Measuring inequities in health over the life cycle: age-specific or life cycle 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 1958 British cohort study and focus on self-assessed health and death as measures of health; we use the first order dominance and Hammond dominance criteria to respect the ordinal and qualitative nature of those health data and measure health inequality. Our results show that the two perspectives impact on the existence and the magnitude of the 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 the South East UK in the second part of their lifecycle, (ii) a reinforcement of inequality of opportunity between regions over the lifetime, and (iii) a U-shaped relationship between maternal age at birth and health status over the whole lifecycle.

Keywords: Inequality, Life cycle, Ordinal Heath variable, First-order and Hammond dominances

1. Introduction

Health status is theoretically conceptualised as a dynamic outcome that evolves over time all along the life cycle (Galama et al., 2013; Grossman, 1972), however the measurement of health inequalities over the life cycle as a whole has rarely been undertaken. Measuring inequalities over the life cycle 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 two alternative aggregating perspectives are not supported by the same ethical principles. The life cycle 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 life cycle. This perspective 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 life cycle 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 life cycle mainly use an age-specific approach. Most of studies on health inequalities are based on the measurement of snapshot health inequalities at certain time points but some studies have also focused on health inequalities over the life cycle at different ages or for different age cohorts (Deaton and Paxson, 1998; Van Kippersluis et al., 2010, 2009). Those studies described the trajectory of age-specific health inequality without, providing a synthetic measure of health inequality for the whole life cycle. They have mainly shown that socioeconomic health inequalities increase with age until a certain age from which socioeconomic inequalities decrease because of population selection effect. Some other empirical studies have used synthetic health indicators over the life cycle, 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 life cycle.

[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.

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 life cycle inequality measurement over the whole life cycle. The use of the mean health as a health indicator over the life cycle 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 the aversion against poorest health statuses.

In this paper, our objective is to propose a methodology to measure health inequality over the life cycle from both the age-specific and life cycle 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 conclusions. 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.

2. Method

2.1. Theoretical concept of age-specific and life cycle perspectives

The difference between the age-specific and the life cycle perspectives comes from which of the two dimensions between ages or individuals is considered first when aggregating. It also raises the question of constructing health indicators as well as social ordering over the life cycle in terms of both welfare and inequality.

Let us now illustrate the two concepts of life cycle and age-specific perspectives using an example from the discussion about uncertainty in Fleurbaey (Fleurbaey, 2010).

We consider two individuals, Bob and Ann and two age periods (Young, Old); at each period they can be either in Poor or Good health. We assume that the social planner is indifferent to the age period and does not have any criteria favoring Ann or Bob therefore apply an anonymity criterion towards age and individuals.

Let us consider two situations (S1, S2) that are described in the following tables; 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 life cycle 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 life cycle. 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 S1 and S2 and there is no inequality in the life cycle perspective.

From an age specific perspective, we first aggregate over individuals for each period and then over periods. The two situations S1 and S2 differ. 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. S2 is therefore preferable to S1 in terms of inequality.

We 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 life cycle perspective, situation S3 is unequal as Bob gets is in Good health in both periods while Ann is in Poor health, 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 life cycle 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 life cycle.

2.2. Age-specific and life cycle 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 this health indicator can be measured at each age and so provide an

age-specific measure of individual lifetime health status. Let us 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 a four items SAH indicator ((i) poor, (ii) fair (iii) very good, (iv) excellent), incorporating death as an extra item would lead us to use a five items indicator described as follows: (i) dead (ii) poor, (iii) fair, (iv) very good, and (v) excellent. In this latter context, we assume that the social planner considers death as a less desirable health status than reporting 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 life cycle 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. A mean value is however only appropriate if health status is measured with a quantitative health indicator while a median could be used in the case of an ordered qualitative health indicator. Nevertheless neither the mean nor the median would fully respect each individual's health trajectory, especially in the case of the mean that 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 h_k. The lifetime health trajectory of individual i is then given by the vector $(H_{i1}, H_{i2}, \ldots, H_{it}, \ldots, H_{iT-1}, H_{iT})$.

We consider that there is no obvious ethical foundation to assume that some ages are more important than others over the life cycle and therefore accounting for time preference using discounting does not appear required[2]. In other words, a health indicator appropriate for a lifecycle perspective should respect the anonymity criteria towards age. Under this hypothesis, the health trajectory of individual i over the life cycle could simply be summarised as a life cycle health distribution ($f_i(h_1)$, $f_i(h_2)\ldots$, $f_i(h_{k-1})$), $f_i(h_k)$, where the frequency $f_i(h_k)$ associated to each of the K response items corresponds to the proportion 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, and 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,

[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 ages are independent. Moreover, we don't compare lifetime health status to any cost as In health economic evaluation. There is therefore no justification to introduce time discounting in the analysis.

Poor, Dead) and Bob's is (Excellent, Poor, Fair, Dead), under the hypothesis of anonymity according to age, the two trajectories are considered equivalent. Their health trajectories only differ with the age at Ann and Bob experience a fair and a poor health statuses and therefore both lifetime health distributions corresponds to the following distribution (0.25; 0.25; 0.25; 0; 0.25).

2.3. Judging inequality within the life cycle

Individual's lifetime health distribution constitutes a potential health indicator to analyse inequalities over the life cycle; 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 concerned with ordered and qualitative attributes. The same criteria will then be used in order to compare health distribution and then to judge inequality in both lifecycle and age-specific perspectives.

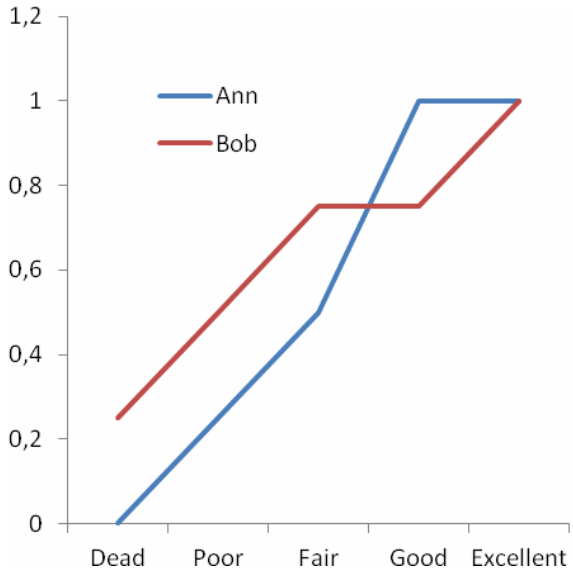
A first criterion for ordering distribution is the first order stochastic dominance criterion. It is based on the comparison of cumulative distributions and characterizes social situations strictly better in terms of expected outcomes if one curve is strictly below another at each point of the distribution.

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 (0; 0; 0; 1) for Ann and (0.25; 0.5; 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

Example A	Example B
	

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), which are respectively equal to (0.25; 0.25; 0.25; 0; 0.25) and (0; 0.25; 0.5; 0.25; 0). These two CDFs which are equal to (0.25; 0.5; 0.75; 0.75; 1) for Bob and (0; 0.25; 0.75; 1; 1) for Ann cross at the level of the Fair item and so cannot be ranked according to the first order stochastic dominance criterion (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. This second criterion would allow ranking distributions introducing aversion toward extreme outcomes. The concept of second order stochastic dominance is more complex for qualitative outcomes such as self-assessed health, and in the case of ordinal outcomes, Allison and Foster (Allison and Foster, 2004) and Abul-Naga and Yalcin (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. In order to order distributions with different medians and to explicitly take into account the aversion of the social planner toward poorest outcomes, Gravel et al. (Gravel et al., 2014) used a

criterion based on the construction of a Hammond distribution curve respecting the principle of Hammond transfer (Hammond, 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 $l \leq g < h \leq i < j \leq k$ (ordered from the worst to the best) such that

$d_l = d_l'$, (symbole quel que soit) $l \neq g, h, i, j$;

$d_g = d_g' - \varepsilon$; $d_h = d_h' + \varepsilon$

$d_i = d_i' + \varepsilon$; $d_j = d_j' - \varepsilon$

for some fraction $\varepsilon > 0$ satisfying $\varepsilon \leq \min \{ d_g', 1- d_h', 1- d_i', d_j' \}$

This 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 criteria proposed by Allison and Foster (Allison and Foster, 2004) and Abul-Naga and Yalcin (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* ($\succeq_H$)

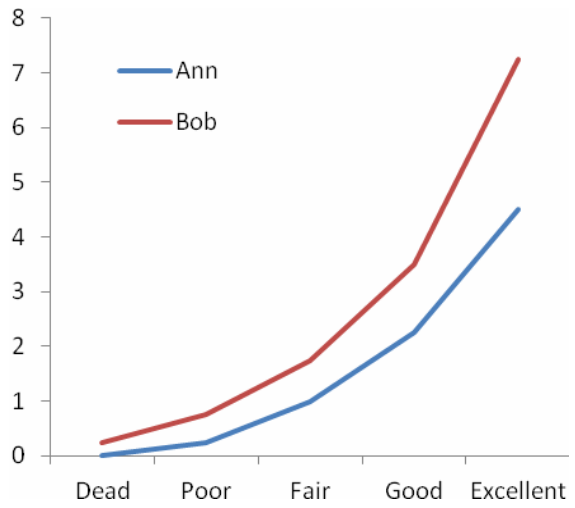
Let us consider c_1 and c_2 two CDFs, c_1 dominates c_2 according to Hammond criterion if $\forall x,$ $F_{Hc_1}(x) \leq F_{Hc_2}(x)$ with F_{HC1} and F_{HC2} the Hammond distributions of health status:

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

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

Cumulative distribution	Hammond distribution
	

2.3 Age-specific or lifecycle social ordering

To test the presence of inequality between social groups over the life cycle (in age-specific and lifecycle perspective), we propose to rely on the same criteria used to compare distribution of ordinal attributes presented in previous section (i.e. first order stochastic dominance, Hammond dominance). We then assume that the social planner has the same preference whether it is at an individual or a collective level. These bilateral orderings demonstrate a preference for a group in case of first order stochastic dominance (F) or Hammond dominance (H) or indifference if no ordering is found.

The lifecycle perspective relies on a unique ordering based on the comparison of the distribution over groups of the life cycle health indicator. In the case of age-specific perspective, we have an ordering at each age and we need to define a way to aggregate these different orderings. If we assume anonymity of the social planer with age as well as the fact that no ages are more important over the life-cycle, we have limited possibilities for aggregating binary relations and among those we propose to retain two main criteria. If we demonstrate a preference for a group in at least one period without inversion of the ordering at any other period, we prove a *weak* age-specific dominance for a group. In the case we demonstrate a preference for a group for each period we prove a *strong* age-specific dominance.

3. An example using a British cohort

3.1 Data

We use the National Child Development Study (NCDS), which provides a follow-up at age 23, 33, 42 and 46 of a cohort of 17 500 British people born in 1958 in one week in March 1958 in England, Scotland and Wales (see Table 1). We use as a measure of health, self-assessed health and vital status, as well as two childhood circumstances, which constitute potential sources of inequality of opportunity in health, namely father 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	17416	12044	10986	10979	9175
Dead		883	953	1000	1045
Balanced sample	8107				

Two samples of data are used in the analysis; a balanced sample of strictly alive individuals, which are followed at the four adult waves and a sample including individuals who have died since 1958. Given the administrative follow-up of mortality and the attrition rate, we include mortality using a weighting procedure to respect the mortality rate of 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%

3.2 Construction of the life cycle health indicator

In this example, we have a four 4 items of SAH status and vital status observed at four points of the life cycle for each individual.

Under the hypothesis of anonymity according to age, there are 35 different potential distributions of lifetime SAH if the analysis is restricted to the individuals who live the 4 periods and 65 different potential distributions of lifetime health status if death is included as an additional 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 distribution but it is the more extreme as it assumes a strict aversion for poorest health status (maximin). The criterion of first stochastic dominance is more restrictive as it allows ranking only 13 distributions among the 35 (without mortality). 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. In the case including mortality, we rank 17 and 34 distributions out of 65 respectively.
This ranking variable is then matched with the individual observed lifetime health distribution and defines the lifecycle health indicator.

3.3 First results

Tables A4 to A7 presented in Appendix provided the results of the comparison of the health distributions according to father's occupation and region at birth, corresponding to the cumulative and Hammond distributions presented in graphs in appendix.

First, those 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 then to highlight inequality in opportunity in health. Whereas first dominance criterion allows rank most of health distributions according to father's occupation even when mortality risk is not taken into account, this criterion doesn't allow to compare health distribution of individuals without father and health distribution of sons of father with unskilled occupation . However, within the life cycle perspective, the health distribution of individuals without father dominates the health distribution of sons of father with unskilled occupation according to Hammond criterion (Graphs G4 and G5). Similarly Hammond dominance criterion reveals the existence of inequality of opportunity related to regions of birth since this criterion allows ranking more health distributions according to regions of birth than the solely first order dominance criterion which was somehow ineffective (Graphs G12-16).

Second, results show the interest of the life cycle and age-specific perspectives for measuring inequalities in 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 life cycle in favor of people born from father who was professional (Graphs G6 and G7) and in favor of individuals without father, when mortality is considered (Graphs G8-G11). The age-specific approach also highlights inequality in favor of people born in South East in the second part of their life cycle, and a reinforcement of inequality of opportunity between other regions over the lifetime.

Finally, the results show the interest of considering both mortality and self-assessed health status for measuring health over the lifecycle. The inclusion of mortality leads to a reinforcement of inequality of opportunity: it highlights significant dominances at the first order 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 previously ordered.

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6. 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 F(Poor)	F(Fair)	F(Good)	F(Exc.)	Rank F	Hammond distribution FH(Poor)	FH(Fair)	FH(Good)	FH(Exc.)	Rank H
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)	F(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 A3: Lifecycle dominance tests according to father professional status (without mortality)

Comparison between Column and Row Health at each age Health aggregated over the lifecycle	I	II	III n.m.	III m.	IV	V	No father dominates
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 A4: Lifecycle dominance tests according to father professional status (including mortality)

Comparison between Column and Row Health at each age Health aggregated over the lifecycle	I	II	III n.m.	III m.	IV	V	No
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	

Table A5: Lifecycle dominance tests according to region at birth (without mortality)

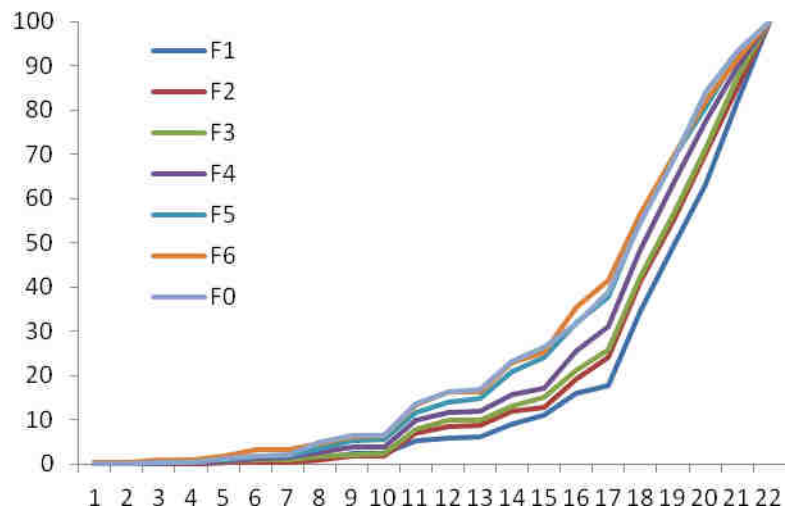
Column versus Row Health at each age Health aggregated over the lifecycle	South West dominates	Wales	Center	South East	North	Scotland
South West		??.. .	??.? .	.?HH .	??.. .	?.?. .
Wales	??HF H		???H H	.?HH ?	??.F ?	???? .
Center	??F? H	???. .		.?FF ?	.??. .	???? .
South East	F?.. H	F?.. ?	H?.. ?		??..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

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

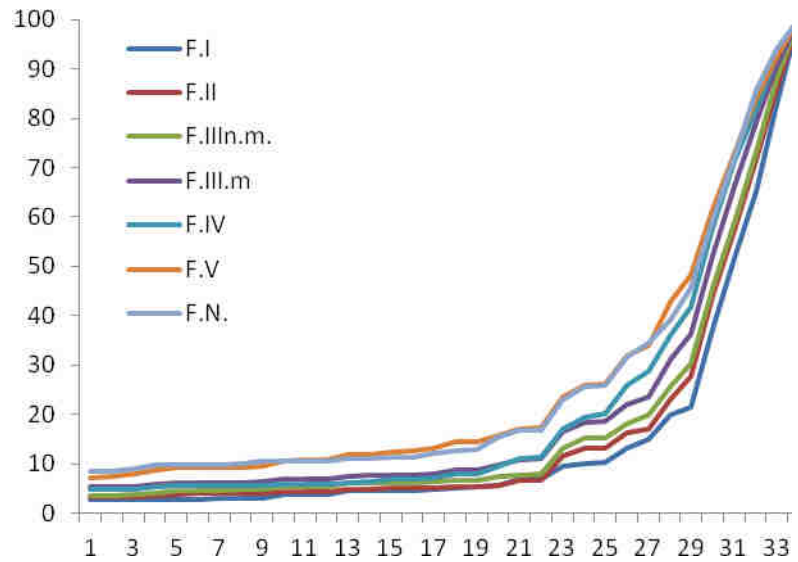
Column dominates Row	South West	Wales	Center	South East	North	Scotland
South West		…. .	…. .	…. .	…. .	…. .
Wales	HHHF H		??.? H	??.? H	??.? ?	…. .
Center	FFFF F	??F? .		?..? H	…. .	…. .
South East	FFFF H	??H? .	?HH? .		.H?. .	…. .
North	FFFF F	??F? ?	HHHH H	F.?H H		…. .
Scotland	HFFF F	HFFH H	HHFF H	HHFF F	FHFF H	

Graphs A. Cumulative and Hammond distributions by father's occupation and regions of birth

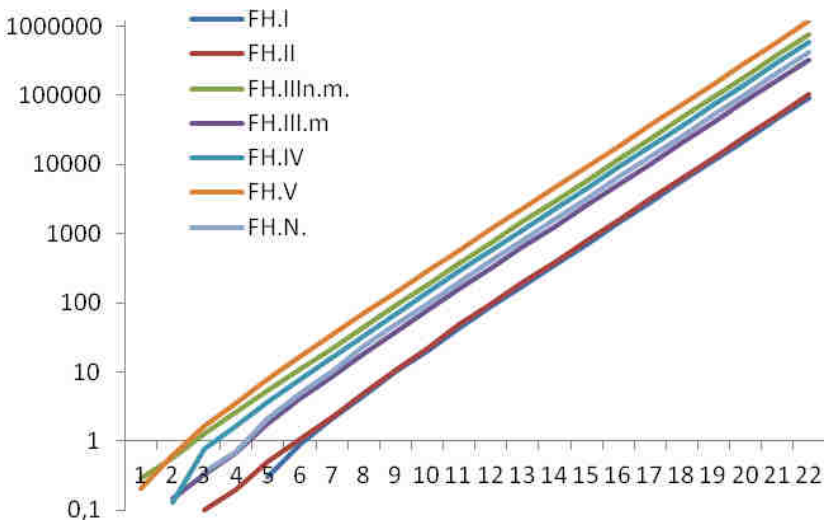
G.1a. Cumulative distributions-life cycle perspective without mortality



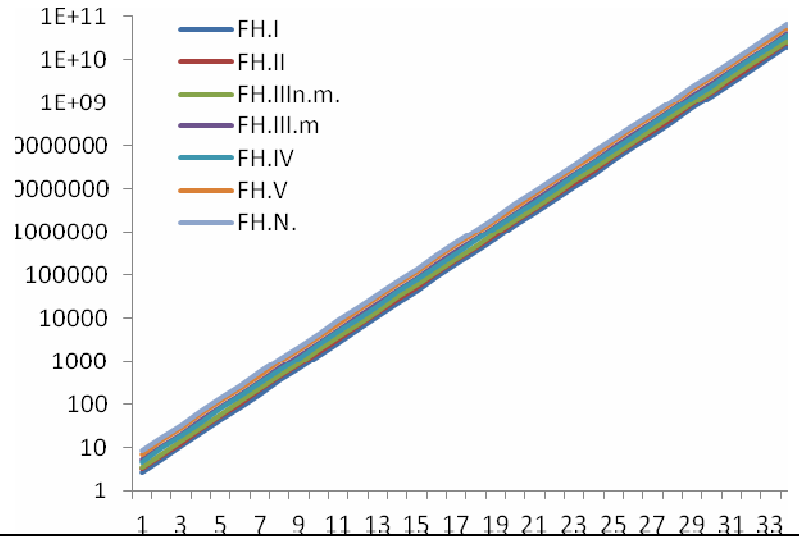
G.2a.Cumulative distributions-life cycle perspective with mortality

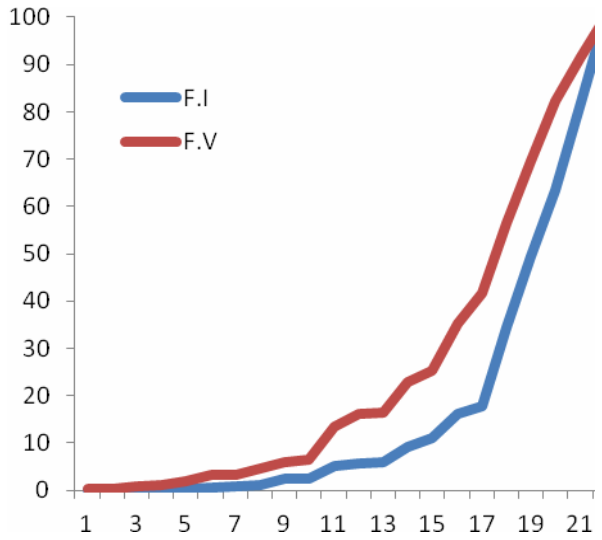
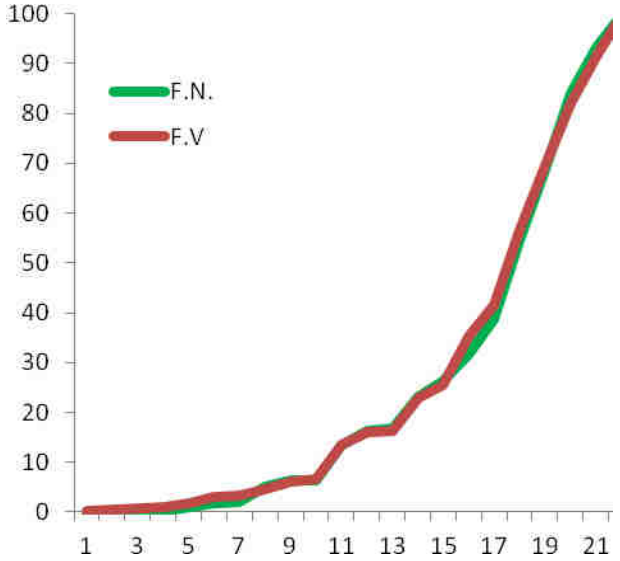
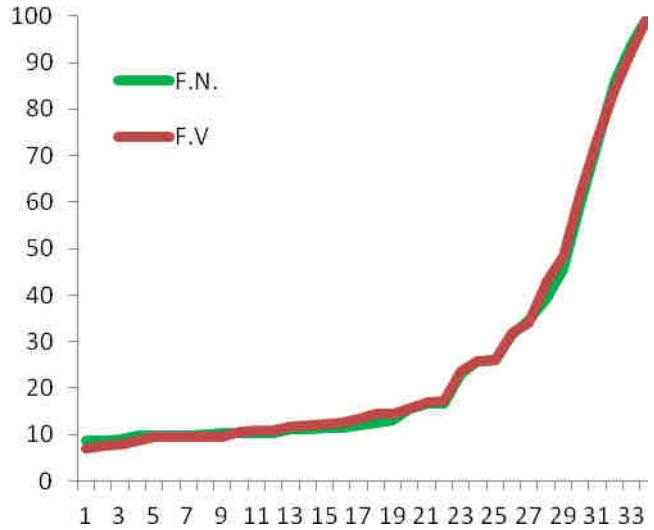
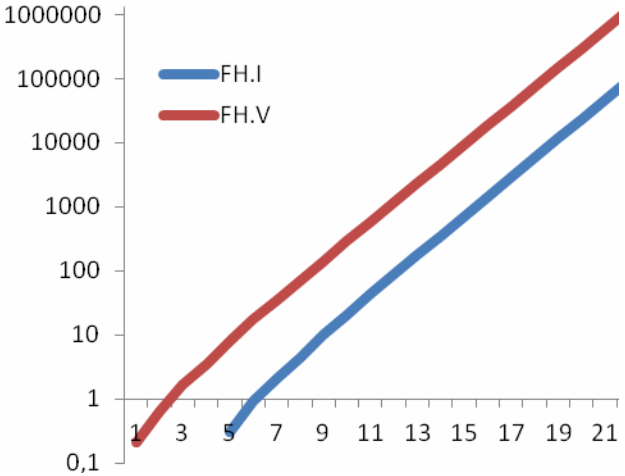
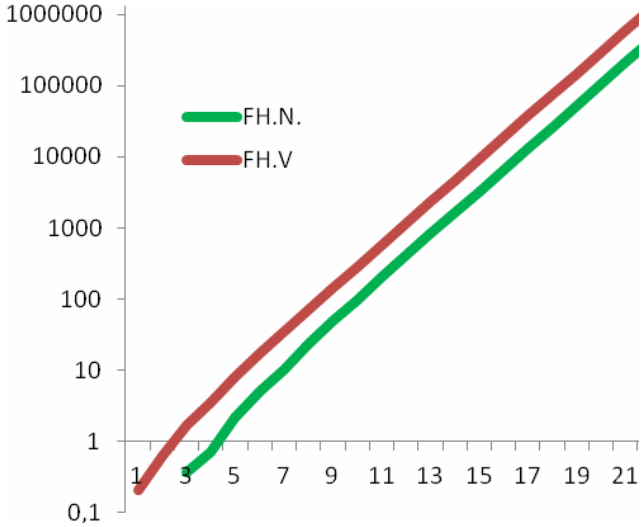
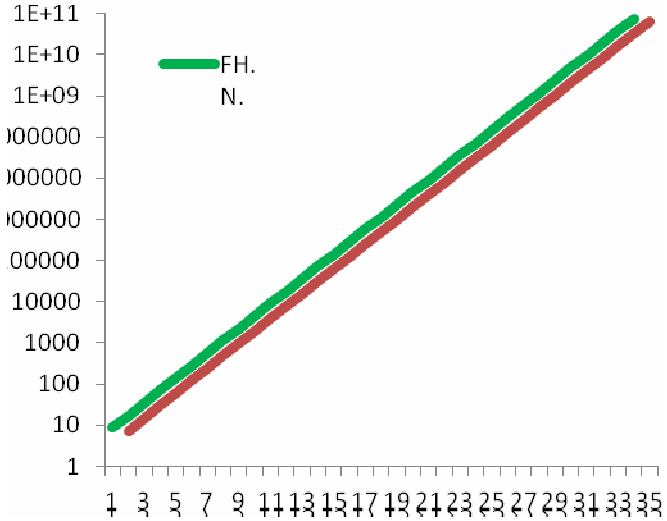


G.1b.Hammond cumulative distributions-life cycle perspective without mortality (logarithmic scale)

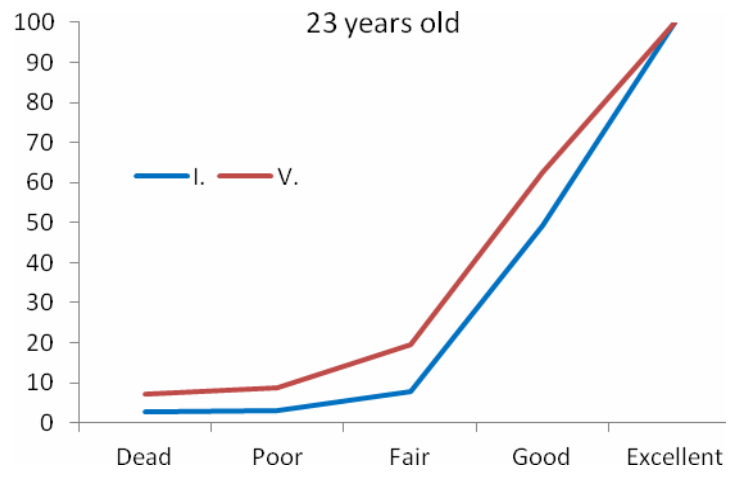


G.2b Hammond cumulative distributions-life cycle perspective with mortality (logarithmic scale)

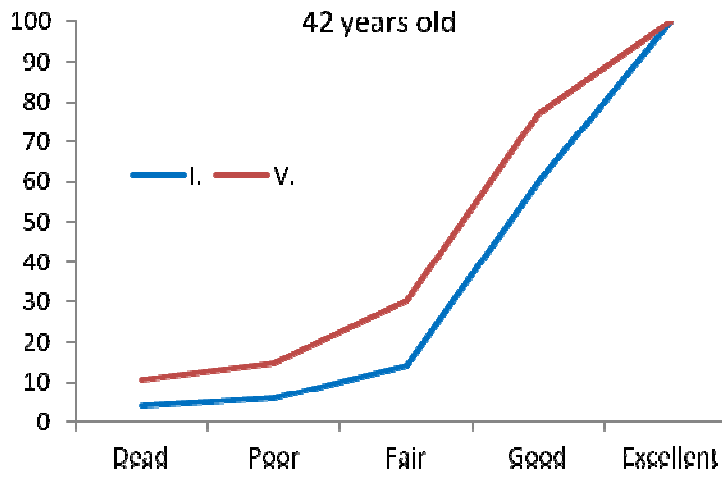


G.3a Cumul. distributions-life cycle perspective without mortality	G.4a.Cumul. distributions-life cycle perspective without mortality	G.5a Cumul. distributions-life cycle perspective with mortality
		
G.3b.Hammond cumul. distributions-life cycle perspective without mortality (logarithmic scale)	G.4b Hammond cumul. distributions-life cycle perspective without mortality (logarithmic scale)	G.5b Hammond cumul. distributions-life cycle perspective with mortality (logarithmic scale)
		

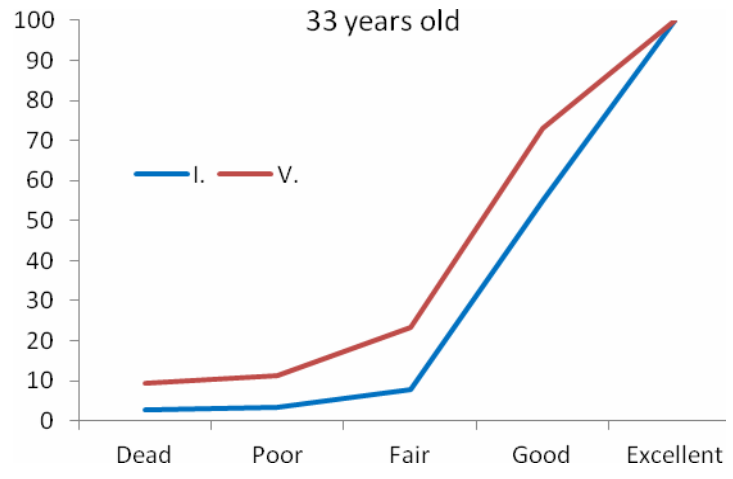
G.6a Cumul. distributions- 23 years old with mortality



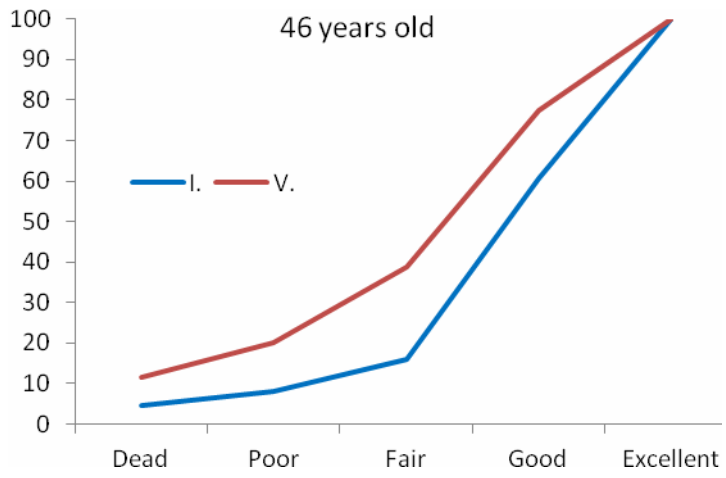
G.7a Cumul. distributions- 42 years old with mortality



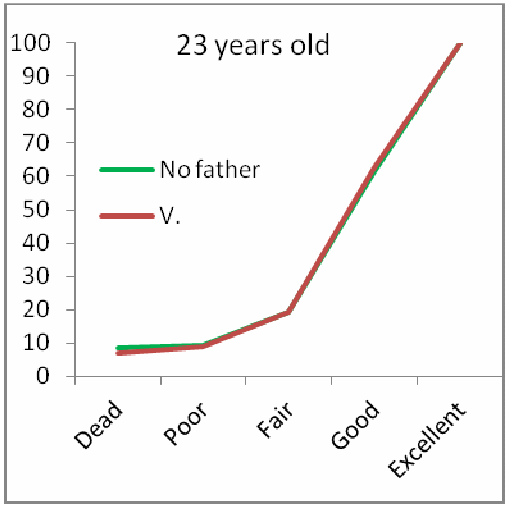
G.6a Cumul. distributions- 33 years old with mortality



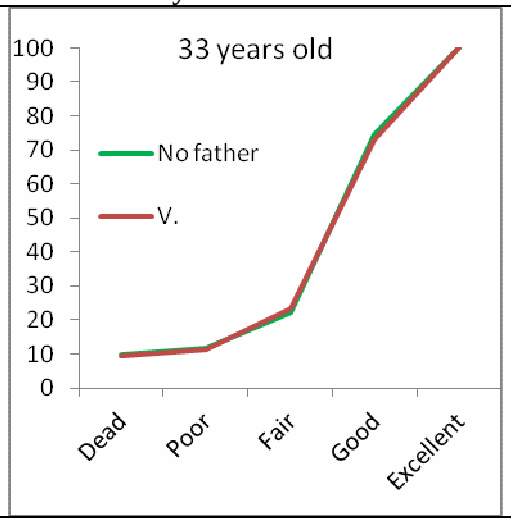
G.7b Cumul. distributions- 46 years old with mortality



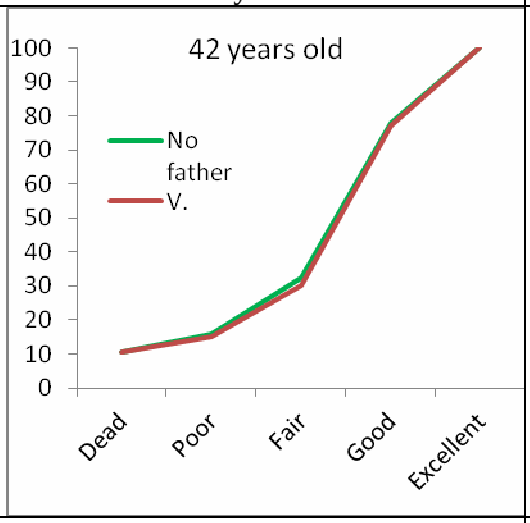
G.8a Cumul. distributions- 23 years old with mortality



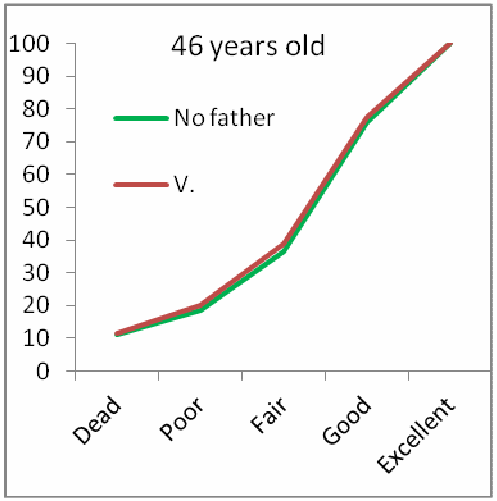
G.9a Cumul. distributions-33 years old with mortality



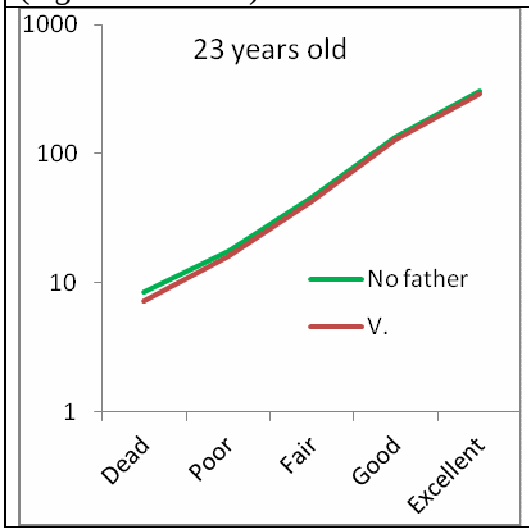
G.10a Cumul. distributions-42 years old with mortality



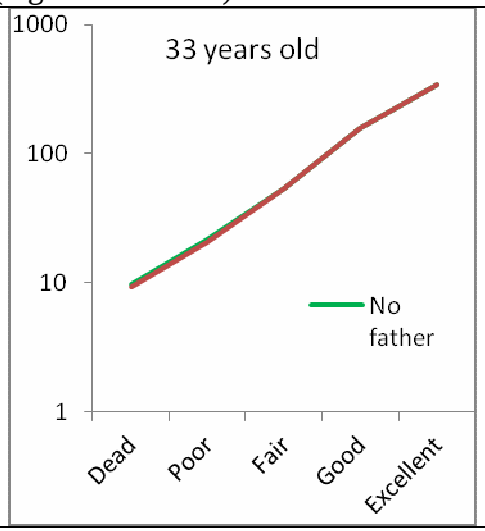
G.11a Cumul. distributions-42 years old with mortality



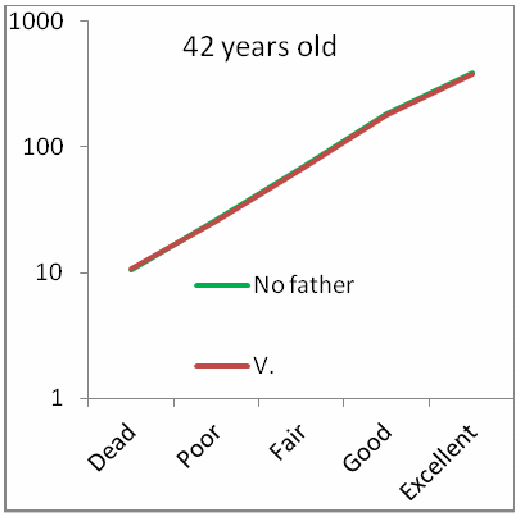
G.8b Hammond cumul. distributions- 23 years old with mortality (logarithmic scale)



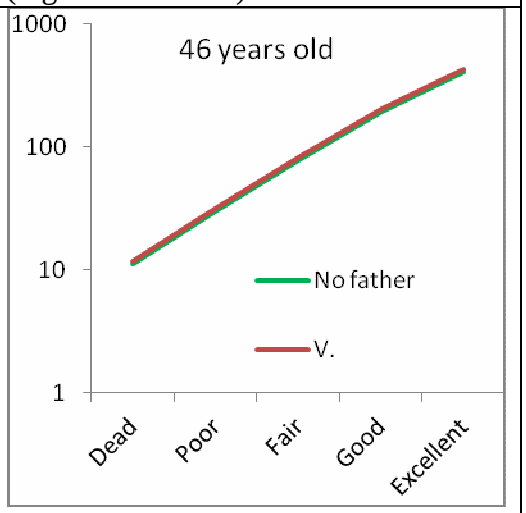
G.9b Hammond cumul. distributions- 33 years old with mortality (logarithmic scale)

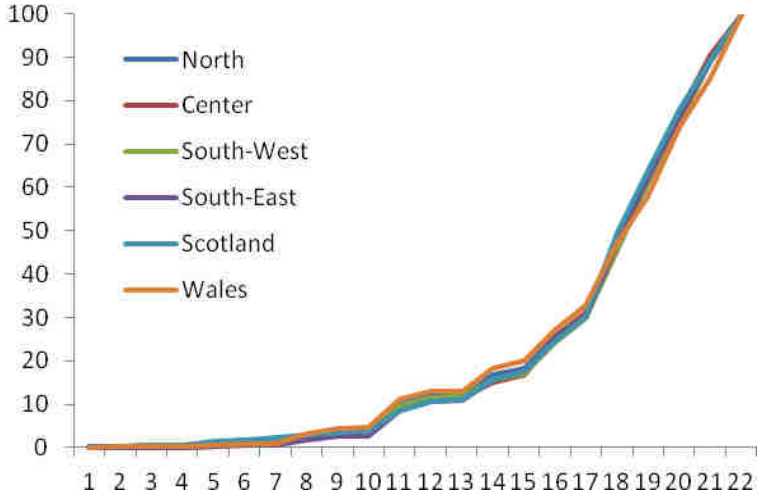
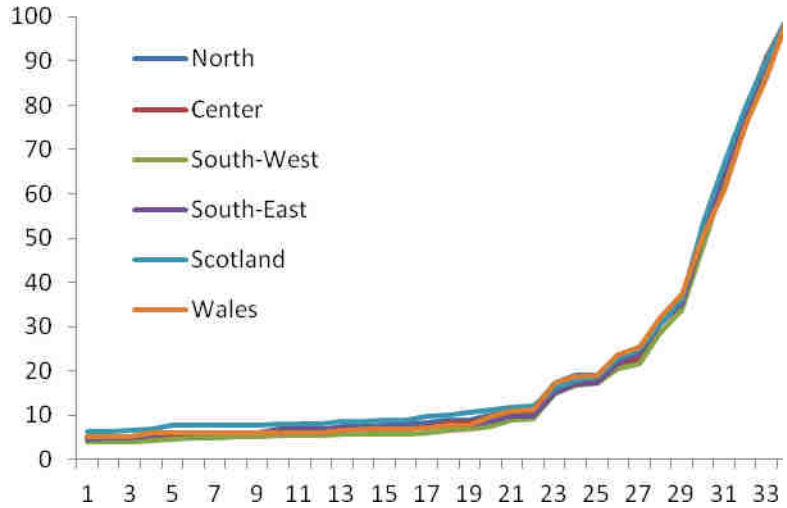


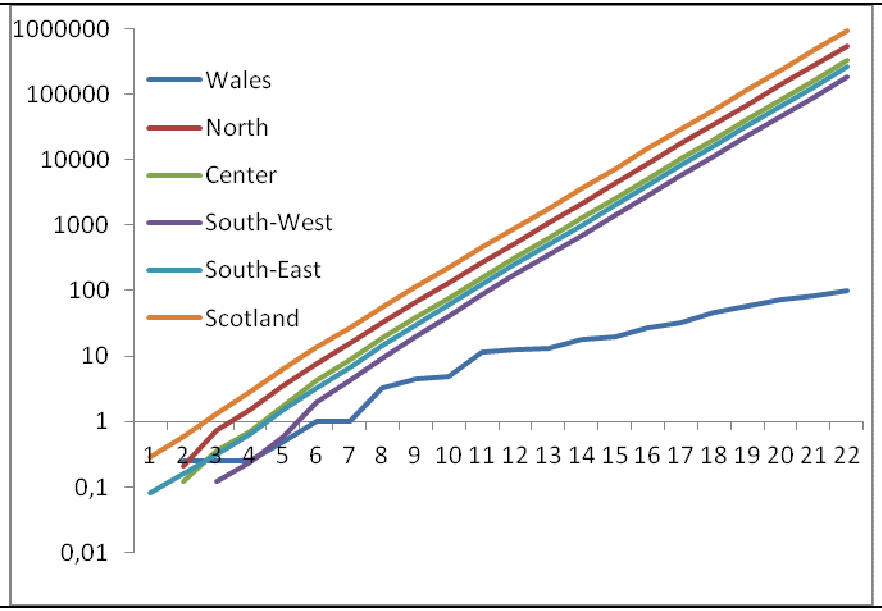
G.10b. Hammond cumul. distributions-42 years old with mortality (logarithmic scale)

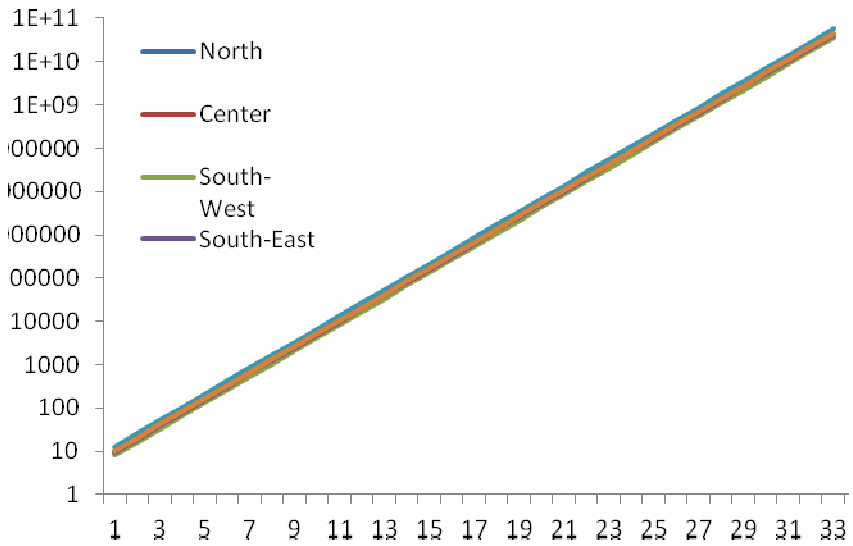


G.11b Hammond cumul. distributions- 42 years old with mortality (logarithmic scale)



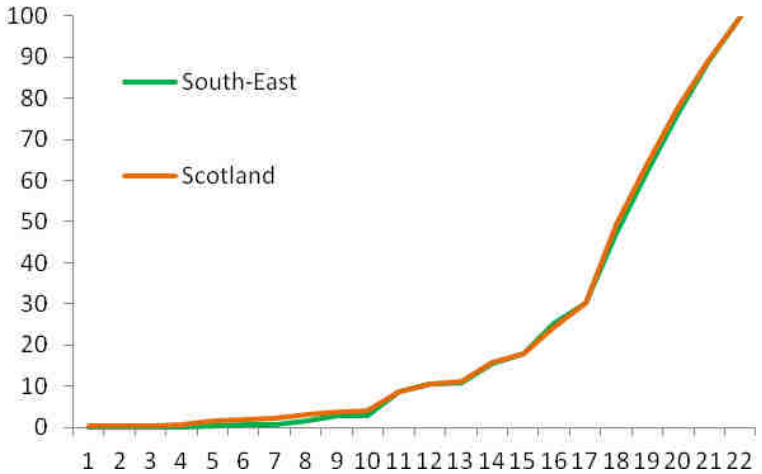
G.12a Cumulative distributions-life cycle perspective without mortality	G.13a Cumulative distributions-life cycle perspective with mortality
	
G.12bHammond cumulative distributions-life cycle perspective without mortality (logarithmic scale)	G.13b Hammond cumulative distributions-life cycle perspective with mortality (logarithmic scale)

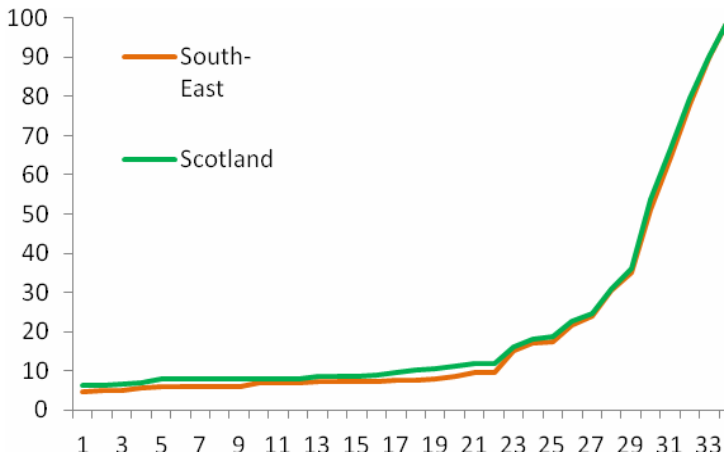




G.14a Cumulative distributions-life cycle perspective without mortality

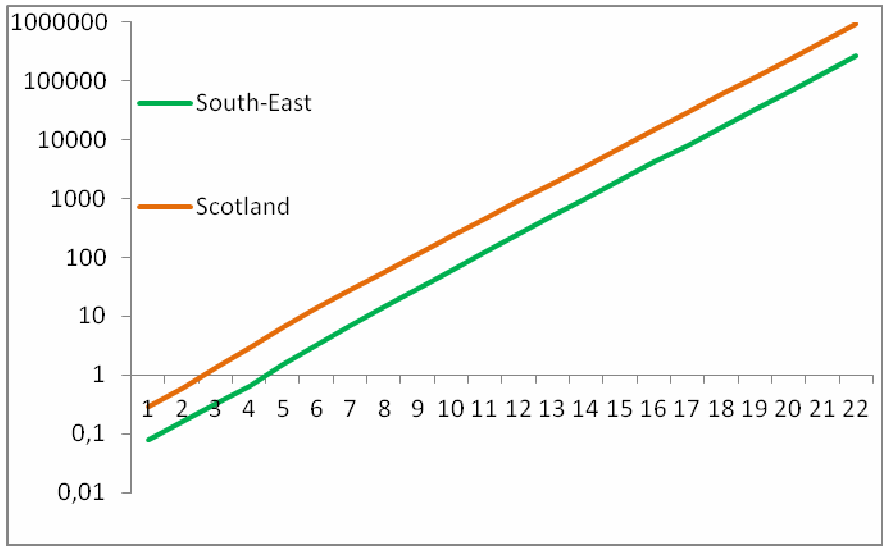
G.15a Cumulative distributions-life cycle perspective with mortality

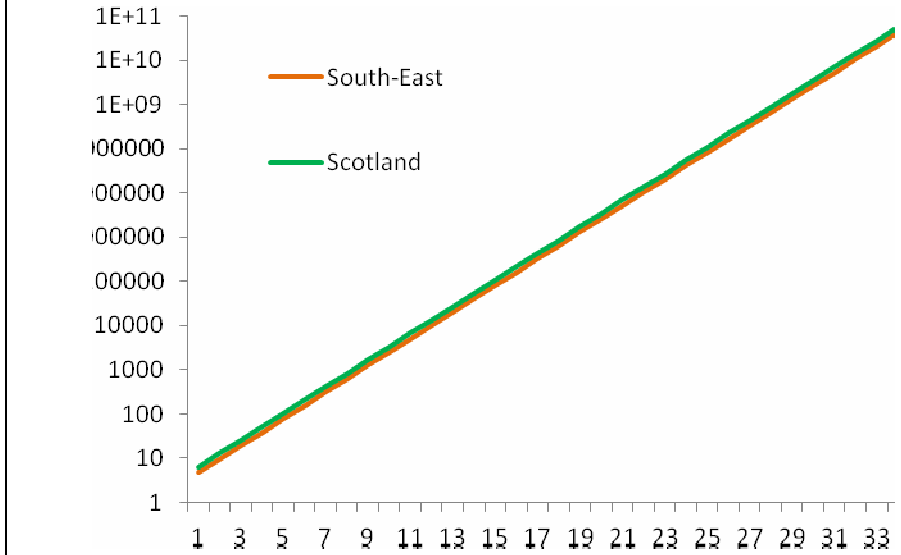


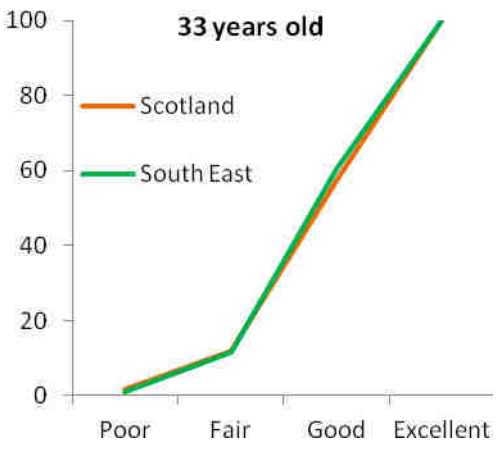
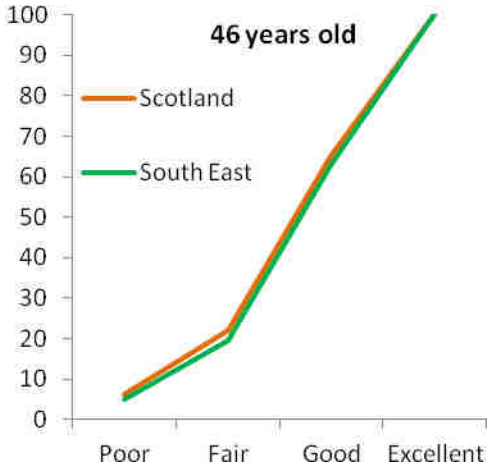


G.14b Hammond cumulative distributions-life cycle perspective without mortality (logarithmic scale)

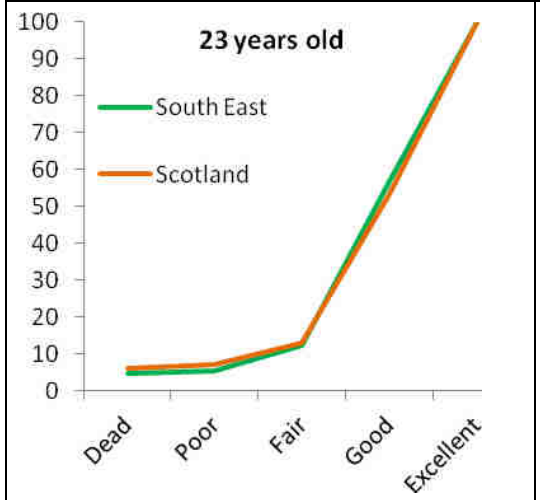
G.15b Hammond cumulative distributions-life cycle perspective with mortality (logarithmic scale)

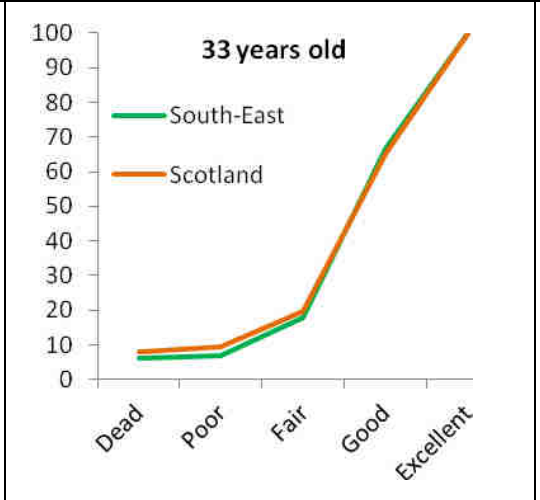


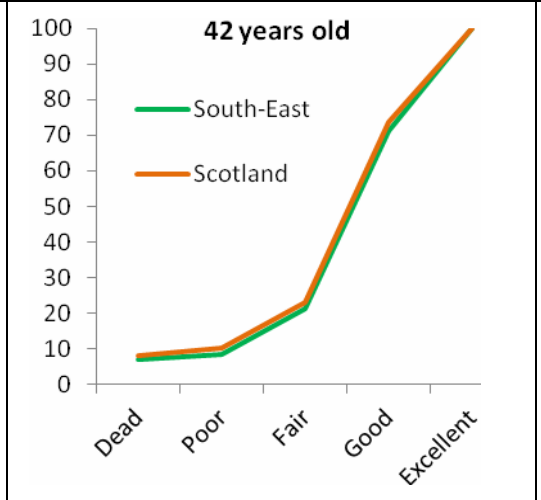


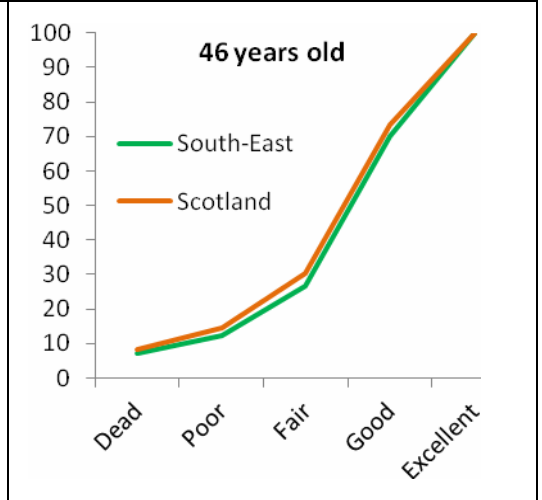
G.16a Cumul. distributions- 23 years old without mortality	G.17a Cumul. distributions-33 years old without mortality	G.18a Cumul. distributions-42 years old without mortality	G.19a Cumul. distributions-42 years old without mortality
			
G.16b.Hammond cumul. distributions-23 years old without mortality (log scale)	G.17b Hammond cumul. distributions-33 years old without mortality (log scale)	G.18b. Hammond cumul. distributions-42 years old without mortality (log scale)	G.19b Hammond cumul. distributions-42 years old without mortality (lo scale)

G.20a Cumul. distributions- 23 years old with mortality	G.21a.Cumul. distributions-33 years old with mortality	G.22a Cumul. distributions-42 years old with mortality	G.23a.Cumul. distributions-42 years old with mortality

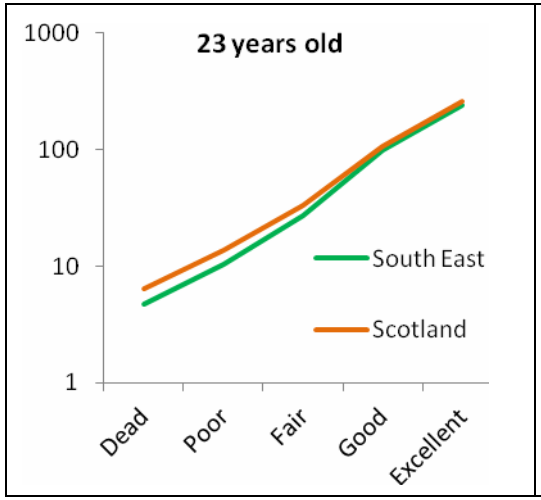


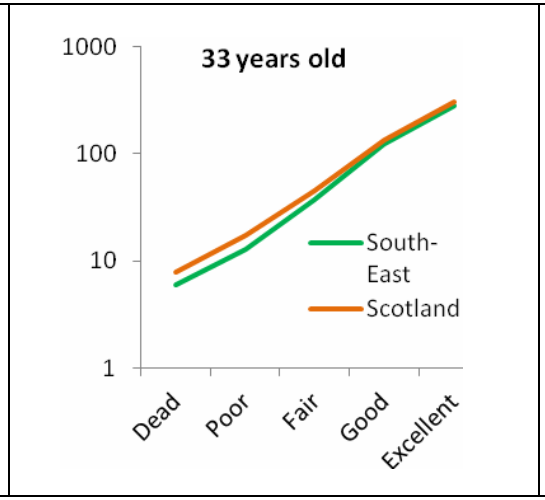


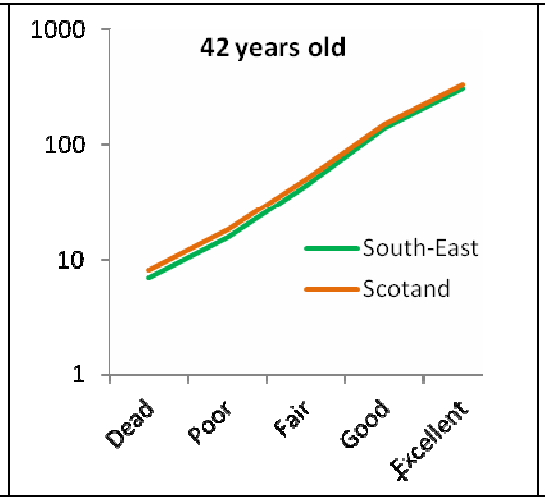


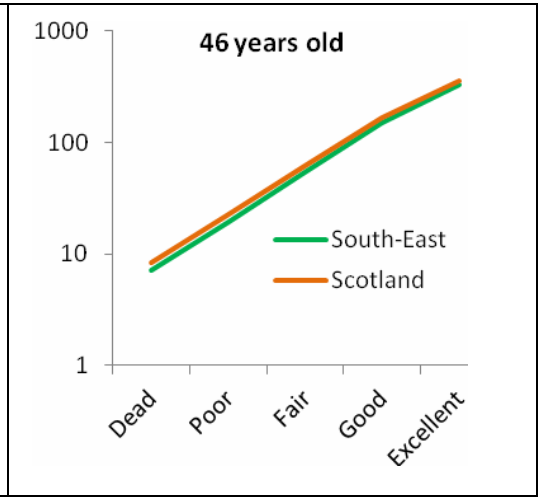


G.20b Hammond cumul. distributions- 23 years old with mortality (log scale)	G.21b Hammond cumul. distributions- 33 years old with mortality (log scale)	G.22b. Hammond cumul. distributions-42 years old with mortality (log scale)	G.23b Hammond cumul. distributions-42 years old with mortality (log scale)


23 years old
1000
100
10
1
South East
Scotland
Dead
Poor
Fair
Good
Excellent


33 years old
1000
100
10
1
South-
East
Scotland
Dead
Poor
Fair
Good
Excellent


42 years old
1000
100
10
1
South-East
Scotand
Dead
Poor
Fair
Good
Excellent


46 years old
1000
100
10
1
South-East
Scotland
Dead
Poor
Fair
Good
Excellent