 | 0.185 | 0.136 | -0.451* | 0.036 | 0.180 |
| Skilled manual | 0.0931 | -0.127 | 0.044 | 0.253 | 0.255 | -0.224 | 0.104 | 0.287 |
| Foreman manual | 0.309 | 0.174 | 0.169 | 0.347 | 0.516* | -0.061 | 0.334* | 0.477* |
| Junior non-manual | 0.542** | 0.0935 | 0.490** | 0.627** | 0.678** | -0.083 | 0.446* | 0.591** |
| Non-manual Foreman | 1.038** | 0.434 | 0.217 | 0.762** | 1.155** | 0.097 | 0.354 | 0.989** |
| Armed forces | 0.782** | 0.449 | 0.244 | 0.715** | 0.958** | 0.181 | 0.299 | 0.742** |
| Office clerks and service workers | 1.018** | 0.566 | 0.475* | 0.641** | 1.194** | 0.450 | 0.636** | 0.927** |
| Prof. self-employed | 0.902** | 1.381** | 0.089 | 0.816* | 1.334** | 1.214** | 0.433 | 1.217** |
| Managers, small | 0.730** | 0.333 | 0.236 | 0.875** | 0.730** | 0.350 | 0.309 | 0.878** |
| Employers | 0.325 | 0.490 | -0.054 | 0.492* | 0.467* | 0.210 | 0.015 | 0.453* |
| Senior managers and professionals | 1.004** | 0.554* | 0.514** | 0.725** | 1.182** | 0.316 | 0.575** | 0.788** |
| Black or other minorities | -0.413 | -0.337 | 0.226 | -0.818** | -0.194 | -0.257 | 0.245 | -0.761** |
| Born outside UK | 0.316** | 0.262 | -0.180 | -0.049 | 0.314** | 0.271 | -0.216 | -0.156 |
| Any accident | | | | -0.442** | | | | -0.468** |
| Residuals: Education equation | | 0.448** | 0.268** | 0.363** | | 0.461** | 0.288** | 0.380** |
| Residuals: High SES equation | | | 0.265** | 0.316** | | | 0.161** | 0.388** |
| Residuals: No-smoker equation | | | | 0.283** | | | | 0.216** |

Significance level: ** p<0.01, * p<0.05

Table 8: Estimates for years 2003-2004

| | 2003 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory Variable | Education | SES | No Smoker | SAH | Education | SES | No Smoker | SAH |
| Gender | -0.247** | -0.469** | -0.049 | -0.152** | -0.272** | -0.503** | -0.089 | -0.195** |
| Age | -0.036 | -0.065 | -0.019 | 0.003 | -0.043 | -0.170* | 0.047 | 0.028 |
| $Age^2$ | 0.001 | -0.003 | 0.002 | -0.001 | 0.002 | 0.001 | -0.001 | -0.003 |
| Father Deceased | 0.425 | 0.194 | 0.302* | 0.439* | 0.347 | 0.369 | 0.243 | 0.538* |
| Agricultural | -0.324 | -0.274 | 0.397* | 0.483 | -0.430 | 0.047 | 0.482* | 0.393 |
| Skilled agricultural | 0.303 | 0.622* | 0.523** | 0.706** | 0.256 | 0.843** | 0.509* | 0.799** |
| Farmers | 0.203 | 0.324 | 0.369* | 0.448 | 0.079 | 0.636* | 0.408* | 0.357 |
| Own account | 0.632** | 0.250 | 0.436* | 0.633** | 0.487* | 0.461 | 0.439* | 0.752** |
| Unskilled | -0.110 | -0.498 | 0.067 | 0.057 | -0.17 | -0.517 | 0.127 | 0.243 |
| Semi-skilled manual | 0.132 | -0.346 | 0.148 | 0.276 | 0.062 | -0.0213 | 0.173 | 0.244 |
| Skilled manual | 0.299 | -0.083 | 0.245 | 0.240 | 0.230 | 0.169 | 0.240 | 0.262 |
| Foreman manual | 0.560** | 0.122 | 0.380** | 0.565** | 0.464* | 0.272 | 0.429** | 0.406 |
| Junior non-manual | 0.777** | 0.239 | 0.578** | 0.650** | 0.659** | 0.520 | 0.417* | 0.495* |
| Non-manual Foreman | 1.246** | 0.226 | 0.615** | 0.991** | 1.121** | 0.726* | 0.616** | 0.840** |
| Armed forces | 0.967** | 0.482* | 0.455** | 0.651** | 0.905** | 0.463 | 0.421* | 0.586* |
| Office clerks and service workers | 1.225** | 0.816** | 0.729** | 1.100** | 1.089** | 0.703* | 0.628** | 0.956** |
| Prof. self-employed | 1.252** | 1.278** | 0.561 | 1.079** | 1.174** | 1.353** | 0.623 | 0.573 |
| Managers, small | 0.784** | 0.206 | 0.335 | 0.580 | 0.634* | 0.108 | 0.459 | 0.730* |
| Employers | 0.546* | 0.282 | 0.111 | 0.501* | 0.448* | 0.537 | 0.142 | 0.476 |
| Senior managers and professionals | 1.245** | 0.606** | 0.670** | 0.927** | 1.180** | 0.810** | 0.732** | 0.836** |
| Black or other minorities | -0.342 | -0.290 | -0.034 | -0.428 | -0.214 | 0.050 | 0.295 | -0.800** |
| Born outside UK | 0.299* | 0.336* | -0.122 | -0.189 | 0.28* | 0.381** | -0.146 | -0.056 |
| Any accident | | | | -0.653** | | | | -0.568** |
| Residuals: Education equation | | 0.442** | 0.298** | 0.431** | | 0.508** | 0.323** | 0.352** |
| Residuals: High SES equation | | | 0.164** | 0.365** | | | 0.173** | 0.340** |
| Residuals: No-smoker equation | | | | 0.220** | | | | 0.266** |

Significance level: ** p<0.01, * p<0.05

Table 9: Estimates for year 2005

| | 2005 | | | |
|---|---|---|---|---|
| Explanatory Variable | Education | SES | No Smoker | SAH |
| Gender | -0.272** | -0.536** | -0.098* | -0.218** |
| Age | -0.054 | -0.230** | 0.0103 | 0.0102 |
| $Age^2$ | 0.001 | 0.001 | 0.001 | -0.002 |
| Father Deceased | 0.439 | 0.411 | 0.289 | 0.702** |
| Agricultural | -0.242 | 0.379 | 0.867** | 0.777** |
| Skilled agricultural | 0.399 | 0.895** | 0.629** | 0.328 |
| Farmers | 0.225 | 0.851** | 0.481** | 0.480 |
| Own account | 0.547* | 0.514 | 0.750** | 0.970** |
| Unskilled | -0.108 | -0.0826 | 0.175 | 0.209 |
| Semi-skilled manual | 0.139 | 0.108 | 0.280 | 0.367 |
| Skilled manual | 0.335 | 0.195 | 0.430** | 0.325 |
| Foreman manual | 0.524* | 0.559* | 0.577* | 0.479* |
| Junior non-manual | 0.770** | 0.480 | 0.526** | 0.712** |
| Non-manual Foreman | 1.157** | 0.722* | 0.718** | 0.975** |
| Armed forces | 0.997** | 0.693* | 0.591** | 0.753** |
| Office clerks and service workers | 1.203** | 0.918** | 0.778** | 1.058** |
| Prof. self-employed | 1.373** | 1.339** | 0.750* | 0.822* |
| Managers, small | 0.760** | 0.664* | 0.714** | 0.694* |
| Employers | 0.478* | 0.682* | 0.278 | 0.475 |
| Senior managers and professionals | 1.286** | 0.825** | 0.800** | 1.013** |
| Black or other minorities | -0.338 | 0.058 | 0.265 | -0.931** |
| Born outside UK | 0.286* | 0.315* | -0.153 | -0.176 |
| Any accident | | | | -0.540** |
| Residuals: Education equation | | 0.465** | 0.373** | 0.396** |
| Residuals: High SES equation | | | 0.147** | 0.330** |
| Residuals: No-smoker equation | | | | 0.316** |

Significance level: ** $p<0.01$, * $p<0.05$

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