Measuring inequities in health over the lifecycle: age-specific or lifecycle perspective?

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Abstract

Health status is theoretically conceptualised as a dynamic outcome that evolves over time along the lifecycle; most inequalities studies focus on snapshots of inequality and rarely consider health inequality over the lifecycle. Measuring inequality over the lifecycle requires dealing with two dimensions: ages and individuals. One can measure inequality over the lifecycle by firstly aggregating health over ages and then measuring inequality by aggregating over individuals; this is the lifecycle perspective. Otherwise, one can measure inequality over individuals at each age and then aggregate inequality over ages; this is the age-specific perspective. This paper proposes a methodology to measure health inequality over the lifecycle from both the age-specific and lifecycle perspectives. We use data from a British cohort study and focus on self-assessed health and death as measures of health. We use first order stochastic dominance and Hammond dominance criteria to respect the ordinal and qualitative nature of those health outcomes and measure health inequality. Our results show that the two perspectives impact on the existence and the magnitude of inequalities of opportunities in health in the UK. While the lifecycle perspective provides a global view of inequality of opportunity, the age-specific perspective highlights (i) a change in the dynamic of inequality of opportunity favoring people born in South-East UK in the second part of their lifecycle, (ii) a reinforcement of inequality of opportunity between regions over the lifetime.

Keywords: Inequality, Lifecycle, Ordinal Heath variable, First-order stochastic dominance; Hammond dominance

I. Introduction

Health status is theoretically conceptualised as a dynamic outcome that evolves over time all along the lifecycle (Galama et al., 2013; Grossman, 1972), however the measurement of health inequalities over the lifecycle as a whole has rarely been undertaken. Measuring inequalities over the lifecycle requires dealing with two dimensions: ages and individuals. One could measure inequality over the lifecycle firstly aggregating health over ages and then measuring inequality by aggregating this lifecycle health measure over individuals; this is what we call the lifecycle perspective[1]. On the other hand, one could firstly measure health inequality between individuals at each age and then aggregate inequalities over ages; this is what we call the age-specific perspective. These alternative aggregating perspectives are however not supported by the same ethical principles. The lifecycle perspective respects individuals' health trajectory as well as their intertemporal choices at each time point. In other words, it means that a good health status at a certain age could in some extent compensate a poor health status at another age. This perspective could also exhibit the permanent component of health due to health state dependence, such as individuals experiencing a permanent poor health status. On the other hand, the age-specific perspective incorporates the impact of transitory components of health such as health shocks on the evolution of health inequalities over the lifecycle. This perspective

[1] To some extent, the same motivation appears when measuring health inequality over the lifecycle as when measuring income inequality. Income and health are sharing the same characteristics: they are path dependent and they are divided between a permanent component and a transitory component. As permanent income is used by individuals to make important choices in terms of investment and consumption decisions, the permanent component of health has consequences in term of intertemporal choices such as health investment and consumption decisions in relation with health, and anticipation in those decisions will affect health over the life cycle. Thus, measuring inequalities in health in a lifecycle perspective is comparable to measuring inequalities in permanent income.

therefore points out specific age-related health problems that will matter from a public policy point of view. Finally, regardless of the perspective used, measuring health inequality over the lifecycle implies to follow individuals from birth to death. This leads to question the way to account mortality in the analysis for dealing with the fact that death is *per se* a health status, which affects socioeconomic groups differentially.

In general, empirical studies on health inequalities over the lifecycle mainly use an age-specific approach. Most studies are based on a measurement of snapshot health inequalities at certain time points and some studies have also focused on health inequalities over the lifecycle at different ages or for different age cohorts (Deaton and Paxson, 1998; Van Kippersluis et al., 2010; Van Kippersluis et al., 2009). These studies describe the trajectory of age-specific health inequality without providing a synthetic measure of health inequality for the whole lifecycle. They have mainly shown that socioeconomic health inequalities increase with age until a certain age from which they decrease because of population selection effect. Some other empirical studies have used synthetic health indicators over the lifecycle, such as Healthy Life Expectancy (HLE) combining health status and mortality (Burström et al., 2005; Gerdtham and Johannesson, 2000). They consist in population-based health indicators and aggregate several individuals' health statuses and mortality risks levels at each age within a population or specific groups. Such population-based health indicators are therefore inappropriate to measure health inequalities between individuals over the lifecycle.

The main issue when measuring health inequalities over the life is to take into account individuals' health trajectory. Some authors have also stressed the importance of considering both long run and short run perspectives in the dynamic of income-related health inequality (Allanson et al., 2010; Allanson and Petrie, 2013; Islam et al., 2010; Jones and Nicolás, 2004; Petrie et al., 2011). In particular, Jones and Nicolás Lopez (2004) have proposed to decompose the contributions of health and income mobility across periods within the evolution of the concentration index over different periods. Their long run measure of health inequalities is based on individuals' mean health status and mean income across periods, and could then be viewed as a lifecycle inequality measurement over the whole lifecycle. The use of the mean health as a health indicator over the lifecycle however needs to be discussed. First this can only be used when health status is available as a cardinal measure, which is very rare as most health measures are discrete and have ordered and qualitative response categories, e.g. self-assessed health (SAH). Secondly, aggregating over ages using mean health status does not fully respect individual health trajectories and assumes a full compensation of health over ages ignoring aversion against poorest health statuses.

In this paper, our objective is to propose a methodology to measure health inequality over the lifecycle from both the age-specific and lifecycle perspectives. We account for the discrete nature of self-assessed health and measure inequalities using first order stochastic dominance and Hammond dominance. We also investigate whether including death as an additional potential health status makes a difference on the findings. We illustrate our methodology using data from the 1958 National Cohort Development Study and evaluating inequality of opportunities in health in this context.

The paper proceeds as follows. In Section 2, we describe the method and the conceptual framework. Section 3 describes the data used in the analysis. The main empirical results and robustness checks are presented and discussed in Section 4 and in Section 5 we highlight our main conclusions.

II. Method

a. Theoretical concept of age-specific and lifecycle perspectives

The difference between the age-specific and the lifecycle perspectives comes from which of the two dimensions between ages or individuals is first considered when aggregating. It also raises the question of constructing health indicators as well as social ordering over the lifecycle in terms of both welfare and inequality. Let us now illustrate the two concepts of lifecycle and age-specific perspectives using an example from Fleurbaey (2010) on uncertainty. We consider two individuals, Bob and Ann and two age periods, Young and Old, and at each period each individual can either be in Poor or Good health. We assume anonymity towards age and individuals, and therefore the social planner is assumed indifferent to the age period and to the individuals. We consider two situations (S1, S2) that are described in the following tables and we would like to compare S1 and S2 in terms of inequality.

Example 1

S1	**Young**	**Old**
Bob	Good	Poor
Ann	Poor	Good

S2	**Young**	**Old**
Bob	Good	Poor
Ann	Good	Poor

From a lifecycle perspective, we first aggregate over periods for each individual and then aggregate over individuals. In the brief sample above, we require a health indicator allowing us to quantify individuals' health over the lifecycle. For example, we could aggregate over periods counting the number of periods in Good health per individual and then compare this count indicator between the two individuals and make a statement in terms of welfare in each situation. Under the anonymity criterion, the two situations S1 and S2 are identical in terms of both welfare and inequality. Bob and Ann each live one single period of Good health in both S1 and S2, and there is no inequality in the lifecycle perspective.

From an age specific perspective, we first aggregate over individuals for each period and then over periods. Situations S1 and S2 differ in this perspective. While in S2, Ann and Bob have identical health at each age period, in S1 Bob is in better health than Ann in Young period whereas Ann is in better health than Bob in Old period. There is health inequality in S1 and therefore S2 is preferable to S1 in terms of inequality.

Let us now consider a new situation S3 that we would like to compare with S1:

Example 2

S1	**Young**	**Old**
Bob	Good	Poor
Ann	Poor	Good

S3	**Young**	**Old**
Bob	Good	Good
Ann	Poor	Poor

From a lifecycle perspective, there is a health inequality in S3 as Bob is in Good health in both periods while Ann is in Poor health in both periods; S1 is therefore preferable to S3. However from an age specific perspective, S1 and S3 exhibit the same level of inequality and the regulator would therefore be indifferent to either situations. This example illustrates that there is incompatibility between the lifecycle and the age-specific perspectives. Notably, the age-specific perspective is looking at inequalities with a concern for periods in which they occur whereas the lifecycle perspective allows compensation between periods and focus on a statement in terms of differences between quantities of health over the lifecycle.

b. Age-specific and lifecycle health indicators

It is relatively straightforward to find a health indicator that is suitable to measuring health in an age-specific perspective. The main requirement is that such health indicator can be measured at each age and so provide an age-specific measure of individual lifetime health status. We consider an ordered and qualitative measure of health status, such as self-assessed health (SAH), which is widely used in the health economics literature. Measuring health over the lifetime implies to consider the health status of an individual from birth until death. In order to take into account differences in age at death, we could also consider death as an additional potential health status. In other words, if we consider an ordered four items SAH indicator such as (i) poor, (ii) fair (iii) very good, and (iv) excellent, incorporating death as an extra item would lead us to use a five items indicator that can be ordered as follows: (i) dead, (ii) poor, (iii) fair, (iv) very good, and (v) excellent. In the context with death, we assume that the social planner always considers death as a less desirable health status than self-reported poor health. The ordered discrete nature of this combined health and mortality indicator has the advantage to allow simple comparisons of health status at each age and can be used to assess health inequality in an age-specific perspective.

On the other hand, a suitable health indicator to measuring health in a lifecycle perspective is less obvious, particularly because this indicator must be suitable to aggregate each individual's health over the lifetime as a single measure. The difficulty of this aggregation comes from both the standard qualitative nature of health indicators and the requirement of respecting the lifetime trajectory of individual health status. A solution would be to use a central tendency indicator such as a mean or a median lifetime health status. Mean health is however only appropriate if health status is measured with a quantitative health indicator while median health could be used in the case of an ordered qualitative health indicator. Nevertheless neither a mean nor a median health indicator would fully respect each individual's health trajectory. In particular, mean health would allow a full compensation between poor and good health statuses. In order to respect each individual's health trajectory, we suggest considering the full vector of health statuses experienced by an individual at each age over his lifetime. Let us assume that an individual i lives at most T periods and his health status is measured at each time $t=1,\ldots, T$ by a qualitative and ordered health indicator H_{it}, with $k=1,\ldots, K$ ordered response items h_k. The lifetime health trajectory of i given by the vector $(\mathrm{H_{i1}}, \mathrm{H_{i2}}, \ldots., \mathrm{H_{it}}, \ldots., \mathrm{H_{iT\text{-}1}}, \mathrm{H_{iT}})$.

We consider that there is no obvious ethical foundation to assume that some ages are more important than others over the lifecycle and therefore accounting for time preference using discounting does not appear required[2]. In other words, a health indicator that is appropriate for a lifecycle perspective should respect anonymity towards age. Under this hypothesis, the health trajectory of individual *i* over the lifecycle could simply be summarised as a lifecycle health distribution ($f_i(h_1)$, $f_i(h_2)$, ..., $f_i(h_{k-1})$, $f_i(h_k)$), where the frequency $f_i(h_k)$ associated to each of the *K* response items corresponds to the proportion of the lifetime lived in each potential health status. For instance, let us assume that Ann and Bob can live during four periods (childhood, adolescence, adulthood, ageing) and that their health status is measured by a combination of mortality status and SAH in a 5-item indicator. If Ann's health trajectory is (Excellent, Fair, Poor, Dead) and Bob's is (Excellent, Poor, Fair, Dead), under the hypothesis of anonymity according to age, the two trajectories are considered equivalent. Health trajectories only differ with the age at which Ann and Bob experience a fair and a poor health state and therefore both lifetime health trajectories correspond to the following health distribution (0.25; 0.25; 0.25; 0; 0.25).

c. Judging inequality within the lifecycle

Individual's lifetime health distribution could be considered to analyse inequalities over the lifecycle; it respects the qualitative nature of health indicators however it cannot be used directly to assess health inequality, as it is not naturally ordered. We therefore propose to order individuals' lifetime health distribution using specific ordering criteria that are concerned with ordered and qualitative attributes. The same criteria will then be used in order to compare health distributions and then judge whether there is health inequality in each perspective.

A robust and first criterion for ordering distribution is the first order stochastic dominance criterion. It is based on the comparison of cumulative distributions and characterises social situations strictly better in terms of expected outcomes if one curve is strictly below another curve at each point of the distribution.

First Order Stochastic Dominance ($\geq_{FO}$)

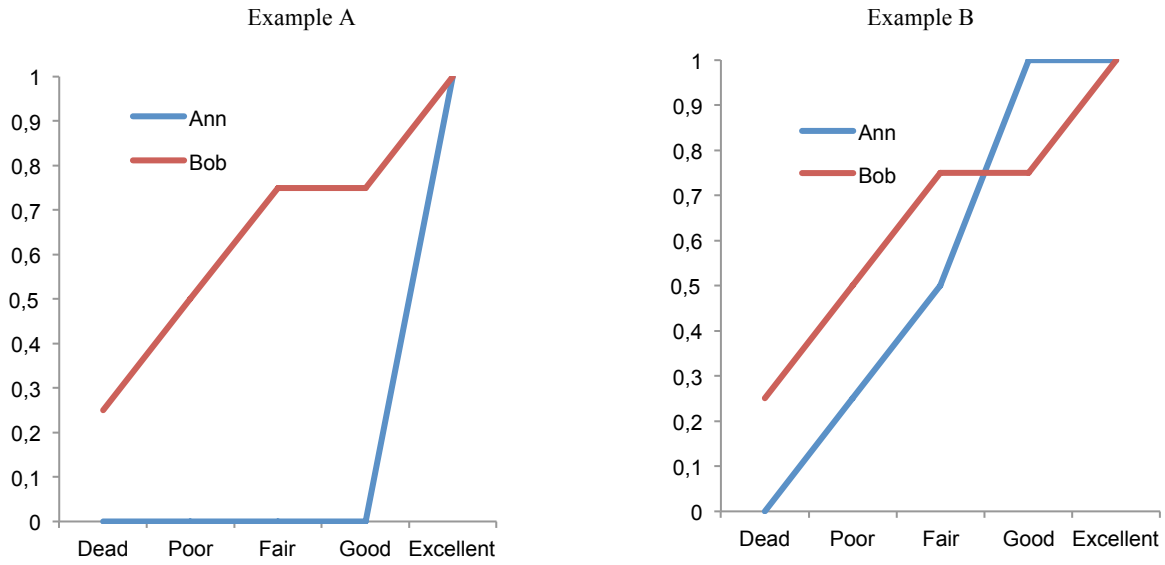
We say that the distribution c_1 first order dominates the distribution c_2 if $\forall h_k,\ F_{c_1}(h_k) \leq F_{c_2}(h_k)$ then $H_{c_1} \geq_{FO} H_{c_2}$ in terms of welfare with F_{C1} and F_{C2} the cumulative distributions of the ordered and qualitative health status with *K* response items.

Let us turn back to Bob and Ann, who live during four periods (childhood, adolescence, adulthood, and ageing); their health status is measured by a 5 items indicator as follows: (i) dead, (ii) poor, (iii) fair, (iv) good, and (v) excellent. Let us assume that Ann's health trajectory is – Excellent, Excellent, Excellent, Excellent – while Bob experiences - Excellent, Fair, Poor, Dead -. Ann's lifetime health distribution is (0; 0; 0; 0; 1) while Bob's is (0.25; 0.25; 0.25; 0; 0.25). Their respective cumulative lifetime health distributions are

[2] There is no ethical foundation to consider it is preferable to be in good health in youngest ages than in oldest ages, if health statuses at each age are independent. Moreover, we do not compare lifetime health status to any cost as in an economic evaluation. There is therefore no justification to introduce a time discount rate in the analysis.

(0; 0; 0; 0; 1) for Ann and (0.25; 0.5; 0.75; 0.75; 1) for Bob. It appears that Ann's health distribution dominates at the first order Bob's health distribution since the cumulative distribution of Ann's health is always below Bob's health CDF (Graph 1, Example A).

Graph 1: Cumulative distributions of Bob and Ann



The first order stochastic dominance criterion is widely used when comparing distributions of both cardinal and ordinal qualitative attributes, in particular in the context of inequality of opportunity (Lefranc et al., 2009). However, it does not allow ordering all distributions, in particular it does not allow judgment in the case of crossing distributions. As an illustration, let us assume that the health trajectories of Bob and Ann are respectively – Excellent, Fair, Poor, Dead – and – Good, Fair, Fair, Poor. Their trajectories are equal to (0.25; 0.25; 0.25; 0; 0.25) for Bob and (0; 0.25; 0.5; 0.25; 0) for Ann and the respective two CDFs are equal to (0.25; 0.5; 0.75; 0.75; 1) and (0; 0.25; 0.75; 1; 1); they thus cross at the level of the Fair item and so cannot be ranked according to the first order stochastic dominance criterion (see Graph 1, Example B). If the social planner favours distributions preserving from premature death, Ann's lifetime distribution is preferred with respect to the poorest health status experienced. On the other hand if the social planner is neutral toward the poorest health status, Bob's distribution may be advantageous as he experienced the best health status in his distribution.

In the case of quantitative attributes, a second order stochastic dominance criterion could be used to compare distributions of outcomes, which are crossing if they have the same mean. A second order stochastic dominance criterion would allow ranking distributions introducing aversion toward extreme outcomes. The concept of second order stochastic dominance is however more complex for qualitative outcomes such as self-assessed health, and in the case of ordinal outcomes, Allison and Foster (2004) and Abul-Naga and Yalcin (2008) have suggested the use of the median-preserving spread, which is a partial ordering for situations with

the same median category. To order distributions with different medians and to take into account the aversion of the social planner toward poorest outcomes explicitly, Gravel et al. (2014) have used a criterion based on the construction of a distribution curve respecting the principle of Hammond transfer (1976), which is consistent with the hypothesis of decreasing marginal utility function. This dominance criterion corresponds to a reduction of inequality within the distribution of an ordinal attribute and consists in a set of transfers that "reduces the gap" between two individuals, irrespective of the "equality of the gain from the poor or the loss of the rich".

Definition Hammond transfer
Distribution d is obtained from distribution d' by means of Hammond equalizing transfer, if there exist four categories $l \leq g \leq h \leq i \leq j$ (ordered from the worst to the best) such that
$d_l = d'_l$, $\forall\, l \neq g,h,i,j$; $d_g = d'_g - \varepsilon$; $d_h = d'_h + \varepsilon$; $d_i = d'_i + \varepsilon$; $d_j = d'_j - \varepsilon$ for a fraction $\varepsilon > 0$ satisfying $\varepsilon \leq \min\{d'_g, 1 - d'_h, 1 - d'_i, d'_j\}$

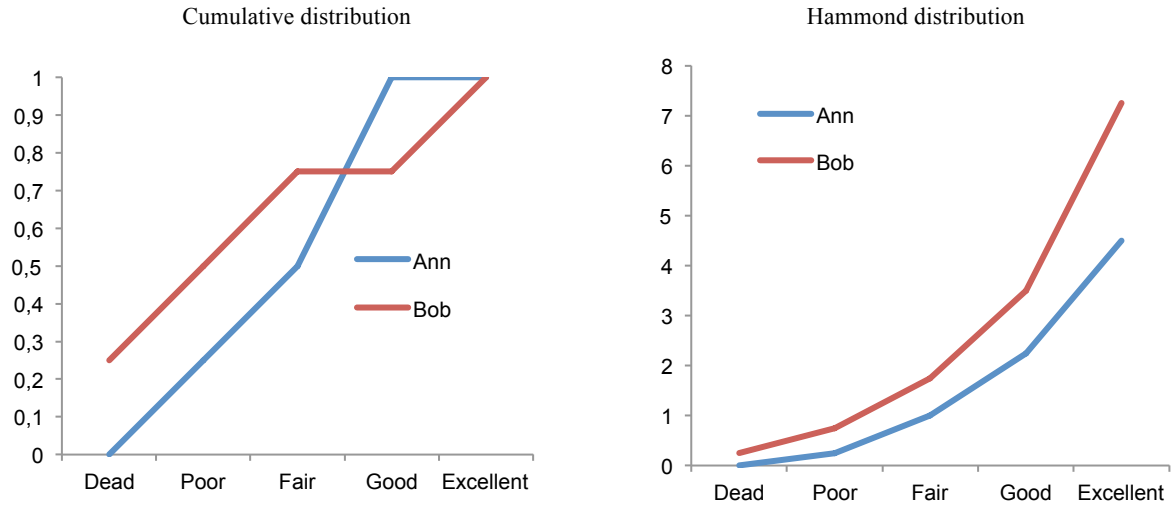
The Hammond transfer is more appropriate for ordinal attributes than the Pigou-Dalton transfer, which is restricted to transfer of equal amount to equalize a distribution. This criterion is also more general than the ordering criteria as proposed by Allison and Foster (2004) and by Abul-Naga and Yalcin (2008), which are both restricted to the case of distributions with equal medians. Statistically, the Hammond transfer relies on the comparison of cumulative distributions giving a larger weight to the poorer category, which is consistent with the hypothesis that the social planner is averse to the poorer health statuses. In addition, this criterion respects the first order dominance criterion.

Definition Hammond-*dominance* ($\geq_H$)
Let us consider c_1 and c_2 two CDFs, c_1 dominates c_2 according to Hammond criterion if $\forall x$, $F_{Hc_1}(x) \leq F_{Hc_2}(x)$ with F_{HC1} and F_{HC2} the Hammond distributions of health status:

$$F_H(i;s) = \sum_{h=1}^{i} \frac{(2^{i-h})n_h^s}{n}$$

If we consider again the example B with the respective lifecycle distributions of Bob (0.25; 0.25; 0.25; 0; 0.25) and Ann (0; 0.25; 0.5; 0.25; 0) the Hammond dominance criterion allows us to rank the two distributions thanks to the introduction of an aversion to poorest health statuses. Ann's lifecycle health distribution could be obtained from Bob's distribution using a Hammond transfer that "reduces the gap" between two distributions as follows: the frequency of the 'fair" health status can be increased by reducing the frequency of the "death", whereas the frequency of the "excellent" health status is reduced by increasing the frequency of the "Good health status". Consistently, the cumulative Hammond lifetime health distribution of Ann is equal to (0; 0.25; 1; 2.25; 4.5) and is always bellow Bob's distribution, which is equal to (0.25; 0.75; 1.75; 3.5; 7.25). Ann's lifecycle health distribution dominates Bob's distribution according to the Hammond criteria.

Graph 2: Cumulative and Hammond distributions of Bob and Ann in the example B



d. Age-specific or lifecycle social ordering

To test the presence of health inequality between social groups over the lifecycle in the age-specific and the lifecycle perspectives, we propose to rely on the two criteria of first order stochastic dominance and Hammond dominance to compare distributions of ordinal attributes. We then assume that the social planner has the same preference whether it is at individual or collective level. These bilateral orderings demonstrate a preference for a group when first order stochastic dominance (F) or Hammond dominance (H) can be found and indifference when no ordering is found.

The lifecycle perspective relies on a unique ordering based on the comparison of the whole health distribution over the lifecycle across groups. In the case of the age-specific perspective, we have an ordering at each age and we need to define a way to aggregate these different orderings over time. Under our assumption of anonymity toward age as well as the fact that no age is more important than another over the lifecycle, we have limited possibilities for aggregating binary relations. Among those possibilities, we propose to retain two main criteria of weak and strong dominance. If we show dominance for a group in at least one period without inversion of the ordering at any other period, we conclude that there is a *weak* age-specific dominance. If we show dominance for a group for each period, we conclude that there is a *strong* age-specific dominance.

III. Empirical example using a British cohort

a. Data

We use data from the National Child Development Study (NCDS), which follows for a cohort of 17,500 British people born in one week in March 1958 in England, Scotland and Wales. We measure health using self-assessed health, which is available at age 23, 33, 42 and 46 combined with vital status at each time point (see Table 1). Our empirical approach aims to assess inequalities of opportunities in health. The concept of inequality of opportunity distinguishes between legitimate and illegitimate sources of inequality. The former are due to factors for which the individual can be held responsible, whereas the latter stem from factors

beyond the individual's control. In Roemer's terminology, these are efforts and circumstances, respectively (Roemer 1998; Roemer and Trannoy 20015). The typical ethical prescription is that inequalities due to circumstances should be compensated for (principle of compensation); whereas those due to efforts, and hence legitimate, should be respected (principle of liberal reward) (Fleurbaey and Schokkaert, 2009). In this empirical application, we consider two variables that measure circumstances during childhood, namely father's professional status and region at birth.

Table 1 : Cohort follow up

	Birth	**NCDS 4**	**NCDS 5**	**NCDS 6**	**NCDS 7**
Year	1958	1981	1991	2000	2004
Age	Birth	23 yo	33 yo	42 yo	46 yo
Collected sample	17,416	12,044	10,986	10,979	9,175
Dead		883	953	1,000	1,045
Balanced sample	8,107				

We use two alternative samples of data in the empirical analysis: a balanced sample of strictly alive individuals, which are followed at the four waves and a sample including individuals who have died since 1958.

Given the administrative follow-up of mortality and the attrition rate in the cohort data, we include mortality as a fifth item of health status using a weighting procedure to respect the mortality rate in the cohort comparing death at each wave to the collected sample at birth (see Table 2 and Table A1 in Appendix the distribution of the sample according to social groups).

Table 2: Distribution of health status and mortality at each wave

Age	23 yo	33 yo	42 yo	46 yo
Dead	4.8%	5.7%	6.3%	6.9%
Poor	0.7%	1.3%	2.6%	6.3%
Fair	7.0%	9.9%	12.3%	14.4%
Good	43.9%	49.2%	49.6%	42.6%
Excellent	43.7%	33.9%	29.2%	29.8%

b. Construction of the lifecycle health indicator

When we consider health status as measured by a 4-item SAH status, there are 35 different potential distributions of lifetime health. However there are 65 different potential distributions of lifetime health status if death is included as an additional item in heath status (see Table A2 and A3).

The lifetime distributions of health are ordered by default using a lexicographic criterion ranking from the best lifetime distribution to the worst. This ranking is used by default as it allows ranking all the potential distributions but it is the most extreme as it assumes a strict aversion for poorest health states (Maximin).

The criterion of first order stochastic dominance is more restrictive than the Hammond criteria and would allow ranking only 13 distributions among the 35. As the ranking is incomplete, we group the intermediate distribution to the closest one following the lexicographic criterion. Using the Hammond dominance criterion, it allows ranking 22 distributions out of the 35 and the same grouping is done for intermediate situation.

When including death as a fifth item in health status, out of 65 distributions we can rank 17 distributions using first order stochastic dominance while we rank 34 distributions using Hammond dominance.

This ranking variable is then matched with the individual observed lifetime health distribution and defines the lifecycle health indicator.

c. Inequalities of opportunities in health

Tables A4 to A7 in Appendix provide the results of the comparison of the health distributions according to the respondents' father's occupation and their birth region[3].

Our findings show the interest of the Hammond dominance criterion in addition to the criteria of first order dominance to compare distribution of ordered and qualitative health indicators in terms of welfare and to exhibit inequalities of opportunity in health. Whereas the first order stochastic dominance criterion allows ranking most of health distributions according to father's occupation whether mortality risk is taken into account or not; this same criterion does not allow comparing the health distributions of individuals without father and of sons of father occupying unskilled jobs.

In the lifecycle perspective, the health distribution of individuals without father dominates the health distribution of sons of men in unskilled occupation according to Hammond criterion. Similarly Hammond dominance criterion reveals the existence of inequalities of opportunity related to regions of birth. This criterion allows ranking more health distributions according to regions of birth than the first order stochastic dominance criterion, which was somehow ineffective.

Our results also show the interest of the two alternative perspectives to measure inequalities of opportunities in health. Whereas the lifecycle perspective provides a global view of inequality of opportunity, the age-specific highlights some changes in the dynamic of inequality of opportunity. Regarding inequality of opportunity related to father's occupation, the results show a reinforcement of inequality all over the lifecycle in favour of people born from a professional father and in favour of individuals without father, when mortality is considered. The age-specific approach also highlights inequality in favour of people born in the South East in the second part of their lifecycle, and a reinforcement of inequality of opportunity between other regions over the lifetime.

Finally, the results show the interest of considering health with and without mortality as a fifth health state item for measuring health over the lifecycle. The inclusion of mortality leads to a reinforcement of inequalities of opportunity in health: it highlights significant the first order stochastic dominance between health distributions which could mainly be judged according to the Hammond dominance criterion without considering mortality risk, and reveals Hammond dominances between distributions which could not be ordered previously.

IV. Discussion

This paper is a primary tentative to compare inequality of opportunities in health over the lifecycle from two alternative perspectives, an age-specific and a lifecycle perspective. It proposes a methodology based on

[3] The corresponding cumulative distributions are available upon request

dominance criterion. While the first order stochastic dominance is a robust criterion for judging inequalities both at individual and collective levels that is valid for any preferences, we seconded the methodology with the Hammond dominance criteria, which introduced a strong aversion to worse health states relying on decreasing marginal utility. The Hammond criterion allows ranking more health distributions, particularly according to regions of birth than the first order stochastic dominance criterion.

The Hammond dominance criterion, particularly the underlying assumptions could be discussed. It is not systematically obvious that worse health statuses will always be preferred to death. Research in health outcomes have underlined that people might consider some states to be worse than death (Macran and Kind, 2001). There might be a trade-off individuals will make between quality and quantity of life that we have ignored in the present paper.

In our approach we also assume anonymity toward age and do not introduce any discount rate for health over time. Our main argument for this assumption is related to the fact that we assume no age to be more important than another over the lifecycle. However the anonymity toward age could be relaxed if the regulator believes that some ages are more important than others, for example children versus older people or working age population versus inactive people. Additionally, if we consider bivariate utility functions depending on wealth and health, discounting for health over time may be needed along with potential for wealth to compensate or not for poorer health states according to the substitutability or complementarity between health and wealth (Crainich et al. 2015).

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VI. Appendix

Table A1 : Distribution of social status variables

Father professional status			
Professional	I	357	4,60%
Managerial/Technical	II	1055	13,50%
Skilled non manual	III n.m.	775	9,90%
Skilled manual	III m.	3775	48,40%
Partly skilled	IV	884	11,30%
Unskilled	V	594	7,60%
No male head	No	355	4,60%
Region at birth			
South West		941	11,68%
Wales		455	5,61%
Center		1953	24,90%
South East		1455	17,95%
North		2172	26,79%
Scotland		814	10,04%

Table A2: Example of construction of lifecycle health indicator – without mortality

Lifetime health function		Cumulative distribution				Rank F	Hammond distribution				Rank H
		F(Poor)	F(Fair)	F(Good)	F(Exc.)		FH(Poor)	FH(Fair)	FH(Good)	FH(Exc.)	
1	(E, E, E, E)	0	0	0	1	1	0	0	0	1	1
2	(G, E, E, E)	0	0	0,25	1	2	0	0	0,25	1,25	2
3	(G, G, E, E)	0	0	0,5	1	3	0	0	0,5	1,5	3
4	(G, G, G, E)	0	0	0,75	1	4	0	0	0,75	1,75	4
5	(G, G, G, G)	0	0	1	1	5	0	0	1	2	5
6	(F, E, E, E)	0	0,25	0,25	1		0	0,25	0,5	1,75	
7	(F, G, E, E)	0	0,25	0,5	1		0	0,25	0,75	2	
8	(F, G, G, E)	0	0,25	0,75	1		0	0,25	1	2,25	6
9	(F, G, G, G)	0	0,25	1	1	6	0	0,25	1,25	2,5	7
10	(F, F, E, E)	0	0,5	0,5	1		0	0,5	1	2,5	
11	(F, F, G, E)	0	0,5	0,75	1		0	0,5	1,25	2,75	8
12	(F, F, G, G)	0	0,5	1	1	7	0	0,5	1,5	3	9
13	(F, F, F, E)	0	0,75	0,75	1		0	0,75	1,5	3,25	10
14	(F, F, F, G)	0	0,75	1	1	8	0	0,75	1,75	3,5	11
15	(F, F, F, F)	0	1	1	1	9	0	1	2	4	12
16	(P, E, E, E)	0,25	0,25	0,25	1		0,25	0,5	1	2,75	
17	(P, G, E, E)	0,25	0,25	0,5	1		0,25	0,5	1,25	3	
18	(P, G, G, E)	0,25	0,25	0,75	1		0,25	0,5	1,5	3,25	
19	(P, G, G, G)	0,25	0,25	1	1		0,25	0,5	1,75	3,5	
20	(P, F, E, E)	0,25	0,5	0,5	1		0,25	0,75	1,5	3,5	
21	(P, F, G, E)	0,25	0,5	0,75	1		0,25	0,75	1,75	3,75	
22	(P, F, G, G)	0,25	0,5	1	1		0,25	0,75	2	4	
23	(P, F, F, E)	0,25	0,75	0,75	1		0,25	1	2	4,25	13
24	(P, F, F, G)	0,25	0,75	1	1		0,25	1	2,25	4,5	14
25	(P, F, F, F)	0,25	1	1	1	10	0,25	1,25	2,5	5	15
26	(P, P, E, E)	0,5	0,5	0,5	1		0,5	1	2	4,5	
27	(P, P, G, E)	0,5	0,5	0,75	1		0,5	1	2,25	4,75	
28	(P, P, G, G)	0,5	0,5	1	1		0,5	1	2,5	5	
29	(P, P, F, E)	0,5	0,75	0,75	1		0,5	1,25	2,5	5,25	16
30	(P, P, F, G)	0,5	0,75	1	1		0,5	1,25	2,75	5,5	17
31	(P, P, F, F)	0,5	1	1	1	11	0,5	1,5	3	6	18
32	(P, P, P, E)	0,75	0,75	0,75	1		0,75	1,5	3	6,25	19
33	(P, P, P, G)	0,75	0,75	1	1		0,75	1,5	3,25	6,5	20
34	(P, P, P, F)	0,75	1	1	1	12	0,75	1,75	3,5	7	21
35	(P, P, P, P)	1	1	1	1	13	1	2	4	8	22

Table A3: Example of construction of lifecycle health indicator – with mortality

Lifetime health	Cumulative distribution					Rank F	Hammond distribution					Rank H
	F(Dead)	F(Poor)	F(Fair)	F(Good)	F(Exc.)		FH(Dead)	FH(Poor)	FH(Fair)	FH(Good)	FH(Exc.)	
1 (E, E, E, E)	0	0	0	0	1	1	0	0	0	0	1	1
2 (G, E, E, E)	0	0	0	0,25	1	2	0	0	0	0,25	1,25	2
3 (G, G, E, E)	0	0	0	0,5	1	3	0	0	0	0,5	1,5	3
4 (G, G, G, E)	0	0	0	0,75	1	4	0	0	0	0,75	1,75	4
5 (G, G, G, G)	0	0	0	1	1	5	0	0	0	1	2	5
6 (F, E, E, E)	0	0	0,25	0,25	1		0	0	0,25	0,5	1,75	
7 (F, G, E, E)	0	0	0,25	0,5	1		0	0	0,25	0,75	2	
8 (F, G, G, E)	0	0	0,25	0,75	1		0	0	0,25	1	2,25	6
9 (F, G, G, G)	0	0	0,25	1	1	6	0	0	0,25	1,25	2,5	7
10 (F, F, E, E)	0	0	0,5	0,5	1		0	0	0,5	1	2,5	
11 (F, F, G, E)	0	0	0,5	0,75	1		0	0	0,5	1,25	2,75	8
12 (F, F, G, G)	0	0	0,5	1	1	7	0	0	0,5	1,5	3	9
13 (F, F, F, E)	0	0	0,75	0,75	1		0	0	0,75	1,5	3,25	10
14 (F, F, F, G)	0	0	0,75	1	1	8	0	0	0,75	1,75	3,5	11
15 (F, F, F, F)	0	0	1	1	1	9	0	0	1	2	4	12
16 (P, E, E, E)	0	0,25	0,25	0,25	1		0	0,25	0,5	1	2,75	
17 (P, G, E, E)	0	0,25	0,25	0,5	1		0	0,25	0,5	1,25	3	
18 (P, G, G, E)	0	0,25	0,25	0,75	1		0	0,25	0,5	1,5	3,25	
19 (P, G, G, G)	0	0,25	0,25	1	1		0	0,25	0,5	1,75	3,5	
20 (P, F, E, E)	0	0,25	0,5	0,5	1		0	0,25	0,75	1,5	3,5	
21 (P, F, G, E)	0	0,25	0,5	0,75	1		0	0,25	0,75	1,75	3,75	
22 (P, F, G, G)	0	0,25	0,5	1	1		0	0,25	0,75	2	4	
23 (P, F, F, E)	0	0,25	0,75	0,75	1		0	0,25	1	2	4,25	13
24 (P, F, F, G)	0	0,25	0,75	1	1		0	0,25	1	2,25	4,5	14
25 (P, F, F, F)	0	0,25	1	1	1	10	0	0,25	1,25	2,5	5	15
26 (P, P, E, E)	0	0,5	0,5	0,5	1		0	0,5	1	2	4,5	
27 (P, P, G, E)	0	0,5	0,5	0,75	1		0	0,5	1	2,25	4,75	
28 (P, P, G, G)	0	0,5	0,5	1	1		0	0,5	1	2,5	5	
29 (P, P, F, E)	0	0,5	0,75	0,75	1		0	0,5	1,25	2,5	5,25	16
30 (P, P, F, G)	0	0,5	0,75	1	1		0	0,5	1,25	2,75	5,5	17
31 (P, P, F, F)	0	0,5	1	1	1	11	0	0,5	1,5	3	6	18
32 (P, P, P, E)	0	0,75	0,75	0,75	1		0	0,75	1,5	3	6,25	19
33 (P, P, P, G)	0	0,75	0,75	1	1		0	0,75	1,5	3,25	6,5	20
34 (P, P, P, F)	0	0,75	1	1	1	12	0	0,75	1,75	3,5	7	21
35 (P, P, P, P)	0	1	1	1	1	13	0	1	2	4	8	22
36 (D, E, E, E)	0,25	0,25	0,25	0,25	1		0,25	0,5	1	2	4,75	
37 (D, G, E, E)	0,25	0,25	0,25	0,5	1		0,25	0,5	1	2,25	5	
38 (D, G, G, E)	0,25	0,25	0,25	0,75	1		0,25	0,5	1	2,5	5,25	
39 (D, G, G, G)	0,25	0,25	0,25	1	1		0,25	0,5	1	2,75	5,5	
40 (D, F, E, E)	0,25	0,25	0,5	0,5	1		0,25	0,5	1,25	2,5	5,5	
41 (D, F, G, E)	0,25	0,25	0,5	0,75	1		0,25	0,5	1,25	2,75	5,75	
42 (D, F, G, G)	0,25	0,25	0,5	1	1		0,25	0,5	1,25	3	6	
43 (D, F, F, E)	0,25	0,25	0,75	0,75	1		0,25	0,5	1,5	3	6,25	

44	(D, P, E, E)	0,25	0,5	0,5	0,5	1		0,25	0,75	1,5	3	6,5		
45	(D, P, G, E)	0,25	0,5	0,5	0,75	1		0,25	0,75	1,5	3,25	6,75		
46	(D, P, G, G)	0,25	0,5	0,5	1	1		0,25	0,75	1,5	3,5	7		
47	(D, P, F, F)	0,25	0,5	1	1	1		0,25	0,75	2	4	8		
48	(D, P, P, G)	0,25	0,75	0,75	1	1		0,25	1	2	4,25	8,5	23	
49	(D, P, P, F)	0,25	0,75	1	1	1		0,25	1	2,25	4,5	9	24	
50	(D, P, P, P)	0,25	1	1	1	1	14	0,25	1,25	2,5	5	10	25	
51	(D, D, E, E)	0,5	0,5	0,5	0,5	1		0,5	1	2	4	8,5		
52	(D, D, G, E)	0,5	0,5	0,5	0,75	1		0,5	1	2	4,25	8,75		
53	(D, D, G, G)	0,5	0,5	0,5	1	1		0,5	1	2	4,5	9		
54	(D, D, F, E)	0,5	0,5	0,75	0,75	1		0,5	1	2,25	4,5	9,25		
55	(D, D, F, G)	0,5	0,5	0,75	1	1		0,5	1	2,25	4,75	9,5		
56	(D, D, F, F)	0,5	0,5	1	1	1		0,5	1	2,5	5	10		
57	(D, D, P, E)	0,5	0,75	0,75	0,75	1		0,5	1,25	2,5	5	10,25	26	
58	(D, D, P, G)	0,5	0,75	0,75	1	1		0,5	1,25	2,5	5,25	10,5	27	
59	(D, D, P, F)	0,5	0,75	1	1	1		0,5	1,25	2,75	5,5	11	28	
60	(D, D, P, P)	0,5	1	1	1	1	15	0,5	1,5	3	6	12	29	
61	(D, D, D, E)	0,75	0,75	0,75	0,75	1		0,75	1,5	3	6	12,25	30	
62	(D, D, D, G)	0,75	0,75	0,75	1	1		0,75	1,5	3	6,25	12,5	31	
63	(D, D, D, F)	0,75	0,75	1	1	1		0,75	1,5	3,25	6,5	13	32	
64	(D, D, D, P)	0,75	1	1	1	1	16	0,75	1,75	3,5	7	14	33	
65	(D, D, D, D)	1	1	1	1	1	17	1	2	4	8	16	34	

Table A4: Lifecycle dominance tests according to father professional status (without mortality)

Column dominates Row	Health at each age						
Health aggregated over the lifecycle	I	II	III n.m.	III m.	IV	V	No father
I		..?. .	..?. .	…. .	…. .	…. .	…. .
II	FF?F H		.. ?. .	…. .	…. .	…. .	…. .
III n.m.	FF?F H	FF?H F		?... H	?... H	…. ?	?... H
III m.	FFFF F	FFFF F	?FFF .		…. ?	…. .	…. ?
IV	FFFF F	FFFF F	?FFF .	FFFF ?		. ?.. .	. ?.. H
V	FFFF F	FFFF F	FFFF ?	FFFF F	F?FF H		FH.F H
No	FFFF F	FFFF F	?FFF .	FFFF ?	H?FH .	..F. .	

F represents Stochastic Dominance at first order
H represents Hammond dominance
. represents being dominated at first order dominance or Hammond
? represents when we cannot conclude on dominance

Table A5: Lifecycle dominance tests according to father professional status (including mortality)

Column dominates Row	Health at each age						
Health aggregated over the lifecycle	I	II	III n.m.	III m.	IV	V	No father
I		…. .	…. .	…. .	…. .	…. .	…. .
II	FFFF H		…. .	…. .	…. .	…. .	…. .
III n.m.	FFFF F	FFFH F		…. .	…. .	…. .	…. .
III m.	FFFF F	FFFF F	FFFF F		???? H	…. .	…. .
IV	FFFF F	FFFF F	FFFF F	???? .		…. .	…. .
V	FFFF F	FFFF F	FFFF F	FFFF F	FFFF F		. ??F .
No	FFFF F	FFFF F	FFFF F	FFFF F	FFFF F	H ??. H	

F represents Stochastic Dominance at first order
H represents Hammond dominance
. represents being dominated at first order dominance or Hammond
? represents when we cannot conclude on dominance

Table A3: Lifecycle dominance tests according to region at birth (without mortality)

Column dominates Row	Health at each age					
Health aggregated over the lifecycle	South West	Wales	Centre	South East	North	Scotland
South West		??.. .	??.? .	.?HH .	??.. .	?.?. .
Wales	??HF H		???H H	.?HH ?	??.F ?	???? .
Centre	??F? H	???. .		.?FF ?	.??. .	???? .
South East	F?.. H	F?.. ?	H?.. ?		??.. ?	?... .
North	??HF H	??F. ?	H??H H	??HH ?		???? .
Scotland	?H?F H	???? H	???? H	?HFF H	???? H	

F represents Stochastic Dominance at first order
H represents Hammond dominance
. represents being dominated at first order dominance or Hammond
? represents when we cannot conclude on dominance

Table A7: Lifecycle dominance tests according to region of birth (including mortality)

Column dominates Row	Health at each age					
Health aggregated over the lifecycle	South West	Wales	Centre	South East	North	Scotland
South West		…. .	…. .	…. .	…. .	…. .
Wales	HHHF H		??.? H	??.? H	??.? ?	…. .
Centre	FFFF F	??F? .		?..? H	…. .	…. .
South East	FFFF H	??H? .	?HH? .		.H?. .	…. .
North	FFFF F	??F? ?	HHHH H	F.?H H		…. .
Scotland	HFFF F	HFFH H	HHFF H	HHFF F	FHFF H	

F represents Stochastic Dominance at first order
H represents Hammond dominance
. represents being dominated at first order dominance or Hammond
? represents when we cannot conclude on dominance