Article

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Health Outcomes, Income and Income Inequality: Revisiting the Empirical Relationship

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Abstract: In this paper we revisit the relationship between health outcomes, income, and income inequality by applying alternative panel methodologies to a dataset of high-income countries spanning the time period 1980–2017. In this direction, we adopt alternative methodological frameworks in order to provide a) meaningful results by taking into account standard errors that alleviate problems of cross-sectional (spatial) and temporal dependence, and b) insights into the underlying relationships at several points of the conditional distribution of the health outcomes dependent variables. The evidence strongly supports the significant role that income plays in determining health outcomes. The findings relating to income inequality and nonlinear terms are more fragmented in that their significance and sign-direction depend on the functional form and the respective quantiles of the distribution the relationships are evaluated.

Keywords: health outcomes, income inequality, infant mortality, life expectancy, panel data

1 Introduction

Over the past decades, the debate about the role of income inequality as a determinant of population health has been intense. Epidemiologists and social scientists have put forward a number of mechanisms that can potentially describe the way income inequality affects an individual's health. However, the specific mechanism through

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which disparities in society's income distribution adversely affects health outcomes remains blurry.

Studies focussing on the relationship between economic inequality and health have developed certain hypotheses that have been inter alia categorized in accordance with a) the implications of increases in individual income on the marginal health benefits, and b) the societal impact of income inequality (Lynch et al. 2004a). Although the empirical literature points towards a negative relationship between income inequality and population health, the preponderance of the empirical evidence indicates that the *relative income hypothesis*, i.e. the proposition that income distribution is an important determinant of population's health, is more complex that initially envisaged (Deaton and Lubotsky 2003; Lynch et al. 2004b; Mellor and Milyo 2002; Osler et al. 2002; Shibuya, Hashimoto, and Yano 2002). Despite the lack of empirical conviction, it is widely acknowledged that since the 1970s the growing income inequality observed in many countries has been detrimental to the welfare of the society (Atkinson, Rainwater, and Smeeding 1995; Lindert 2000).

A somewhat small portion of the literature has explored the impact of health changes on economic inequality whilst another part looked at the relationship between economic inequality and the size of health disparities between different educational or economic groups. The mechanisms through which health affects inequality have been explored through labour market effects, educational effects, and marriage market effects (see, Haas 2006; Mayer and Sarin 2005). On the epidemiology front, the increasing interest in the health effects of income inequality has assumed prominent role and more emphasis is placed on whether physical and social environmental characteristics can also significantly affect the health of individuals (Diez Roux 1998; Matthew and Brodersen 2018).

The income inequality-health nexus has significant implications that are directly related to redistributive economic policies that target greater social justice and better population health. Thereby, the premise that income inequality is a determinant of population health implies that countries where policies distribute income more equally will be promoting a healthier population more effectively (Avanceña et al. 2021; Kawachi and Kennedy 1999; Wiederspan, Rhodes, and Shaefer 2015). It is also worth noting that inequality is distinctly different from poverty, in that income inequality might or might not be significantly associated with health, whereas poverty is almost invariably negatively correlated to health. In particular, there is evidence that suggests the existence of a strong and negative relationship between absolute poverty observed in poor countries – where incomes are relatively unequal – and health (Eibner and Evans 2005).

The advancement of econometric methodologies and more specifically of panel data analysis, has spawned new research to emerge that moves beyond the cross-sectional or time series dimension to more insightful and complex-type analyses that consider clusters of countries or regions. In relation to measurements used, the majority of studies have employed expected longevity or mortality as proxies for population health whilst a new trend of papers uses self-reported biomarkers or socioeconomic indicators. In this study, we contribute to the extant literature by exploring the relationships between income inequality and population health outcomes using two different measures of income inequality and three different measures of health outcomes. In this direction, we adopt alternative methodological frameworks in order to provide a) meaningful results by taking into account standard errors that alleviate problems of cross-sectional (spatial) and temporal dependence, and b) insights into the underlying relationships at several points of the conditional distribution of the health outcomes dependent variables. In general, the evidence generated in this study support the significant role that income (proxied by GDP per capita) plays in determining health outcomes. The findings however relating to income inequality and nonlinear terms are more fragmented in that their significance and sign-direction depend on the functional form and the respective quantiles of the distribution the relationships are evaluated.

The rest of the paper is organized as follows. Section 2 provides an overview of previous studies in the area whilst Section 3 presents the methodological frameworks employed for the empirical investigation. Section 4 reports the results and Section 5 discusses the emerging evidence. Finally, Section 6 provides some concluding remarks.

2 Related Literature

The existing literature on the relationship between income inequality and health is replete and several theoretical contributions have emerged. The majority of the relevant studies seem to share the same point of departure, namely the *absolute individual income hypothesis*, according to which health improves as individual income increases but this increase is nonlinear hence implying that after a certain point diminishing returns to health benefits set in.

Preston (1975) was one of the first scholars to provide evidence on the positive impact that redistribution of income has on population health. More studies followed that focused on the significant role that absolute individual income has on improving health (Gravelle 1998; Rodgers 1979). Wilkinson (1992) entertained this idea and even went one step further to suggest that income inequality affects health directly irrespective of the position that one assumes in the distributional pyramid. The premise of his argument was based on the notion that, unlike unequal societies, more egalitarian societies are associated with greater social cohesion, less stress and generally better health for individuals (Cohen et al. 1997; Wilkinson 2000). Further evidence indicated that income inequality leads individuals to experience chronic stress which medically has been known to affect their cardiovascular and immune systems, and inevitably lead to worse health outcomes (Wilkinson 2006; Vilda et al. 2019).

In the realm of epidemiolocal research, however, the arguably direct link between health and income inequality has been received with scepticism, hence questioning the validity of the original findings (Deaton 2003; Gravelle 1998) or rejecting previous findings as merely statistical artefacts. It is suggested that the existence of such a relationship at an aggregate level is to be understood in a more intricate framework of analysis where the relationship between individual income and health is concave. Moreover, a review of existing aggregated studies provided little support on the strength of the underlying relationship between income inequality and health when rich countries were considered (Lynch et al. 2004a).

Further probing into the statistical relationship between income inequality and health spawned new studies to emerge that shifted the focus on the causal dimension. A case in point is the study by Kravdal (2008) who used a Norwegian population census dataset and found that income inequality at a municipal level had a significantly negative effect on mortality in the adult population, net of individual income. Once however he allowed in his modelling for unobserved characteristics of those municipalities, the results turned out to be rather mixed.

Despite the existing and growing scepticism about the inequality-health hypothesis, more recent evidence provided fresh support for its existence. More specifically, Pickett and Wilkinson (2015) considering an epidemiological causal framework of analysis found that 131 out of 155 studies leaned on the proposition that income inequality adversely affects health. Furthermore, Matthew and Brodersen (2018) in a study for the US economy, after controlling for demographic and socioeconomic characteristics, found that income inequality had a significant impact on behavioural, physical, and mental health outcomes. Gugushvili, Reeves, and Jarosz (2020) explored the association between perceptions of inequality and health using a dataset of 31 European and Eurasian countries and found that perceptions of increasing inequality which are formed through experiences of inequality in communities are associated with reports of bad health outcomes.

Moreover, Kondo et al. (2008) in a meta-analysis consisting of about 60 million subjects in 9 cohort studies and about 1.3 million subjects in 19 cross-sectional studies found that reducing the Gini coefficient (a measure of inequality) to below 0.3 would result in the prevention of a significant number of deaths in 30 OECD countries. In the same spirit, Curran and Mahutga (2018) estimated fixed effects models and established a global gradient in the relationship between different measures of income inequality and population health.

In another multilevel study where both micro individual income-health indicators and macro income inequality-health indicators were considered, Subramanian and Kawachi (2004) indicated that the geographic scale is also an important characteristic that has to be taken into account. In this context, when smaller geographical units are considered, residential segregation is a key determinant of income inequality. As such the health of people living in deprived neighbourhoods could be more effectively explained by their status in relation to wider society and not by income differences within the poor neighbourhoods (Wilkinson 1997). In the same spirit, Wilkinson and Pickett (2006) sustain that a potential factor that inhibits out effort from finding clear evidence about the income inequality-health hypothesis is the lack of analytical data that capture social class differences and social heterogeneity.

Additional ambiguity is also evident on the impact of public expenditure on health and income inequality. Saint-Paul and Verdier (1993), in the context of voting behaviour, showed that more inequality is associated with higher spending on education in so far as the median voter prefers higher rate of taxation. The same outcome can also be expected for health-related spending, but qualifications have to be made in the event where poorer population segments vis-à-vis richer ones do not actively participate in the electoral process or the prevalence of the rich elite who demand lower taxes. In this context, Schwabish, Smeeding, and Osberg (2006) found that the larger the distance between the 90th and 50th percentiles in market incomes, the less is the likelihood that the rich elite will support public expenditures. The existing theoretical ambiguity is effectively summarised by Deaton (2003) who argues that higher spending on medical care does not necessarily lead to better health outcomes and Neckerman and Torche (2007) who argue that the mechanisms accounting for these relationships are not well understood.

Arguably, the inconsistent nature of the existing evidence might be due to the stage of economic development that the countries are going through. As Deaton (2003) and Pritchett and Summers (1996) argue, economic resources are instrumental in determining health outcomes. Thereby, models using a combination of countries experiencing different developmental trajectories are bound to produce evidence that are rather mixed or counterintuitive.

The preceding analysis suggests that there is a large and growing body of literature exploring the income inequality-health nexus. Ever since the 1970s, researchers using different measures of health and income inequality suggested that such a relationship might reflect a nonlinear pattern between health and income. However, more recently it has been suggested that the population-level relationship between health and income inequality may reflect other causes, such as social cohesion or social capital, the relativities in society, such as relative deprivation, relative income, and relative social status. In the following sections we revisit the relationship between health outcomes, income, and income inequality by applying alternative econometrics methodologies to provide novel and meaningful evidence.

3 Data and Methodology

We explore the determinants of the relationship between health outcomes, income, and income inequality by estimating unbalanced panels with annual data for the period 1980–2017. We focus on high income economies and following the World Bank country income classifications[1] our estimation sample consists of 47 countries (Australia, Austria, Bahamas, Barbados, Belgium, Canada, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Greenland, Hong Kong, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Panama, Poland, Portugal, Qatar, Saudi Arabia, Seychelles, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Trinidad and Tobago, United Kingdom, USA, Uruguay).

The baseline health outcome regression model follows the standard specifications encountered in the literature (see, Beckfield 2004):

$$\text{health}_{\text{it}} = \alpha_i + \beta_1 \text{inequality}_{\text{it}} + \beta_2 \mathbf{X}_{\text{it}} + \epsilon_{\text{it}} \tag{1}$$

where α_i is the constant term (fixed effects) and ε_{it} is the white noise error term.

In Equation (1) *health* denotes health outcomes as these are captured by life expectancy at birth (*lifexpe*) and infant mortality (*infantmort*). For robustness we additionally employ the incidence of tuberculosis as a proxy for morbidity (*morbidity*) (see, Herzer and Nunnenkamp 2015). We employ a Gini index of inequality in equivalized household disposable income (post-tax, post-transfer) and a Gini index of inequality in equivalized household market income (pre-tax, pre-transfer) which were developed by Solt (2020) and sourced from the Standardized World Income Inequality Database (SWIID 8.3). Given that benefits assume a key redistributive role for any government in the battle against

1 The World Bank classifies economies into four income groups: high, upper-middle, lower-middle, and low. For 2018, the country income classifications define high income economies as those with a GNI per capita of $12,055 or more, upper-middle income economies as those with a GNI per capita between $3896 and $12,055, lower-middle income economies as those with a GNI per capita between $996 and $3,895, and low income economies are those with a GNI per capita of $996 or less.

inequality, we have adopted the view that benefits (as a share of income) tend to be more concentrated at the bottom of the income distribution than direct taxes, hence the greater impact of benefits vis-à-vis direct taxes (Bourquin and Waters 2019). In view of this we opted for incorporating both measures of income inequality for robustness and comparison purposes. Equation (1) also includes a vector **X** that consists of GDP per capita and non-linear terms that are explored by incorporating squared terms of income inequality and GDP per capita. Table A1 in the Appendix presents detailed descriptions of all variables and their sources, while Tables A2 and A3 provide descriptive statistics and the correlation matrix.

Considering the different econometric approaches that have been adopted in this area it would be helpful to provide a brief account of the rationale of the empirical strategy employed in this paper. In panel data analysis it is well established that spatial or spillover effects can lead to cross-sectional dependence which can yield biased statistical inferences. In this direction we implemented the Pesaran (2015) cross-sectional dependence test to check for the presence of strong dependency in our series. The results are presented in Table A4 in the Appendix and indicate that innovations to the variables are strongly cross-sectional dependent. In view of this, we employ a panel fixed-effects approach using the Driscoll and Kraay (1998) nonparametric covariance matrix estimator which produces heteroscedasticity- and autocorrelation-consistent standard errors that are robust to general forms of cross-sectional dependence.

Standard regression techniques measure differences in outcome variables between populations at the mean (e.g. OLS) once you have adjusted for other explanatory variables of interest. In such settings an assumption that the regression coefficients are constant across the population has to be made. However, there are cases when we might be interested in group differences across the distribution of a given dependent variable rather than only at the mean. This is important in our context since it is reasonable to expect that the influence of income and income inequality may vary across quantiles of the conditional distribution of health outcomes. Therefore, given the significant role that the distribution of income plays in modelling health outcomes we employ Powell's (2016) quantile panel estimator with non-additive effects which is designed to estimate varying effects at different points in the conditional distribution of the dependent variable. The panel quantile approach traces its origins to the seminal paper of Koenker and Bassett (1978) aiming to produce estimates at different points of the conditional distribution which are more robust to non-normal errors and outliers.

Most panel quantile estimators include additive fixed effects in the quantile function and provide estimates about the distribution of $(Y_{it} - a_i|D_{it})$, where Y_{it} is the outcome, D_{it} are exogenous or endogenous treatment variables, and a_i denotes the fixed effects. However, as Powell (2016) notes, observations at the top of $(Y_{it} - a_i)$, may actually be at the bottom of the Y_{it} distribution and, consequently, additive fixed effect models can provide information about the outcome-relative-to-fixed-effect distribution rather than the effects of the treatment variables on the outcome distribution. Powell (2016) proposed a panel data quantile method that provides estimates for the distribution of $(Y_{it}|D_{it})$ while allowing for individual level heterogeneity and maintaining the non-separable disturbance term typically used in quantile estimation. This novel panel quantile estimator produces point estimates that can be interpreted in a similar way as cross-sectional regression results and are consistent for small T.

4 Empirical Results and Discussion

For each of the health outcomes measures (life expectancy at birth and infant mortality) we estimate alternative specifications of Equation (1) which include the natural logarithm of GDP per capita and its squared term as well as the Gini indices of income inequality (Tables 1 and 2, Models 1–4) and their natural logarithms (Models 5–8). We additionally include squared terms which can capture potential nonlinearities between health outcomes, income, and income inequality (see, Gravelle, Wildman, and Sutton 2002; Leigh and Jencks 2007). Overall, the different specifications (level-log, quadratic, log-log and translog) can help us realize the potential differences that stem from the underlying functional forms. Estimation of such alternative functional forms is common in the relevant literature (see Gravelle, Wildman, and Sutton 2002; Herzer and Nunnenkamp 2015).

One general key finding that has emerged is the paramount and significant role that GDP per capita plays in affecting health outcomes across the majority of functional forms. What is equally interesting is the fragmented in terms of significance and direction of sign impact of income inequality which appears to follow an inconsistent pattern across the various specifications.

In passing, it should be noted that we have applied the alternative methodological frameworks to four datasets consisting of low, lower-middle, upper-middle, and high income economies (World Bank country income classifications). In view of the similar unfolding pattern of empirical results across all income groups we present a detailed account of the results for the high-income economies only for economy of space.[2]

2 Full estimation results for all income groups can be provided upon request.

Table 1: Life expectancy panel fixed effects results.

Panel A: Dependent variable *lifeexp*				
	Model 1	**Model 2**	**Model 3**	**Model 4**
ln*GDPpc*	2.969	3.970	3.824	4.082
	(2.461)	(2.460)	(2.504)	(2.525)
ln*GDPpc*^{2}	−0.074	−0.124	−0.117	−0.132
	(0.128)	(0.129)	(0.129)	(0.132)
ginidisp	0.048[a]		−0.212[b]	
	(0.017)		(0.088)	
ginimarket		0.056[a]		0.357[a]
		(0.012)		(0.122)
ginidisp^2			0.004[a]	
			(0.001)	
ginimarket^2				−0.003[b]
				(0.001)
Constant	49.025[a]	43.038[a]	48.614[a]	35.942[a]
	(11.770)	(11.649)	(11.269)	(10.997)
Observations	1486	1486	1486	1486
R^2 within	0.948	0.949	0.949	0.949
Panel B: Dependent variable ln*lifeexp*				
	Model 5	**Model 6**	**Model 7**	**Model 8**
ln*GDPpc*	0.073[b]	0.090[b]	0.078[b]	0.091[b]
	(0.034)	(0.034)	(0.034)	(0.035)
ln*GDPpc*^{2}	−0.003	−0.003	−0.003	−0.004
	(0.002)	(0.002)	(0.002)	(0.002)
ln*ginidisp*	0.016[b]		−0.276[b]	
	(0.007)		(0.114)	
ln*ginimarket*		0.035[a]		0.589[b]
		(0.008)		(0.262)
ln*ginidisp*^{2}			0.044[b]	
			(0.017)	
ln*ginimarket*^{2}				−0.073[b]
				(0.034)
Constant	3.765[a]	3.600[a]	4.226[a]	2.548[a]
	(0.156)	(0.153)	(0.157)	(0.449)
Observations	1486	1486	1486	1486
R^2 within	0.946	0.947	0.946	0.947

Driscoll and Kraay's (1998) robust standard errors are provided in parentheses. Time dummies are included in the estimations but not shown here to save space. [a] and [b] denote statistical significance at the 1 and 5% level, respectively.

Table 2: Infant mortality panel fixed effects results.

Panel A: Dependent variable *infantmort*				
	Model 1	**Model 2**	**Model 3**	**Model 4**
ln*GDPpc*	−60.476[a]	−59.581[a]	−61.824[a]	−59.438[a]
	(7.915)	(7.278)	(8.587)	(7.087)
ln*GDPpc*^{2}	2.999[a]	2.955[a]	3.065[a]	2.944[a]
	(0.429)	(0.397)	(0.461)	(0.384)
ginidisp	0.083		0.498	
	(0.044)		(0.281)	
ginimarket		0.070		0.414
		(0.042)		(0.484)
ginidisp^2			−0.007	
			(0.004)	
ginimarket^2				−0.004
				(0.005)
Constant	315.817[a]	310.797[a]	316.647[a]	302.645[a]
	(35.237)	(31.611)	(35.455)	(24.206)
Observations	1434	1434	1434	1434
R^2 within	0.890	0.891	0.892	0.891
Panel B: Dependent variable ln*infantmort*				
	Model 5	**Model 6**	**Model 7**	**Model 8**
ln*GDPpc*	−0.637	−0.994	−0.677	−0.998
	(0.522)	(0.514)	(0.555)	(0.511)
ln*GDPpc*^{2}	0.011	0.029	0.013	0.030
	(0.027)	(0.027)	(0.029)	(0.026)
ln*ginidisp*	−0.344[b]		2.161	
	(0.151)		(2.172)	
ln*ginimarket*		−0.732[a]		−3.801
		(0.143)		(3.989)
ln*ginidisp*^{2}			−0.375	
			(0.318)	
ln*ginimarket*^{2}				0.404
				(0.515)
Constant	8.898[a]	12.264[a]	4.951	18.100[b]
	(2.548)	(2.557)	(2.694)	(7.339)
Observations	1434	1434	1434	1434
R^2 within	0.889	0.892	0.890	0.892

Please see Table 1 notes.

4.1 Fixed Effects Estimates

Table 1 presents the panel fixed effects estimations, using different functional forms, where life expectancy is employed as the dependent variable. According to the results, GDP per capita is found to have a statistically significant and positive effect on life expectancy in models 5–8 but in contrast the respective quadratic terms are not significant. These results suggest that the notion that life expectancy increases with income but at a diminishing rate as suggested by Preston (1975), Deaton (2003), and Leigh and Jencks (2007), is not confirmed.

When the two different measures of income inequality are considered, the results are mixed. In particular, the Gini coefficient based on disposable income (*ginidisp*) is found to be significant bearing a positive sign in models 1 and 5, whereas in models 3 and 7 the relationship with life expectancy is negative suggesting that as income inequality increases life expectancy dwindles (see Beckfield 2004). The quadratic term is also found to be significant and positive in models 3 and 7. As for the Gini coefficient based on market income (*ginimarket*) the evidence points towards a positive and significant relationship with life expectancy (see models 2, 4, 6 and 8) whereas the quadratic term is negative and significant in both models 4 and 8.

To an extent our results stand at stark contrast to Rodgers (1979) findings where the Gini has a significant negative impact on life expectancy, i.e. in support of the *relative income hypothesis* (Duleep 1995; Kawachi et al. 1997; Wilkinson 1996). However, the inconsistency of the results as this is reflected by the significant and positive relationship in some estimated models might point to other problems associated with the measurements of inequality per se. Zheng (2012) argues that potentially long lags should be included to capture effects on life expectancy while Torre and Myrskylä (2014, p. 4) suggest that “the contribution of mortality at ages below 50 on life expectancy at birth is relatively small in developed countries”.

Table 2 presents the panel fixed effects estimations where infant mortality is employed as the dependent variable. We note that in models 1–4, GDP per capita is highly significant and negatively related to infant mortality while the squared term is positive and significant. Mixed results are produced again when the measures of income inequality are included. More specifically, both Gini coefficients are found to be negative and significant in models 5 and 6 but insignificant in the rest of the specifications. This is counterintuitive to what Beckfield (2004) suggested, i.e. income inequality affects infant mortality positively. No significant impact is established when the squared terms are used.

4.2 Panel Quantile Estimates

In addition to fixed effects estimations, we employ Powell's (2016) quantile estimator for panel data with non-additive fixed effects and the results are presented in Tables 3 and 4. As it can be discerned the previous fixed effects estimates are partly confirmed at different points of the conditional distribution as well. In the specification where life expectancy is the dependent variable the evidence is rather inconsistent as in some estimated models GDP per capita appears to be exerting a negative and significant impact on life expectancy whilst in some others the impact turns out to be positive across various quantiles. The estimates for the quadratic term are rather mixed as the nature in terms of signs and significance changes across different quantiles and functional forms. As previously established, the findings for the inequality measures and their quadratic terms are inconsistent, producing both positive and negative associations with life expectancy at different levels of the distribution.

Regarding infant mortality, the results appear to be supporting the paramount and significant role that GDP per capita plays in determining health outcomes as established previously. More specifically, GDP per capita is found to be negatively affecting infant mortality in the majority of low as well as high points of the conditional distribution. The results for the squared term are akin to what we established previously with most of the models pointing to a positive relationship with infant mortality, thus confirming nonlinear effects. The findings for the income inequality measures as well as their quadratic terms suggest that there is not a consistent relationship between income inequality and infant mortality. The nascent evidence is mixed and the nature of the relationship depends on both the points of the distribution as well as the functional form without however being able to provide a clear pattern.

4.3 Robustness

In so far as life expectancy and infant mortality are thought to be measures of mortality rather than morbidity, we proceed by exploring the effect of income and income inequality on morbidity which, according to Soobader and LeClere (1999), serves as a more representative proxy for health responses emanating from income inequality when compared to mortality. Given that summary measures of morbidity relating to physical, psychosomatic or mental conditions are not readily available, we employ a specific measure of morbidity, i.e. the tuberculosis incidence rate which is available for most countries of our dataset.

Table 3: Life expectancy panel quantile results.

Panel A: Dependent variable *lifeexp*										
	Model 1					**Model 2**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	−28.949	−8.125[b]	−0.561	−2.130	−85.445	1416.350	−12.355[a]	15.407[a]	−10.907	−12.509
	(31.911)	(3.379)	(2.362)	(12.621)	(163.757)	(1847.203)	(2.505)	(0.380)	(15.564)	(13.006)
ln*GDPpc*^{2}	1.839	0.642[a]	0.213	0.203	4.074	−61.365	0.841[a]	−0.583[a]	0.631	0.765
	(1.718)	(0.176)	(0.113)	(0.619)	(7.685)	(80.687)	(0.126)	(0.019)	(0.758)	(0.629)
ginidisp	−0.319	0.124[a]	0.094[a]	0.081	0.120					
	(0.343)	(0.022)	(0.026)	(0.051)	(0.093)					
ginimarket						−1.630	0.160[a]	0.136[a]	0.077	0.169[a]
						(2.329)	(0.007)	(0.012)	(0.053)	(0.036)
Observations	1486	1486	1486	1486	1486	1486	1486	1486	1486	1486
	Model 3					**Model 4**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	31.159[a]	−5.357[a]	10.856[a]	3.512	−6.162	−2.522	−9.311[a]	−0.096	−0.778	−18.129
	(3.509)	(1.489)	(1.113)	(3.811)	(3.891)	(2.374)	(3.415)	(8.188)	(4.799)	(14.738)
ln*GDPpc*^{2}	−1.390[a]	0.470[a]	−0.336[a]	0.024	0.441[b]	0.352[a]	0.689[a]	0.210	0.248	1.080
	(0.181)	(0.073)	(0.054)	(0.186)	(0.196)	(0.125)	(0.174)	(0.422)	(0.262)	(0.707)
ginidisp	0.358[a]	0.966[a]	0.466[a]	−0.431[a]	0.171[a]					
	(0.041)	(0.034)	(0.063)	(0.108)	(0.060)					
ginimarket						0.807	1.095[a]	1.112[a]	−0.734[a]	0.318
						(0.428)	(0.224)	(0.373)	(0.262)	(0.404)
ginidisp^2	−0.005[a]	−0.013[a]	−0.005[a]	0.008[a]	−0.002					
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)					

Table 3: (continued)

Panel A: Dependent variable *lifeexp*										
	Model 1					**Model 2**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ginimarket^2						−0.007	−0.010[a]	−0.011[b]	0.010[a]	−0.001
						(0.005)	(0.002)	(0.005)	(0.003)	(0.004)
Observations	1486	1486	1486	1486	1486	1486	1486	1486	1486	1486
Panel B: Dependent variable ln*lifeexp*										
	Model 5					**Model 6**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	0.403	−0.068	0.055	−0.143	−2.773	−0.289	−0.106[b]	0.003	0.025	−0.198
	(1.776)	(0.067)	(0.040)	(0.208)	(3.340)	(0.826)	(0.048)	(0.038)	(0.063)	(0.280)
ln*GDPpc*^{2}	−0.010	0.007	−0.000	0.008	0.139	0.021	0.008[a]	0.003	0.001	0.011
	(0.081)	(0.003)	(0.002)	(0.010)	(0.167)	(0.038)	(0.002)	(0.002)	(0.003)	(0.014)
ln*ginidisp*	−0.148[b]	0.059[a]	0.016	0.020	−0.008					
	(0.059)	(0.008)	(0.023)	(0.019)	(0.039)					
ln*ginimarket*						0.093	0.094[a]	0.023	0.084[a]	0.094[a]
						(0.146)	(0.003)	(0.017)	(0.008)	(0.014)
Observations	1486	1486	1486	1486	1486	1486	1486	1486	1486	1486
	Model 7					**Model 8**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	0.172[a]	−0.030	0.029	0.147[a]	−275.528	−0.025	−0.074	0.259[a]	0.200[a]	−0.143
	(0.017)	(0.053)	(0.015)	(0.030)	(808.173)	(0.097)	(0.056)	(0.026)	(0.047)	(0.115)

Table 3: (continued)

	Panel B: Dependent variable ln*lifeexp*									
ln*GDPpc*^{2}	−0.007[a]	0.004	0.001	−0.006[a]	13.301	0.004	0.007[b]	−0.011[a]	−0.008[a]	0.009
	(0.001)	(0.003)	(0.001)	(0.002)	(39.004)	(0.005)	(0.003)	(0.001)	(0.002)	(0.006)
ln*ginidisp*	1.306[a]	2.001[a]	−0.511[a]	−1.667[a]	−1061.362					
	(0.027)	(0.365)	(0.040)	(0.467)	(3109.669)					
ln*ginimarket*						1.730	1.718[a]	0.600	−0.548	1.182
						(1.766)	(0.571)	(0.597)	(0.492)	(1.211)
ln*ginidisp*^{2}	−0.192[a]	−0.289[a]	0.083[a]	0.247[a]	156.325					
	(0.004)	(0.054)	(0.006)	(0.068)	(457.970)					
ln*ginimarket*^{2}						−0.227	−0.212[a]	−0.065	0.087	−0.141
						(0.239)	(0.074)	(0.080)	(0.064)	(0.159)
Observations	1486	1486	1486	1486	1486	1486	1486	1486	1486	1486

The adaptive Markov Chain Monte Carlo optimization procedure is employed. Standard errors are provided in parentheses. [a] and [b] denote statistical significance at the 1 and 5% level, respectively.

Table 4: Infant mortality panel quantile results.

Panel A: Dependent variable *infantmort*										
	Model 1					**Model 2**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	−134.002	−46.396[a]	−58.532[a]	−82.638[a]	232.925	−40.525[a]	−52.988[a]	−57.880[a]	−81.791[a]	−52.125[a]
	(222.548)	(14.826)	(5.061)	(9.840)	(363.431)	(2.489)	(6.042)	(3.075)	(4.365)	(9.195)
ln$GDPpc^2$	6.474	2.232[a]	2.856[a]	3.848[a]	−8.270	1.907[a]	2.545[a]	2.757[a]	3.863[a]	2.274[a]
	(10.904)	(0.718)	(0.239)	(0.482)	(19.491)	(0.117)	(0.299)	(0.195)	(0.234)	(0.455)
ginidisp	3.516	−0.060	0.030	0.192[a]	−11.400					
	(8.202)	(0.186)	(0.034)	(0.032)	(25.513)					
ginimarket						0.149[a]	−0.010	−0.003	0.025	0.016
						(0.038)	(0.052)	(0.020)	(0.016)	(0.093)
Observations	1434	1434	1434	1434	1434	1434	1434	1434	1434	1434
	Model 3					**Model 4**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	−41.231[a]	−45.094[a]	−129.604[a]	−76.717[a]	−47.456[a]	−41.686[a]	−55.434[a]	−61.012[a]	−77.395[a]	−38.347[b]
	(3.922)	(3.261)	(33.260)	(9.960)	(2.114)	(2.523)	(3.877)	(3.298)	(9.392)	(17.186)
ln$GDPpc^2$	1.918[a]	2.108[a]	6.162[a]	3.560[a]	1.953[a]	1.959[a]	2.650[a]	2.852[a]	3.611[a]	1.731[b]
	(0.181)	(0.161)	(1.651)	(0.483)	(0.106)	(0.120)	(0.200)	(0.166)	(0.495)	(0.846)
ginidisp	−0.070	−0.824[a]	−1.099[a]	−0.601[a]	−1.373[a]					
	(0.292)	(0.149)	(0.358)	(0.154)	(0.186)					
ginimarket						−0.323	−0.554[b]	0.325	0.751	−0.539
						(0.332)	(0.232)	(0.198)	(0.463)	(3.139)

Table 4: (continued)

Panel A: Dependent variable *infantmort*										
	Model 1					**Model 2**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ginidisp^2	0.002	0.014[a]	0.017[a]	0.013[a]	0.020[a]					
	(0.005)	(0.002)	(0.006)	(0.002)	(0.002)					
ginimarket^2						0.005	0.006[a]	−0.003	−0.008	0.005
						(0.003)	(0.002)	(0.002)	(0.005)	(0.034)
Observations	1434	1434	1434	1434	1434	1434	1434	1434	1434	1434
Panel B: Dependent variable ln*infantmort*										
	Model 5					**Model 6**				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	−2.039[a]	0.124	−0.461	−2.790[b]	1.609	4.408	−2.723[a]	−3.598[a]	−2.133	−2.023[a]
	(0.671)	(3.781)	(0.348)	(1.170)	(2.179)	(3.782)	(0.162)	(0.692)	(3.021)	(0.027)
ln*GDPpc*^{2}	0.089[a]	−0.001	−0.004	0.124[b]	−0.122	−0.280	0.111[a]	0.166[a]	0.087	0.068[a]
	(0.031)	(0.181)	(0.018)	(0.063)	(0.108)	(0.200)	(0.008)	(0.037)	(0.165)	(0.001)
ln*ginidisp*	0.472[a]	−1.910[b]	0.377[a]	−0.020	−2.465[b]					
	(0.049)	(0.899)	(0.082)	(0.158)	(0.982)					
ln*ginimarket*						3.841	0.112[b]	−0.402[a]	−0.176	−1.360[a]
						(2.002)	(0.045)	(0.116)	(0.228)	(0.015)
Observations	1434	1434	1434	1434	1434	1434	1434	1434	1434	1434

Table 4: (continued)

Panel B: Dependent variable ln*infantmort*										
	Model 7					Model 8				
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**
ln*GDPpc*	−0.675	−1.883[a]	−2.032[b]	−5.676[a]	−0.681	−0.999	−2.822[a]	−3.948[a]	−0.016	−1.827[a]
	(1.610)	(0.326)	(0.959)	(0.666)	(1.760)	(0.566)	(0.209)	(0.317)	(0.424)	(0.061)
ln$GDPpc^2$	0.025	0.077[a]	0.077	0.273[a]	0.011	0.010	0.119[a]	0.183[a]	−0.028	0.056[a]
	(0.077)	(0.015)	(0.051)	(0.032)	(0.090)	(0.029)	(0.010)	(0.016)	(0.018)	(0.003)
ln*ginidisp*	−4.652[a]	0.175	−9.116	−10.705[a]	−20.721[a]					
	(0.944)	(2.104)	(7.135)	(0.930)	(3.793)					
ln*ginimarket*						−24.972	−24.736[a]	0.307	−19.129	0.697
						(16.435)	(2.279)	(4.331)	(20.382)	(1.955)
ln$ginidisp^2$	0.787[a]	0.045	1.394	1.668[a]	3.011[a]					
	(0.124)	(0.306)	(1.048)	(0.133)	(0.561)					
ln$ginimarket^2$						3.345	3.258[a]	−0.090	2.463	−0.283
						(2.151)	(0.298)	(0.560)	(2.739)	(0.252)
Observations	1434	1434	1434	1434	1434	1434	1434	1434	1434	1434

Please see Table 3 notes.

Table 5 presents the fixed effect estimates. What emerges from this set of estimates is the robustness of the results relating to the negative and nonlinear impact of GDP per capita on morbidity. The findings regarding the income

Table 5: Morbidity panel fixed effects results.

Panel A: Dependent variable *morbidity*				
	Model 1	**Model 2**	**Model 3**	**Model 4**
ln*GDPpc*	−267.157[a]	−246.773[a]	−333.171[a]	−248.846[a]
	(36.062)	(35.171)	(38.089)	(32.980)
ln*GDPpc*^{2}	12.975[a]	11.935[a]	16.298[a]	12.037[a]
	(2.020)	(1.946)	(2.081)	(1.831)
ginidisp	−1.842[a]		5.803[a]	
	(0.187)		(0.912)	
ginimarket		−0.975[a]		0.373
		(0.155)		(1.973)
ginidisp^2			−0.114[a]	
			(0.015)	
ginimarket^2				−0.014
				(0.022)
Constant	1446.458[a]	1334.109[a]	1648.748[a]	1313.003[a]
	(157.140)	(156.733)	(176.781)	(184.056)
Observations	803	803	803	803
R^2 within	0.260	0.242	0.288	0.242
Panel B: Dependent variable ln*morbidity*				
	Model 5	**Model 6**	**Model 7**	**Model 8**
ln*GDPpc*	−4.431[a]	−4.033[a]	−5.815[a]	−4.112[a]
	(0.606)	(0.615)	(0.873)	(0.581)
ln*GDPpc*^{2}	0.229[a]	0.211[a]	0.298[a]	0.215[a]
	(0.032)	(0.031)	(0.047)	(0.030)
ln*ginidisp*	−1.264[a]		25.084[a]	
	(0.351)		(7.779)	
ln*ginimarket*		−0.495		8.051
		(0.343)		(15.257)
ln*ginidisp*^{2}			−3.863[a]	
			(1.099)	
ln*ginimarket*^{2}				−1.114
				(1.960)
Constant	0.000	0.000	−9.946	7.268
	(0.000)	(0.000)	(12.179)	(30.532)
Observations	800	800	800	800
R^2 within	0.336	0.324	0.353	0.324

Please see Table 1 notes.

inequality measures are again fragmented and their significance depends on the functional form. We can conclude that when tuberculosis is used as a proxy for morbidity, it does not provide additional insights into the relationship between income inequality and health outcomes other than what we have already established from the fixed effects and quantile estimates when life expectancy and infant mortality are used.

5 Discussion

On the whole, the preceding empirical investigation has produced evidence that bolsters up the notion that population health (proxied by life expectancy or infant mortality) improves with average income, but at a diminishing rate. The observed non-linearities may reflect diminishing returns to increases in income, i.e. increases in income would have larger positive effects on health outcomes among poorer groups of the society than among richer (Preston 1975). Gravelle (1998) however, suggests that diminishing returns to personal income when observed at aggregate might be a *statistical artifact*. In this context, Grossman (1972) argues that if health is considered to be durable capital stock, then it should produce an output of healthy time, the marginal product of which depends positively on wage rates. So, it would be reasonable to predict that the demand for health and medical care is positively affected by wage rates and per capita income. In a similar vein, Waldmann (1992) argues that the fact that health care is plausibly a superior good implies that diminishing returns to income should be ruled out in so far as additional spending on health care directly affects health outcomes.

The notion that the health of individuals also depends on income inequality suggests that any beneficial effects arising from absolute income dissipates at higher income levels (i.e. epidemiological transition). In this context, the distribution of income assumes a more significant role as population health declines with increasing income inequality, after accounting for the effects of per capita income (Wilkinson 1996).

Progressive taxation is potentially a policy option that governments can implement to achieve multiple goals, such as increasing the disposable income of families and individuals, decoupling the role of income in accessing health-promoting resources, and reducing the magnitude of income inequality, which, as we pointed out, is associated with adverse health outcomes (Avanceña et al. 2021). Additional redistributive policies such as universal basic income and negative income taxes are also though to alleviate inequality (Wiederspan, Rhodes, and Shaefer 2015).

The findings in this study regarding income inequality measures are more fragmented in that the statistical significance and sign direction depend on the functional form and the respective quantiles. In different specifications income inequality appears to adversely affect health outcomes which is consistent with previous studies (see, Rodgers 1979; Torre and Myrskylä 2014; Waldmann 1992) whilst in other specifications the evidence points to a positive relationship. Given the failure of many studies in the area to provide consistent evidence on the impact of income inequality on health, Wilkinson (1996, 1997, 2000), argues that one would have to first take stock of the epidemiological transition from infectious diseases to chronic and degenerative diseases before we assume that differences in mortality and health shifts from (absolute) material deprivation to (relative) social disadvantage which is a key characteristic unequal society (see also Sapolsky 2004). Furthermore, Deaton (2003, p. 152) suggests that there might be some link between income inequality and relative deprivation “but there is little that suggests it is income inequality”.

6 Conclusions

The widely held views that absolute individual income has a significant impact on improving health and that redistributive policies are needed to improve health outcomes in unequal societies has provided the motivation to reassess Gravelle (1998), Rodgers (1979) and Wilkinson (1996) findings that the distribution of income is potentially one of the most significant factors affecting population health. Furthermore, the extant mixed and scant evidence in the empirical literature provided an additional drive to explore empirically the underlying relationships.

In this study we use a comprehensive panel dataset consisting of high-income countries and we assess the impact of income and income inequality on population health. In this direction we use alternative empirical methodologies in an attempt to provide robust and meaningful insights pertaining to the underlying relationships. Generally, the evidence produced provides support to the view that population health improves with increasing income. As Pritchett and Summers (1996) argue, wealthier nations are bound to be healthier nations and any gains from rapid economic growth will be translated into health gains. Health outcomes may also depend on country-specific factors such as education, nutrition or the speed and effective delivery of health-related services but also on exogenous factors such as for instance, advances in medical technology and the diffusion of health technology (Preston 2007).

As far as the evidence on the impact of income inequality measures on health outcomes are concerned, these appear to be more fragmented. The inconclusive evidence might be due to that fact that income inequality is a consequence of political and cultural factors as well as other holistic aspects that relate to health determinants at both micro and macrolevel. The existence of any direct effects of income inequality on health outcomes is reduced to a hypothesized relationship that works through one or more health determinants.

Undoubtedly, health outcomes improve when income differentials shrink, and societies become more socially cohesive. A healthy population contributes to productivity gains and economic growth as well as to the sustainability of an ageing population. Despite the mixed evidence produced in this study, policy makers should bear in mind that decisions which increase inequality in our society, apart from creating a great sense of unfairness and injustice, are also bound to affect wellbeing. Redistributive policies that target income inequality are therefore needed to improve both societal coherence and population health.

Modelling health outcomes is indeed a complex exercise as there are a host of different factors that should be considered. The evidence generated suggests that the expected estimation outcomes might not be so straightforward to capture and effectively interpret after all. It is therefore imperative that future research considers various technical modelling aspects such as reciprocal association, relationships with time lags as well as refine further the available data by accounting for morbidity or time spent in poor health, so as to gain further insights into health conditions and differences within countries or segments of the population.

Appendix A

Table A1: Description of variables.

Variable	Definition	Source
lifeexp	Life expectancy at birth (years)	World Development Indicators
infantmort	Infant mortality rate (per 1000 live births)	World Development Indicators
morbidity	Incidence of tuberculosis (per 100,000 people)	World Health Organization
ginidisp	Gini index of inequality based on household disposable (post-tax, post-transfer) income	Standardized World Income Inequality Database 8.3
ginimarket	Gini index of inequality based on household market (pre-tax, pre-transfer) income	Standardized World Income Inequality Database 8.3
GDPpc	GDP per capita (constant 2010 US$)	World Development Indicators

Table A2: Summary statistics.

Variable	Obs.	Mean	St. Dev.	Min	Max
lifeexp	1785	76.04	4.042	62.86	84.68
infantmort	1706	9.034	7.034	1.50	68.30
morbidity	846	21.45	27.89	0	234
ginidisp	1551	31.65	6.875	17.50	51.20
ginimarket	1551	46.07	4.082	34.30	55.20
GDPpc	1,656	30,352	18,840	3,837	111,968

Table A3: Correlation matrix.

Variable	*lifeexp*	*infantmort*	*morbidity*	*ginidisp*	*ginimarket*	*GDPpc*
lifeexp	1.00					
infantmort	−0.60	1.00				
morbidity	−0.55	0.36	1.00			
ginidisp	−0.32	0.71	0.38	1.00		
ginimarket	−0.09	0.12	0.16	0.35	1.00	
GDPpc	0.59	−0.46	−0.39	−0.38	−0.25	1.00

Table A4: Pesaran (2015) test for cross-sectional dependence.

Variable	CD statistic
lifeexp	183.463[a] (0.000)
infantmort	178.707[a] (0.000)
morbidity	132.447[a] (0.000)
ginidisp	47.150[a] (0.000)
ginimarket	71.912[a] (0.000)
GDPpc	159.231[a] (0.000)

p-values are provided in parentheses. [a]Denotes statistical significance at the 1% level.

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