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Longitudinal analysis of income-related health inequality

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ABSTRACT

This paper considers the characterisation and measurement of income-related health inequality using longitudinal data. The paper elucidates the nature of the Jones and López Nicolás (2004) index of "health-related income mobility" and explains the negative values of the index that have been reported in all the empirical applications to date. The paper further presents an alternative approach to the analysis of longitudinal data that brings out complementary aspects of the evolution of income-related health inequalities over time. In particular, we propose a new index of "income-related health mobility" that measures whether the pattern of health changes is biased in favour of those with initially high or low incomes. We illustrate our work by investigating mobility in the General Health Questionnaire measure of psychological well-being over the first nine waves of the British Household Panel Survey from 1991 to 1999.

1. Introduction

A strong relationship between socioeconomic status and health has been documented in numerous studies: for example, individuals with high income are healthier than those with low income (Benzeval and Judge, 2001; Deaton, 2003; Gerdtham and Johannesson, 2004). While there has been an increasing amount of literature on health inequality, income-related health inequality and its determinants (Wagstaff and Van Doorslaer, 2000), little attention has focused on measuring health mobility or whether the health of the poor is improving relative to the rich over time. This is an important issue since significant income-related inequalities in health have persisted, and even increased, in some western countries over the last decade in spite of considerable improvements in average health status (Van Doorslaer and Koolman, 2004). As a result, most European governments have recognised the need to tackle income-related health inequalities. For example, England is committed to reduce socioeconomic inequalities in infant mortality and life expectancy at birth by 10% from 1997 to 1999 baseline levels by 2010 (Department of Health, 2008).

The main measure of income-related health inequality within the health economics literature is the concentration index (Wagstaff and Van Doorslaer, 2000). This captures the extent to which good health in any period is concentrated among the rich compared to the poor and is equal to twice the covariance between health and income rank normalised by average health. Changes in the concentration index over time can be analysed in the manner of Wagstaff et al. (2003) or Gravelle and Sutton (2003) using repeated cross-sections, but it is not possible thereby to track the experience of individuals but only of groups, such as the poor, whose composition may change over time. To better understand the dynamics of health and income, longitudinal or panel data on individuals are required. For example, longitudinal data are required to distinguish between income-related health inequalities arising from chronic or persistent social disadvantage as opposed to those due to transitory episodes of both poverty and sickness, where the former would call for policies to tackle the structural problems that trap some individuals in deprivation and ill-health while the latter might demand measures such as improvements in acute health services or temporary welfare assistance.

In a pioneering paper on the use of longitudinal data to analyse income-related health inequalities, Jones and López Nicolás (2004; hereafter JLN) aim to explain the relationship between a set of T period-specific or short-run concentration indices CI^t ($t = 1, \ldots, T$) and the long-run concentration index CI^T obtained from

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income and health data averaged over all T periods. In particular, they propose an index of "health-related income mobility", modelled on Shorrocks' (1978) income mobility index, that measures the extent to which income-related health inequality is greater or smaller in the short-run than in the long-run. JLN illustrate the use of the index with data for the UK and it has since been employed in a number of other empirical studies (Lecluyse, 2006; Hernández-Quevedo et al., 2006; Brandrup and Kortt, 2007) using health data sets for Belgium, European Union member states and Australia respectively. All these studies report negative values for the health-related income mobility index, suggesting that income-related health inequality, unlike income inequality (see Wodon and Yitzhaki, 2003), is typically greater the longer the time span over which the measurements are taken. JLN use a numerical example to illustrate that negative values will arise if "individuals who are downwardly (income) mobile, in the sense that, in the long run, their income rank is lower than in the short run ... have a lower than average level of health in the short run, compared to individuals who are upwardly mobile" (JLN, p. 1019). However, it is not entirely obvious what this means in terms of the relationship between health and income as the mathematical properties of the measure are not self-evident.

The current paper makes two main contributions. First, the paper further elucidates the nature of the JLN index of health-related income mobility. In particular we show that the negative values of the index reported in the literature may be explained by the common unimodal shape of the income distribution (Chotikapanich, 2008) in conjunction with the strength of the positive association between income and health in the long-run compared to the short-run. Secondly, the paper develops a complementary approach to the analysis of longitudinal data that brings out other policy-relevant aspects of the evolution of health-related inequalities over time. In particular, we propose a new index of "income-related health mobility", based on a decomposition of the change in the short-run concentration index CI^t over time, which measures whether the pattern of relative health changes between two periods is biased in favour of those with initially low or high incomes. We illustrate our work, like JLN, by investigating mobility in the General Health Questionnaire (GHQ) measure of psychological well-being (Goldberg and Williams, 1988) over the first nine waves of the British Household Panel Survey (BHPS) from 1991 to 1999. The structure of the paper is as follows: Section 2 presents a critical review of the JLN mobility index. Section 3 presents our alternative mobility analysis and explores the properties of the proposed new indices. Section 4 summarises and concludes the paper.

2. A critical exposition of the JLN health-related income mobility index

We start by providing a brief outline of JLN's measurement framework in order to establish the basis for our subsequent analysis. JLN investigate the relationship between the set of T short-run CIs:

$$CI^t = \frac{2}{\bar{h}^t}\operatorname{cov}(h_{it}, R_i^t) = \frac{2}{N\bar{h}^t}\sum_i (h_{it} - \bar{h}^t)\left(R_i^t - \frac{1}{2}\right); \quad t=1,\ldots,T \tag{1}$$

and the long-run concentration index defined over all T periods,

$$CI^T = \frac{2}{\bar{\bar{h}}^T}\operatorname{cov}(h_i^T, R_i^T) = \frac{2}{N\bar{\bar{h}}^T}\sum_i (h_i^T - \bar{\bar{h}}^T)\left(R_i^T - \frac{1}{2}\right) \tag{2}$$

where h_{it} is a cardinal measure of health for individual $i (i = 1, \ldots, N)$ in period t, $\bar{h}^t$ is the average health of the population in period t, h_i^T is the average health of the individual over the T periods and $\bar{\bar{h}}^T$ is the average health of the population over all T periods[1]; R_i^t is the individual's relative rank in the period t income distribution and R_i^T is the individual's relative rank in the distribution of total income over all T periods.

JLN show that CI^T can be decomposed into a weighted sum of the CI^t's and a residual, which they denote "Term 2", that reflects the covariance between levels of health and fluctuations in income rank over time:

$$\begin{aligned} CI^T &= \sum_t w_t CI^t - \frac{2\sum_i\sum_t (h_{it} - \bar{h}^t)(R_i^t - R_i^T)}{NT\bar{\bar{h}}^T} \\ &= \sum_t w_t CI^t - \frac{2\sum_i\sum_t (h_{it} - \bar{\bar{h}}^T)(R_i^t - R_i^T)}{NT\bar{\bar{h}}^T} \end{aligned} \tag{3}$$

where the weights $w_t = N\bar{h}^t/NT\bar{\bar{h}}^T$ equal the share of the total health of all N individuals in time period t relative to the total health of all individuals in all T periods combined. JLN note that "Term 2" will be non-zero only if people switch income ranks over the T periods and these changes are related to health.

JLN use Eq. (3) to define a measure of "health-related income mobility" M that is modelled on Shorrocks' (1978) index of income mobility:

$$M = \frac{\sum_i w_t CI^t - CI^T}{\sum_i w_t CI^t} = \frac{((2/NT\bar{\bar{h}}^T)\sum_i\sum_t (h_{it} - \bar{\bar{h}}^T)(R_i^t - R_i^T))}{\sum_i w_t CI^t} \tag{4}$$

M is defined as the difference between the weighted average short-run and the long-run concentration indices, which is equal to "Term 2", normalised by the weighted average of the short-run concentration indices. JLN observe that M will differ from zero as a result of a systematic association between changes in the income rank of an individual and differences in health. The larger the difference between the weighted average short-run and the long-run inequality measures the larger the value of M. If there is no difference between the short-run and long-run inequality measures, then M equals zero.

Using the first nine waves of the BHPS, JLN employ the index to investigate the dynamics of income and mental health, as measured by a rescaled version of the GHQ measure of psychological well-being that is increasing in health.[2] They report a health-related income mobility index over the nine waves of −0.15 and −0.055 for men and women respectively, which implies that long-run income-related health inequalities are greater than would be inferred from the short-run cross-sectional measures alone. JLN show that such negative values arise when "individuals who are downwardly (income) mobile, in the sense that, in the long run, their income rank is lower than in the short run ... have a lower than average level of health in the short run, compared to individuals who are upwardly mobile" (JLN, p. 1019). But it is not clear if this condition is likely to hold in general or what it exactly implies about the nature of the dynamic relationship between health and income.

We argue below that one of the underlying reasons why the index has commonly been found to be negative is because individuals whose average short-run income position is better (worse) than their long-run position will tend to have lower (higher) than average long-run health. We further show that, even if this is the

[1] Note that JLN denote health as y. In contrast, we employ h, since we follow common practice in using y to represent income later in the paper.

[2] The GHQ measure is an (additive) Likert scale which can take values between 0 and 36 with higher values corresponding to worse states of mental health. JLN use (36-GHQ) to obtain a health measure that is increasing in good health.

case, then negativity of the JLN index additionally requires that the positive association between health and income be sufficiently stronger between individuals on average (i.e. in the long term) than for individuals over time (i.e. in the short term).

Our analysis is based on a further decomposition of M into two sub-components that result from the variation in the health of each individual over time and the variation in average health between individuals:

$$(h_{it} - \bar{\bar{h}}^T) = (h_{it} - h_i^T) + (h_i^T - \bar{\bar{h}}^T) \tag{5}$$

where h_i^T is the average health of individual i over the T periods. Hence M can be re-written from (4) as the sum of contributions due to health variation "within" and "between" individuals:

$$M = M^W + M^B = \sum_i v_i M^i + M^B \tag{6}$$

where the "within" individuals health-related income mobility index M^W is equal to the weighted sum of the individual indices:

$$M^i = \frac{2\sum_t (h_{it} - h_i^T)(R_i^t - R_i^T)/T}{h_i^T \sum_t w_t CI^t} = \frac{2\sum_t (h_{it} - h_i^T)(R_i^t - \bar{R}_i)/T}{h_i^T \sum_t w_t CI^t}; \quad i = 1, \ldots, N \tag{7}$$

with $\bar{R}_i = \sum_t R_i^t/T$ defined as the average of the individual's short-run income ranks and weights, v_i, equal to the ratio of each individual's total health over the T periods compared to that of all individuals:

$$v_i = \frac{Th_i^T}{TN\bar{\bar{h}}^T}; \quad i = 1, \ldots, N \tag{8}$$

and M^B is the "between" individuals health-related income mobility index:

$$M^B = \frac{2\sum_i \sum_t (h_i^T - \bar{\bar{h}}^T)(R_i^t - R_i^T)/NT}{\bar{\bar{h}}^T \sum_t w_t CI^t} = \frac{2\sum_i (h_i^T - \bar{\bar{h}}^T)(\bar{R}_i - R_i^T)/N}{\bar{\bar{h}}^T \sum_t w_t CI^t} \tag{9}$$

In principle both M^W and M^B could be either positive or negative with the signs of both indices typically determined by the signs of the numerators in (7) and (9) respectively, given that average health and the weighted average short-run concentration index are normally positive. It is likely, however, that M^W will generally be positive as there is typically a positive association between short-run movements in income and health. Hence the numerators in (7), which are defined for each individual as the covariance between health and income rank over time, will tend to be positive. In contrast, we would argue that M^B will generally be negative given the typical shape of the income distribution and the positive nature of the long-run association between health and income. To see why this is the case, note that the slope of a cumulative distribution or relative rank function (cdf) is given by the probability density function, so the cdf of the typically unimodal income distribution (see Chotikapanich, 2008) will be convex below the mode and concave above it. It follows from the stochastic nature of income and Jensen's inequality (Greene, 2008, p. 1046) that the average of the short-run income ranks of individuals with low (high) average incomes will typically be above (below) their long-run income rank (see Appendix A for further discussion). This combined with the assumption of a positive long-run association between health and income, results in both the poor and rich, in particular, contributing negatively to the numerator in (9), with the overall value of M^B likely being negative as a result.

In the light of our further decomposition we can interpret the numerical examples provided by JLN in Cases 2 and 3 as isolating the separate effects of health variation "within" and "between" individuals respectively. Specifically, they provide numerical examples that give rise to a positive value of $M = M^W$ in Case 2, in which all individuals have the same health on average in the long-run, and a negative value of $M = M^B$ in Case 3, in which all individuals have constant health over time. In practice, empirical data will reflect both "within" and "between" variation in health, with the resultant mobility index reflecting the combination of these effects. Given these effects will typically be opposing, what remains to be explained is why the "between" effect usually appears to dominate giving rise to the negative values of the mobility index reported in all empirical studies to date.

To investigate this issue we turn to the observation that the original Shorrocks' measure can not be negative given the convexity of the Gini coefficient (Shorrocks, 1978). Thus, if we define an (income-related) income mobility index S analogous to the (health-related) income mobility index M, by replacing health status h with income y in (1) through (4), then this index will be greater or equal to zero irrespective of the balance of income variation "within" and "between" individuals. To proceed further it is useful to define S^W and S^B in a similar manner to the definition of M^W and M^B in (6). The first point that can then be made is that the reason for positive values of S is not because the between individuals income mobility index S^B will be positive in this case, as the argument made above concerning the sign of M^B is equally applicable given that income and income ranks are positively correlated by definition. Furthermore, making use of the formulation of the Gini suggested by Milanovic (1997), we can write M^W and M^B as:

$$\begin{aligned} M^W &= \frac{M^W}{S^W} S^W = \left(\frac{2\sum_i \sum_t (h_{it} - h_i^T)(R_i^t - \bar{R}_i)/NT\bar{\bar{h}}^T}{2\sum_i \sum_t (y_{it} - y_i^T)(R_i^t - \bar{R}_i)/NT\bar{\bar{y}}^T} \right) \left(\frac{\sum_t s_t G_y^t}{\sum_t w_t CI^t} \right) S^W \\ &= \frac{\rho_h^W}{\rho_y^W} \left(\frac{\sigma_h^W/\bar{\bar{h}}^T}{\sigma_y^W/\bar{\bar{y}}^T} \right) \left(\frac{\sum_t s_t G_y^t}{\sum_t w_t CI^t} \right) S^W = R^W F^W \left(\frac{\sum_t s_t G_y^t}{\sum_t w_t CI^t} \right) S^W \end{aligned} \tag{10}$$

$$\begin{aligned} M^B &= \frac{M^B}{S^B} S^B = \left(\frac{2\sum_i (h_i^T - \bar{\bar{h}}^T)(\bar{R}_i - R_i^T)/N\bar{\bar{h}}^T}{2\sum_i (y_i^T - \bar{\bar{y}}^T)(\bar{R}_i - R_i^T)/N\bar{\bar{y}}^T} \right) \left(\frac{\sum_t s_t G_y^t}{\sum_t w_t CI^t} \right) S^B \\ &= \frac{\rho_h^B}{\rho_y^B} \left(\frac{\sigma_h^B/\bar{\bar{h}}^T}{\sigma_y^B/\bar{\bar{y}}^T} \right) \left(\frac{\sum_t s_t G_y^t}{\sum_t w_t CI^t} \right) S^B = R^B F^B \left(\frac{\sum_t s_t G_y^t}{\sum_t w_t CI^t} \right) S^B \end{aligned} \tag{11}$$

where

$$\rho_h^W = \left(\frac{\sum_i \sum_t (h_{it} - h_i^T)(R_i^t - \bar{R}_i)}{\sqrt{\sum_i \sum_t (h_{it} - h_i^T)^2} \sqrt{\sum_i \sum_t (R_i^t - \bar{R}_i)^2}} \right) \sigma_h^W = \sqrt{\sum_i \sum_t \frac{(h_{it} - h_i^T)^2}{NT}};$$

$$\rho_h^B = \left(\frac{\sum_i (h_i^T - \bar{\bar{h}}^T)(\bar{R}_i - R_i^T)}{\sqrt{\sum_i (h_i^T - \bar{\bar{h}}^T)^2} \sqrt{\sum_i (\bar{R}_i - R_i^T)^2}} \right); \qquad \sigma_h^B = \sqrt{\sum_i \frac{(h_i^T - \bar{\bar{h}}^T)^2}{N}};$$

and σ_y^W, ρ_y^W, σ_y^B and ρ_y^B are defined conformably with income replacing health; G_y^t and s_t are the income Gini and share of total income in each period; R^B and R^W are defined as ratios of correlation coefficients and will both equal +1 (−1) if health is a positive (negative) linear function of income alone, and will equal zero if there is no association between health and income; and F^B and F^W are defined as ratios of normalised measures of dispersion and will both be less (greater) than 1 if the variability in health is less (greater) than in income, and will equal 1 if the variability is the same.

It follows that M^B will only dominate M^W, leading to negative values of M, if $-R^BF^BS^B > R^WF^WS^W$. Given that $-S^B \leq S^W$ as Shorrocks' measure is non-negative, a necessary condition for this inequality to hold is that $R^BF^B/R^WF^W > 1$. R^B may in general be expected to be greater than R^W given that the relationship between health and income is likely to be stronger between individuals on average than for individuals over time: persistent health differences between individuals may well be associated with long-run or permanent income disparities whereas short-run movements in individual health may only be weakly associated with transitory income shocks (Benzeval and Judge, 2001). In contrast, it is not clear whether F^B will exceed F^W or, equivalently, whether the variation between individuals compared to within individuals is larger for health than for income, which will depend on the relative persistence of health compared to income.[3] We conclude that it is an empirical question as to whether our condition for M to be negative will hold in any particular sample, but that this has likely been the case in all the published studies using the JLN measure to date.

We illustrate our analysis by replicating the empirical application in JLN, which investigates mobility in the (rescaled) GHQ measure of psychological well-being for males over the first nine waves of the BHPS from 1991 to 1999. Our results differ slightly from those reported in JLN, possibly due to the use of an updated release of the BHPS data (University of Essex, Institute for Social and Economic Research, 2007),[4] though the differences are not of a substantive nature.

Table 1 is an expanded version of Table 8(a) in JLN, reporting income-related GHQ concentration and mobility indices for men only. Like JLN we find that "Term 2" and, thus, health-related income mobility, M, is negative in all waves after the first one, but we are able to further explain why this is the case. The first point to note is that M^W is positive in all waves, consistent with the existence of a positive association between health and income in the short-run. M is therefore negative because M^B is both negative and larger than M^W. Examining the decomposition of M^B by income class shows that the first and last quartile, the poor and rich respectively, contribute negatively in all waves as expected on the basis of the argument above concerning the shape of the income distribution and the positive long-run association between health and income. Indeed the contribution of all quartiles is negative in the later waves. Finally, the results from the Milanovic-type decomposition show that $R^B > R^W$ in all waves because, as expected, the association between health and income ranks is consistently stronger in the long-run than in the short-run. In contrast, $F^W > F^B$ in all waves, which is consistent with other evidence showing the greater persistence of disparities in income compared to those in the GHQ measure of psychological well-being (see Jarvis and Jenkins, 1998; Hauck and Rice, 2004 respectively).[5] Nevertheless $(R^BF^B)/(R^WF^W) > 1$ for all waves giving rise to the uniformly negative values of both "Term 2" and the mobility index M.

We conclude that the negative result obtained by JLN for their health-related income mobility measure is dependent not only on the typically unimodal shape of the income distribution but also on the strength of the positive association between income and health in the long-run compared to the short-run.

3. A new approach to the longitudinal analysis of income-related health inequalities

The particular value of the JLN index to health policy-makers is that it shows the persistence of income-related health inequalities. In particular the negative estimates that have been reported to date imply that long-term or chronic problems of income-related health inequalities are typically more severe than would be inferred from cross-sectional estimates. By implication, policies designed to tackle income-related health inequalities need to address structural problems that trap some individuals in deprivation and ill-health and not just deal with transitory episodes of poverty and sickness. However, it is important to recognise that the JLN index is symmetric in the sense of Yitzhaki and Wodon (2004) and therefore cannot be used to evaluate the success or otherwise of such polices as the value of the index is invariant to the ordering of the years. For example, the index will be unable to distinguish between equalising and disequalising income changes even though these have diametrically opposed implications for the level of income-related health inequality over time.[6] By way of illustration consider the case of three individuals A, B and C with health of 1, 2 and 3 and incomes of 10, 20 and 30 respectively in some initial period, such that income-related health inequality is a maximum given the observed health outcomes. If in the next period, the health of each individual remains the same but incomes are now 20, 15 and 30 then the concentration coefficient will fall as a result of A and B exchanging ranks in the period 2 income distribution. Nevertheless, A still has the lowest total income over the two periods and the JLN index will therefore be negative because, in period 2, A has a better short-run than long-run income position and below average health.[7] But the JLN index will also take the same value if the ordering of the periods is reversed even though income-related health inequality would then rise rather than fall over the two periods.

Moreover, the JLN measure is specifically an index of health-related income mobility, not of income-related health mobility, in that it will equal zero if there is no income mobility "regardless of whether there is health mobility" and, conversely, may not equal zero even if "there are no health changes" (see JLN, p. 1019). Thus, the JLN mobility index would equal zero in the preceding example if incomes had remained the same in both periods but health outcomes changed such that all three individuals had health equal to 2 in the second period, even though income-related health inequality would have dropped to zero. More generally, the index is uninformative on issues such as whether the health of those who were poor at a particular point in time is improving relative to the rich, which also is likely to be of interest to policy-makers.

To address these other aspects of the evolution of income-related health inequalities we develop a complementary analysis of longitudinal data based on the decomposition of the observed change in income-related health inequalities between two periods. Both Wagstaff et al. (2003) and Gravelle and Sutton (2003) have previously analysed changes in health inequalities over time using cross-sectional data. Wagstaff et al. (2003) show how a change in the concentration index between two periods is determined both by changes in the means and inequalities of the determinants of health and by changes in the effects of those

[3] Note that $F^B > F^W$ implies $(\sigma_h^B/\sigma_h^W) > (\sigma_y^B/\sigma_y^W)$.

[4] In particular, we obtain an additional six observations for males although we apply the sample restrictions reported in JLN.

[5] Note that this may not hold for other measures of health, such as self-reported health or the presence of limiting long-term illnesses, or for other countries or periods (see, for example, Contoyannis et al., 2004; Hernández-Quevedo et al., 2008; Halliday, 2008).

[6] Benabou and Ok (2001, p. 15) make a similar criticism of the Shorrocks measure on which JLN base their index.

[7] Note that in period 2, B has a worse short-run than long-run income position but this does not contribute to the value of the index as she has the average health.

Table 1
Income-related GHQ concentration and mobility indices (males).

	BHPS wave	1	2	3	4	5	6	7	8	9
SR concentration index	CI^t	0.01017	0.00600	0.00550	0.00402	0.00504	0.00769	0.00745	0.00407	0.00868
LR concentration index	CI^T	0.01017	0.00843	0.00739	0.00644	0.00634	0.00667	0.00692	0.00706	0.00744
Weighted sum of CI^ts	$\sum_t w_t CI^t$	0.01017	0.00810	0.00723	0.00643	0.00615	0.00641	0.00656	0.00625	0.00652
"Term 2"		0	−0.00033	−0.00016	−0.00001	−0.00019	−0.00026	−0.00036	−0.00081	−0.00092
JLN mobility index	M	0	−0.04076	−0.02163	−0.00131	−0.03116	−0.04026	−0.05525	−0.12946	−0.14184
"Within" mobility index	M^W	0	0.01328	0.02498	0.06495	0.06165	0.06696	0.05951	0.01593	0.02768
"Between" mobility index	M^B	0	−0.05403	−0.04661	−0.06626	−0.09282	−0.10722	−0.11477	−0.14538	−0.16952
Decomposition of M^B by income class[a]										
1st income quartile		–	−0.02384	−0.04329	−0.05249	−0.04913	−0.05518	−0.06379	−0.07307	−0.07520
2nd income quartile		–	−0.00638	−0.00685	0.00312	−0.01050	0.00164	−0.00590	−0.01234	−0.02572
3rd income quartile		–	−0.01534	0.01781	0.02349	0.01558	0.00701	−0.00716	−0.01499	−0.01444
4th income quartile		–	−0.00847	−0.01427	−0.04038	−0.04876	−0.06069	−0.03792	−0.04498	−0.05415
Results from the Milanovic-type decomposition of M^W and M^B										
"Between" correlation coefficient ratio	R^B	–	0.1076	0.0536	0.0579	0.0686	0.0775	0.0814	0.0938	0.1091
"Within" correlation coefficient ratio	R^W	–	0.0073	0.0085	0.0164	0.0134	0.0142	0.0123	0.0030	0.0052
"Between" normalised dispersion ratio	F^B	–	0.2922	0.2897	0.2854	0.2858	0.2841	0.2827	0.2827	0.2813
"Within" normalised dispersion ratio	F^W	–	0.5121	0.4686	0.4643	0.4524	0.4489	0.4477	0.4467	0.4387
	$R^B F^B / R^W F^W$	–	8.4041	3.9212	2.1731	3.2253	3.4560	4.1806	19.9201	13.4592

[a] *Notes*: The contribution of each income quartile to M^B is calculated by summing the numerator of the index in (9) over only those individuals who belong to that quartile and then dividing through by the denominator. The sum of the contributions over all quartiles is equal to M^B by construction.

determinants on health. Gravelle and Sutton (2003) implement a similar approach that accounts for changes in the concentration index of directly standardized health in terms of changes in the share of health attributable to income and changes in income inequality. However, as previously argued, there are important aspects of income-related health inequality changes that are not revealed by examining changes in cross-sectional data over time. For example, examining the change in the cross-sectional concentration index does not pick up any change when individuals swap both health and income ranks among each other as in JLN's Case 2. By extension, it is not possible to determine to what extent a fall in income-related health inequality over time might be due to a relative improvement in the health of those who were initially poor as opposed to an improvement of their position in the income distribution, where the former might be due to healthcare interventions targeted at the poor and the latter to broader changes in welfare/income provision and economic conditions.

Our new approach is based on the observation that any change in income-related health inequality over time must arise from some combination of changes in health outcomes (i.e. "health mobility") and changes in individuals' positions in the income distribution (i.e. "income (rank) mobility"). By decomposing the change in the concentration index between two periods, we provide an index of income-related health mobility that captures the effect on cross-sectional income-related health inequality of the relationship between relative health changes and individuals' initial level of income. Thus, the index addresses the question of whether the pattern of health changes favour those with initially low or high incomes, providing a natural counterpart to measures of income-related health inequality that address the issue of whether those with better health tend to be the poor or rich. In addition, like JLN, we obtain an index of health-related income mobility which in this case captures the effect of the reshuffling of individuals within the income distribution on cross-sectional socioeconomic inequalities in health.

Accordingly, we decompose the change in the short-run CI between any initial or start period s and any final period f into two parts:

$$\begin{aligned} CI^f - CI^s &= \frac{2}{\bar{h}^f}\mathrm{cov}(h_{if}, R_{if}) - \frac{2}{\bar{h}^s}\mathrm{cov}(h_{is}, R_{is}); \quad s, f = 1, \ldots, T; \ s \le f \\ &= \left(\frac{2}{\bar{h}^f}\mathrm{cov}(h_{if}, R_{if}) - \frac{2}{\bar{h}^f}\mathrm{cov}(h_{if}, R_{is})\right) \\ &\quad + \left(\frac{2}{\bar{h}^f}\mathrm{cov}(h_{if}, R_{is}) - \frac{2}{\bar{h}^s}\mathrm{cov}(h_{is}, R_{is})\right) \\ &= (CI^f - CI^{fs}) + (CI^{fs} - CI^s) \\ &= M^R - M^H \end{aligned} \tag{12}$$

where CI^s and CI^f are the CI's in periods s and f respectively, and CI^{fs} is the CI obtained when health outcomes in the final period are ranked by income in the initial period. This decomposition is analogous to that provided by Kakwani (1984) of the redistributive effects of taxation, which is generalised to the S-Gini class of indices by Jenkins and Van Kerm (2006) in their analysis of income mobility.

In (12), the index $M^H = (CI^s - CI^{fs})$ provides a measure of income-related health mobility, which captures the effect of the relationship between relative health changes and individuals' initial level of income. M^H is positive (negative) if health changes are progressive (regressive) in the sense that the poorest individuals either enjoy a larger (smaller) share of total health gains or suffer a smaller (larger) share of total health losses compared to their initial share of health, and equals zero if relative health changes are independent of income or there are no health changes. M^H in turn depends on the progressivity and scale of health changes:

$$\begin{aligned} M^H \quad M^H &= (CI^s - CI^{fs}) = \left(\frac{2}{\bar{h}^s}\mathrm{cov}(h_{is}, R_{is}) - \frac{2}{\bar{h}^f}\mathrm{cov}(h_{if}, R_{is})\right) \\ &= \left(\frac{2}{\bar{h}^s}\mathrm{cov}(h_{is}, R_{is}) - \frac{2}{\overline{\Delta h}}\mathrm{cov}(h_{if} - h_{is}, R_{is})\right)\left(\frac{\overline{\Delta h}}{\bar{h}^f}\right) \\ &= (CI^s - CI^{\Delta s})\left(\frac{\overline{\Delta h}}{\bar{h}^f}\right) = Pq \end{aligned} \tag{13}$$

where $CI^{\Delta s}$ is the concentration coefficient of health changes ranked by initial period income[8] and $\overline{\Delta h} = \bar{h}^f - \bar{h}^s$ is the average

[8] Note that $C^{\Delta s}$ will be negative (positive) if individuals with low initial incomes experience a larger (smaller) share of total health gains or losses than those with

age health change between the two periods. Progressivity is captured by the Kakwani (1977)-type disproportionality index $P = (CI^s - CI^{\Delta s})$. For any given P, the gross impact on final period income-related health inequalities is proportional to the scale of health changes, $q = \overline{\Delta h}/\bar{h}^f$, measured as the ratio of average health changes to average final period health. Thus, P can provide a useful measure of the performance of health improvement programmes in targeting the poor: a given reduction in income-related health inequality can be achieved either by a small-scale but highly targeted intervention to improve the health of the very poor or by a larger scale but broader health programme. The impact of welfare programmes may also be progressive if the payment of income support to the poor results in contemporaneous improvements in health. Note that if the average health change is negative, then P will be negative (positive) if health depreciation is progressive (regressive) such that relative health losses tend to be larger (smaller) for rich individuals than poor ones.

However, the income-related health mobility index M^H will not generally equal the change in income-related health inequality because it does not allow for the effect of changes in the ranking of individuals in the income distribution between the initial and final periods. This effect is captured by the health-related income mobility index $M^R = CI^f - CI^{fs}$, which is analogous to the re-ranking index proposed by Atkinson (1980) and Plotnick (1981) but may be negative since the concentration index of final period health outcomes ranked by initial income can exceed that ranked by final income. The impact on income-related health inequality of health interventions targeted at the poor will be diminished to the extent that health improvements lead to contemporaneous increases in income (rank), though this may not necessarily be an undesirable outcome. Conversely, welfare programmes may reduce inequality due to re-ranking if recipients move up the income distribution and income (rank) gains are not matched by contemporaneous improvements in health. Note that M^R will be equal to zero if final period health is uncorrelated with changes in income rank, irrespective of the degree of reshuffling of individuals in the income distribution, or if there are no changes in income rank.

To illustrate our proposed approach we repeat the preceding application to the male BHPS data on the above (rescaled) GHQ measure, treating Wave 1 as the initial period throughout and considering the implications of lengthening the time span over which the change in socioeconomic inequality is measured. Table 2 shows that both average health and income-related health inequality were highest in Wave 1, though there was no clear trend in either measure over subsequent waves. The decline in average health is not unexpected given the balanced nature of the panel. The decline in income-related health inequality implies that the change in inequality between Wave 1 and each subsequent wave was negative. The decomposition of this change reveals three main points of interest. First the index of income-related health mobility M^H is positive over all time spans implying that the relationship between relative health changes and individuals' initial level of income had the effect of reducing socioeconomic inequalities in health. Accordingly, health depreciation may be deemed to have been progressive, with the negative value of the progressivity index P implying that the concentration of health losses among the better-off in Wave 1 was greater than the concentration of their initial health. Second, the health-related income mobility index M^R is positive for comparisons across all but one wave as final health generally had a higher correlation with final than initial income rank, which implies that current health was more strongly related to contem-

high incomes, and will equal zero for a universal flat-rate gain or loss.

Table 2
Decomposition of changes in income-related health inequality from Wave 1 (males only).

	BHPS wave	1	2	3	4	5	6	7	8	9
Average health	$\bar{h}^t$	26.00	25.68	25.77	25.73	25.74	25.59	25.60	25.55	25.69
Health concentration index	CI^t	0.0102	0.0060	0.0055	0.0040	0.0050	0.0077	0.0074	0.0041	0.0087
Average health change	$\overline{\Delta h}$	–	−0.3171	−0.2324	−0.2646	−0.2641	−0.4108	−0.3979	−0.4529	−0.3107
Concentration index of health changes based on initial income ranks	$CI^{\Delta s}$	–	0.5340	0.8244	0.7362	0.6138	0.4697	0.3233	0.3084	0.3908
Concentration index of health changes based on final income ranks	$CI^{\Delta f}$	–	0.4990	0.6758	0.4948	0.4113	0.3128	0.2846	0.3692	0.1412
Change in inequality	$CI^f - CI^s$	–	−0.0042	−0.0047	−0.0061	−0.0051	−0.0025	−0.0027	−0.0061	−0.0015
Change decomposition analysis										
Income-related health mobility	M^H	–	0.0065	0.0073	0.0075	0.0062	0.0074	0.0049	0.0053	0.0046
Progressivity index	P	–	−0.5238	−0.8142	−0.7260	−0.6036	−0.4595	−0.3131	−0.2983	−0.3807
Scale factor	q	–	−0.0123	−0.0090	−0.0103	−0.0103	−0.0161	−0.0155	−0.0177	−0.0121
Health-related income mobility	M^R	–	0.0023	0.0027	0.0013	0.0011	0.0049	0.0021	−0.0008	0.0031
Alternative change decomposition analysis										
Income-related health mobility	$M^H_\#$	–	0.0060	0.0060	0.0050	0.0041	0.0048	0.0042	0.0064	0.0016
Progressivity index	$P_\#$	–	−0.4930	−0.6703	−0.4907	−0.4063	−0.3052	−0.2772	−0.3651	−0.1326
Scale factor	$q_\#$	–	−0.0122	−0.0089	−0.0102	−0.0102	−0.0158	−0.0153	−0.0174	−0.0120
Health-related income mobility	$M^R_\#$	–	0.0018	0.0013	−0.0012	−0.0010	0.0023	0.0015	0.0003	0.0001

poraneous income than to lagged incomes.[9] The effect of income re-ranking was therefore typically to exacerbate income-related health inequalities compared to what they would have been otherwise, since those who moved up the income ranking tended to be healthier in the final period compared to those who moved down. Finally, health rather than income rank changes accounted for the major part of the overall change in income-related health inequality observed over the period. Thus, the disequalising effect of income re-ranking was never enough to reverse the progressive nature of health changes, with inequality higher in the first wave than in any subsequent wave.

Finally, we note that our decomposition is not unique given the familiar index number problem.[10] The particular attraction of our chosen decomposition is that it yields a measure of income-related health mobility that can be used for the ex ante evaluation of performance of health interventions in tackling health inequalities. It may also be of interest, however, to obtain alternative perspectives on the co-evolution of health and income by adding and subtracting reference statistics other than CI^{fs} in (12). In particular, replacing CI^{fs} with CI^{sf}, the CI of health outcomes in the initial period ranked by final period income, yields the parallel decomposition:

$$\begin{aligned} CI^f - CI^s &= (CI^{sf} - CI^s) + (CI^f - CI^{sf}) = M^R_\# - M^H_\# \\ &= (CI^{sf} - CI^s) - (CI^{\Delta f} - CI^f)\left(\frac{\overline{\Delta h}}{\bar{h}^s}\right) = M^R_\# - P_\# q_\# \end{aligned} \qquad (14)$$

where $M^R_\#$ captures the redistributive effect of income rank changes weighted by initial health status and $M^H_\#$ the effect of the relationship between relative health changes and individuals' final level of income. The income-related health mobility index $M^H_\#$ may in turn be expressed as the product of the progressivity of changes based on final income rankings $P_\#$ and the scale of health changes relative to initial health $q_\#$, where $CI^{\Delta f}$ is the concentration coefficient of health changes ranked by final period income. $M^H_\#$ may be used for the ex post evaluation of healthcare interventions and also provides an appropriate basis for the evaluation of marginal changes to policies (for example, to consider the potential impact on the final concentration index for a marginal change in the benefit of a healthcare intervention).

The lower panel of Table 2 provides results of this alternative decomposition analysis, which show that the effect of health changes over the period had the effect of reducing income-related health inequalities, implying that health changes were progressive from an ex post as well as an ex ante perspective. The negative value of the progressivity index $P_\#$ implies that those who were poor in the final period had experienced smaller relative health losses compared to the rich. The effects of income rank changes were again typically disequalising as initial health in general had a higher correlation with final rather than initial income rank, which indicates that current income was less strongly related to current health than to lagged health. By implication, those who moved up the income ranking tended to be healthier in the initial period compared to those who moved down.

For this study the results are largely invariant to the choice of perspective, though the impact of health changes on income-related health inequalities is typically weaker from an ex post rather than an ex ante perspective. More generally, the extent to which the two perspectives will differ will depend on the specific nature of the dynamic relationship between the health and income measures.

[9] It is readily shown from Milanovic (1997) that $CI^f > CI^{fs}$ implies $corr(h_{if}, R_{if}) < corr(h_{if}, R_{is})$.

[10] We are grateful to an anonymous referee for pointing out the significance of the issue in this context. See also Lerman and Yitzhaki (1995).

4. Conclusions

The characterisation and measurement of the evolution of income-related health inequalities in a population over time is important for the design and evaluation of policies to reduce such inequality. This study has extended a key paper in the literature by demonstrating that the common negative value of the JLN health-related income mobility index is likely to be explained by the stronger positive association between permanent, income and health disparities across individuals than between short-run income changes and movements in individual health, given the common unimodal shape of the income distribution.

The JLN index provides important information about the extent to which cross-sectional estimates of income-related health inequalities understate the underlying level of long-run income-related health inequalities. This study has presented an alternative approach to the analysis of longitudinal data that brings out complementary aspects of the evolution of income-related health inequalities over time. The particular attraction of our proposed mobility indices is that they are able to distinguish between equalising and disequalising health and income changes, since the indices are sensitive to the ordering of the years. Our decomposition of changes in income-related health inequality into income-related health mobility and health-related income mobility provides a useful indication of the mechanisms underlying the evolution of inequalities and may indicate potential points of intervention. In particular, the income-related health mobility index is useful for evaluative purposes in that it can serve to identify whether health changes are progressive or regressive and, thereby, determine which members of society are the winners and losers from different health policies. Moreover, the health-related income mobility index will reflect the extent to which health-related welfare or insurance payments have served to protect those with poor health from moving down the income rank given that better income insurance policies will serve to reduce health inequalities (Deaton, 2003).

Our illustrative analysis of this new approach investigates mobility in the (rescaled) GHQ measure of psychological well-being for males over the first nine waves of the BHPS. We find that the observed fall in income-related health inequalities from Wave 1 was largely due to income-related health changes rather than health-related income rank changes. Health changes in the sample were found to be progressive, whether ranked by initial or final income, but were partially offset by the disequalising effect of income rank changes. Taken at face value, the progressivity of the health changes in this sample might reflect that disparities in healthcare provision or outcomes have declined over the sample period. It would be premature, however, to try to draw such policy-relevant conclusions because the results are based on a balanced panel and socioeconomic health differentials may be expected to have changed over the period simply due to the ageing of the sample (Kiula and Mieszkowski, 2007) or, in other words, health depreciation may be naturally progressive. Moreover, the progressivity index is likely to be biased upward due to non-random sample selection given that the sample excludes those surveyed in Wave 1 and dead before Wave 9, who are disproportionately likely to have been among the poor in Wave 1.

In future research, we aim to develop our methodology further to account for the affect of mortality on income-related health inequalities and standardize our measures to control for factors such as age and other demographic characteristics. This will allow us to benchmark one country's performance against another in terms of addressing income-related health inequalities over time. It also opens up the possibility to model and evaluate the effectiveness of specific interventions on reducing income-related health inequalities.

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Appendix A. Technical note on why M^B may generally be negative

We first explain why, when the income distribution takes a common unimodal shape, those with low (high) incomes will tend to have a long-run rank which is lower (higher) than the average of their short-run ranks in the absence of income growth. We then consider the implications of income growth and show why it may still be reasonable to assume in most cases that M^B will be negative.

Note that the slope of the cumulative distribution or relative rank function (cdf) is given by the probability density function. Hence, for a unimodal distribution, the cdf will be convex below the mode and concave above it, as shown in Fig. 1. Assume $T = 2$ for simplicity (all arguments readily generalise to $T > 2$). Consider the case where individuals experience income fluctuations but where the income distribution is stable over time (so there is a single cdf, common to each period and the long-run average). For poor (rich) individuals, with incomes in both periods below (above) the mode, it follows immediately from Jensen's inequality that the average of the short-run ranks will be above (below) the long-run income rank. This is illustrated in Fig. 1 where the average of the short-run ranks (A) for a poor individual is above her long-run rank (B), such that she will contribute negatively to M^B if her long-run health is below the population average. The above argument relies on the assumption that most income fluctuations are relatively short-range in nature, which is supported by the empirical evidence (see e.g. Jarvis and Jenkins, 1998). Note that if the income distribution was bimodal not unimodal, such that the cdf of the income distribution was instead concave at low incomes and convex at high incomes then the opposite result would arise with poor (rich) individuals tending to have an average short-run rank lower (higher) than their long-run rank.

To consider the impact of income growth in the unimodal case, first note that the above argument continues to hold if growth is uniform in absolute terms as this will merely result in a parallel shift in the cdf over time and, thus, not change the concavity/convexity of the cdf at different income ranks. However, the more realistic case is that growth will lead to a rise in absolute income dispersion over time (e.g. due to equiproportionate growth), particularly if incomes are not deflated as in JLN, leading to changes in both the location and shape of the income distribution over time. To think about the implications of disequalising growth, consider a simple model in which income is uniformly distributed and dispersion increases from period 1 to period 2 such that the (uniform) slope of the cdf is lower at every rank in period 2. Hence an individual whose income rank is lower (higher) in period 1 than in period 2 will have an average short-run rank that is less (more) than their long-run rank. This is illustrated in Fig. 2, in which the long-run cdf bisects the horizontal distance between the period-specific cdfs by construction, where the average of the short-run ranks for an individual who increases her income rank between periods 1 and 2 will be below her long-run rank since a is greater in length than b. In general, the average health of individuals who increase their income rank over time is likely to be better than that of those who are moving down the income distribution. Thus, increases in absolute income dispersion over time may further contribute to negative values of M^B. Fig. 2 may also be used to consider the effects of a recession that leads to a fall in absolute income dispersion over time, by swapping the cdfs for periods 1 and 2. In this case it can be seen that the opposite result (a positive contribution to M^B) may occur.

In conclusion, M^B may be expected to be negative as a result of two separate but mutually reinforcing reasons: (i) positive correlation between health status and income, given the shape of the income distribution, and (ii) negative correlation between average health status and changes in short-run income rank over time, given the likely increase in income dispersion over time. The second reason is less likely to be a significant factor if incomes are measured in real rather than nominal terms and may in fact counteract the first effect in the event of a recession.

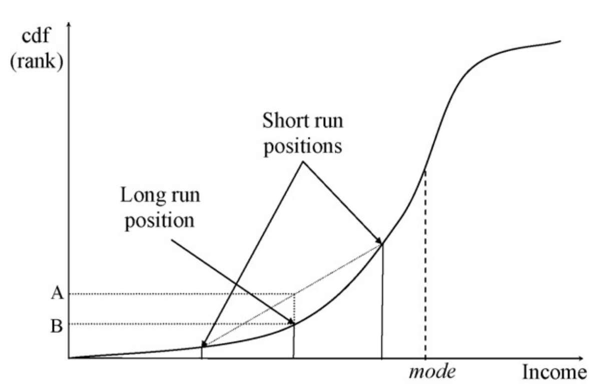

Fig. 1. Short-run and long-run ranks with a unimodal cdf of income.

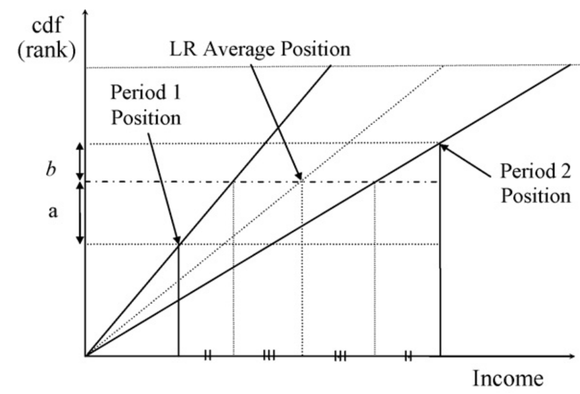

Fig. 2. Short-run and long-run ranks with increasing income dispersion over time.

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